VI. *On a Collection of Rock Specimens from the Island of Socotra.*

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[Plates 6–7.]

The specimens of rocks—about 500 in number—collected by Professor Bayley Balfour during his late exploration of the Island of Socotra, were forwarded to me for examination. Several of these specimens, as was to be expected under the circumstances, were in a condition unfavourable for precise determination, being often fragments from weathered surfaces and sometimes much decomposed. Each, however, has been described as far as the circumstances would admit, and microscopic slides have been prepared for me by Mr. Cuttell from about 80 of the more interesting.

As it happens, certain of these offer difficulties which in the present state of our knowledge are almost insuperable. While the use of the microscope has dispelled much confusion in our petrological ideas and supplied us in many respects with a firm basis of knowledge, it has not in every case—owing to the novelty of this mode of research and the inherent difficulties—enabled the student to feel perfect confidence in some of his conclusions, especially when he is restricted to this method of examination. Perhaps the greatest of our petrological difficulties is the distinguishing in every case between certain highly metamorphosed rocks and those of similar chemical composition which are truly igneous. It has, indeed, been maintained by some eminent geologists that certain sedimentary materials may be so altered by the combined action of water, heat, and pressure as to be converted *in situ* into a rock indistinguishable from one of those commonly held to be of igneous origin. Accordingly we read not seldom of "metamorphic granite" and of "gneiss passing into granite," for it is of these that the above opinion is commonly held. Other geologists, indeed, go yet further and make a similar assertion, not only of the more coarsely crystalline rocks such as syenite, diorite, and gabbro, but even of the more compact varieties of felstone and greenstone, which in like manner are said to afford indubitable examples of transition into beds of true sedimentary origin. As regards this view, we may admit that if a mass of clastic materials be once reduced to a molten magma its past history is obliterated; and, further, that there is no reason, so far as we know, why this melting down should not occur. In this sense, any igneous rock whatever may possibly deserve the name of metamorphic. But, while admitting the *à priori* possibility of

such a change, I must confess to being sceptical as to whether any case of it has yet been fully proved to exist. I have studied not a few of the alleged instances patiently and, as I trust, without prejudice, always with the following results—either that there was no evidence which was conclusive on either side, or that to a practised eye there was very clear evidence against the asserted transition—*i.e.*, that (to refer to the instance named above) either the so-called granite was clearly only a granitoid gneiss or else that it was distinctly intrusive in the schistose rock. In these investigations the microscope is a very great help, but I freely admit that there are many cases where we cannot rely upon it alone, and must also study the rock in the field. Our knowledge at present does not enable us to pronounce upon the classificatory value of certain structures which we observe in the microscopic study of some specimens. This difficulty, however, is one which time and experience will probably remove. To admit the existence of cases where it is at present safer to suspend the judgment in no way concedes that it is impossible ultimately to arrive at a conclusion. So then, while not professing in every case from examination of hand specimens alone to decide whether a rock is a granitoid gneiss or a true granite, I believe in the distinctness of the two rocks. As it happens, some of the specimens from Socotra belong to this dubious class; and I cannot say positively, even after microscopic examination, whether in certain cases we have a granitoid gneiss or a true granite, and in others a hornblendic rock of sedimentary origin or a true diorite.

In drawing up my report on Professor BALFOUR'S collection I have thought it best to give, first, a general description of the petrology of those parts of the island over which he travelled, and then to describe the more important varieties of each group of rocks with which his journey has furnished us.*

The island of Socotra is about 72 miles long from east to west and about 22 miles in breadth. The general physical features are thus described by Professor BALFOUR in his account of the island printed in the volume of reports of the British Association for the year 1881 :—

"The surface features of Socotra at the present time are those of an island mountainous in the extreme. The shore line on its southern aspect is, as the map shows, a tolerably continuous one, unbroken by deep inlets or bays. On the northern side occur a few shallow bays at the mouths of the streams, which afford the only anchorage to be obtained around the island, but no one of them is safe at all seasons of the year. On all sides the hills rise with considerable abruptness over a wide area, forming bold perpendicular cliffs of several hundred feet in height, whose base is washed by the waters of the Indian Ocean, but at other places leaving plains varying in breadth up to as much as five miles between their base and the shore. On the south side of the island is the largest of these shore plains (Nogad), which, extending

* In writing the first draft of this paper I followed the other plan, and described the specimens as they were collected by him during each section (generally representing a day) of his journey; but as I found this involve prolixity and needless repetition, I have recast the paper into its present form.

nearly the whole length of the island, is for miles covered with dunes of blown sand. On the north these plains occur chiefly at the mouths of the streams, and are the sites of the only places which may be called towns.

"The internal hilly part of the island may be roughly and shortly described as a wide undulating and intersected limestone plateau of an altitude averaging 1,000 feet, which flanks on the west, south, and east a nucleus of granitic peaks approaching 4,000 feet high. The whole of this hilly region is deeply cut into by ravines and valleys. These in the rainy season are occupied by roaring torrents, but the majority of them remain empty during the dry season. There are, however, many perennial streams on the island, especially in the central granitic region, where amongst the hills the most charming bubbling streams, dashing over boulders in a series of cascades or purling gently over a pebbly shingle, make it hard to believe that one is in such proximity to the desert region of Arabia. Few of the perennial streams reach the shore in the dry season—most of them are fiumaras.

"The eastern end of the island is most destitute of water. Here in the dry season are no rivers, and, springs being rare, it is the most arid region.

"Igneous, metamorphic, and sedimentary rocks compose the island. The fundamental rock is granitic. This crops out, as I have mentioned, towards the middle of the island, forming a series of bare pinnacles and crags, projecting, with singularly fantastic look, from the plateau below. This rock also shows on the slopes of the valleys and ravines below the compact limestone which caps it and forms the surface rock of the hill plateaux. This limestone attains in places, as seen on the cliff faces, a thickness of two or three hundred feet. Superficially, over wide areas it is rotted and broken into a jagged surface, over which progression is by no means easy, while at other spots it forms broad, smooth slabs. A shaly rock and coarse-textured purple sandstone, in beds dipping at all angles, crop out in the valleys and on the shore, whilst forming the shore-plains and the bases of the valleys is a recent breccia and conglomerate. Cutting through all these rocks, and altering them to a considerable extent, occur dykes and extensive masses of doleritic rocks and felstones, which vary much in texture."

Professor Balfour landed on the shore of Gubbet Gollonsir at the north-western extremity of the island and explored the district fringing this bay for some distance inland, so as to examine the high ground on either side of the level valley which opens out to the sea. The uplands here consist of a thick deposit of limestone, probably of middle tertiary age, but in many cases remarkably compact and hard, so that it has at times considerable resemblance to the well-known dolomites of the Italian Tyrol. This mass of limestone rests unconformably upon a group of highly crystalline gneisses, associated with diorites and perhaps with hornblende schists, which in general character correspond with the Hebridean series in the north-west of Scotland. These older rocks are frequently exposed in the beds of valleys and in the lower part of the walls of the plateau. The same description applies to the elevated districts traversed by Professor

Balfour on his way to the shore in Kurmeh Bay; but judging from the specimens which he has brought, I think it probable that some true granite is also associated with the gneissic series. The limestone, supported as usual by the latter, extends along the shore of Kurmeh Bay, and towards the eastern part it is cut (together, of course, with the older rocks) by basalt dykes. Felsite also occurs somewhere in this district, probably inland towards the south-east.

Further east along this plain, in the vicinity of Kadhab village, basalt dykes are seen cutting the limestone rock, and there are scattered boulders of granite or granitoid rock, of red felsites and rhyolites, and of a hornblendic diabase. The cliffs by the sea between Kadhab village and Hadibu Plain are composed chiefly of the usual massive limestone, which rests on a green flinty shale or argillite. The lower part of the limestone is a breccia, in which are fragments of the subjacent rock, and bands in it even resemble the latter (possibly being composed of the same material redeposited). In this neighbourhood occurs a mass of a kind of kersantite, the presence of which may account for the peculiar "baked" aspect of the shale.

Similar argillites occur along the line of strike in the valley to the south-east of Tamarida village, overlain as before by the limestone. They have a rather sharp dip to the south-south-west, and "an imperfect vertical cleavage, or possibly, jointing." Apparently beneath, but possibly intrusive in the argillites, are some compact pale grey felsites.

