22. NOTES *on some* VOLCANIC *and other* ROCKS, *which occur near the* BALUCHISTAN-AFGHAN FRONTIER, *between* CHAMAN *and* PERSIA.

By Lieut.-Gen. C. A. McMAHON, V.P.G.S., and Capt. A. H. McMAHON, C.I.E., F.G.S. (Read March 24th, 1897.)

[PLATES XVIII–XX.]

Part I.—THE BALUCHISTAN DESERT, SOUTH OF THE HELMAND RIVER. By Capt. A. H. McMAHON.

WHILE engaged, in the deserts south of the Helmand River, in the delimitation of the boundary between Afghanistan and Baluchistan, I made a small collection of such rock-specimens and fossils[1] as I thought were characteristic of the geology of the country. I regret to say that I am not myself a geologist, else my collection would have been perhaps a more methodical one, and would probably have been supplemented by notes on the positions and surroundings of the specimens collected, and on other points of geological interest. I say perhaps, because even if I had been the most learned of geologists I doubt whether political and other duties would have allowed me time to do more than I did. At any rate my collection would not have been a larger one, for the simple fact that, owing to long marches and want of water and food, our transport-camels were almost unfit for work, and the mortality among them rendered it a matter of difficulty for us to carry even the necessaries of life.

Turning now to the physical geography of the country, one finds in it various natural phenomena on a gigantic scale, the study of which I venture to think may throw light on similar phenomena seen elsewhere on a smaller scale. It is a country almost uninhabited by man, where man has left nature to do as she pleases undisturbed. If you look at the map (Pl. XVIII), you see high mountain-ranges fringing it on the east and south-east. These vary in height from 6000 to 8000 feet above the sea. West of them lies a vast wilderness of plains stretching away some 300 or 400 miles to the mountain-ranges along the Persian border which fringe them on the west. Rising like rocky islands out of the midst of this vast sea of plains are mountain-ranges upwards of 7000 feet high. The north of this tract is bounded by the Helmand River.

We will consider firstly the plains and their drainage-system, and then the mountains.

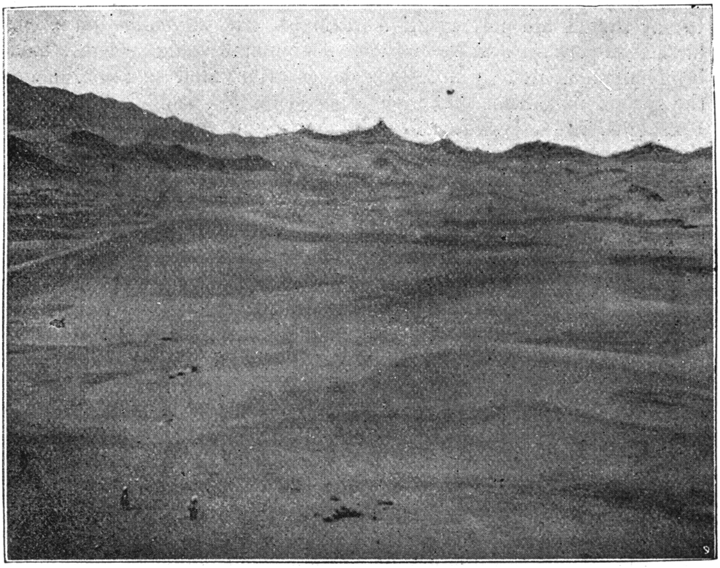
The Plains.

We have first of all a wide level plain of alluvial soil which includes the whole of Shorawak, and then, spreading out from Nushki on the east to Chagai on the west, it stretches southward to

[1] These fossils have been made over to the British Museum (Natural History).

the foot of the Ras Koh and other mountains running south and west from Nushki. You see the Lora River coming out of the mountains and crossing the plain in the direction of the Lora Hamun, where it comes to an end. This river never reaches the Lora Hamun, except in flood-time, and then it makes the Hamun a broad lake of shallow water. This soon evaporates, and for the greater part of the year the Hamun is nothing but a vast sheet of dry, solid salt. It is evident that not only the Hamun, but all this plain, must once have been a great lake, thus accounting for the rich alluvial soil of which the plain is formed. North of this plain and stretching to the Helmand River lies the Registan sand-desert—a wide stretch of billows upon billows of sand with crests some 200 feet high. This

Fig. 1.—*View showing sand-dunes covering lower slopes of mountains and gradually overwhelming the higher spurs.*



[From a photograph.]

sand-desert, interspersed with level plains of black gravel, stretches from the Chagai and other mountains to the Helmand westward as far as the Persian border. In places this sand-desert is like unto a fairly calm sea, and the waves of sand are only of moderate height. In other places, especially along the north of the Koh-i-Sultan, Damodim, and Amir-Chah ranges, it resembles a wild stormy sea with great waves 100 or 200 feet high breaking against the sides of the mountains like the Atlantic surge on a rock-bound coast (see fig. 1). Here the sand-hills assume the proportions of sand-mountains. Many of the mountains themselves have become buried in sand and are no longer visible—others still tower with their black crags above the sandy waste, but the sand banked some 1000 or 2000 feet above the level of their base foretells a similar fate in store for them.

The phenomena of sand-hills—their origin, formation, and prevailing shapes—are in themselves an interesting and difficult study, and it will be remembered that recently Mr. Vaughan Cornish read a valuable paper on the subject before the Royal Geographical Society, which, with the record of the discussion that followed, deserves the notice of geologists.[1] Suffice it here to note that some of the speakers on that occasion laid stress on the fact that, however devouring an element sand may be, water always has the upper hand, and that a small stream of water will always cut its way through sand. But in the country here described this principle does not hold good. If one looks at the map one sees that the drainage of the mountains from Chagai westward runs in the direction of the Helmand River, and farther west still it runs towards the God-i-Zirreh Lake. Little of that drainage ever reaches the Helmand River; none of it, so far as I can ascertain, reaches the God-i-Zirreh. In each case it is stopped by the sand. After rain, immense volumes of water must run down from the mountains in the numerous torrent-beds, but it is easy to see that this water never travels beyond the first few opposing lines of sand-hills. The God-i-Zirreh was at one time fed by flood-water from the Helmand, but it does not appear to have received any replenishment since 1880, that is 17 years ago, and it is now a lake of salt brine fringed by an ever-encroaching margin of solid salt. The great Helmand River farther north comes to a standstill in the lakes and swamps of Seistan.

The Mountains.

The line traced on the map (Pl. XVIII) from north of Chaman to Nushki marks the course of a gigantic fault, or earthquake-crack, which was discovered when we came to carefully examine this country. It runs in a well-defined line of indentation, as well marked in places as a deep, broad railway-cutting. It starts at the edge of the plain north of Chaman and runs along the foot of the mountains to the point on the Chaman and Quetta railway-line where the earthquake of December, 1892, so curiously distorted the track, and shortened the distance between Chaman and Quetta by no less than 2½ feet, as described by Mr. C. L. Griesbach, now Director of the Geological Survey of India, in the May number of the Records of that Survey for 1893.[2]

From that point the fault runs on, gradually ascending diagonally the slopes of the Khwaja Amran range, until it crosses the crest of the main range near its highest peak, at an elevation of about 7000 feet. Descending again into the Spintizha Valley it thereafter ascends diagonally the slopes of a continuation of the Khwaja-

[1] Geogr. Journ. vol. ix. (1897) pp. 278–309.
[2] Vol. xxvi. pt. ii. pp. 57–61 with 3 plates.

Amran range. Cutting this in a similar manner, it descends to the Lora River, and, crossing that river, runs along the whole length of the base of the Sarlat range to Nushki. Beyond this point the duties connected with boundary-work prevented us from tracing it.

