
AFGHAN AND PERSIAN FIELD NOTES.

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Afghan and Persian Field notes, by C. L. GRIESBACH, F.G.S., Deputy Superintendent, Geological Survey of India, on duty with the Afghan Boundary Commission.

Introduction.—Since writing my last short report on the geology of the Herat province,¹ I have been moving about the Herat valley and Eastern Khorassan, whenever I could obtain permission to do so from Her Majesty's Commissioner.

From Bala Murghab, where our Commission remained during the extreme cold weather of last winter, we moved about the middle of February last, marching *vid* Kila Maúr and Chaman-i-Béd to Gulrán. There General Sir Peter Lumsden, G.C.B., gave me permission to examine some of the ranges in Eastern Khorassan, and accordingly I spent some time in studying the rocks of the Bezd and the Estoí ranges, rejoining the Commission at Tirpúl. From there, I made a short trip to the Doshakh range, and afterwards went for some time to the hills north of Herat. Later on an opportunity occurred to visit the Davéndar range east of Herat, and the march of the Commission to Thagan Robot gave me an opportunity of revisiting the Turmust range. In August last Colonel Sir West Ridgeway, K.C.S.I., gave me permission to go again to Eastern Khorassan, where I remained over two months, extending my excursions as far west as the turquoise mines of the Nishapur district.

I have already given a short sketch of the geological structure of the Herat province as far as it has come under my own observation. I have a little to add to this and some to modify. In publishing these notes now, it must be clearly understood that many of the observations contained in them may hereafter have to be modified when the material brought together will have been worked out and compared with collections from other parts of the world.

The following formations are represented in the Herat valley and Khorassan :—

Recent and aerial.	Alluvial deposits, fans, blown sand.	Igneous rocks.
POST-TERTIARY	"Loess" beds, with mammalian bones, of Badghis. Red and white clays with sandstone and gypsum deposits. Conglomerate and sandstone } Tirpúl beds. Plant shales	
MIOCENE	Calcareous sandstone and clays, with <i>Ostrea multicostrata</i> Desh. in Badghis and Khaf. Conglomerate and sandstone of Firaiman near Mashhad.	
Eocene	Grey shaly limestone with Brachiopods. Coral limestone with nummulites. Grey shales and limestone with nummulites.	Rhyolites and trachytes.

¹ Rec. Geol. Surv. of India, Vol. XVIII, Part I, page 57.

Recent and aerial.	Alluvial deposits, fans, blown sand.	Igneous rocks.
CRETACEOUS	Upper { Coral limestone with Hippurites. <i>Inoceramus crispus</i> , Mant., zone. Light-coloured marls. Lower { Dark shales. Trigonia limestone.	Basaltic rocks. Syenitic granite.
PLANT-BEARING SYSTEM. Jurassic and rhætic Trias and permian. Talcchirs?	Red grit group; marine limestone with Brachiopods; Paropamisus, Estoi range, &c. Sandstone with marine fossils and Gondwana plants, Gaukharchang pass, &c., &c. Marine limestone, — Kelat-i-Nadri section. Conglomerates, Brachiopod limestone, sandstone, green shales, thin leafy coal and plant-remains. Kholi Biaz section, &c. Palezkar beds.	Melaphyre and great masses of felsite porphyry. Melaphyre.
CARBONIFEROUS	Massive dark limestone and sandstone with many fossils; Davéndar range, &c., &c.	
OLDER PALÆOZOIC	Limestone and calcareous sandstone; fossils; Dehrud pass.	Trap.

The hill ranges of the Herat province and Eastern Khorassan are all structurally connected, and form long and generally parallel lines of anticlinal folds, which nearly all show much the same succession of beds. The intervening wide troughs of the valleys are filled by tertiary and later deposits. By far the largest share in the structure of these ranges belongs to the beds of the plant-bearing (permotrias and jurassic formations) and to the cretaceous systems. The carboniferous and older palæozoic rocks I only met in a few sections.

Palæozoic rocks, carboniferous and older palæozoic formations.—I found rocks belonging to these systems in the Davéndar and the Doshakh ranges in the Herat province, and in the Bizd and Binalut ranges of Khorassan.

The most complete section of palæozoic rocks I have yet met with in Khorassan, is the one between the villages of Dehrúd and Gulistán on each side of the Dehrúd pass, which crosses the Binalut range south-west of Mashhad. The structure of the range is that of an anticlinal fold, in some places showing inversion and much disturbance of the strata by crushing. Igneous rocks, too, obscure a great deal the actual succession. The carboniferous and older rocks are seen between the village of Dehrúd (4,800') and the top of the pass (8,750').

Lower carboniferous or devonian, Dehrúd pass.—The oldest rock *in situ* appears

to be a calcareous sandstone of dark grey to purple colour, with an indurated limestone which contains some few fossils, amongst which a *Productus* and *Orthis* (?) seem the commonest forms. The beds dip to the north about 35° to 40° , and are conformably overlaid by *Productus*-limestone of the carboniferous system both on the north and south side of the pass, and the latter by hardened greenish-grey shales and interstratified trap (melaphyre).

Binalut range.—I crossed afterwards the Binalut range further to the north-west, from Madán to Chinaran, but the route proved more or less useless to me, as it winds in and out of a wide depression in the range, along which nothing older than cretaceous rocks are exposed.

Yaktán range.—In a line south-east of the Binalut range is a lofty chain of hills, which on our old maps is named the Yaktán range, a name which seems unknown in that part of Persia. The high peak at the south-east termination of the chain is called the Bezd hill. When I visited it in March, I crossed it twice, but it was still thickly covered with snow, and consequently I had to keep near the lower slopes and the passes, where little of the rocks in situ is found. I was however able to make out the structure of the range, which is similar to the Binalut range, inasmuch as it is formed of a high anticlinal fold of carboniferous rocks, flanked by the permo-triassic plant-bearing series. The carboniferous rocks consist of solid grey (mostly very dark) limestones in beds of one to two feet thick containing many characteristic carboniferous fossils, corals and Brachiopods. Iron pyrites and small nests of antimony are found in many places in the range; the latter is extracted near Rawand and used by the natives. The plant-bearing series, consisting of green and grey shales with sandstone and conglomerate, appears to rest quite conformable on the older rocks.