Inland rises the fine Haggier range whose outlines somewhat remind us of the peaks of Sinai. The bulk of the specimens from this place are reddish or pinkish felspathic granites, not generally very rich in quartz and always poor in the third constituent, generally rather coarsely crystalline, to which we may give the name of pegmatite.* This is cut by veins of a more compact granite and by at least one dyke of mica-trap. It is possible that gneiss also is present in this region. About the margin of the range the limestone rests upon the granite, and contains detritus from the latter in its lower part. The approximately highest point of the range is a pegmatite. On the south side about Adona we have the same pegmatites with a more hornblendic granite, and intrusive dykes or veins of compact purplish quartz-felsite or rhyolite.

Eastwards from Hadibu, on the way to Jebel Omhari, blocks of reddish felsite or rhyolite are shown on the plain, and the limestone is presently reached. The extreme north-west of the Girgha range is formed of pegmatites similar to those of the Haggier mountain, varying from coarse to fine in texture, and of a rather compact quartz-felsite; the latter constitutes a considerable hill mass, and is probably intrusive in the former. There is also some intrusive diabase.

Between Kami and the hamlet Ma-aber, on the Motaha, the rocks vary considerably. Granites of the usual type, compact reddish or greyish quartz-felsite or rhyolite alter-

* There is some authority for applying this term (often used vaguely) to granites which consist almost wholly of quartz and felspar. Of these, "graphic granite" is a variety.

nate one with another. A mica-trap is also found. Evidently this is an extension of the last group of rocks. A specimen of an epidotic quartzite proves that there are, at any rate, some indications of the metamorphic series.

Following the Motaha river in a south-south-west direction we find pegmatites, coarse and fine-grained felsites, red, buff, and grey in colour, together with a greenstone so much decomposed that it is difficult to decide whether it be augitic or hornblendic. The specimens prove that the typical rocks of the Haggier range extend at least thus far to the east.

Returning to Ma-aber and continuing the section eastwards for three or four miles to Gedidery, Professor BALFOUR found first more red felsite, and then, near the latter place, much variation in the character and the colour of the rocks—"grey, white, yellowish, and red beds alternating." The specimens from these show that the following rocks are represented: fine-grained granite, compact felsites, diorite or, possibly, hornblendic schist and decomposed greenstone. It is also seen that the felsite, like the granite, is overlain by the usual limestone.

Between Gedidery and Gharrieh fine-grained granites and compact quartz felsites were collected, indicating that the Haggier group is prolonged as far as Khor Gharrieh, where these rocks come down to the sea. The granitic series was traced inland up the course of a stream, flowing generally north-north-west as far as the hamlet Vishas, and is cut by diorites. From this place up the Goahal Valley, in an easterly direction, crystalline rocks may be traced beneath the limestone, but some of the specimens must, I think, be gneisses, so that the ancient metamorphic series probably occurs in the eastern as well as in the western part of Socotra. Probably it could be traced still further east, but Professor BALFOUR, owing to indisposition, was unable to collect any specimens for the next seven miles. The limestone plateau stretches away to the eastern extremity of the island, specimens of this rock being brought from Ras Mom, a hill at the neck of the long terminal peninsula, which was the turning point of the expedition.

After retracing his steps for a few miles to the west, Professor BALFOUR travelled for some distance over the limestone plateau as far as Kittim, shortly after leaving which place he turned to the north-north-west, passing first over considerable masses of rhyolitic breccias, conglomerates, and grits. A specimen was also brought from a vein of calcite, containing fragments of red rhyolite and pinkish felspathic granite. Some of these fragments appear to be of volcanic origin, and there are masses of compact quartz-felsite, and of rhyolite with distinct fluidal structure, which, as Professor BALFOUR remarked, appeared very like lava flows. All these rocks are overlain by the plateau limestones.

From Azorah Professor BALFOUR turned in a west-south-west direction, following the Mitgahon gorge down to Baha, a village lying at the base of a peak called Töf, the easternmost summit of the Haggier range. Very compact quartz-felsites, and rhyolites abound. They form a conspicuous hill called Afero, which appeared to him

to resemble the neck or "core" of a volcano. Near the opening of the gorge are doleritic rocks, which extend for some distance, and are, at any rate in some cases, intrusive in the granitic series which is sometimes fine-grained and is more hornblendic than usual. The red felsite also occurs.

After returning to Hadibu Professor BALFOUR crossed the Haggier range, and travelling in a general southerly direction reached the Nogad plain about the middle of the south coast of Socotra. But few specimens were collected during this part of the expedition, and the only two of interest were a red rhyolite, near Feraighey, and a rather peculiar dolerite, which will be more minutely described under their proper heads. On the plain were loose blocks of a hard conglomerate containing well-rounded pebbles (up to about 1 inch or longer in diameter) of compact red quartz-felsite and purplish rhyolite with well marked fluidal structure embedded in a silicious paste. Besides these, blocks were found of white cherty fragments, also in a silicious matrix, which contains grains of the above igneous rocks. After leaving the Nogad plain Professor BALFOUR again crossed the limestone plateau to the north coast near Gubbet Kadhab, whence he returned to Hadibu.

I now proceed to describe the more conspicuous and interesting varieties of rocks in Professor BALFOUR'S collection, taking the more crystalline and most ancient series first in order.

Gneissic rocks.

The existence of a series of highly crystalline metamorphic rocks in the Island of Socotra is indubitable, notwithstanding the difficulty already mentioned, of deciding without further examination whether certain of the specimens are to be referred to the granitoid gneisses or the granites. This series forms the floor on which rest the great limestone plateau and some other sedimentary deposits, and is well exposed in the western and to some extent in the eastern part of the island, being replaced in the central and most elevated region by true granites. The following are the principal varieties: (*a*) gneisses, not conspicuously foliated, consisting of quartz, felspar (generally of pinkish colour) and mica, black and white, and possibly hornblende. As a type of these a specimen from a hill near the opening of Gollonsir Valley was examined microscopically. The slide exhibits quartz, felspar, little elongated clusters of green hornblende with some epidote, opacite, ferrite, and a few scales of white mica. The felspar is chiefly microdine, a variety which is remarkably abundant in the Hebridean gneisses and in others of great antiquity. There is also a plagioclase, probably albite,* and some of the felspar crystals contain groups of small colourless microliths with a parallel arrangement. This structure I have also observed in some of the old gneisses from Greenland. The quartz contains small cavities (rarely with

* In attempting to determine the species of the felspar I have made use of the optical tests given by Professors FOUQUÉ and LÉVY (among others) in their magnificent work "Roches Eruptives Françaises." I cannot, however, say that I feel great confidence in the results of the method.

bubbles), prismatic microliths of very pale green colour, and numerous colourless hair-like microliths, scattered irregularly throughout the grain. The resemblance of the specimens to examples from the Hebridean series of Scotland, the Laurentian series of America, and other Archæan rocks is very striking. [4115], one of a large series from the right bank of the upper part of the Gollonsir Valley, contains a fair proportion of black mica instead of hornblende. Apatite can be recognised, and the small, almost colourless, prismatic microliths already mentioned, some of which may be referred to this mineral, though I am of opinion that the majority are different. There is no microcline, but a good deal of plagioclase, probably both albite and oligoclase. [4124] contains hornblende with a black mica and sphene. (*b*) granitoid gneisses, consisting mainly of quartz and felspar, belonging to the group for which I have proposed the name granitoidite.* In these the quartz and felspar correspond with those described above, and the principal difference is that the rock is mainly composed of these two minerals, with an occasional grain of iron peroxide and a flake or two of iron glance or a ferruginous mica, hornblende or epidote. (*c*) hornblendic rocks, which we shall notice in the next paragraph, and (*d*) an impure quartzite from near Kami, north-east of the Haggier range. This rock consists of quartz, decomposed felspar, epidote, and perhaps a little hornblende, with, in parts, a good deal of magnetite.

Diorite and other hornblendic rocks.

I have made this division somewhat vague for two reasons: one that in rocks of igneous origin the hornblende is not unfrequently of secondary origin, having replaced augite or diallage, so that the rock is more properly a uralitic or hornblendic diabase than a true diorite: the other, that the means of making a thorough study of some difficult examples of these rocks—corresponding with those already mentioned in the gneisses and granites—are only now being obtained by me.† From the hill near the opening of Gollonsir Valley is a series of specimens, which, according to Professor Balfour, come from what appears to be a dyke in the Archæan series. Some are coarser in texture than others. Two of these [4009] and [4005] have been examined microscopically, of which the former was *in situ*, the latter from a loose block. They consist of a decomposed felspar, in which, however, the remains of the twinning characteristic of plagioclase can occasionally be discerned, of hornblende, black mica, and opacite, with some apatite, and a few grains of epidote. The hornblende is green in colour and exhibits very characteristic cleavage. The mica is sometimes altered to a greenish mineral, and often contains needles and grains of opacite, generally arranged parallel with the principal cleavage planes. In [4053] "from the slope of the hill

* Quart. Jour. Geol. Soc., vol. xxxv., p. 322.