The length of this line, as surveyed by us, is no less than 120 miles. Along the whole course of it we found springs of water, and, both from the presence of water and from its forming a short cut across innumerable mountain-spurs, this fault-line is largely used by the natives as a thoroughfare. The old greybeards of the tribes living near it told us that on some three occasions during their lifetime, after severe earthquake-shocks, deep fissures had appeared along this line, and that similar accounts had been handed down to them by their fathers. After one of these earthquake-shocks the water-supply of the springs along the crack had, they said, been largely increased.

The rocks along the east of this fault-line appear to be sedimentary, and the mountains on the east are all of clay-slate. The rocks on the west are for the most part volcanic and igneous, but there are a few sedimentaries among them.

In the mountains on the Persian border we again come to shales and other sedimentary rocks. The Chagai, Koh-i-Sultan, and other mountains appear to be volcanic; some, like Damodim, retain their crater-form better than others. Lava, ash, and pumice abounded in all those localities where the mountains showed above the sand. The pumice was found lying about in large quantities, and it was abundantly sprinkled over the sand—whither it may have been blown by the wind.

Unfortunately, circumstances did not allow of a visit to the crater of Damodim. Natives told us that in the deep hollow at the top of that mountain there is some good soil which they are able to cultivate. All these volcanoes have no doubt long been inactive, but some 90 miles south-west of them lies the great Koh-i-Taftan, also known as the Koh-i-Chehaltan, 12,600 feet high, which is said to be still an active volcano.[1]

[1] [Since this paper was read the authors have been in personal communication with Capt. P. Molesworth Sykes, British Consul at Karman, now in England on leave, who climbed the mountain on Christmas Eve, 1893. After gradually ascending ravines in the foot-hills around the mountain, the exploring party arrived at the foot of the cone, at an elevation of 10,000 feet above the sea. Thence up to 11,000 feet the ground traversed consisted of boulders; but from 11,000 feet up to the top it was covered with fine volcanic ash, into which the foot sank deeply at every step. Throughout this portion of the ascent the smell of sulphur was unpleasantly strong. The summit consists of a plateau covering an area of about 400 square yards. On its northern and southern sides there are slight elevations, separated from each other by a narrow but shallow valley. The northern elevation forms the Sacrifice Hill, where goats are sacrificed by pilgrims: while the southern portion is called Madar Koh (Mother Hill). On the latter were, at the time of Capt. Sykes's visit, two apertures, some yards apart, each apparently 3 or 4 yards wide, which appeared to be connected with each other. From both of these dense white sulphurous smoke and flames were issuing. So strongly sulphurous and suffocating was the smoke that these holes could be approached only from the windward side, and even that was difficult, owing to the smoke and heat. Sulphur

The Koh-i-Sultan mountains deserve a few remarks, owing to the curious and grotesque shapes of their high peaks, which remind one irresistibly of Gothic cathedrals and churches. Here, too, we find a high natural pillar which, as seen at a distance from the plains below, looks like an artificial monolith on the crest-line of the range. On approaching it, we found that it was a huge natural pillar of stupendous size, made up of volcanic agglomerate. From the width of the base, which is over 100 yards in diameter, I calculate that its height must be over 800 feet. Deep fissures down its sides, caused no doubt by the action of rain, give it a fluted appearance from a distance. (See fig. 2, p. 294.)

So much for the general character of the country. In considering the present condition of its surface and the geological and other natural phenomena to be found there, it is advisable to note carefully the natural agents which are at work in that region with a force and activity unknown in most other countries. First of all, we have the agency of water, which is a more particularly destructive agent here precisely because this part of Baluchistan is one of the driest countries in the world. Rain comes but seldom, but when it comes it pours with great violence, and from the absence of vegetation or surface-soil, it rushes off the mountain-sides in huge torrents. The high-water marks in the dry torrent-beds and the large rounded boulders piled one upon another in those beds show with what volume and force those torrents come down.

Then we have the wind. I have never travelled in a country where strong winds are so frequent and continued. There is one wind alone which blows there with hurricane violence continuously

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and sal ammoniac were, however, extracted from the edge of one of these apertures.

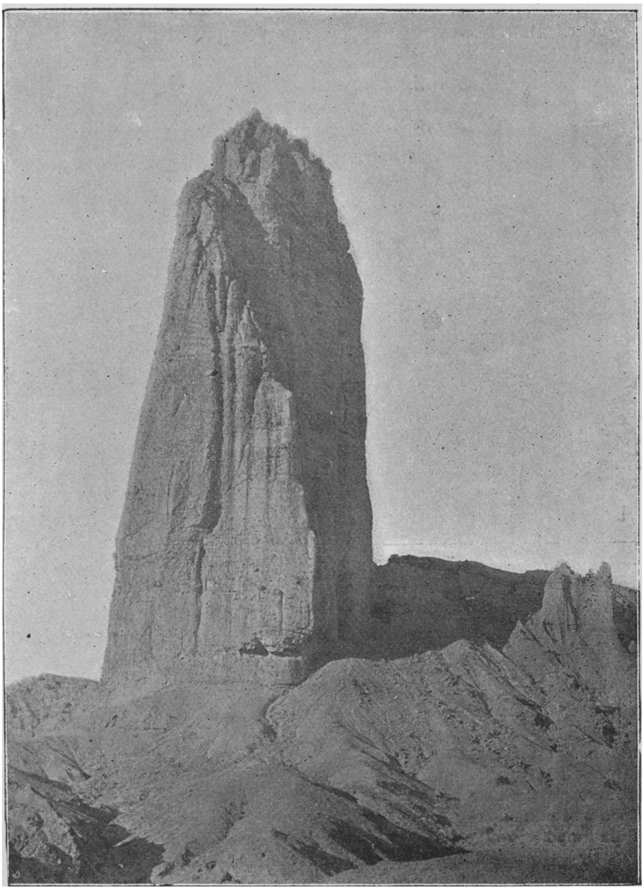
Capt. Sykes has paid several visits to the burning petroleum-springs at Báku, on the western shore of the Caspian Sea, and he is satisfied that the heat, smoke, and flames on the summit of the Koh-i-Taftan were not due to petroleum. There was no smell of petroleum, nor was the smoke dark and carbonaceous.

As the summit of the Koh-i-Taftan is still thickly covered with fine ash, this volcano must have been active during a recent geological period; but as no very fresh lava-streams appear to have been observed on the way up the mountain, it is not probable that the volcano has been active during the lifetime of the present generation. The authors infer from Captain Sykes's observations that the volcano is now in the solfataric stage of its existence. The flames seen were probably due to the emission of hydrogen sulphide (H_2S), a very common and inflammable product of solfataric action.

Capt. Sykes brought home with him a specimen of lava found *in situ* on the Koh-i-Taftan, and this proves, on examination under the microscope, to be a vesicular hornblende-andesite. The hornblende belongs to the orthorhombic group, and is identical with the very peculiar red-brown and brilliantly dichroic variety of anthophyllite described in Part II. of this paper. It is very abundant in the Koh-i-Taftan slice. Augite is also sparsely present in it, but there is no olivine. Magnetite and ferrite also occur. The anthophyllite has strongly marked resorption-bands, and it is undoubtedly an original mineral. It is interesting to note that this peculiar mineral is a characteristic constituent of the lava of the Persian volcano Koh-i-Taftan as well as of some of the somewhat older lavas of Baluchistan described in this paper.—May 15th, 1897.]

for four months, from May to September, every year, and we found from sad experience that violent storms were not confined to that season alone. In considering this country we must neither overlook these strong winds, nor the effect which they have on the sand, nor

Fig. 2.—*The Neza-i-Sultan, a natural pillar of volcanic agglomerate.*



[From a photograph.]

the destructive effect which, combined with the sand, they have on everything else.