Doshakh range.—Continuing the strike of the Yaktán range, one reaches the Doshakh peak, on whose north flank I found again carboniferous rocks. The Doshakh range assumes a more west-east to north-east strike, and is in a line with the Davéndar range east of Herat. The north flank of both ranges consist of carboniferous rocks overlaid by the plant-bearing series, and the whole appears to have formed an anticlinal fold, the southern half of which has subsided along a line of fault, which has now brought cretaceous limestones in close and abrupt contact with the palæozoic rocks. This feature is well seen at the north foot of the Doshakh peak itself and in the hills north of Pahri, where hippuritic limestone is faulted against carboniferous limestone with *Producti*, &c. It will thus be seen that the structure of these four ranges is precisely the same, and that they must therefore be considered as belonging to the same system. The Doshakh, Yaktán and Binalut ranges form part of the great Central Asian watershed, and it would have been of the highest importance to follow up the continuation of this line to the east into the ranges which form the upper Hari Rud valley; it is a matter of regret to me that I was not allowed to avail myself of the opportunity offered by the presence in this part of the world of a mission composed of British officers, to carry out my researches to a legitimate end.

The minor ridges on the north side of the Doshakh range, including the Robot-i-Pai peak, are composed mainly of a great thickness of carboniferous beds which have an average dip to the north-west.

I ascended the stream which flows from the foot of the Doshakh peak more or less in a north-westerly direction and which irrigates a considerable extent of land near the village of Kashmarú. I found in descending order :—

4. Near Kashmarú hard reddish-grey sandstone, somewhat resembling the Chunar (Vindhyan) sandstones; regular flaggy beds, weathering dark-purple and black, and then resembling igneous rock from a distance. Dip 40° north-west.

3. Grey splintery and hard shales with ferruginous partings and irregular beds of hard dark limestone. No fossils. Several hundred feet thickness, weathers greenish-grey with brown ferruginous spots. Jointed; dip 50° north-west.

2. Impure earthy limestone of dark colour, overlaid by hard grey calcareous sandstone in thick beds. Dip 70° north-west. The limestone contains many fossils, mostly Brachiopods, *Athyris roissyi*, *Productus* sp. &c.

1. Near the Doshakh ziarat. Black or dark-grey very friable shales, alternating with ferruginous impure limestone breaking into jointed fragments; the limestone weathers a brown rusty colour. A few Brachiopod remains, badly preserved. Dip 60° north-west-by-north.

The beds of this series are here, near the foot of the Doshakh peak, faulted against the upper cretaceous limestone, which composes the peak itself.

Along the line of fault, which is nearly from east to west, the Zinjatak valley and pass has been scooped out by denudation. Some igneous rocks (melaphyres) have protruded along the fault, and have greatly obscured the actual contact of the palæozoic with the cretaceous series.

Chillingkhak pass.—The pass over which the road from Pahre to Zindijan leads, and which seems known as the Chillingkhak, exposes a similar section to the above. A few miles north of Pahre the cretaceous series abruptly ends, and the fault already noticed at the Doshakh brings the carboniferous rocks in close contact with the hippuritic limestone of the Pahre hills. The carboniferous system consists here of a great thickness (probably 2,000 feet) of hard dark-grey limestones, sandstones and splintery calcareous shales with many traces of *Producti*, *Fenestella*, &c. The beds dip to the north, at 30° to 40°, below the recent fan deposits of the Hari Rud valley.

Robat-i-Pai, in the Doshakh range.—A ravine runs in a northerly direction through the spurs which jut out from the group of high peaks known as the Robat-i-Pai. At the head of the ravine is the ancient and celebrated shrine of the "Sacred feet." I may here mention that the depressions on the waterworn sides of the ravine, which (with a little artificial help perhaps) resemble somewhat the shape of gigantic human foot-marks, are nothing else but water-worn hollows in the rock, of the same nature as are the well-known pot-holes. Some years ago a deadly strife originated when some devotees of Mashhad nearly succeeded in carrying off these sacred marks. Several had already been removed by carefully under-cutting and chipping off of the block on which the marks existed, when the perpetrators of the deed were caught in the act,—and of course met their reward. The entire mass of the Robat-i-Pai peaks consists of thick even beds of hard dark-blue limestone with calcspar veins, with some hard grey sandstone, both of which contain many carboniferous fossils. I recognised amongst them *Productus semireticulatus*, *Athyris roissyi*, *Fenestella*, and other carboniferous

fossils. The beds dip 50° to 75° north, below the recent deposits of the Hari Rud valley.

Davéndar range.—The Davéndar range consists of the main ridge, rising to over 11,000 feet in height in one or two peaks, with outer parallel ridges, the whole forming an anticlinal arch, the lowest beds of which are found not in the main range but in the auxiliary range north of the Davéndar, running parallel with the latter, and in which the Sang-i-Ajal and Kholi Biaz are situated.

I crossed this outer range between Jaúzá and Naorozabad near the Kholi Biaz hill, and found the latter to consist of carboniferous strata, represented by hard, dark, splintery limestone, containing many *Producti*, *Fenestellæ*, *Crinoids*, &c., characteristic of the carboniferous limestone of the Himalaya. Not much of these beds is exposed; both flanks of the Kholi Biaz, with the Davéndar range to the south of it, consisting of younger strata, belonging to the plant-bearing series (permo-trias) which I shall describe below.

Igneous rocks of the older palæozoic.—Igneous rocks are found in the neighbourhood of all the carboniferous localities which I described, but they belong most probably to the upper jurassic epoch, during which enormous outpourings of melaphyre took place. Only in the carboniferous series of the Dehrúd pass of the Binalut range have I found trap apparently interstratified with *Productus*-limestone.