† It must be remembered, in excuse for this ignorance, that it is of no use to purchase specimens for study of these difficult cases, or, as a rule, to trust the statements which one finds in print. The student must collect his own specimens, and to do this it is necessary to visit distant localities and expend much time and money. Hence difficulties are but slowly removed.

above Hanigon, to the west of the former locality," the felspar is less altered, and some of it, if we may trust the optical tests, is albite, and more of the green mineral appears to be an altered mica. Among the Archæan rocks on the right bank of the upper part of the Gollonsir Valley are two dykes. One of these [4145], a dark speckled rock with the felspathic constituent weathering yellow, consists of long narrow crystals of rather decomposed plagioclastic felspar and a hornblendic mineral; some of this shows very characteristic cleavage, other crystals when cut parallel with the edges of the prism exhibit a rather fibrous structure and look as if they might be of secondary origin. One or two possibly replace magnesia-mica. There is a little quartz, epidote, and some black iron peroxide, with, perhaps, a little apatite. The other dyke has much of its hornblende in long narrow crystals with the same secondary aspect, and the felspar crystals also, which to a great extent are replaced by secondary microliths, are long and narrow like those of a dolerite. A third specimen [4197] from a rock on the bank of a stream is of the same character, but rather more porphyritic. Many of the felspar crystals show a zonal structure, and the outer part remains clear, while the inner is replaced by secondary microliths. The small extinction angle, where observable, leads me to conclude that oligoclase is the dominant felspar. In this slide magnesia-mica is recognisable.

From the tracts traversed on the east of Ghubbet Kurmeh a remarkable rock has been brought, which, with some hesitation, I class among the diorites. The compact matrix is a dark blue, almost black colour, in which are thin crystals of felspar often nearly 1″ long. With the microscope the ground mass is seen to consist of small elongated felspar crystals having a rather fibrous or "teazed" aspect, associated with much opacite and some green microliths of hornblende or chlorite, rather irregularly disseminated, and some flakes of brown mica. The larger crystals of plagioclase felspar show the greatest absorption at very small angles with the vibration planes of the crossed nicols, and parallel lamellæ extinguish almost simultaneously, so that they are probably oligoclase. The hornblende, however, has very much the aspect of a secondary product, and I am disposed to regard the rock rather as a hornblendic diabase than a true diorite.

From an isolated hill in the middle of the Gharrieh Plain (mainly limestone), which is covered with a peculiar vegetation, come some dioritic rocks (associated apparently with granites or granitoid gneisses). One of these consists of a plagioclastic felspar, which (though in part replaced by microliths) from its large angle, where unaltered, between successive extinctions (often quite 30°) is probably, in part at least, anorthite, and of hornblende, also with a secondary aspect, some chlorite, with epidote, apatite, and a dichroic fibrous lamellar green mineral, which extinguishes parallel with the lamellæ, and is more probably an altered mica than hornblende. A few grains of quartz are also present.

Other hornblendic rocks were noted during my examination of the specimens. Those described above certainly appear to be in all cases igneous rock, but it is quite

possible that among them may have been some of metamorphic origin referable to the Archæan series, for, as my experience in Cornwall and Scotland has shown me, it is sometimes by no means easy to distinguish the one from the other in hand specimens.

Dolerites, basalts, &c.

The information furnished to me does not allow me to attempt any classification of this group. Some of the basalts cut the limestones and so are among the most modern known igneous rocks of the island, but whether all these augitic rocks are of the same date it is impossible to say: probably they are not.

A dolerite from the plain on the south-west of the stream in Gollonsir Valley [4051], is a rather coarsely crystalline rock, consisting mainly of whitish felspar and black augite. The former, under the microscope, proves to be well preserved labradorite, the crystals of which have fairly regular linear boundaries, and in form are rather broad oblongs. The augite, which has solidified after the felspar, is full, in one or two cases, of irregular grains of opacite, which sometimes make up almost the whole of the crystal. Incipient conversion into uralite is exhibited, crystals of augite having sometimes an irregular border of the latter mineral; while sometimes minute scales of it are disseminated in the nearly colourless augite crystal. In one or two instances almost the whole crystal is replaced by uralite.

One of the dykes near Kadhab village [4198], I leave, after microscopic examination, with some hesitation among the basalts. It retains some traces of a clear glassy base crowded with opacite and other microliths, some acicular and colourless, which with some larger crystals are rather like anorthite, others are of a greenish-yellow colour, fibrous or filmy; these being generally associated in irregular patches, with interspersed specks of opacite. They are most like replacements of an augitic constituent. A little hornblende can also be recognised. There are some indications of fluidal structure, and the rock evidently approaches the augite-andesite group.

[4454], one of a group of rocks of doleritic aspect, from the base of Azalin on the bank of the Hasainho, speckled whitish and blackish, consists of (*a*) labradorite in well defined crystals, evidently the first mineral to consolidate; (*b*) a slightly brown, rather dichroic augite, which in one case approaches diallage in its close cleavage; (*c*) a dark brown hornblende, sometimes inclining at the edges to sap-green (Plate 7, fig. 1). This paragenesis—for I think the whole aspect of the hornblende forbids the idea that it is of secondary formation (the uralites being generally green, and often quite pale)—though not very common is far from being unprecedented. It seems, for example, rather frequently in the old diabases of North Wales, and in the gabbro of Mont Colon (Pennine Alps). [4449], one of a very similar group of specimens, from the "rocks of which Azalin is composed," consists of well crystallized labradorite in good preservation, olivine, sometimes partially replaced by serpentinous microliths, opacite, augite, with a little diallage and hornblende. Some of the last mineral is certainly of secondary

origin, bordering augite crystals, but one or two grains of darker colour may possibly be original constituents. The latter specimen then comes near to the true dolerites, the former to the Labrador-diorites.

From boulders in the bed of a stream-course near Fernaighey (no rock occurring *in situ*), come some specimens, of which [4499] may be taken as a type. The ground mass consists of a mass of small crystals of a white felspar and a black mineral, in which are scattered larger felspar crystals, sometimes 2 inches long. Under the microscope the rock is seen to consist of a rather decomposed labradorite, of a dull green, dirty-looking mineral associated with and occasionally replaced by opacite, probably a decomposed augite or diallage, and of a fibrous or scaly green mineral, giving bright tints with crossed nicols, also associated with grains of opacite. These aggregates have probably replaced olivine. There are also some fair sized crystals of apatite. The rock then has been an olivine-dolerite, but would now be more properly classed with the diabases.

Granites.

For the reasons given above I am unable to decide whether some of the specimens brought by Professor BALFOUR are true granites or only exceptional examples of the granitoid gneisses or granitoidites.* At the same time we need not hesitate to admit the existence of a considerable amount of this rock, especially in the more central part of the island, as for instance in the Haggier range. The granites of Socotra, as a rule, consist mainly of quartz and felspar, and so belong, as we have said, to the variety pegmatite. The latter mineral usually predominates and is commonly of a reddish colour. They are frequently much decomposed and not seldom show some indications of a graphic structure. It will suffice to select two or three from a large series as examples. [4249], "from the high cliff on the northern face of the Haggier range, one of the specimens typical of the rock forming the highest peaks," is a good example of the coarse red and white pegmatite. Microscopically it consists of a decomposed felspar, most, if not all, being orthoclase, quartz with numerous microlithic enclosures and minute fluid cavities, and a little of a dark green strongly dichroic mineral. Some of this is hornblende, but part of it much resembles tourmaline, to which mineral some acicular microliths, in one case in a tufted group, almost certainly belong. A second [4241] "from the slopes above Hadibu," has among it felspar, microcline, and a fair quantity of plagioclase (? oligoclase), grains of magnetite and a green chloritic mineral associated with clots of opacite, evidently replacing a magnesia-mica, associated with which is a little of a colourless mineral, possibly apatite. [4264], from the same region, is a "vein-granite, which cuts the coarser variety." It is a very finely crystalline quartz-felspar rock of a warm grey colour, containing some dark crystals about 0·25″ long. With the microscope it is seen to consist of intercrystallised quartz and felspar, the latter often exhibiting close twinning and sometimes being probably microcline.