Last but not least, great extremes of heat and cold are the rule here, greater extremes perhaps than are found anywhere else in the world. The summer heat is terrific, while in the winter there is very severe cold; and not only is there a wide seasonal range of temperature, but also a very wide diurnal range. Our solar radiation-thermometer would register 205° F. on cloudless days, while the nights in the sandy tracts were often bitterly cold. The diurnal variation must sometimes have been as much as 150° F. It is needless to point out how powerful an agent these wide variations of daily and annual temperature must be in the disintegration of the surface of the country. Nor is there cause for astonishment, if we think of the peculiar conditions of water, wind, and sand-action and of heat and cold obtaining in this country, that its surface should present curious and unusual features.

Part II.—Petrological Notes *on the* Rocks.

By Lieut.-Gen. C. A. McMahon.

A number of rock-specimens collected by my son, Capt. A. H. McMahon, C.I.E., Boundary Commissioner, when engaged in the delineation of the boundary between Baluchistan and Afghanistan up to the borders of Persia, were made over to me for examination. Selected samples of these were sliced and studied under the microscope, and the results are embodied in the following pages.

Andesites.

[The numbers are those of the slides in my own collection.]

No. 1424.	Augite-hornblende-andesite.	Sp. gr. =	2·682
„ 1438.	„ „ „	„	2·727
„ 1464.	Hornblende-andesite	„	2·645
„ 1425.	„ „	„	2·715
„ 1426.	„ „	„	2·625
„ 1430.	Mica-andesite	„	2·549
„ 1443.	„ „	„	2·597
„ 1436.	Andesite	„	2·645

The andesites enumerated above are in some respects very peculiar rocks, of a type not commonly met with. They vary in colour from grey to almost white. Many of them are very trachytic-looking, and some years ago would probably have been classed as trachytes. As, however, the felspar of which they are built up is a plagioclase, and not sanidine, they cannot be called by that name.

The specimens grouped together in the above list possess several features in common.

The first point to be noted is their low specific gravity, which averages 2·648. The mean specific gravity of quartzless andesites, according to text-books, ranges from 2·7 to 2·8; so that the average density of the rocks now described is somewhat low. The percentage of silica is evidently high, but I have not observed any free quartz in any of my slides.

The ordinary method of determining the specific gravity of a rock cannot be applied to these specimens, in consequence of their porosity. I boiled the samples for some time and allowed them to soak in water from 24 to 48 hours before weighing them in fresh unboiled water, but the specific gravity even after these precautions had been taken was in almost every case too low. The specimens doubtless contained hidden vesicles filled with air, or gas, which the water failed to reach. The specific gravities given above were obtained by the use of a specific-gravity bottle. The rock was reduced to powder and boiled, and the weighing was done with the aid of a chemical balance.

The low specific gravities obtained are, I think, innate and characteristic of these rocks. In one case the low density is due to the alteration of the felspars, which in this sample were mere pseudomorphs. Fragments of them were isolated, and their specific gravity determined with the aid of a heavy liquid and a Westphal's balance. It was too low for any felspar. I do not think, however, that this explanation applies to the rocks generally, for the felspars in them appear fairly fresh. Oligoclase appears to predominate, and the density of this species ranges from 2·65 to 2·67. The low specific gravity of these rocks is due, I think, to the acid character of the felspars; to the fact that they contain inclusions of glass; and to the presence of a glassy base. The mean density of pitchstone is 2·34 and of obsidian 2·40. Glass of low specific gravity seems to be present in sufficient quantity to balance the basic ferro-magnesian silicates, and leave the rock, as a whole, at the density of the dominant felspar contained in them, which in these rocks I would not put higher than 2·65.

The andesites grouped together in the above list are mainly composed (the accessory minerals will be alluded to later) of idiomorphic crystals and microliths of felspar embedded in a base which appears amorphous in ordinary light, but which when revolved between crossed nicols remains dark in some cases, and in others breaks up into cryptocrystalline or into microgranular felsitic material. In one of the first-named cases the glassy base has been converted into yellow palagonite, but in places the original purple-brown coloured glass remains. The glassy base during the later stages of the lava's history exercised a distinctly solvent action on the comparatively basic minerals that had crystallized out from the still fluid magma, for all the original minerals have been more or less corroded by it.

The felspar-microliths vary in numbers very much in different slices. In some the base is crowded with them, but in one or two they are sparse. They do not exhibit in their orientation indications of fluxion except partially, and locally, in their relation to the larger felspars. In all cases they belong to the oligoclase-felspar species. Binary twinning, combined with simultaneous extinction, is common, though, in some cases, more than two macles are to be seen. The high refraction of those with binary twins, as compared with the refraction of the Canada balsam of the slide, shows that they are not orthoclase.

The felspars larger than microliths cannot be classed as felspars of first and second generation, for, as a rule, they dwindle gradually in size from large tabular crystals, or aggregates of crystals, down to the smallest microlith. In short, there is a gradation in the size of the felspars from the largest down to the most minute: this characteristic is found not only in the felspars, but in all the original minerals.

Zonal structure is well seen in all the large phenocrysts; and that this is due to gradual growth is apparent from the fact that the angles of extinction of the different zones vary, and indicate a gradual change in the basicity of the mineral.

The larger felspars are sometimes oligoclase and sometimes andesine, though the former would seem to predominate. Their species were determined partly by the evidence afforded by the angles of extinction measured in suitable cases, and partly by the determination of the specific gravity of isolated fragments.

There can be no question about the species of a considerable number of the crystals, because the simultaneous extinction of twins is not uncommon; and that those which exhibit binary twinning, combined with simultaneous and straight extinction, are not orthoclase, is shown by the fact that, whenever they occur in contact with the Canada balsam of the slide, their refraction is invariably found to be higher than that of the balsam. This method of distinguishing between orthoclase and oligoclase, recommended by M. Michel-Lévy,[1] seems to be a valuable and reliable test.

The large felspars are, generally speaking, fairly fresh, but some are considerably altered. No. 1425 contains some calcite, as a secondary product of decomposition, in the interior of the felspars; and those of No. 1438 contain dusty-looking matter, arranged either in a central core or as a zonal band inside a rim of water-clear felspar. This dusty matter may be microscopic granules of limonite, but it is not magnetite. Fresh felspars, notably those of No. 1424, contain very characteristic glass- and stone-inclusions with fixed gas- or air-bubbles, and inclusions of the base. Others possess liquid inclusions, a few of which contain e x t r e m e l y minute moving bubbles.

Magnetite and apatite appear to be original minerals common to all these rocks. Magnetite is present in all the slices and varies in size from large grains to minute dots; sometimes it has been largely converted into ferric oxide. It occurs as a secondary as well as an original mineral.

Apatite is present in seven out of the nine slides, and it is sometimes very abundant. The contact-action of the acid base has in some few cases corroded the crystals, and in some others has produced a dark 'resorption'-ring. The crystals that exhibit this unusual peculiarity are probably mangan-apatites. The hand-specimens treated with nitric acid reacted strongly for phosphoric acid. Apatite appears to have been one of the first minerals to crystallize out of the magma.

The three specimens which stand at the top of my list (p. 295)

[1] 'Étude sur la Détermination des Feldspaths,' 1894, p. 62.

contain, in addition to the minerals above mentioned, a rhombic amphibole. In transmitted light it is of a rich brown-red colour and is powerfully dichroic, changing from a golden yellow, when the direction of elongation of the crystal is at right angles to the principal section (longer diagonal) of the polarizer, to a rich brown-red, or red-brown, when the direction of elongation is parallel to the longer diagonal of the nicol. The mineral possesses straight extinction, and it appears to be anthophyllite.

Slice No. 1424 contains some very characteristic cross-sections of prisms of this mineral, which show the intersection of the prism-faces and the intersection of the prismatic cross-cleavages. They are quite typical cross-sections of amphibole. The major (+) axis is, as in rhombic amphibole, at right angles to the direction of elongation. Moreover, I isolated fragments of this mineral and determined its specific gravity with the aid of a heavy liquid and Westphal's balance, and found it to be exactly that of anthophyllite: namely, between 3·1 and 3·2.