The permo-trias and jurassic formations.—Towards the close of the carboniferous period a change of physical conditions seems to have occurred in the entire Central Asian area. The beds which rest in all the sections of the Herat province and Khorassan upon the upper carboniferous rocks, consist of deposits such as are formed near a coast line and near the estuaries of great rivers, namely conglomerates, sandstones and shales, which not only contain marine fossils but also plant-remains. In several sections which I examined I found great thicknesses of plant-bearing sandstones, probably deposited near or in the estuaries of rivers, alternating with irregular deposits of massive limestones containing many marine fossils. I believe therefore that the present watershed of the Binalut-Yaktán-Doshakh ranges, south of which I have not found any beds of this plant-bearing series, also marks more or less the old permo-trias coast line.

From the observations of Blanford,¹ Grewingk,² H. v. Abich,³ and others, it appears certain that the same beds occupy large areas in the Elburz range, and in the Armenian provinces of Asia Minor. From Mushketoff's researches in Central Asia it also appears that the same group of strata are found over a large area in Russian Turkomania, near Tashkend, Samarkand, &c.

I found beds belonging to the plant-bearing system on the flanks of the Binalut, the Yaktán, Doshakh and Davéndar ranges, and the Paropamisus, Estoi and Jam ranges are almost entirely made up of rocks belonging to the series. It would be of the highest importance to trace these littoral formations eastwards until a junction could be effected with the Himalayan marine beds of the same age.

¹ East Persia, Vol. II, by W. T. Blanford. London, 1876.

² Grewingk : die geogn. und orogr. Verhältn. d. nordl. Persiens, 1853.

³ Vergl. geogn. Grundzüge, &c.

The system is capable of being divided into the following groups :—

Overlying Cretaceous beds.	
TITHONIAN . . .	Light-coloured sandstones and grits with plants; marine beds with fossils.
UPPER JURASSIC . . .	Red grit group.
LOWER JURASSIC AND LIAS . . .	<div style="display: flex; align-items: center;"> { <div> <p>Marine limestone.</p> <p>Green sandstone with Goudwana plants.</p> <p>Limestone with Brachiopods.</p> </div> </div>
RHETIC TRIAS AND PER- MIAN . . .	<div style="display: flex; align-items: center;"> { <div> <p>Limestone with Brachiopods.</p> <p>Sandstones, conglomerates and green plant shales.</p> </div> </div>

Underlying Carboniferous limestone.

1. *The plant-bearing system in Afghanistan.*

In describing the carboniferous of the Davéndar I have mentioned that the auxiliary range north of and parallel to the Davéndar is partly composed (near the Kholi Biaz and Sang-i-Ajal) of carboniferous limestone. This is overlaid on each side by younger rocks, belonging to the plant-bearing series, and by great outbursts of igneous rocks (mostly melaphyres) belonging to the upper jurassic group.

The section on the north slope of the pass between the Sang-i-Ajal and Kholi Biaz is in natural order and very clear. It is in descending order.

14. Red grit group with igneous rocks. From about 4 to 5 miles south of Naorozabad, extending over the greater part of the valley of the Kurukh stream towards the north, red grits with purple and greenish conglomerate, volcanic breccia and tufa, and a dark trap rock are in situ, deeply eroded into ravines by the streams draining into the Kurukh river. The dip is variable, but on the south side of the valley is chiefly to the north and north-west.

13. Sandstone and hard flinty limestone, alternating with red grit beds,—dip about 30°, west to north-west.

12. Red sandstone and grit with grey sandstone, entirely composed of material derived from the older igneous rocks.

11. Limestone breccia and conglomerate, with limestone beds (traces of fossils). The fragments of the breccia are chiefly made up of carboniferous rocks and trap.

10. Great thickness of greenish-grey, very friable shales, with traces of plants.

9. Soft sandstone bed, a few feet thick, of olive green colour, enclosing reed stems; with irregular thin-bedded shaly sandstone, containing *Vertebraria* (?)

8. *A thin coal-bed*,—about 1 inch in thickness.

7. Gritty sandstone with pebbles, chiefly of limestone.

6. Green shales interstratified with sandstone.
5. Green sandy micaceous shales, with coaly particles and some plant impressions.
4. Thin bed of greenish-grey fine grit, or coarse sandstone, weathers brown.
3. Grit, with limestone fragments of the carboniferous group, containing fossils.

2. Hard altered sandstone of felsitic character with shaly beds (phyllite), of considerable thickness, alternating with gritty beds.

1. Hard dark-grey to black limestone in regular beds, containing in the upper strata numerous crinoidal stems and fragments; also many Brachiopod remains; *carboniferous (upper)*.

The Sang-i-Ajal and Kholi Biaz hills are entirely made up of beds belonging to the carboniferous group, dipping about 65° north, on the north slope of the Kholi Biaz, and nearly vertical at the southern base of the pass leading over that range. The plant-bearing beds resting on the carboniferous group are quite conformable to the latter, and the dip gradually lessens towards the centre of the Kurukh valley.

The southern portion of the Davéndar section differs in some respects from the Kholi Biaz succession. Descending from Jauza Killah to the pass just described, I observed the following beds,—in descending order:—

7. Igneous rocks (melaphyre) associated with the red grit group; dip about 30 to 40° south to south-west. The red grit group forms all the lower spurs which extend from the Jauza H. T. S. towards the junction of the Kurukh and Herat rivers, and may be observed to form also the Jauza hill with the lower slopes of it. The dip is rather rolling, but in the main to the south-west. Thick red sandstone with grit and conglomerates, and a few thin beds of micaceous shales (red) are interstratified and *laterally* replaced by igneous rocks (melaphyre). Some of the most conspicuous points and nearly all the craggy hills in the ranges are composed of the trap. The Jauza hill (over 11,000 feet) is almost entirely made up of a dark augitic rock.