* Quart. Jour., Geo. Soc., vol. xxxv., p. 322.

The crystals occasionally exhibit rectilinear boundaries, but often interlace one with another and with the quartz in a very complicated way, as is not seldom the case in vein-granites. The slide contains some brown mica and tourmaline, the latter certainly a pseudomorph after the former. Two crystals retain a cleavage resembling hornblende, but behave optically as a uniaxial mineral, and when properly placed absorb the polarised beam far more completely than is usual with hornblende—a curious case of pseudomorphism, which, however, is not without parallels (Plate 7, fig. 2). [4205], an erratic near Kadhab village, doubtless from the western part of the Haggier range, is a red felspar-granite rather similar to the last, with a little iron-mica. [4207], a rather similar rock from the same region, exhibits in part a distinct micrographic structure; the decomposed felspar crystals are intimately interbanded with quartz, possibly of secondary origin; these two are most likely vein-granites. [4439], near Hesainho, in a region cut by felstone dykes, is a fine-grained pink and white granite with green specks, which under the microscope shows intercrystallised quartz and decomposed felspar (orthoclase and (?) oligoclase), with an approach to a graphic structure, besides some altered biotite—the rock is cut by a dyke of gabbro. Between these two rocks is a thin zone composed of the granite and the gabbro crushed, and to some extent mingled, though the materials of the former predominate. The constituents have been subsequently recemented, probably by deposition of quartz; this crushing was doubtless subsequent to the solidification of the newer rock. From the north-west of the Girgha range comes a series of specimens varying from coarse to moderately fine crystalline, and consisting of quartz and felspar with small quantities of hornblende and black mica, having a general resemblance to those already described from the Haggier range. Microscopic examination of one [4335] shows that the felspar is orthoclase, and perhaps microcline, with oligoclase. Small quantities of a chloritic mineral and a few microliths, possibly of tourmaline, are also present. The structure of the rock is rather abnormal for a granite, having some resemblance to the granitoid gneisses, but as there has been some local crushing and recementation, it may, notwithstanding, be a true granite.

Felstones and rhyolites.

Under this head I have retained a large number of rocks, which in some cases it would have been easy, but in others impossible, to subdivide. Petrologists are at present hardly in a position to agree upon precise definitions for the names of certain of the more acid igneous rocks, or upon the classificatory value of some of their minute structures. For example, a felstone must have a ground mass which is either microcrystalline or cryptocrystalline. But at present we cannot say whether or not these two structures correspond with different conditions in the past history of the rock, and so are of specific rather than of varietal value. Again, the latter structure, in some cases, appears to have been produced during the solidification of the mass, in others long afterwards. These, at present, it is often impossible to distinguish. Again,

although we can often make a reasonable conjecture, we have no sure criteria for distinguishing between specimens taken from a dyke and from a flow, if they happen to have solidified under approximately similar circumstances. Hence, seeing that while in the present extensive series from Socotra there are some which are certainly from intrusive masses and others which are almost as certainly from lava flows, there are several which I cannot separate, either lithologically or petrologically, I have thought it better to group them under one general title, and indicate in the description what seems the most probable history of the rock from which the specimen has been taken. The majority of these Socotra felstones are of a warm red or purplish colour, though some of a grey tint also occur. They vary from minutely crystalline (approaching on this side vein-granites) to very compact subvitreous rocks which sometimes show a well marked fluidal structure. It will, perhaps, be more convenient to describe them as they occur geographically rather than to attempt to make a lithological arrangement.

The first specimen [4049] is from a dyke in the Archæan series, not far from the coast of Gubbet Gollonsir, about $1\frac{1}{2}$ mile east of Ras Bedu, at the western extremity of the northern coast of Socotra. It is a compact dull-coloured felsite, weathering a pale yellowish-brown, containing many little black crystals. Under the microscope the rock appears to have a glassy base, stained with ferrite so as to present a rather muddy aspect, in which are scattered many small and well-formed crystals, both of felspar and green hornblende; among the former orthoclase and a plagioclase, possibly albite, can be recognised; the latter crystals are generally well formed but sometimes include portions of the ground mass. This, when examined with the two nicols, is to be seen full of minute microliths of felspar, but there appears to be some remains of a glassy base. There is no free quartz. The rock then appears to be intermediate between the hornblende andesites and the sanidine (or orthoclase) trachytes. From the same neighbourhood also comes a rather granular quartz-felsite containing some hornblende. Several specimens have been examined from an interesting series obtained on the plain near Kadhab village; unfortunately none of these occur *in situ*, but, as Professor BALFOUR informs me, they doubtless come from a part of the Haggier range lying to the south-east. [4206], a compact dark felsite with paler spots and wavy bands of a more crystalline material, containing small scattered crystals of pink felspar, exhibits under the microscope a clear base (perhaps not wholly devitrified) studded with numberless minute granules and rods of opacite, indicating a fluidal structure. The spots and bands prove to be groups of spherulites crowded together with irregular interlocking edges.* There is some green hornblende, generally in clustered granules, possibly associated with minute tourmaline. The larger felspar crystals resemble orthoclase or sanidine, and there is a little free quartz. It is therefore a rhyolite, but not one of the kind which, judging from this collection, is so common in Socotra. Of this [4203, 4213, 4214] are types, "compact red felstones or

* As in the figures of a devitrified glass: DAUBRÉE, 'Études Synthétiques de Géologie Expérimentale,' 1re Partie, pp. 170 and 171.

rhyolites," exhibiting on their weathered surfaces a beautifully distinct and rather parallel fluidal structure. This is most perfect in the second specimen. Microscopic examination shows it to be produced by ferrite-stained bands and lines of opacite granules and trichites with clearer interspaces. Small crystals of quartz, felspar, and little spherulites occur occasionally. The ground mass seems to be wholly devitrified. The first specimen shows traces of "flow brecciation" and is more unequally devitrified, with but few imperfect spherulites. The last [4214] has irregular spherulites and bands with a brush-like arrangement of microliths: it contains a little more free quartz. From "the banks of the Kereguiti stream, south of Hadibu," apparently intrusive in the green slaty rocks and the lower part of the overlying limestone, come pale buff or grey felsites. [4234] exhibits under the microscope an extremely minute devitrified structure, the slide is slightly clouded with ferrite and contains small scattered granules of quartz and felspar and minute specks of (?) hornblende. This rock is not unlike some of the most compact varieties of felstone from the Bala group of North Wales. From "the spurs of the Haggier range running towards the sea" come compact red quartz-felsites and rhyolites, generally resembling those already described. [4285] is cryptocrystalline, with a rather coraloid or arborescent structure, occasionally spherulitic; it is much stained with ferrite, contains a few scattered grains of quartz, decomposed felspar, iron peroxide, and hornblende or tourmaline, and is more probably from a dyke than from a flow.

A pinkish quartz-felsite [4331] "from the interbanded group of rocks underlying the conglomeratic base of the limestone, south of Ma-aber," has a cryptocrystalline ground mass of quartz and decomposed ferrite-stained felspar; the former mineral, which is very abundant, has at first sight a rounded or polygonal outline, giving the rock a superficial resemblance to one of fragmental origin. In this ground mass are scattered grains of quartz, crystals of felspar, and (probably) magnetite. In the eastern part of the Haggier range near Adona the coarse red pegmatite is cut by dull purplish compact felstone dykes. [4399] has been taken from a vein only about $\frac{3}{4}''$ thick. The junction with the granite is beautifully exhibited in the slide, one or two small fragments of the latter being included in the former. This exhibits a cryptocrystalline structure, almost microcrystalline in parts, which, however, is in no respect remarkable. In the other [4368], also a junction specimen, the intrusive rock is minutely devitrified, shows slight fluidal structure, and has a general resemblance to the rhyolites already described; a small band of crushed granite occurs at the junction, as shown in the figure (Plate 7, fig. 3).

The felsites, which are associated with the argillites and calcareous rocks on the banks of the Kereguiti stream (Hadibu Plain), being apparently intrusive in them, are of a different character; they are compact flinty felsites of a pale buff or grey colour. One [4234] under the microscope exhibits an extremely minute cryptocrystalline structure, the ground mass being irregularly and lightly clouded with ferrite, containing

specks of a hornblendic or chloritic mineral, with grains of quartz and felspar, some of which show the twinning of plagioclase.