The anthophyllite appears to be an original mineral in these rocks. Crystals of felspars are caught up in it, and in Pl. XIX, fig. 3, a case is depicted where a large augite has caught up and enclosed a fragmentary-looking crystal of anthophyllite. That the latter is an original inclusion in the augite appears plain, from the fact that contact-action has produced a dark halo round the anthophyllite.

The case represented in Pl. XIX, fig. 4, is an interesting one, and bears directly on the question at issue. The anthophyllite, when it began to crystallize, formed on the lower half of a felspar-microlith. The growth of the felspar in that direction was arrested, but it continued to grow and widen along its upper half where the anthophyllite did not interfere with it. Similar cases of interference between growing crystals of augite and felspar are often seen in basalts; but the case has a special importance in the study of these rocks, as it shows conclusively that the crystallization of the smaller felspars and the anthophyllite was contemporaneous.

Rosenbusch, in his work on rocks,[1] notes that a brown hornblende with an extinction-angle ranging from small to nothing is known to occur in some andesites. In the slices above described the angle of extinction is uniformly *nil*.

In Nos. 1424, 1438, and 1464 all the amphibole consists of anthophyllite; but the first two contain in addition a considerable amount of augite. In transmitted light it is of a somewhat pale brown-green colour, sometimes putting on a purplish tint: it shows no dichroism. A single cleavage predominates, but more or less distinct traces of a cross-cleavage may sometimes be seen. The augites occasionally exhibit crystallographic outlines, but are more frequently allotriomorphic.

The augite-hornblende-andesites, Nos. 1424 & 1438, are remarkable for containing crystals of olivine. Rosenbusch, in his work already referred to, mentions that olivine sometimes occurs in andesites, but one would certainly not expect to meet with this mineral in a

[1] 'Mikroskopische Physiographie der Massigen Gesteine,' 2nd ed. (1887) p. 659.

rock of the intermediate class which inclines towards the acid type. In transmitted light it is of so pale a greenish-white as to be almost colourless. The refraction is high, and the surface is rough and shagreened. Traces of a fine interrupted cleavage are to be seen, and the mineral has straight extinction with reference to this cleavage. It has also the deeper and more irregular cracks so commonly seen in olivine. The form is sometimes roughly idiomorphic, and photographs of two (one from No. 1424 and the other from No. 1438) are reproduced in Pl. XIX, figs. 5 & 6, which show the pointed terminations characteristic of olivine.

Several of these olivines, as in Pl. XIX, fig. 5, have a deposit of the brown-red anthophyllite round a portion of the outer edge of the olivine. Rosenbusch[1] notes the alteration of olivine, beginning with the periphery of the latter mineral, into needles of tremolite, actinolite, and anthophyllite, owing to the mutual influence of the olivine and the adjacent rock-constituents, and states that this is known to occur only in the Archæan rocks. At first sight, the anthophyllite-fringe above described would seem to be a case of alteration similar to that noted by Rosenbusch; but in view of the fact already shown, that the anthophyllite in these rocks is an original congenital mineral, I think it is more probable that the anthophyllite round the margin of the olivines is of the nature of an intergrowth. It does not occur in needles, and so far from these andesites being of Archæan age, there is reason to believe that they are, geologically speaking, comparatively modern. Numerous crystals of anthophyllite occur in these slides, in forms that could not possibly be referred to olivine.

In the next two slides, Nos. 1425 & 1426, ordinary monoclinic hornblende takes the place of anthophyllite. It is of a brownish-green colour—the green element being very distinct; it is strongly dichroic, and the angle of extinction is small. It was evidently one of the first minerals to crystallize out, and it has suffered much from the corrosive action of the more acid magma. Many of the crystals are rounded and corroded, and all have a broad black 'resorption-' margin of magnetite.

The condition of the hornblende in these sections confirms the conclusion arrived at regarding the anthophyllite: namely, that the amphibole in these rocks is an original mineral, and crystallized out before the magma ceased to be fluid.

In Nos. 1430 & 1443 amphibole gives place to mica. In transmitted light the mica varies from a yellow-brown to a greenish brown. It has suffered much, and has been corroded by the solvent action of the liquid magma. It is present in good-sized leaves and packets, and also (No. 1443) in the form of fibrous microliths.

No. 1436 closely resembles the rocks above described in its general characteristics, but it does not contain any amphibole. It is much altered and contains some secondary minerals, such as zoisite and ferric oxide, the latter partly infilling some of the felspars. There is also apparently the remnant of an augite.

[1] 'Microscopical Physiography of Rock-making Minerals,' transl. & abridged by J. P. Iddings, 1888, p. 217.

Felspathic Lavas.

No. 1434.	Sp. gr.=2·751.	From the	Shibian Kotal.
„ 1429.	„ 2·847.	„	Amir Chah.
„ 1416.	„ 2·851.	„	Amir Chah.

These rocks seem to lie intermediate between the andesites proper and the basaltic lavas.

No. 1434 is a light greyish, yellow-ochre-coloured, slaty-looking felsite. It is composed of crystals of oligoclase set in a micro-felsitic base. The felspars look like fragments, and suggest the possibility of the rock being an altered ash; but I think this is probably owing to the partial remelting and deep corrosion of the felspars by the base when liquid. The rock is considerably altered, being dotted over with epidote, which has also formed in some of the felspars.

No. 1429 is a dark, blackish-grey, compact lava. The slice is composed of a matted mass of microliths and idiomorphic phenocrysts of felspar, set in what seems to have been originally a glassy base. The base, together with the major part of the large felspars, has been altered into a structureless chlorite. Opalescent quartz and epidote have been introduced along and adjoining cracks, and the slice is dotted over with colourless epidote, and minute spots of a mineral, opaque in transmitted but white in reflected light, which is probably a leucoxenic variety of sphene. The microliths and small felspars have straight extinction, and their refraction is precisely that of the Canada balsam in which the slice is set. They are probably oligoclase.

No. 1416 is a light grey lava, mottled with crystals of felspar visible to the unaided eye. Under the microscope it is seen to be made up of felspar-phenocrysts and a matted mass of microliths, embedded in a microgranular devitrified base. Some of the phenocrysts are quite rounded, others present more or less perfect crystalline forms. (See Pl. XX, fig. 2.)

The porphyritic felspars are so highly altered that their species cannot be satisfactorily made out. For the most part they appear to possess straight extinction, but it is impossible to say whether this is a property of the original felspar or of the pseudomorphous and extremely feeble birefringent mineral that has more or less replaced it. Two fragments of these felspars yielded respectively specific gravities of 2·840 and 2·735. The refractive index of the latter proved to be 1·557. Taken together, these data point to the felspar being labradorite; but the alteration that the mineral has undergone prevents me from pronouncing a definite opinion as to its identity.

The microliths have straight extinction, but the medium-sized felspar-prisms extinguish obliquely. There is no uniformity in their size or shape. Some are rectangular, some lath-shaped. Some are short and stumpy; others are long and slender. Many of them are ragged and 'unfinished' at their ends, and some have rod-like microprisms projecting from their terminal faces. Some are quite skeletal, and contain inclusions of the base. A few exhibit binary twinning obscurely—none multiple twinning. The microliths are presumably oligoclase.

Basaltic Rocks.

No. 1463. Sp. gr. = 2·828. From Bharab Chah.
,, 1422. ,, 2·888. ,, Amir Chah.