6. Near the centre of the great anticlinal, or rather dome, of the Jauza section, I came upon an impure reddish-grey hard limestone, with brecciated beds. The limestone is in parts oolitic in structure; I noticed a few traces of fossils (Brachiopods) north of Jauza Killah, but could not get them out of the rock. The beds of limestone are apparently not very regular, though I always found them near, or immediately below, the red grit beds. North of Jauza village, in the stream which runs into the Kurukh river near the village of Kurukh, the limestone beds are again seen just below the red grit series, and at that locality I found some well preserved Brachiopods, of a rhætic or liassic character. The bed is evidently of very varying thickness, for on the north slope of the Zurmust I met it in very considerable development. Immediately below it I met—

5. Calcareous grit and breccia with green shales (phyllites) containing angular fragments of igneous rocks.

4. Reddish and green shales with leafy impure limestone, traversed by innumerable veins and joints filled with calcspar.

3. Greenish micaceous shales (phyllites); considerable thickness.
2. Felsitic rock with imbedded trap.
1. Limestone, conglomerate and grit.

The lower beds of this section, from 1 to 6, comprise the greater part of the section seen on the north side of the Kholi Biaz hill, beds 3 to 11. This group of beds has probably been deposited near a shallow coast, and both the lower (permo-trias) and the middle section (jurassic) of the series attain a much greater thickness further north and north-west, and in Khorassan attain enormous thicknesses.

The centre of the anticlinal which forms the Davéndar range is therefore not to be found in the main range, but north of it, and is marked by the Malúma stream valley, where the older (carboniferous) rocks are exposed.

The Kurukh valley, from near the point where the stream leaves the hills before entering the Herat valley, to many miles east of the Davéndar hills is formed chiefly by the red grit group.

The Paropamisus range, bounding the valley on its north side, also forms an anticlinal, considerably disturbed by minor faults, and in some places the beds are so crushed as to leave great doubts concerning their relative position. Fortunately I was able to go over the Zurmst section a second time and thus satisfy myself about the correct interpretation of the structure of the range.

The red grit group with its igneous rocks forms a great trough, in which the Kurukh stream has eroded a deep channel. On the left side of the valley the beds forming the group dip nearly north, whereas in the Zurmst range the red grit group and interbedded melaphyre dip at an angle of 65° to 70° to the south-east.

The entrance to the Zurmst is occupied by a purple and red grit, which in places becomes quite a conglomerate, extremely hard, and seems to have been subjected to alteration near the contact with the trap. From that point to the height of the Zurmst pass there is an alternation of grits, red shales, volcanic tufa and melaphyre, with an amygdaloid rock.

The igneous rocks assume much greater thickness towards the east, the upper Kurukh.

Tithonian.—North of the Zurmst pass, and in the range over which the Kashka Kotal leads to Naratú, the red grit group is seen to underlie a group composed of white sandstones and grits with plant-remains, and interstratified limestones containing marine fossils.

I had no further opportunity this year of revisiting the Naratú-Kilnaú section which I have already described in my last notes. But from observations of rocks further west it appears certain to me that the Naratú plant sandstones, overlying the red grit group, belong to the tithonian horizon and form a passage from the upper jurassic into the neocomian limestones and marls which are seen between Chakan and Kilanaú, on the road to Bala Murghab.

Marbich and Band-i-Baba.—The Paropamisus between the Zurmst pass and the Marbich shows nearly the same structure as I observed in the Zurmst section, but although the general feature of the range is that of a great anticlinal or anticlinals, it has undergone such great disturbances, and the beds composing

it are so much shattered, that the true succession of strata could hardly be made out anywhere between these points, if the neighbouring region had not afforded a key for its interpretation.

Fault of the Paropamisus.—Between the Band-i-Baba and the Zurmüst it may easily be seen that a line of fault runs east and west, south of the main range; and beds of the middle of the plant series (the red grit group) are thrown against and partly thrust over some of the white sandstones and grits of the uppermost group (tithonian). Near the Thagan Robat, north of the Zurmüst pass, the fault has thrust the red grit group partly over the younger white sandstone (tithonian).

Near the Marbich pass the fault crosses to the north side of the Paropamisus, crushes beds of the red grit group against upper cretaceous, and is lost further west below the tertiary deposits of Badghis. In the Estoi range, in Khorassan, the fault appears again plainly, and may be traced in a more or less north-westerly direction along the Kat-i-Shamshir hills. The hot spring of Garm-ab (115° F.), north of Tiraman, rises along this fault.

The Band-i-Baba.—The main range, over which the Band-i-Baba pass leads from Kushk is composed of the uppermost group of the jurassic series, represented by light-coloured sandstones and grits with intercalated limestone with marine fossils. The same beds are seen in the Kashka Kotal, north of the Thagan Robat, and at Naratú, and I believe represent as nearly as possible the tithonian stage of Europe. I found in descending order:

- | | | | | |
|-----------|---|---|---|--|
| Tithonian | . | . | } | <ol style="list-style-type: none"> 1. Sandstone, dark grey, fine-grained, with numerous <i>Ostrea</i> remains and calcareous beds entirely composed of an <i>Ostrea</i> species 2. Sandstone, light grey, with greyish-white sandy shales; the first contains some plant-remains; the latter a few bivalves. The dip is rolling, but generally to the north. 3. Sandstone and grit with zones of conglomerate. Resembles strongly upper Gondwaona sandstone and contains plant-remains. |
|-----------|---|---|---|--|

The series may be seen in all the ravines which lead towards the Marbich and Band-i-Baba from the grassy slopes of the Kushk valley, and the beds dip under an angle of about 25° to 30° to the north.