Rhyolites of a purplish colour, exhibiting fluidal structure, and of the former type, occur among the boulders on the plain between Girgha and Omhari, and pinkish quartz-felsites come from the extreme north-west of the Girgha range, where, in the ascent of a valley from the Hadibu plain, "red granite, white granite, reddish felstone, and intrusive dark rock, alternate one with another with marvellous rapidity, and disappear under the limestone on the northern side." One of the quartz-felsites [4285] under the microscope exhibits a rather irregular cryptocrystalline structure, approaching coralloid or aborescent, here and there spherulitic; the spherulites having an irregular outline. The slide is stained with ferrite, contains a few scattered grains and imperfect crystals of quartz, decomposed felspar, with microliths of iron-peroxide, and hornblende or tourmaline. From the group of compact felsites or rhyolites, which are members of a very variable series of rocks near Gedidery, one of the most compact, of a purplish colour [4364], exhibits under the microscope a clear base, interspersed with minute aggregated granules of ferrite, varying from a sienna-brown colour to almost black, which gives a mottled aspect to the slide. Scattered in this are crystals of sanidine and plagioclase (? albite), and other crystals, now occupied by yellowish-brown secondary minerals and clotted ferrite, but which, judging from their outlines, have in some cases almost certainly been augite, others, however, may have been biotite. The felspar crystals have a curiously rounded outline, and contain numerous enclosures of brown glass. No free quartz is visible, so that the rock must be classed with the sanidine trachytes. The compact red felsites intrusive in granites "from the side of Khor, near the village of Gharrieh," are very much of the normal type, compact reddish or pinkish felsites, containing minute specks of quartz and of a greenish mineral, with small felspar crystals. [4359], examined microscopically, exhibits one of the slightly "arborescent" cryptocrystalline structures already noticed, and is clearly related to types described above. [4350], from the same region, is very closely related to the vein-granites in structure. The ground mass is microcrystalline; the quartz, which occurs in irregular grains of variable size, has many microlithic enclosures; there are one or two distinguishable crystals of orthoclase, and clusters of small crystals of biotite.

Several specimens of compact felsites or rhyolites have been brought from the district to the west of Kittim and then north-north-west as far as Azorah, where these, together with a conglomerate or agglomerate containing a similar rock, form a large part of the hills of this district. Ten slides have been examined microscopically, but after what has been already said it will be needless to do more than indicate their distinctive features. [4443] and [4482] are microcrystalline and exhibit an imperfect micrographic structure, the former having a more porphyritic structure. It contains a good quantity of plagioclase (? albite) among its felspars and a few specks of decomposed grown mica. [4458], [4472], and [4473] are reddish rhyolites with a cryptocrystalline

ground mass, and more or less of a spherulic structure. The second is a particular interesting example, longish microliths of ferrite-stained felspar being scattered, or irregularly grouped, among clear quartz and occasionally formed into true spherulites, which are often enclosed by a dark ring. The microliths frequently indicate by their grouping an incipient micrographic structure (Plate 7, fig. 4). [4408] and [4413] are rhyolites showing a very marked fluidal structure, the former affording one of the best examples of "flow brecciation" that I have ever seen; fragments of lava, often differing considerably in their minor characteristics, being entangled in the matrix of the slide, showing that the partially solidified rock from time to time has been broken up and swept along by the pressure of the still liquid mass behind (Plate 7, fig. 5). The rock has been subsequently cracked and the fissures cemented by infiltrated minerals, among which is opal. The locality of the last two rocks is indicated as "close to Azorah (almost half way between the north and south coasts)." [4446] and [4448] are rocks of a dull purple colour, with small amygdaloids (Plate 7, fig. 6). The matrix consists of very minute elongated felspar microliths in a base, rendered almost opaque with ferrite and opacite; opal, chalcedony, and a clear mineral resembling felspar occupying the vesicles of the rock. Its relations are perhaps rather with the andesites than the true trachytes. [4431], from nearer Kittim, where it is associated with conglomerates and forms low hills, looking in places much like a lava flow, differs from the others in colour, being a compact pale grey rock like some of those which I have obtained from Moneadhmore Glen, in Arran, or even from North Wales; it has a rather variable cryptocrystalline base, ferrite-stained, in which are scattered many small felspar crystals (probably orthoclase), quartz, and a chloritic mineral. Apart from the confirmatory evidence given by Professor BALFOUR, I should have felt no hesitation in asserting that some, at least, of these rocks formed parts of lava flows; they are anterior in date to the limestone beneath which they pass.

From the hill of Afero, which, Professor BALFOUR states, reminded him of a volcanic neck, west-south-west of Azorah, approaching the eastern end of the Haggier range, come more reddish compact quartz-felsites and rhyolites of the usual type. A specimen [4436] which has been examined microscopically exhibits a fluidal structure, in parts cryptocrystalline, in parts rather microcrystalline, and much ferrite-stained; but it is needless to dwell on points of only varietal interest.

The last specimens from this group of rocks examined microscopically were collected *in situ* near Feraighey, on the southern side of the Haggier range. [4440] is a very compact pale Indian-red felsite, resembling a group described above [4458, &c.], but is a little more spherulitic. [4420] is nearer to [4446] in general character; there are some curious rounded concretionary spots of opacite, and perhaps one or two minute amygdaloids.

Mica-traps.

From Socotra we have one or two representatives of this outlying and rather vague but convenient group. One [4270] is from a dyke forming the floor of a gully on the

northern side of the Haggier Mountains, inland from Hadibu. The gully is excavated in the coarse reddish pegmatite, which is cut by a vein granite [4264] (p. 282). This mica-trap is a rather compact variety consisting of a reddish felspar, mica, and a dull greenish mineral. Microscopically it consists of felspar, mainly orthoclase, in which are scattered numerous microliths of opacite, hornblende and mica, with larger crystals of brown and white mica, chiefly the former, hematite and hornblende, the last being often crowded with opacite and clear microliths, perhaps apatite. The rock then is a minette and follows its usual habit of occurring in a dyke or vein.

From the shore west of Hadibu, near the argillites (p. 289), comes a very minutely crystalline rock of dull-grey colour, which when microscopically examined consists of decomposed felspar, probably plagioclase, altered magnesia-mica, iron peroxide, a little hornblende, apatite (?), and interstitial quartz. This then is a kersantite.

From between Kami and the hamlet Ma-aber, on the Motaha, comes a minutely crystalline rock [4309] associated with felspathic granitoid rocks already mentioned (p. 276), which consists of pale grey felspar, mica, and some quartz, grains of each occurring porphyritically in the ground mass. The microscope shows that a good deal of the felspar is plagioclase, some being oligoclase, but orthoclase is also present; the larger crystals often enclose numerous clear microliths, there is also much biotite and some quartz, with grains of iron peroxide. The rock then is a quartz-kersantite.

Unaltered clastic rocks.

Passing now to the comparatively unaltered clastic rocks, we have first to notice the agglomerates or conglomerates from the district near Kittim, where they occur in large masses in association with the rhyolites as already described (p. 277). There are conglomerates and breccias (generally rather decomposed) of a compact red rhyolitic rock, some of which reminded me in appearance of the specimens of late Precambrian age, which are so common to the west-south-west of Bangor, a mile or two from the town.*

[4437] has been examined microscopically. It is composed of fragments of rhyolitic lava, subangular to rather rounded, with some quartz grains, containing very minute cavities, and a very little of a cementing matrix, which is generally stained with ferrite or viridite. The lava fragments vary considerably in their structures. One, containing some small felspar microlites, has a marked fluidal structure, being banded with very dark ferrite; it is almost certainly a fragment of scoria or from the slaggy exterior of a lava flow; others exhibit various fluidal and microlithic structures. Most of them are ferrite stained, and more or less devitrified: materials derived probably from more than one source. There are also some grains of viridite, these being probably altered fragments of augite or hornblende. The rock is a rhyolitic grit, the materials of which are certainly of volcanic origin, but probably (in this particular case) have been transported by water. The resemblance already noticed to the Welsh Precambrian

* Quart. Journ. Geol. Soc., vol. xxxv., p. 309, and Geol. Mag., Dec. ii., vol. vii., p. 298.

rocks does not disappear under the microscope, and I think we have in this group of specimens evidence of volcanoes of very considerable geologic antiquity.