No. 1463 occurs as a dyke $4\frac{1}{2}$ feet wide, running up vertically through the granite of which a hill at Bharab Chah is composed. It is a compact, dark greenish-grey basalt. Under the microscope it is seen to be composed of crystals of augite, felspar, and magnetite. The augites are sometimes club-shaped, but are mostly in very irregular forms. They are much cracked and penetrated by infiltration-canals. The pyroxene exhibits no dichroism, and its double refraction is not strong, showing generally the yellow, and occasionally the red, of Newton's first order. It extinguishes at from 25° to 30° from the cleavage-lines, when only one set is seen. Cross-cleavage is not well developed, but when visible a single bar is seen in converging polarized light.

The felspar-prisms are mostly lath-shaped, and generally show straight extinction. Multiple twinning is not to be seen, but a few show traces of binary macles. The refraction of the felspar is higher than that of the Canada balsam, which shows that they are not orthoclase. The binary twinning and straight extinction seem to indicate that some of the felspars, at any rate, are oligoclase. This is not improbable, as this rock is probably allied to the andesites previously described, and oligoclase is very characteristic of them.

This specimen is highly altered. None of the minerals are at all fresh, and the felspars especially have become very opaque from the formation of secondary granular mineral matter in them. A chloritic-serpentinous mineral, varying in colour from pale green to reddish brown in some cases and yellow-green in others, is very abundant: it is distinctly dichroic. Whether this represents in places a glassy base, or whether it is wholly altered felsitic matter, is difficult to say. The rock would, by many, be called a melaphyre or diabase, but I prefer to name it altered basalt.

No. 1422 is a compact rock of purple-black colour, which is said to be very abundant at Amir Chah. It consists of iron microgranules, set in a base composed of aluminous serpentine.

The iron is in part magnetite and in part limonite. It varies from opaque to translucent, and in colour from a deep brown to a black-brown. It is disseminated through the slice in microgranules and in irregularly-shaped patches, which rarely coalesce into uniform and unbroken masses. It nowhere presents crystalline outlines.

The serpentinous groundmass remains dark when revolved between crossed nicols, but countless fibres and dots of doubly-refracting material, probably chrysotile or kaolin, shine like stars in the Milky Way. In this groundmass, pseudomorphs of felspars, pyroxene, and olivine can be made out, the original shapes of the minerals being outlined by deposits of iron oxide. No trace of twinning can be discerned in the felspars, as none of the original substance of any of the minerals remains, all having been converted into iron oxide and serpentine.

Pieces of the rock ground down to fine powder were digested in hot hydrochloric acid, and yielded a large amount of iron, a considerable amount of magnesia, an appreciable amount of alumina, and a little lime. The residue consisted of quartz with mineral matter caught up in it. This was treated with hydrofluoric and sulphuric acid, and it yielded a little iron, a little lime, and a good deal of magnesia. The residue untouched by the hydrofluoric and sulphuric acids consisted of iron that dissolved in hot nitrohydrochloric acid.

The rock does not attract the magnet, showing how much limonite preponderates over magnetite.

Pumice.

No. 1423. From Amir Chah.
,, 1433. ,, ,, ,,

These are samples of the pumice sprinkled in abundance all over the country around Amir Chah.

No. 1423 is a highly vesicular lava. The remains of felspars are abundant in the slice, but they are all so highly altered that they remain dark between crossed nicols. The slice contains flecks of calcite here and there, and some leucoxene-pseudomorphs after ilmenite.

No. 1433 is also a highly vesicular lava, and is composed of a colourless glass, drawn into fibres and full of air or gas-bubbles round the vesicles. The slice contains some fibres of mica, one or two fragments of hornblende, one or two felspars with straight extinction, and some small flakes of quartz, evidently extraneous fragments. It is dotted over with granules of calcite, and the hand-specimen effervesces strongly with an acid.

Volcanic Ash-beds.

No. 1418.	From	the west side of the great fault.	Sarlat Range.
,, 1427.	,,	Gazi-Chah hills.	
,, 1428.	,,	,, ,,	
,, 1439.	,,	Shibian Kotal.	
,, 1440.	,,	,, ,,	
,, 1441.	,,	,, ,,	
,, 1445.	,,	Gargarok.	
,, 1450.	,,	west side of the great fault.	
,, 1465.	,,	natural monolith, Neza-i-Sultan.	

The above specimens of volcanic ash do not require separate description. They are all fine-grained, almost compact-looking rocks, varying in colour from purple-grey to greenish grey. They are composed of fragments of various kinds of lavas of the intermediate class, fragments of limestones and crystals of felspar. These ashes have been much altered by aqueous agencies, and some of them intensely so. In No. 1418 the interstitial portions have to some extent been converted into a serpentinous product, and in others epidote and calcite have been found as secondary products.

No. 1427 was difficult to interpret, as the fragments were all of very much the same kind of lava; but on having a thicker slice made, and after digestion in hot hydrochloric acid, the distinction between the different lavas could be well seen, and the fragmentary character of the rock came out clearly.

Among the lapilli are fragments of a dark basic lava, but I have not observed any of olivine-basalt.

No. 1465, from the natural monolith of Neza-i-Sultan, is a fine ash made up of fragments of trachyte-looking andesites, so like each other that it is difficult to distinguish the ash from a lava.

Holocrystalline Rocks.

No. 1462. Biotite-hornblende-granite.

The hill at Bharab Chah previously mentioned (p. 301) is composed of this granite. The slice taken from my hand-specimen contains orthoclase, oligoclase, quartz, apatite, biotite, and a little hornblende, zircon, and sphene.

The hornblende is brown-green in transmitted light. It is not by any means as plentiful as the biotite, which is a good deal decomposed and here and there altered into chlorite. Apatite is rather abundant. The quartz deeply corrodes the felspars, hornblendes, and micas. (See Pl. XX, figs. 5 & 6.)

The solvent action of the acid matrix on the more basic materials that had previously crystallized out seems to be a rather frequent feature in granites, and it appears to mark that stage in the history of the rock when the granite, full of crystals formed under plutonic conditions, was moved upwards into place, and partial re-solution commenced from relief of pressure and consequent lowering of the point of fusion and from other causes. The corrosion of phenocrysts by the matrix in the case of quartz-porphyries has been often described; but in the case of granites this partial re-solution of the first-formed minerals does not appear to have been noticed by previous observers.

Liquid inclusions are common in the quartz, but no moving bubbles of any size are to be seen.

No. 1421. Quartz-syenite. Sp. gr. = 2·750.

From the west side of the great fault at Chili Katch in the Sarlat Range.

The hand-specimen exhibits a somewhat obscure parallelism of structure which is not noticeable under the microscope. The slice contains oligoclase, orthoclase, quartz, hornblende, biotite, apatite, sphene, and magnetite, with some epidote, calcite, and chlorite, as secondary products of decomposition.

Oligoclase is the most abundant mineral. The quartz and orthoclase are present in about equal proportions, but each taken separately is very subordinate to the plagioclase. The latter, by its extinctions and specific gravity, is seen to be oligoclase.

Both felspars are fairly fresh, and as a rule are allotriomorphic; but there are two crystals enclosed in biotite which possess crystallographic outlines.

In transmitted light the hornblende is of a green to brownish-green, and the biotite of a greenish to reddish-brown colour. The biotite is altered in places to chlorite. Epidote occurs, intergrown with chlorite in elongated granules running in the direction of the biotite and chlorite cleavage-planes. The hornblende and biotite are deeply corroded by both the quartz and the plagioclase. (See Pl. XX, figs. 3 & 4.)

Apatite is abundant, and occurs in the biotite, felspar, and quartz, while the magnetite, as one so often sees in igneous rocks, is often formed upon the apatite.

Sphene is somewhat abundant, and is in good-sized grains; it rarely shows any approximation to crystalline shape. It is distinctly dichroic, and exhibits a tendency to a fibrous habit. It has the prism-cleavage strongly developed in one direction, with traces of another cleavage crossing it at an angle of 111° to 117°.