South of the pass I found that beds belonging to the red grit group are faulted against the mass of light-coloured grits of the Band-i-Baba, and the strata composing the upper jurassic are dipping 25° to the south. Near the actual contact great disturbance and crushing is noticeable, the beds of the red grit group being here and there raised up vertically and even inverted. Between the top of the Band-i-Baba and the ravine south of Robat-i-Khona, leading to Palezkar, the red grit group is as follows in descending order:—

- | | | | |
|----------------|---|---|---|
| Red-grit group | . | } | <ol style="list-style-type: none"> 3. Hard bluish-green sandstone, forming very thick beds with grit zones and trap pebbles. The sandstone is composed of volcanic material. |
|----------------|---|---|---|

- Red-grit group
- 2. Breccia, same as 1, but in thinner beds, alternating with a clay shale or concretionary clay of dark green or red colour; this group is of great thickness, and can hardly be less than 1,200 to 1,500 feet.
 - 1. Dark brownish-red and purple conglomerates and grits the fragments made up of igneous material, alternating with great layers of trap breccia and volcanic tufa. The fragments are all derived from igneous rocks, generally melaphyre, cemented by a black or dark-green tufaceous matrix. Interstratified with red grits and sandstones.

Palezkar beds, Talchirs?—The low hilly ground between the hills immediately north of Herat and the foot of the Band-i-Baba range itself, is formed by a synclinal, much disturbed and in some places completely crushed. Between the village of Palezkar and Robat-i-Surkh, in the Herat valley, some of the lower beds of the plant-bearing series are exposed. They consist of a group of sandstones and green shales, associated with interstratified trap (amygdaloid melaphyre), which may be seen well exposed near the high conical hill known as the Hissar-i-Ghulamán, and in the ravines of the Palezkar and Shorán streams, which drain into the Kurukh river.

Nearer Robat-i-Surkh, I noticed a greenish-grey impure shale, micaceous, with traces of plant-remains (*Vertebraria*?) associated and alternating with conglomerate and a trap breccia in thick beds.

Towards the south-east they are overlaid by coarse brown sandstones and grits, with badly preserved plant impressions, and towards Muchkhandak by the red grit group.

Altogether the Palezkar beds resemble in some respects the Talchirs of India, and still more so the lower (*Ecca*) beds of the Karoo formation of South Africa, and recall to me vividly the sections seen a few miles south of Pietermaritzburg in Natal, and the beds exposed in the ravines of Kleine Karoo and the Bokkeveld of the Cape.

I believe they belong to the beds 2 to 7 which I described as overlying conformably the carboniferous limestone of the Kholi Biaz hill, in the Davéndar range, and form most probably a passage from the upper carboniferous into the trias, comprising perhaps the upper Kuling beds of Himalayas with *Otoceras woodwardi*.

Hills north of Herat.—The hill range which runs almost east to west, and within 2 miles of Herat, is composed of several groups of rocks, which form three separate zones. The greater part of the range, from a point half way between Parwana and Herat to Robat-i-Surkh, is formed by the older beds of the plant-bearing system, which dip to the north-east, and apparently rest on hard grey splintery limestone, which forms the range between the Parwana stream and the Sinjao valley, and which may be carboniferous.

I crossed the Paropamisus between the Band-i-Baba and the Hari Rud by the Ardewan, Chasma Sabz and Robat-i-Surkh passes, and partly explored the Marchich route.

Marbich and Koh-i-Kaitu.—The latter route skirts both the Koh-i-Kaitu and Marbich peaks, which, in their general features, resemble the Band-i-Baba. The southern half with the Koh-i-Kaitu is composed of the red-grit group which is faulted against the tithonian grits and Ostrea limestones of the Marbich.

Ardewan.—The beds composing the Ardewan all belong to the red-grit group with a part of the higher tithonian white sandstones and grits overlying it. The structure presents one or more folds, with a considerable amount of local disturbance. North of the pass, where the road enters the grassy slopes of the Kushk drainage, the sandstones of the tithonian group have been faulted and crushed against beds (white marly limestone) of the upper cretaceous formation. I believe this to be on the same line of fault which I could trace from point to point through the Paropamisus and the Jam hills of Khorassan.

The rocks, which compose the red-grit group of the Ardewan, consist of thick beds of grit, sandstone and conglomerate, mostly of a dense reddish-brown to purple colour, in general character resembling the rocks of this group at the Zurmust pass. The conglomerate changes locally into a volcanic breccia, which is well shown in the cliffs just north of Kush Robot, near the south entrance to the pass. I found no trap *in situ*, but thick beds of volcanic ash, with embedded bombs of malaphyre, are intercalated between the conglomerates. The general dip of the group varies from north-west to north-east, but in one or two places small folds repeat the series of beds.

Beyond the watershed of the Sinjao stream and the stream which drains into the Kushk, the red-grit group is overlaid conformably by coarse sandstones (with ferruginous nodules) and grits with calcareous beds, containing marine shells, which I believe to belong to the tithonian horizon, continuous with rocks of the same age of the Marbich, Band-i-Baba, and Kashka Kotals. The sandstone is cut off by the fault already noticed, and crushed against upper cretaceous limestone with *Inoceramus cripsi*, Mant.

Chasma Sabz pass.—The section exposed at the Chasma Sabz pass is almost identically the same as the one seen in the Ardewan. It consists of a series of beds of the red-grit group, dipping 15° to 20° north-east, and in descending order I found :

4. Densely red grits and ferruginous sandstone, forming a lower and parallel range north of the Chasma Sabz pass.
3. Grey friable needle shales, conglomerates and partings of clay shales.
2. Grits and greyish needle shales with bluish-grey hard clay shales.
1. Red and brown to purple sandstone with coarse conglomerate and volcanic ash beds.

2. The plant-bearing system in Khorassan.

The Gaúkharchang pass and the Kat-i-Shamshir range.—The great fault described on page 56, and which runs more or less south-east to north-west through the Paropamisus, divides also the range of hills which bears the name of the Kat-i-Shamshir on our old maps. Here the fault runs close along the north side of the watershed between the Jam river valley and the drainage which falls lower down into the Hari Rud. The fault is well exposed in the Gaúkharchang pass

itself, and further to the north-west at the hot spring of Garu-ab (115° F.), it is lost amidst the tremendously crushed strata.