The conglomerates of rhyolite and felsite, which occur as boulders on the Nogad plain (p. 278), though their materials have been derived from the same group of igneous rocks, are probably far more modern than the last. These I have not deemed it necessary to examine microscopically. Breccias and conglomerates of various kinds are not infrequent in Socotra, but generally present no special interest. Some occur just at the base of the limestone series, others may be quite modern; subærial or stream detritus, cemented by tufaceous deposit.

Argillites.

This group of rocks, found underlying the limestone near Hadibu Bay (p. 276), is one upon the exact nature of which it is difficult to decide. I am not able to satisfy myself, from the specimens which I have received, whether there is a true cleavage or not; the rock has a somewhat porcellaneous aspect, as if it were at least of palæozoic age, but as there appear to be intrusive rocks in the neighbourhood, one hesitates without further evidence to assign it to a remote geologic period. As, however, there is at the base of the limestone a breccia of fragments, seemingly in the same mineral condition, and as there seems to be an unconformity here, the interval between the two groups of rocks is probably considerable. Shaly bands are, indeed, said to occur in the lower part of the limestone, but it is possible that these may be formed of detrital material from the older group. Microscopic examination does not throw much light on the history of the latter. The specimens are composed of earthy material and minute, rather angular, fragments of a clear mineral (quartz, with possibly some felspar), and a number of exceedingly minute, doubly-refracting, rather highly-tinted granules; these are probably in some cases a variety of hornblende, in others epidote.

Limestone and dolomite.

Several specimens of the massive limestones which form so much of the upland district in Socotra are among Professor BALFOUR'S collection. Generally they are compact in texture, with a clean subconchoidal fracture, buff, whitish, or sometimes pinkish in colour; in aspect often remarkably like the ordinary dolomitic rock of the Italian Tyrol. The weathered surfaces are sometimes curiously rough and cavernous. I have examined microscopically a few specimens from different parts of the island. The first [4168] is one of a series collected in the district extending from the head of the Gollonsir Valley towards the Kadhab Plain. These are compact in structure with a subconchoidal fracture, buff coloured and pinkish, the former being more crystalline. The specimen examined is a very pretty pinkish rock that would take a good polish. It contains numerous organisms, both tolerably perfect and fragmentary, among which

foraminifera abound. Among these we can recognise* *Globigerina* (abundant) *Rotalinæ*—probably two forms of *Planorbulina*, one like *Ammonoides*, and the other outspread like *Mediterranensis*—*Textularia* (more than one form), *Amphistegina*, and possibly a small *Nummulites*, with fragments of mollusca, polyzoa (?), and of other organisms which I cannot recognise. The matrix is rather earthy.

A specimen [4048] from the cliff capping the ridge above Hainjou (west end of the island) is a very compact pale cream-coloured limestone. Microscopic examination shows a matrix of dusky grey material, with minutely-crystallized calcite and probably a little dolomite, which occurs also in thin veins, and some minute granules which may be glauconite. It contains several *Rotalinæ*, possibly *Planorbulina* and *Discorbina*, and perhaps *Rotalia*, together with a large fragment rather resembling a piece of a *Cristellaria*.

Buff limestones from the Kadhab Plain, [4188] and [4195]. The former contains numerous mineral fragments, apparently quartz and felspar, with organisms broken and whole, among which *Amphistegina* and *Miliola* are recognisable, and bits of the shells of mollusca. The organisms are more or less dolomitized. The latter contains many *Globigerinæ* with *Amphistegina* (small), perhaps an *Orbitoides*, and fragments of mollusca and polyzoa. This rock also is slightly dolomitized.

A specimen of limestone [4107] from the plateau west of Ras Mom, near the eastern extremity of Socotra, is a buff-coloured rock with a minute oolitic structure, the weathered surface being full of small holes. Under the microscope we found a clear dolomitic matrix full of darkish rings, circular to irregular oval in form, with a radial-fibrous structure, and as a nucleus commonly either a fragment of quartz or of a foraminifer, though sometimes they inclose simply the matrix; sometimes also the concentric structure extends to the centre of the oolitic grain.

[4456]—a very compact pale buff limestone from the top of Ras Mom, in appearance almost exactly like a bit of Schlern or Dachstein dolomite, is shown on microscopic examination to be a true dolomite. It contains numerous organisms, which, as is commonly the case, are more completely dolomitized than the matrix, and so rendered rather difficult of identification. There are many foraminifera, among them certainly *Amphistegina*, and perhaps *Nummulites*, *Globigerina*, with fragments which I believe to be polyzoa.

As regards the geologic age of these limestones, *Globegerina* has had a long existence, like *Textularia*; *Nummulites* began long since, and still lingers, but was most abundant in the eocene time; *Orbitoides* began in cretaceous and disappeared before the latest part of the tertiary age; *Amphistegina*, however, which is one of the most

* As I have not worked much at thin sections of foraminiferal limestone, I submitted all these slides to Professor Rupert Jones, F.R.S. With his wonted kindness, though at the time far from well, he examined them and gave me a series of notes, which are embodied in the text, so that the identifications rest upon his authority, than which it would be difficult to find a better.

abundant foraminifers in these rocks, ranges from the miocene upwards, hence it is probable that the age of these Socotra limestones is miocene.

Conclusion.

From the above remarks it would appear that in Socotra we have, as the foundation stones and "core" of the island, if the phrase be permissible, a mass of rock of very great antiquity. There is clear evidence of the presence of gneissic rocks which in their lithological characters resemble closely those which exist in the north-west of Scotland, the Malvern Hills and one or two other localities in our own island, in Northern America, and in many other parts of the globe. By whatever name these may be called, and however they may be correlated one with another, it is evident that their antiquity is enormously great, and that they had attained their present mineral condition before the earliest palæozoic rocks were deposited. Associated with these are granites, which, though of later date, are probably also of great antiquity. In the Sinai peninsula we have also gneiss, schists, and various granitic rocks. Of the latter I possess a small collection, given to me by Professor E. H. PALMER,* and the resemblance of some of the specimens to those of Socotra is very remarkable. In the geological notes added by the Rev. F. W. HOLLAND to the Report of the Ordnance Survey (ch. viii.) we find it stated, indeed, that the prevailing rock, in the Sinai region, is syenite (by which term probably hornblendic granite is meant), so that out of several hundred specimens he only possessed two or three of true granite. This may be, but my specimens from the summits of Serbal, of Jebel Musa, and Um Shomer closely resemble some of the Socotra rocks, especially the first and second, which are coarse reddish granites composed almost wholly of quartz and felspar (pegmatites). From the summit of Serbal also comes a finer grained granite, and I have an ordinary granite from Wady Sigillia. Other specimens, exactly as in the Socotra collection, might be either true igneous or highly metamorphic rock. In the Sinai region the old gneiss appears only to have been recognised in the northern part, where it forms an irregular trough to the north of Jebel Serbal, the higher peaks (like the Haggier range in Socotra) being granite. I miss, however, from the Socotra district, or find but feebly represented—for there is one specimen which may belong to it—the friable variably-coloured sandstones which form so marked a feature in some parts of the Sinaitic peninsula (*e.g.*, Wady Mokatteb)†. These, after having been assigned to more than one geological epoch, were referred by Mr. HOLLAND, on the evidence of fossils, to the

* He was a member of the Sinai Survey Expedition in 1868–9. Two months after this paper was read, he was murdered by Arabs. The circumstances of his death are well known, but I may be allowed to pay a passing tribute to the memory of a singularly accomplished and learned man and very valued friend.

† This absence of the sandstone is probably an accident (the rock being very friable), for Professor BALFOUR mentions "purple sandstones" (see p. 275).

carboniferous. In Sinai, as in Socotra, we have huge masses of limestone, which in like way form great plateaux—as, for example, the Tih—and were deposited in an ocean, in which the well-known peaks of Sinai probably formed rocky islands, but deposition there commenced at an earlier period than we can venture with the evidence at present before us to claim for Socotra, for the limestones of Sinai are assigned to part of the cretaceous and to the eocene age; the Nummulitic limestone, for example, being finely developed as in Wady Dhaghadeh. Coraliferous beds of miocene age are, however, found in that region.* The rocks of Sinai are cut by dykes of "basalt, greenstone, and porphyrite," the first of which, as in Socotra, are probably comparatively modern, but we do not find there, so far as I can learn, representatives of the great group of the quartz-felsites and rhyolites which seem so enormously developed in Socotra and were certainly connected with active volcanos. The geological age of these cannot be determined. They are undoubtedly older than the limestone group; so that, if no part of this is earlier than the middle tertiary, they might belong to any geological period between that and the latest Precambrian, to the volcanic rocks of which they have, indeed, considerable resemblance. I am not aware that the "argillite" of Socotra—of which I can only say that it is older than the limestone—is represented in Sinai. As here, so also in Socotra, there are basalts of comparatively late geologic age—post miocene—and in the latter some compact trachytic rocks, which, however, differ from the older rhyolites, and are generally paler in colour.