The quartz contains liquid cavities with small moving bubbles and fine needle-shaped crystals which are probably rutile.

Sedimentary Rocks.

No. 1410.	From	Amir Chah.
„ 1411.	„	„
„ 1412.	„	„
„ 1414.	„	„
„ 1415.	„	„
„ 1449.	„	the east side of the great fault.
„ 1453.	„	the west side of the great fault.

The first five samples are apparently very fine-grained sedimentary rocks of the character of indurated muds. They are porcellanous-looking, and not unlike felsites. They do not exhibit cleavage or lamination. They are brittle, and fuse at the edges, but the fused edge is not magnetic.

The groundmass of some felsites and porphyries resembles the structure of these rocks as seen under the microscope; but these samples do not contain any embedded crystals, or other indication of igneous structure.

No. 1449 is a glossy, silty shale, with much of the aspect of a slate. Under the microscope it is seen to be extremely fine-grained.

No. 1453 is a fine-grained, indurated silt, formed of flaky silica deeply impregnated and stained a reddish-brown colour with limonite. The groundmass contains a number of round, oval, and angular grains and elongated fibres of calcite scattered through it. In some cases opal has replaced the calcite. The quartz is in irregularly-shaped flakes.

The rock contains countless vein-like cracks, which are wide at one end and branch out freely until they dwindle down into channels of hair-like fineness and disappear. These cracks anastomose, bifurcate, cross each other at various angles, and sometimes disappear to reappear farther on. They are all filled with calcite. In some of the hand-specimens not sliced, and not enumerated above, the calcite in quantity at least equals the silt with which it appears to be inextricably mixed up.

One of the sub-rounded grains of opal is traversed by two calcite-filled cracks, whence it would appear that the rounded bodies composed of calcite and opal were original components of the silt, and were not introduced by infiltration when the calcite-veins were formed.

The silty part of the rock, from its appearance under the microscope, I should say was probably formed in the sea at or near the foot of a coral reef. Whether the cracking was caused by shrinkage on consolidation, or whether the rock is a fault-breccia, cannot be determined from the examination of hand-specimens alone.

In conclusion, I proceed to enumerate briefly various rocks and ores given to me for determination. The most convenient plan will, I think, be to group them under the localities in which they were found.

Saindak Mountains.

(1) Galena, or sulphide of lead. This appears to be fairly pure.

(2) Silicate of copper (chrysocolla).

(3) Calcareous epidote-rock. It is composed principally of epidote, calcite, and iron. It is probably the product of the alteration of a volcanic or igneous rock.

(4) Reddle, or earthy hydrated ferric oxide, containing numerous crystals of selenite, lumps of gypsum, and small crystals of anthophyllite.

(5) Sand. This fine-grained, somewhat earthy-looking sand was found, on examination under the microscope, supplemented by some chemical tests, to be composed of minute fragments of the following minerals and rocks:—quartz, calcite, dolomite, carbonate of iron, garnet, tourmaline, muscovite, a reddish-brown mica, orthoclase- and plagioclase-felspars, and fragments of siliceous rocks. The calcite and dolomite were probably derived from limestone and magnesian-limestone rocks, near at hand.

Koh-i-Sultan.

(1) Yellow ochre, used by the natives as a dye. This rock is composed of limonite, with some sulphide of iron and a good deal of silica as impurities.

(2) Red ochre. The red ochre contains many crystals of gypsum and numerous minute crystals of anthophyllite.

(3) Sulphur, with some yellow limonite as an impurity.

Koh-i-Malik Siah.

(1) Red jasper interspersed with white quartz and chalcedony.
(2) Epidote-rock, composed of epidote- and quartz-crystals, the former predominating. The quartz contains inclusions of ferric oxide.
(3) Chrysocolla, in a matrix composed principally of silica, with fragments of mica and other minerals.
(4) Galena or sulphide of lead.
(5) Small fragments of basic igneous rocks.
(6) Fragments of fine-grained biotite-granite.

Malik Dokhand.

Crystalline granular gypsum (alabaster).

Malik Ainak.

Selenite.

EXPLANATION OF PLATES.

Plate XVIII.

Sketch-map of the Baluchistan-Afghan frontier, on the scale of $\frac{1}{3,000,000}$ or 47·3 miles=1 inch.

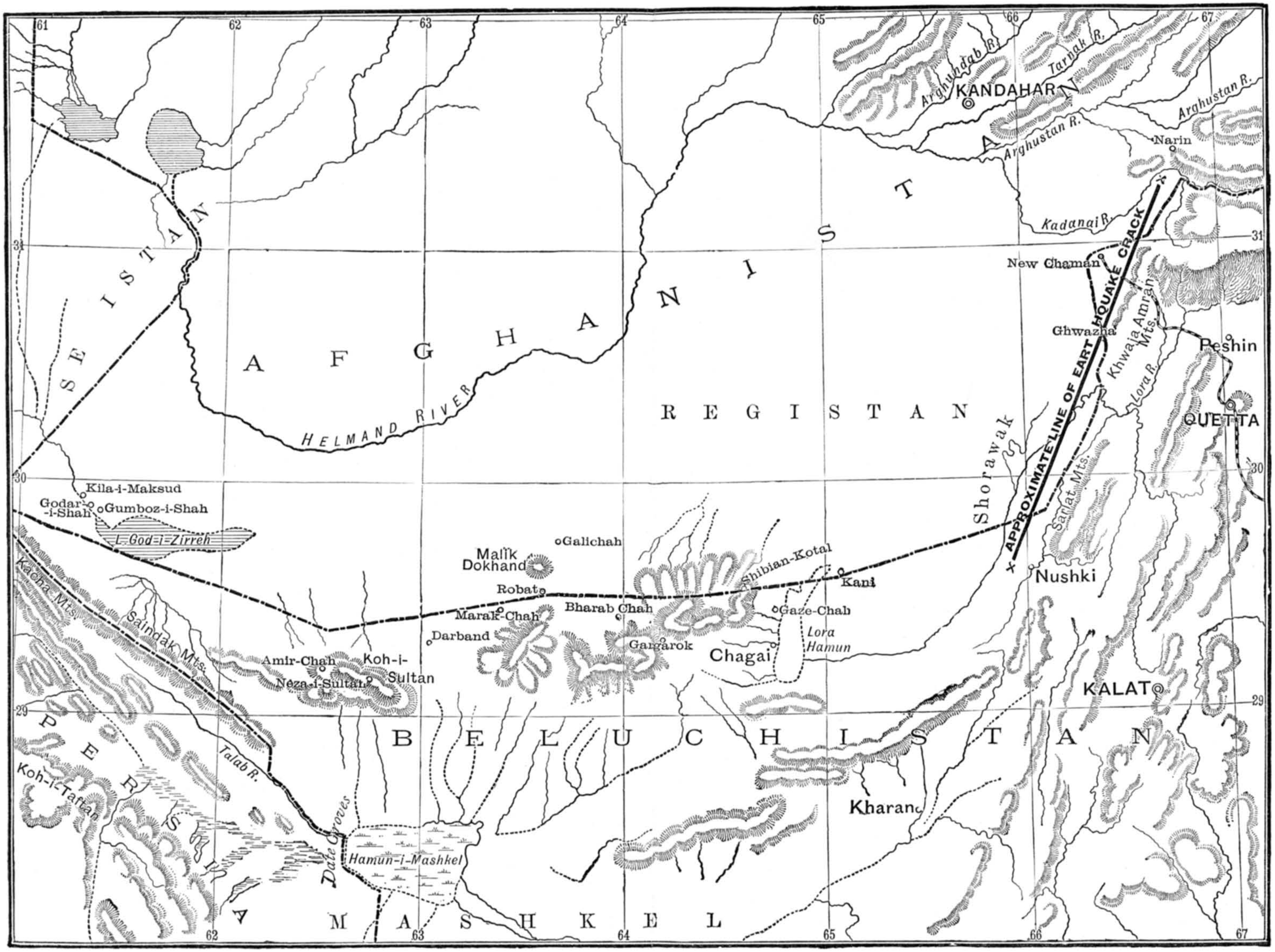
Plate XIX.

a=biotite. *c d e*=quartz. *f*=anthophyllite. *h*=hornblende. *o*=olivine.