The southern half of the Gaúkharchang pass, which leads from the Jam valley north of Turbat-i-Sheikh-Jam to Zohrabad, is composed of fragments of sandstones and grits belonging to the red-grit group with great masses of igneous rocks. The prevailing rock is a melaphyre, with long strips of a syenitic granite, which I believe to belong to a later epoch. Ash beds and volcanic conglomerates are found between the enormous layers of bedded melaphyre, dipping gently to the south below the late tertiary deposits of the Jam valley.

The northern half of the pass between the fault and the Zohrabad plateau, past the Burj-Kalich-Khan, is formed chiefly by beds belonging to the middle and upper groups of the jurassic system. The structure is that of one or more anticlinal arches, somewhat crushed here and there, but sufficiently clear to establish the following groups in descending order :

Tithonian	{	3. Light-coloured sandstone, grit and limestone beds; the latter with <i>Ostrea</i> sp.
Red-grit group, upper jurassic.	{	2. Dark-grey to black finely bedded shales, very friable, with ferruginous partings. Great thickness. Fragments of plant-remains. Coarse red grit and sandstone in thick beds.
Lower and middle jurassic.	{	1. Greenish-grey coarse sandstone with ferruginous partings, and dark-grey, fine needle shales. The grey shales show some badly preserved plant-impressions, but the sandstone (near Burj-Kalich Khan) yielded a great number of both marine lower jurassic fossils, Brachiopods, Bivalves, Echinoderms, &c., and also of remains of <i>Glossopteris</i> sp., and other Gondwana plants in a fairly good state of preservation.

It is remarkable how the red-grit group and the higher grits of the tithonian have dwindled down in thickness in this section, compared to the great deposits of sandstone and volcanic ash beds which form this group in the Paropamisus sections. The stream of Paídáh Ján Murád, north-east of the Burj Kalich Khan, has formed picturesque escarpments in the red-grit group, resembling greatly the escarpments in the Mahadeva sandstones of Sirguja and Palamow in India.

Robat-i-Surkh pass.—Approaching the Robat-i-Surkh pass from the north (Gulrán), one has to pass over rolling hills of rounded outlines, composed, as far as I could judge from the scanty exposures seen *en route*, of nothing else but the soft argillaceous beds and soft sandstones which I believe belong to the upper Siwalik horizon. Near the north slope of the pass a number of low spurs are seen to run out from the Mash range, and I found them to consist of light-brown sandstones and grits in thick beds, which resemble the plant-bearing sandstones of the Band-i-Baba. The beds dip here gently to the north below the Gulrán beds.

The pass itself shows a group of sandstones, generally thick-bedded, which in

its upper portions is alternating with reddish and greenish marly beds. I found no fossils in any of the strata, but I believe the whole to belong to the red-grit group, which it closely resembles.

The structure seems to be that of a wide anticlinal curve; the pass itself is formed by simple erosion of two streams, flowing north and south, separated by a low watershed of only a few hundred feet in width.

Further to the north-west, the red-grit group swells again in thickness, and on the left side of the Kashaf Rud valley forms all the lower slopes underlying the cretaceous rocks of the Takht-i-Gauzak.

The pass, which leads from Sang-i-Safed (near Firaiman) over to Kat-i-Shamshi to Garm-ab, reveals a section very like the one traversed by the Gaúkharchang pass. The beds of the red-grit group, which compose the entire range at this point, are much shattered and folded. Near the south entrance to the pass, the beds dip to the south-west and are overlaid unconformably by younger tertiaries, conglomerates, and sandstone. The red-grit group of this pass consists of densely red conglomerates, grits and volcanic ash beds with trap interstratified, between the layers of which irregular beds of grit often appear. There are also some earthy black shales associated with the grit, and several irregular masses of hard splintery grey sandstone, traversed by numerous calcspar veins. The lower strata of the red-grit group resemble the beds seen on the north slope of the Jauza hill in the Davéndar section; immediately below the grit I found a greenish-grey concretionary shaly sandstone which overlies a fine-grained, hard greenish-grey and reddish-grey sandstone similar to the one which I met in the Jauza section, south of the Kholi Biaz.

Near Garm-ab, on the north side of the pass, I found the bedding much disturbed, and near the fault much shattered. Near Kummer Sard, a small settlement of Nomads north-west of Garm-ab, I saw the red-grit group conformably overlying the lower jurassic black plant shales.

Between Bareili and the Takht-i-Gauzak.—The trough between the Bareili hill, the highest part of the Kat-i-Shamshir range, and the Takht-i-Gauzak, south-west of Pul-i-Khatun, is formed by a succession of folds composed of lower and upper jurassic rocks. The former are developed as black or dark-grey shales with greenish-grey sandstones, which yield lower jurassic marine shells and some Gondwana species of plants. They are overlaid by the red-grit group which dips below the tithonian and lower cretaceous of the Takht-i-Gauzak.

The country between the two ranges is more or less uninhabited now, and water is only obtainable at a few points. I had therefore to hurry over it too quickly to make very detailed observations.

The plant-bearing system in the Yoktan range and Bizd hill.—The Yaktán range runs in a north-west south-east direction between the Jami and Shahr-i-Nao valleys, and forms a continuation of the Binalut range. At its south-eastern extremity is the Bizd hill, south-west of Turbat-i-Sheikh-Jami. As already described, the range is formed by a steep anticlinal fold, the centre of which is composed of carboniferous marine limestones, overlaid on each flank by beds belonging to the plant-bearing system. When I examined the range in March of this year, the greater part of it was still covered with thick masses of snow, and only at one

locality (near Raband) was I able to penetrate the outer hills to the inner core of carboniferous limestone. The depression between the latter and the outer hills was then almost filled by snow, so that I have not been able to see either the contact between the two systems of formations, nor the lower beds of the plant-bearing series.