We have, then, in Socotra, as it seems to me, evidence of rocks of an immense, and a land surface of a very great, antiquity. Excepting this argillite of uncertain age and limited extent, and perhaps some sandstone (also local), there is no evidence in the specimens before me to show that this island was submerged during any part of the palæozoic or mesozoic period.† During the kainozoic it undoubtedly shared in the downward movement which affected so large a portion of the globe in and about the North African and mid-Asiatic districts; but I should infer that the invasion of the sea commenced much earlier in the Sinaitic peninsula, and think it possible that the topmost peaks of the Haggier Mountains were at no time wholly submerged. As it again rose from the waves—perhaps being for a while connected with the African continent—the meteoric forces resumed their work of sculpture and the waves began their work of insulation. Since then the fauna and flora have undergone their own modifications, but in the Haggier Hills we have probably a fragment of a continental

* Bauerman, Quart. Jour. Geol. Soc., vol. xxv., p. 37.

† "Africa south of the Sahara was probably a stable area during many of the alterations of the relative levels of land and sea of the north and of Europe."—Professor P. M. Duncan, Presidential Address to Geol. Soc. 1877, Journal, vol. xxxiii., p. 86 (Proceedings). West of the Sinai Peninsula old schists and granite crop out in Egypt, and east of it on the opposite side of the Gulf of Akabah, flanked in both cases by "Nubian sandstone." See the map attached to the Presidential Address to the Geologists' Association (delivered November 3, 1882), by Mr. W. H. Hudleston (Proceedings, vol. viii., p. 1), in which is given an admirable summary of the Geology of Palestine and the neighbouring districts.

area of great antiquity and of a land surface which may have been an "ark of refuge" to a terrestrial fauna and flora from one of the very earliest periods of this world's history.

Description of Plates.

PLATE 6.

Sketch map of Socotra.

The information at the Author's disposal has not enabled him to attempt to lay down the geological boundaries with any accuracy or to insert minor features, such as dykes, &c. It will be understood that the rock in the parts left blank (except where alluvial plains occur) is limestone of approximately middle tertiary age. Only the more important names are placed on the map.

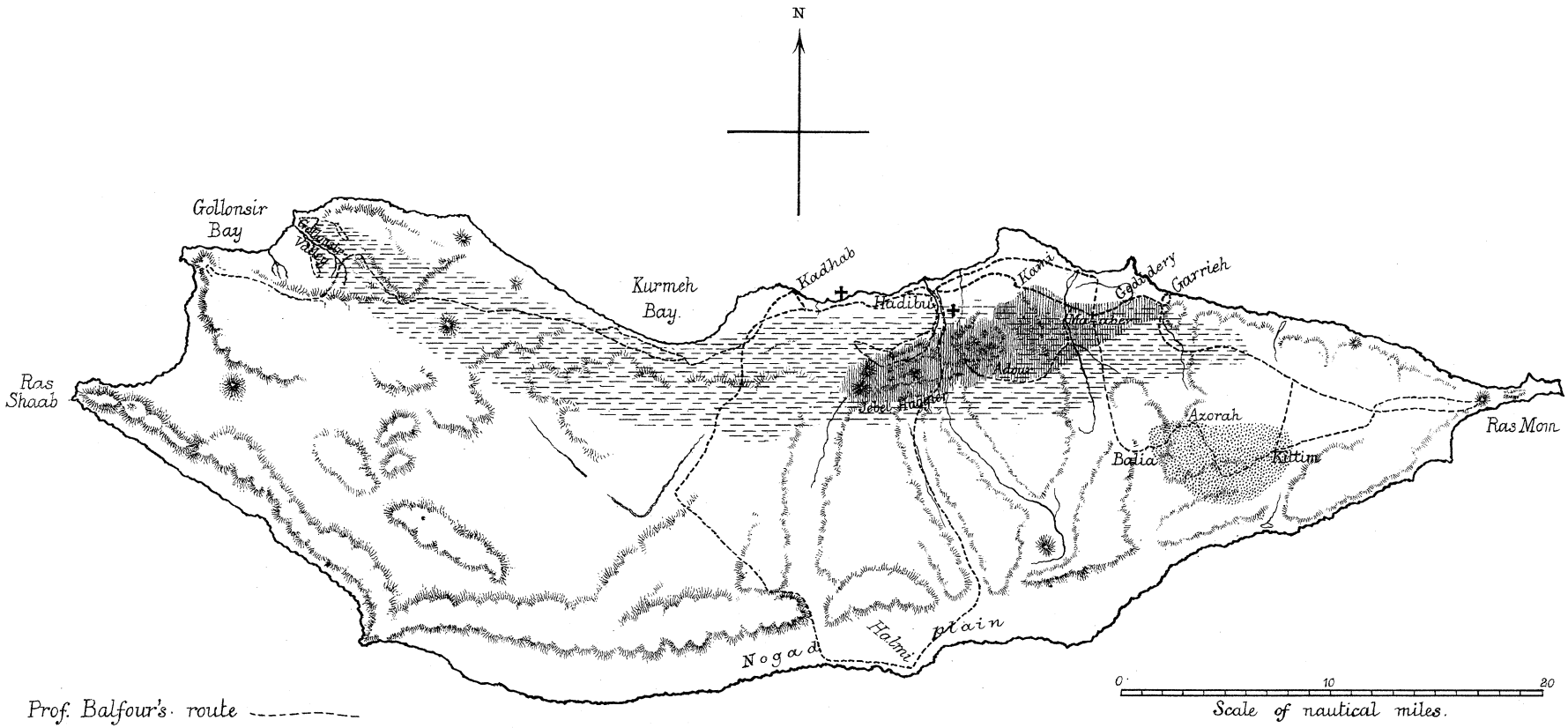
PLATE 7.

1. Labrador diorite from base of Azalin (p. 281) × 20.
   (*a*.) Labrador felspar, in parts rather decomposed; the striping is indicated as when a polarizing apparatus is used. This has consolidated before the hornblende.
   (*c*.) The sap-green hornblende, within which is a crystal of iron oxide, probably ilmenite, and the pyroxenic constituent (*b*) of the text. Since writing this I have noticed that one of the two vertical sections of the mineral extinguishes when the cleavage lines coincide with the vibration planes, and is rather dichroic, giving reddish and greenish tints, according as the vibration of the polarized beam is perpendicular to or parallel with the cleavage lines of the mineral. The cross sections, though much resembling augite, are rather abnormal in some respects. Thus, though the evidence is insufficient for certainty, I think it possible that we have here the rhombic pyroxene (hypersthene ?) lately described by Mr. Whitman Cross ('Amer. Jour. Science,' Feb., 1883) and Mr. Teall ('Geol. Mag.,' Dec. ii., vol. x., p. 145).
2. Vein granite from the slopes above Hadibu (p. 283) × 20.

   The figure contains two crystals, selected from different parts of the slide, to represent those crystals which while resembling hornblende in cleavage have optical characteristics agreeing with tourmaline. They are extremely dichroic, changing from a clear sap-green to a blue-black.

3. Junction of felsite and granite. Haggier range, near Adona (p. 285) × 20.
   (*a*.) Very compact felsite.
   (*b*.) Crushed granite.
   (*c*.) Granite.
   Drawn with polarized light.
4. Rhyolite with spherulites. Azorah district (p. 287) × 40.
   Selected as a fairly typical example of a rather frequent type of rock.
5. Rhyolite exhibiting "flow brecciation," near Azorah (p. 287) × 20.
   The dark streaky part (*a*) is the general ground mass of the rock in which fragments are entangled; (*b*) exhibits small lath-like crystals of a decomposed felspar in a ferrite stained ground mass somewhat resembling that of the last slide; (*c*) exhibits a minute "speckled" devitrification structure; (*d*) with a high power exhibits minute felspar microlites crowding a dark ferrite-stained base, while in the centre of the slide is a fragment showing a well-marked fluidal structure, the lighter parts of which are devitrified. It is of course possible that some of the fragments may be entangled lapilli, but the absence of a slaggy border and the general cleanness of their edges corresponds better with the idea of their having formed parts of the flow.
6. "Trachyte" with minute amygdaloidal cavity. Near Azorah (p. 287) × 30.
   The minute felspar microliths are slightly more evident in the slide than in the drawing, and one or two of the cavities are larger than that figured, but unfortunately their contents have partly torn away in grinding.