Fig. 1. General view of augite-hornblende-andesite. No. 1424.
2. Section of the anthophyllite seen in fig. 1 (enlarged).
3. Brown-red anthophyllite (with contact-halo) enclosed in an aggregate of pyroxene-grains and prisms, the granular complex having the form of a crystal. See p. 298.
4. Contemporaneous crystallization of plagioclase and brown-red anthophyllite. See p. 298.
5. Olivine, with deposit of brown-red anthophyllite round its margin; enlarged from No. 1424 (fig. 1). See p. 299.
6. General view of augite-hornblende-andesite, No. 1438, showing olivine. See p. 299.

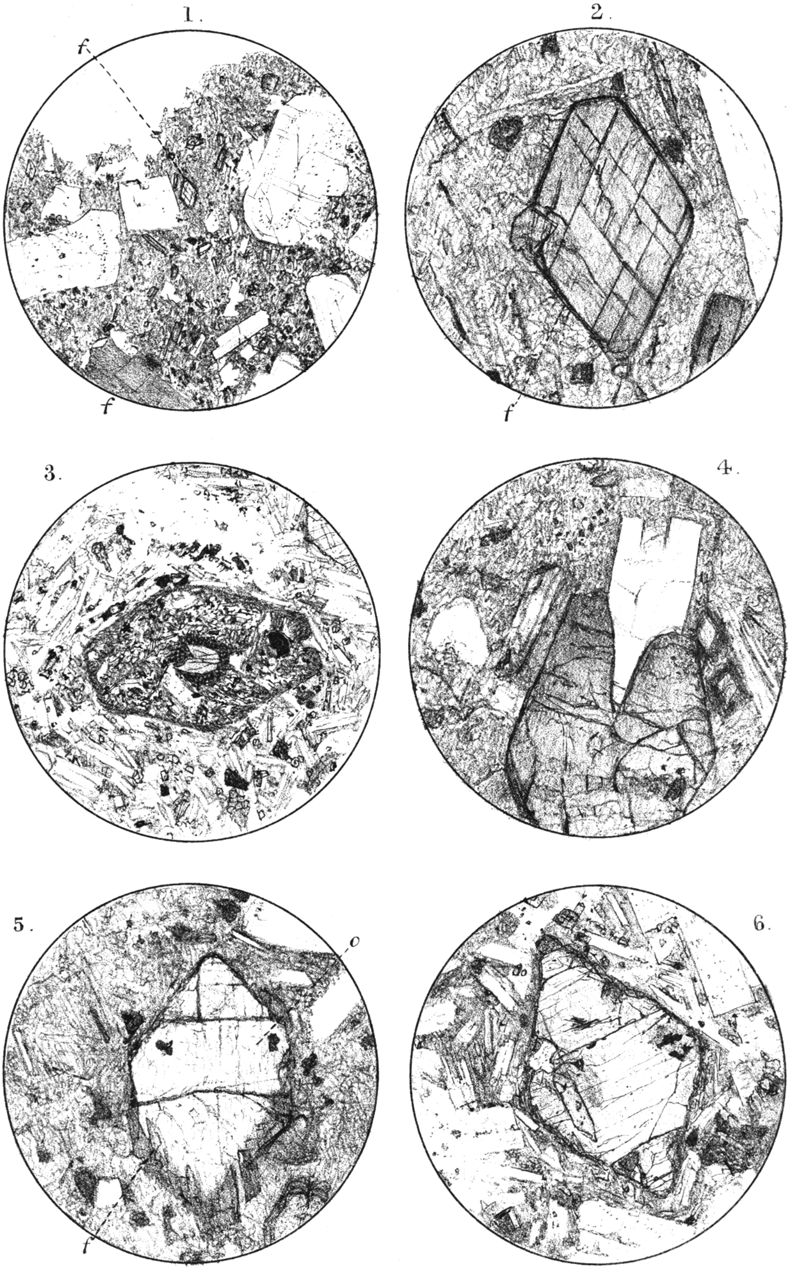
Plate XX.

Fig. 1. Augite-hornblende-andesite. Another portion of No. 1438 (Pl. XIX, fig. 6).
2. Felspathic lava. No. 1416. See p. 300.
3. Quartz-syenite. Corrosion of hornblende by quartz. Between *d* and *h* and between *c* and *h* the quartz has eaten deeply into the hornblende all round. At *d* it has forced its way into cleavage-cracks; while at *b* the process has proceeded further, and a piece has been split off from the main crystal of hornblende. See p. 304.
4. Quartz-syenite. Corrosion of biotite by quartz. The quartz has cut deeply into the biotite all round its margin. Between *b* and *d* the quartz by its solvent action has nearly severed the biotite into two portions. This can be seen with the aid of a pocket-lens.
5. Hornblende-biotite-granite. Corrosion of hornblende and biotite by quartz. The biotite has at *d* been cut in half and corroded all round by the quartz. Seven distinct bays of corrosion can be counted.
6. Hornblende-biotite-granite. Corrosion of hornblende by quartz. Bays of corrosion are to be seen all round the hornblende. See p. 303.



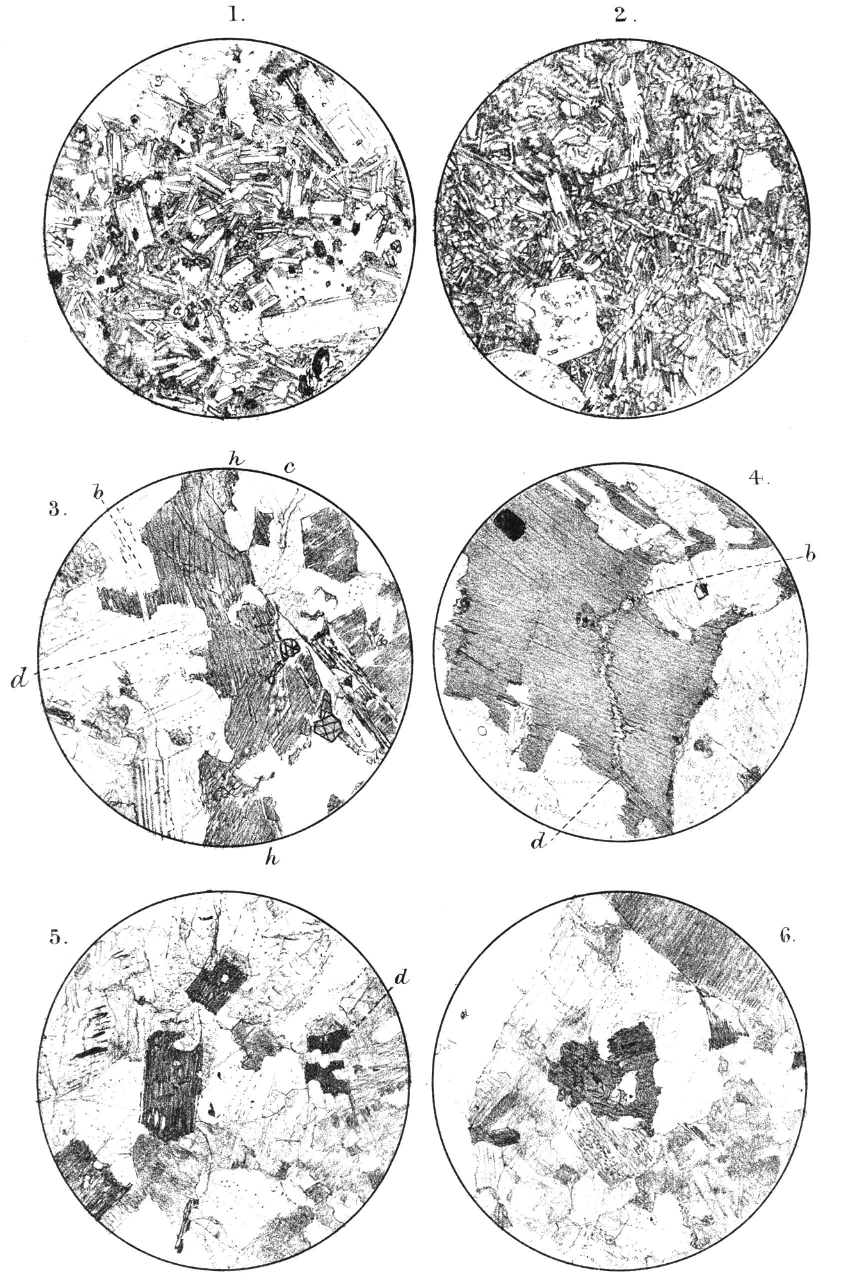
SKETCH-MAP OF THE BALUCHISTAN-AFGHAN FRONTIER.