The Bizd hill itself is composed of igneous rocks (melaphyres) with sandstone and conglomerates of the red-grit group of precisely the same lithological character as noticed in the sections of the Paropamisus.

The same rocks with great deposits of volcanic ash beds and tufa are seen all along the northern slope of the Yaktán range. The beds of conglomerate and sandstone with interstratified igneous rocks dip to the north-west, and apparently are conformable to the carboniferous limestone which form the main range, but the actual contact I have not seen.

Plant beds of Kalanderabad.—Near Kalanderabad the outer range separates into a chain of isolated low hills, which consist of a hard, light-grey, splintery limestone, overlaid by plant-bearing beds. I remember having observed a similar bed of grey splintery limestone in the plant-beds of Palezkar, near Herat.

The Kishti Pukhta pass from Kila-i-Nao to Amun-Jaffre (and Aliyek).—The rocks composing the parallel ridges of the pass which leads over the Yaktán range, belong nearly all to the plant-bearing series with its igneous rocks.

Near the northern side of the pass (near Kalanderabad), I observed greenish-brown sandstones, with shaly partings, dipping 50° west. They yielded a few poor specimens of plants, the common reed-like fragments.

The series of beds is contorted, and forms a synclinal near the centre of the pass. The structure is too complicated to allow a careful survey during a hasty march, but I noticed the close connection of igneous rocks with the plant-bearing sandstones and conglomerates. The igneous rocks are chiefly melaphyres with a red felspathic rock, very common in the red grit group. With it occurs a volcanic breccia, containing some rolled boulders of large sizes, embedded in a porous volcanic tufa, with angular fragments of igneous rocks.

The sedimentary rocks of the group form narrow strips within the belt of igneous rocks, and are, with few exceptions, all sandstones of reddish-brown and greenish colour. Some high cliffs on the left side of the valley, near the Kila-i-Nao entrance to the Kishti Pukhta pass, are composed of a great thickness, of a coarse brown sandstone, with grit partings, showing false bedding well marked. Several beds of a coarse conglomerate occur with it. In the lower layers I found a few irregular deposits of reddish-brown clay. A large deposit of irregular thickness of the boulder breccia, already described, I noticed at the base of the sandstone, forming the right side of the valley and overlying the igneous rocks.

Another patch of sandstone, which reminded me of the Talchirs of India, I found near the south side of the pass, not far from Amun-Jaffre. It is a soft, olive-coloured sandstone, with small ferruginous concretions in some of the strata and partings of olive-green shales. I found no fossils in them. Near the southern side of the watershed I found an irregular thick bed of white limestone of a fine crystalline texture, very hard and splintery, enclosed in the igneous rocks of the group, and apparently belonging to it.

Karat range.—The range which separates the Khaf plain from the Shahr-i-Nau valley, and which bears the name of the Karat range on our maps, I have unfortunately not visited, but from the distance it appears that the higher range with the peak Koh-i-Khaf is composed of a dark rock, presumably limestone, dipping to the south at a low angle.

North to north-west of it, I noticed other rocks, of a lighter brownish-green colour, dipping gently towards the Khaf range. This latter rock I believe to be the group of igneous rocks, shales and sandstone of the plant-beds.

Binalut range.—The Binalut range is similar in structure to the Yaktán hills, and is in fact only a continuation of the latter. Only in the Dehrud pass section did I cross the plant-bearing series, which north of the Dehrud pass itself, between it and the village of Golistán, overlies conformably the carboniferous limestone with marine fossils.

The plant-bearing group is here represented by hard grey and green shales associated with volcanic ash beds and a variety of eruptive rocks. I found no fossils in the shales.

Red-grit group of Madán.—North-west of Nishapur, the ancient capital of Khorassan, some spurs branch off the Binalut range which seem all to belong to rocks of the red-grit group of precisely the same lithological character as those seen in the hills east of the Band-i-Zurmúst.

The Madán hill itself is composed of volcanic ash belonging to the group, with some contact rock, which will have to be carefully analysed hereafter. In this contact rock the celebrated turquoises are found, and there are now about a thousand "mines" in and around the hill, of which about a hundred only are worked; the best stones are found in pits sunk in the mountain talus, where of course the mineral is easily extracted from the crumbling decomposed mass.

The extraction from the surrounding matrix seems the difficulty in obtaining good and large stones, which otherwise abound in great quantities.

Unfortunately the hill mass of Madán is so completely enshrouded on all sides by recent tertiary deposits, that I have been unable to trace the actual connection of the rock composing it with the lower plant-bearing series of the Binalut range.

The rhætic and jurassic deposits of the Kelat-i-Nadri section.—The section between Mashhad and Kelat-i-Nadri is one of the most interesting in Khorassan. There the entire series from the rhætic to the upper cretaceous is represented by marine beds.

A stream, running almost due north-south, has eroded a deep and very narrow gorge through the hard limestones of the upper rhætic and jurassic series; in some places so narrow that there is only room for a laden mule to pass through. The Arka-bun-Shah pass leads into the gorge excavated by the Kelat stream, running north, which has eroded a similar gorge through a succession of limestones and hard shales.

The section is an extremely good one and presents a succession of folds mainly composed of hard splintery limestones and dolomites with some shaly partings, which in several horizons yielded fossils, chiefly Brachiopods, belonging to the upper rhætic or lower lias. The upper beds contain a few sandstone part-

ings, and yielded, besides marine fossils, some rather badly preserved plant-remains. These beds, which I believe to be lower jurassic, are overlaid by massive limestones (with corals) and red grits, somewhat resembling the red-grit group rocks. This marine system is conformably overlaid by the cretaceous rocks of Kelat-i-Nadri.

The cretaceous rocks of the Herat province.