SOCOTRA.



Gneiss appearing on low ground from beneath a general capping of Limestone

Chiefly Granite

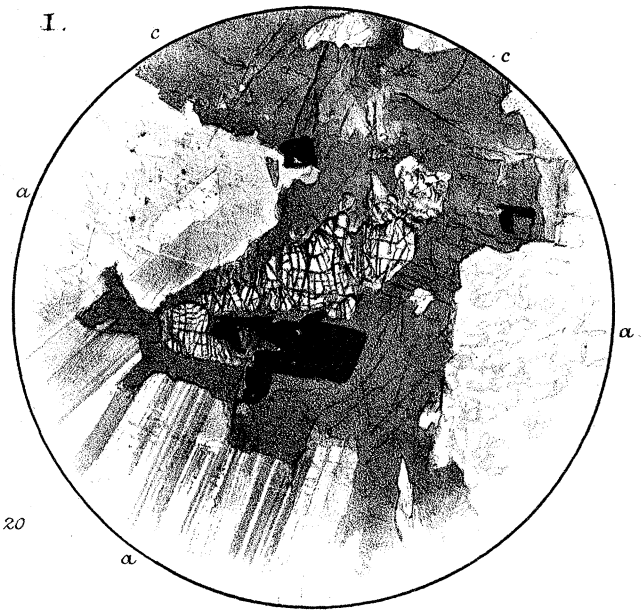
Rhyolite & Felsite with (?) Agglomerate

Argillite

W. H. Wesley lith.

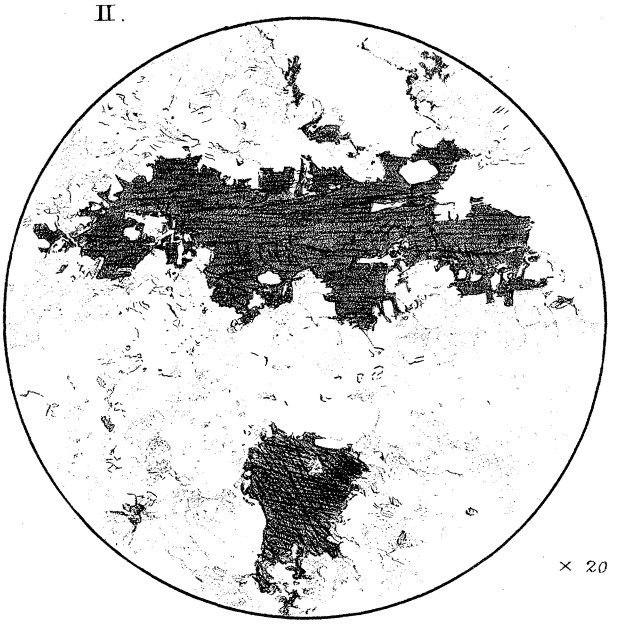
West Newman & Co. imp.

I.



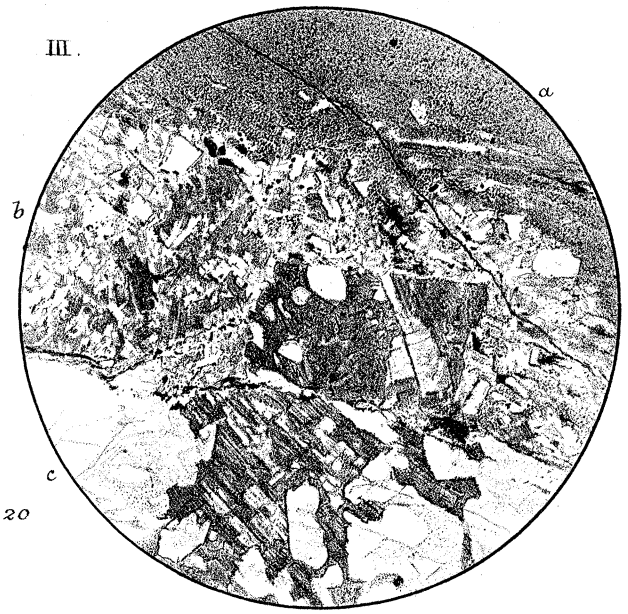
× 20

II.



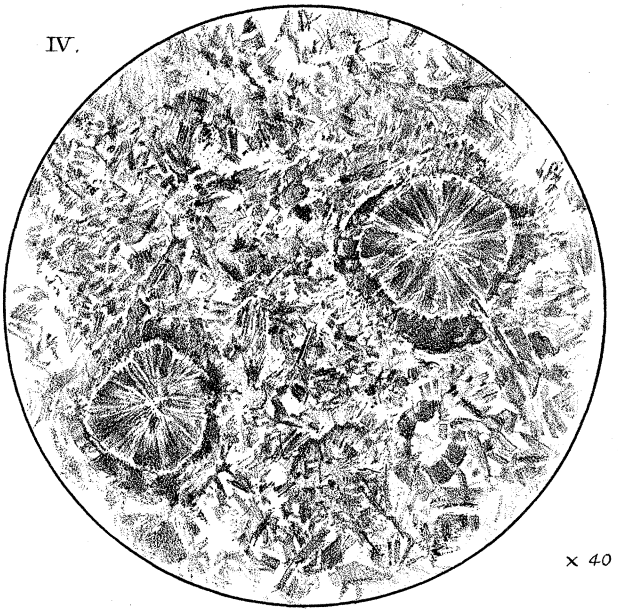
× 20

III.



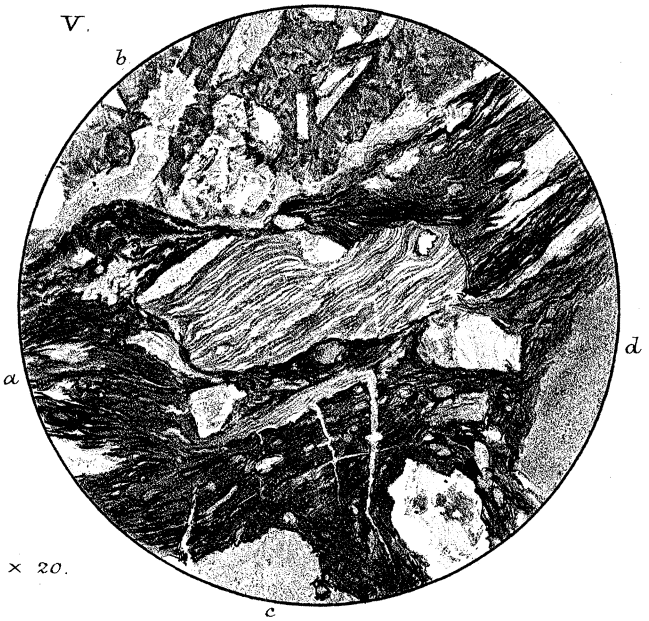
× 20

IV.



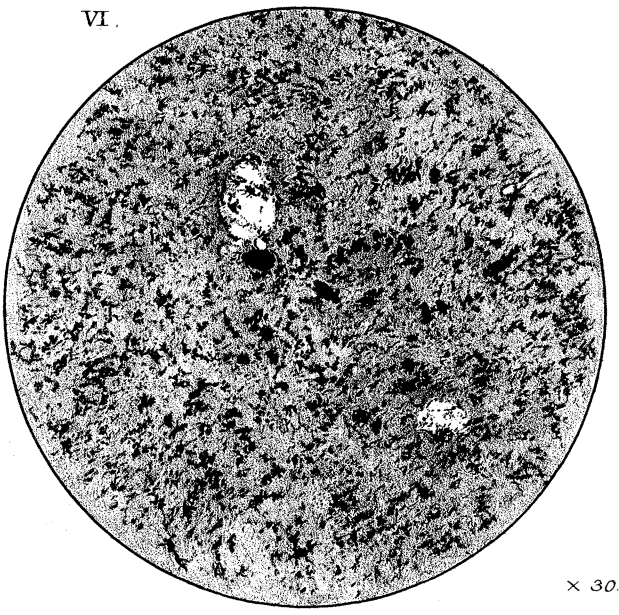
× 40

V.



× 20.

VI.



× 30.