[Scale: $\frac{1}{3,000,000}$ or 47·3 miles = 1 inch.]



F.H. Michael del. et lith. Mintern Bros. imp.

ROCKS FROM THE BALUCHISTAN-AFGHAN FRONTIER



F. H. Michael del. et lith.

Mintern Bros. imp.

ROCKS FROM THE BALUCHISTAN-AFGHAN FRONTIER.

Discussion.

The President commented on the advantage of heredity in taste, and on the excellent observations made by Capt. McMahon, as well as the valuable information which he had brought back. Concerning the corrosion of basic minerals by silica, he observed that silica might be truly a corrosive mineral, but hitherto the idea had been that the basic mineral had decomposed *in situ*, and that the silica had filled up the hollows and cracks resulting from this decomposition. It was perhaps a general mistake to suppose that faults always run along valleys. Faults may often be indicated by valleys, but in many parts of the country they run across the ridges as well.

Mr. Griesbach considered the paper just read a valuable contribution to our knowledge of Baluchistan. But, having spent some years in that part of Asia himself, he wished to point out that there is abundant evidence to show that the Pliocene deposits which are seen in Shorawak and the neighbouring Registan have not been laid down in a lake-basin, but are chiefly of a fluviatile nature. The range of hills, of which the northern portion is known as the Koh-i-Khwaja Amran, is composed mostly of rocks belonging to the later Cretaceous and Nummulitic formations, with great masses of intrusive igneous rocks. Of these latter the peak of Khwaja Amran is the nucleus, and represents a remarkable series of acid rocks, followed by 'Nachschübe' of basic rocks. The long fault-line or 'earthquake-crack' does not, however, mark the boundary-line between sedimentary and igneous rocks in that part of the world. Quite close to the line of fault, west of Chaman, Hippuritic Limestone may be seen *in situ*; and rocks of Cretaceous and Tertiary age form great mountain-chains north-east of Chaman and west of the 'earthquake-crack.' It is questioned whether there is any foundation of truth for the rumoured existence of actual recent craters in the desert west of the Koh-i-Sultan. Nearly all the ridges and peaks of volcanic rocks in this Baluchi desert are due to their having been laid bare by the decomposition and removal of the softer sedimentary strata into which they have been intruded.

Dr. W. T. Blanford congratulated Capt. McMahon on the series of interesting observations brought before the Society. He noticed the great prevalence of Tertiary and Cretaceous rocks throughout the wide area extending from the Indus to Mesopotamia. The volcanic rocks of Eastern Baluchistan, like the Deccan traps of India, appear to be of Cretaceous and Lower Eocene age; but the igneous formations near the Baluchistan and Persian frontier must be, in part at all events, of far more recent origin, some of the cones of loose materials seen by the speaker between Bampur and Bam having undergone no change through denudation. Possibly the great volcanic eruptions of this area had some connexion with the lateral compression of the rocks in Southern Baluchistan, Tertiary rocks being found vertical or nearly so, from near the shores of the Indian Ocean to Jalk, about 150 miles across the strike. The remarkable pinnacles of agglomerate noticed by Capt. McMahon were difficult to explain.

The Rev. EDWIN HILL said that the paper teemed with points of interest. The pinnacle shown resembled a magnified earth-pillar. Was the water which disappeared in the sand ultimately evaporated? That the great fault in its course disregarded mountains seemed an indication of its depth.

Prof. MILNE made special reference to the fault which Capt. McMahon had described, and compared it with a fault which in 1891 had been formed in Japan. The time at which the Indian fault had been created was not known; but, from earthquakes which from time to time originated along its length, it was clear that the forces which had crushed together and uptilted the strata in this region were not yet extinct. One of the most striking phenomena which accompanied the formation of the Japan fault was the permanent compression of the land in its vicinity. River-beds were reduced in width to an extent of 1 or 2 per cent., while certain plots of ground had their sides shortened in the ratio of from 10 to 7.

Mr. CADELL said that the remarkable peaks described by the Author, which were said to be of agglomerate, might be explained on the supposition that these were the necks of old volcanoes, the upper parts of which, together with the surrounding strata, had been denuded away.

Prof. JUDD called attention to the great steep-sided masses of volcanic agglomerate which rise up in the midst of the town of Le Puy in Central France, and are crowned by the Cathedral and the church of St. Michel. These seem comparable, though of smaller dimensions, with the great columnar masses described by Capt. McMahon. There is no doubt that the masses of Le Puy are relics left by denudation of a mass of volcanic agglomerate that once filled the whole valley. The reason why these masses have escaped removal by denudation is probably not because they are 'volcanic rocks,' but because these materials have been consolidated by the action of siliceous, calcareous, or chalybeate springs.

Dr. H. WOODWARD and Mr. W. W. WATTS also spoke.

Capt. McMAHON observed, with reference to what Mr. Hill had said about the way in which the drainage from the mountains had disappeared when intercepted by the sand, that, although it disappears below the surface, water can be found in places at a very slight depth below the sand, sometimes only a foot or two below the surface. The great difficulty is to find those spots, as the configuration of the country does not guide one so much in finding it as in the case of sub-surface water under other conditions.

Then with reference to the supposition that the pillar of Neza-i-Sultan may be the neck of some old volcano, he pointed out that there are numerous peaks of grotesque shape in the near neighbourhood of the Neza-i-Sultan, all apparently made of the same rock and all probably reduced to their present curious shapes by the same natural process. If the Neza-i-Sultan is to be considered the neck of a volcano, these other peaks should, by the same process of reasoning, be also considered to be necks of old volcanoes. But their number and proximity to each other would tend to throw doubt on the correctness of that supposition.

Gen. McMahon, in reply to Mr. Griesbach, remarked that the Authors had not attempted to determine the precise age of the lavas, as the fossils brought home by one of them were still under examination in the Natural History Museum; but the volcanic eruptions had evidently extended over a considerable period. The Neza-i-Sultan (Spear of Soliman) contained fragments of the peculiar augite-hornblende-andesite identical with the lava found *in situ* elsewhere, showing that the latter must have consolidated before the beds of agglomerate were formed. The subsequent erosion of hundreds of feet of agglomerate, moreover, indicated the lapse of a long period since the formation of these beds.

With reference to Mr. Hill's remarks, he suggested that a considerable amount of water might be retained near the surface of sand-hills by capillary attraction, and instanced the growth of good autumn crops on the borders of Bikanir, on hills that seemed to the eye pure drifted sand.