In the Herat valley itself, I have not met with any cretaceous rocks, but the southern half of the Doshakh range, with the peak itself, belongs to the widespread hippuritic formation, which forms nearly all the hill ranges of South and Western Afghanistan. The Zingaták pass from Kashmarú to Pahri marks approximately a fault which has brought the palæozoic rocks of the northern half of the Doshakh range with the Robat-i-Pai peak in direct contact with hard white and grey coral limestone, which yielded many hippurites, some badly preserved ammonites and bivalves.

I have nothing to add to my description of the cretaceous rocks of the Tirband-i-Turkestan, which I have not been able to revisit.

Cretaceous rocks north of the Paropamisus.—North of the Ardewan pass, crushed against the upper jurassic or tithonian sandstones and grits, I met white marly limestones, which contain *Inoceramus cripsi* Mant. in excellent preservation, a species common in the upper cretaceous formation of Hungary and South-Eastern Europe.

The cretaceous system occupies a large area north of the Estoi and Paropamisus range, and I found the upper horizon with *Inoceramus cripsi* in almost all the sections which I have seen of the cretaceous beds of that region. Most probably the shell limestones of Kushk, of Chakan, and the greater part of the Tirband, belong to the same system.

The cretaceous rocks of Khorassan.

Cretaceous beds may be traced from Kelat-i-Nadri in a south-east direction to the range of the Takht-i-Ganzak and the cliffs of the Hari Rud between Pul-i-Khatun and Zolfikar. Most of the ground north of the Estoi hills to the Kashaf Rud valley is also covered by beds belonging to the cretaceous system.

I found that the system, which cannot be less than about 3,500 to 4,000 feet in thickness, can be divided into—

- | | | |
|------------------|---|--|
| Upper cretaceous | } | 4. Earthy brownish-white limestones, with flaggy beds of white limestones. Forms high cliffs along the Hari Rud, Kelat-i-Nadri, &c. Yielded many cretaceous fossils, amongst them <i>Inoceramus cripsi</i> Mant. |
| Lower cretaceous | } | 3. White earthy limestones and chalk with indurated clay; fossils in bad state of preservation. |
| | | 2. Dark shales, with ferruginous partings. |
| | | 1. Yellowish-white earthy limestones, many well-preserved fossils,—Brachiopods, <i>Trigonia</i> , &c. |

Between Kelat-i-Nadri and Zolfikar this section may be seen at any point, and the beds seem hardly disturbed at all, generally sloping gently to the north-east, showing steep scarps towards the south and south-west.

The cliffs along the Hari Rud, between Pul-i-Khatun and Zolfikar, are entirely formed by these rocks and offer complete and undisturbed sections.

The massif of Kelat-i-Nadri is a synclinal basin formed of cretaceous rocks, through which the Kelat treams has eroded a transverse valley, or rather gorge.

Cretaceous rocks in the Binalut range.—Limestones with some fossil remains which I found dipping below nummulitic beds near Sultan Maidan, in the Binalut range, probably belong to the cretaceous system.

Granite and gneissose rocks of Herat cretaceous.—Immediately north of Herat, from a point nearly north-west of the city to north-east, including the low hills of Ghazegah, a gneissose rock with syenitic granite dykes is found, which seems identical with similar rocks of the Upper Kurukh valley and the Davendar peak itself. This belt of granitic and gneissose rocks may be traced along the south slope of the Estoi hills (in the Gaúkharchang pass) to Sangbast, south-east of Mashhad, and I believe belongs to a period subsequent to the red-grit group, possibly to the same outburst which has converted so much of the upper cretaceous rocks of Southern Afghanistan into fine marble.

Nummulitic rocks.

Beds with nummulites, and associated with younger eruptive rocks, rhyolites and trachytes, I have only come across near Madán, north-west of Nishapur, in Khorassan. The nummulitic beds here occupy a large area, south of Madán; and on the Sultan Maidan, north of the turquoise mines, I found nummulites in a calcareous dark limestone and in sandy beds, closely associated with great masses of rhyolite, which has changed the sedimentary beds locally, and partly converted them into semi-metamorphic masses.

At the Sultan Maidan the nummulitic group seems to rest conformably on a grey shell limestone which I believe to be cretaceous, and which forms the western slope of the Binalut range, north of Madán.

On the outer slopes of the Kat-i-Shamshir between Sang-Safed and Sangbast, south-east of Mashhad, I found the beds with nummulites in descending order:

- | | | |
|-----------------------|---|---|
| Miocene or oligocene? | { | 5. Red conglomerate and sandstones in thick beds, dip 28° to 30° west to south-west-by-west. |
| | { | 4. Conglomerate, consisting of nummulitic limestone pebbles. |
| Nummulitic | { | 3. Grey shaly limestone with Brachiopods. |
| | { | 2. Yellowish-white limestone, corals, Ostrea, nummulites. |
| | { | 1. Dark-grey shales with intercalated concretionary limestone, which contains many bivalves, echinoderms, nummulites, &c. |

The beds below this are obscured by recent deposits, but a few miles south-east of the locality cretaceous beds dip below the fan of recent accumulations of

clay and conglomerate and most probably would be found to conformably underlie the nummulitic group.

Miocene.—Miocene rocks seem to be widely distributed north of the Paropamisus and on the Sarakhs plain, but I have not myself been able to identify them. Captain Yate and Dr. Owen of the Afghan Boundary Commission have brought me well-preserved specimens of *Ostrea multicosata*, Desh.; the first from the Nimaksar, north-east of Zolfikar, and the latter from Khwaja Kallandar, north-east of Kushk, in Badghis. I have not been able to visit either of these localities. Apparently the fossils occur in a light-coloured clay associated with the salt-bearing and gypsiferous group, which is largely developed in Northern Badghis.

Younger tertiaries.—To the description of the younger tertiaries given in my last "notes" I have nothing to add of any importance. Good sections through the upper groups of the tertiary system are seldom met with, as they are generally hidden below enormously thick masses of alluvial deposits and fans.

CAMP, SHEIKH-I-WAN, HERAT VALLEY,

13th November 1885.