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MEMOIRS

OF

THE GEOLOGICAL SURVEY OF INDIA.

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VOL. XXXV, PART 1.

GEOLOGY OF WESTERN RAJPUTANA, *by* TOM D. LA TOUCHE, B.A., *Superintendent, Geological Survey of India.*

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CHAPTER I.—INTRODUCTION.

The Geological Survey of Western Rajputana, of which the present memoir is the outcome, was primarily undertaken as a continuation of Mr. R. D. Oldham's investigations in the years 1885-87 regarding the possibility of the existence of Gondwana coal measures in Jaisalmir. The presence of boulder beds of glacial origin at Pokaran and other places between Jodhpur and Jaisalmir had been noted by Mr. W. T. Blanford in 1876. These beds were supposed by him to underlie the Vindhyan sandstones of Jodhpur, but Mr. Oldham found that similar beds occurring at Bap, about 40 miles north-west of Pokaran, contained boulders of Vindhyan limestone, and he identified them as Talchirs, " the beds which everywhere in India underlie the coal measures."[1] The existence of strata of upper Gondwana age had

[1] Rec. Geol Surv. Ind., Vol. XIX, Pt. 2, p. 123.

already been noted further to the west in Jaisalmir, and it was therefore thought that the coal measures of the lower Gondwanas might be found in the intervening ground. After making a preliminary examination of the country, Mr. Oldham suggested that borings should be put down in the area west of Bap, but subsequent investigation led him to modify his opinion, as he found that there was strong evidence that the boulder beds were unconformably overlaid by sandstones of upper Gondwana age, and that in consequence the existence of the coal measures in this area was purely a matter of speculation.[1]

So the matter remained until the year 1896, when I was sent to survey the country to the south of the Jodhpur-Jaisalmir road, the geology of which was till then only slightly known. So far as the presence of the coal measures in that direction is concerned, I may say at once that my investigations have been completely barren of results. Not only are there no exposures of the Talchir boulder beds to the south-west of Pokaran, but the country in that direction is so buried in sand that no rock is visible until the old land surface of the volcanic rocks in the Barmer desert is reached. All the rocks met with during my three seasons' field work, with the exception of the Vindhyan sandstones of Jodhpur and a few isolated exposures of sandstone of upper Mesozoic age in the Barmer desert, belong to various crystalline types. They include schists, quartzites and granitoid gneisses belonging to the Aravalli system, ancient volcanic lavas and tuffs of extremely acid composition, intrusive granites, and dykes of basic rock.

As regards the rocks that may be concealed beneath the sand, little or no information is available. Nothing can be learnt from well sections, for where the wells are sunk close to the hills, as is usually the case, the rocks pierced by them are naturally the same as those forming the hills themselves, while those that have been sunk further out in the plain either do not pierce the alluvium or are lined with cement or otherwise protected to prevent the sides falling in, so that nothing can

[1] Rec. Geol. Surv. Ind., Vol. XXI, Pt. 1, p. 30.

be seen of the strata passed through. At the same time, the total absence of any traces of sedimentary rocks on the flanks of the hills except in Barmer, and the frequent appearance of patches of the crystalline rocks among the sandhills, leads me to suspect that the alluvium generally rests directly upon a platform of the older rocks, and that at the time of the deposition of the Gondwanas and marine sediments of Jaisalmir, the greater part of Marwar must have been dry land.

Previous Observations.

1854. Dr. H. J. Carter.

In a long paper on the "Geology of India" published in the Journal of the Bombay Branch, Royal Asiatic Society, Vol. V, Dr. Carter refers [1] to the presence of granite in the neighbourhood of Barmer; to the conglomerate of Barmer,[2] which he identifies with the "Greywacke or Steatitic sandstone" placed below the Transition Gneiss in the table given on page 200 of the paper cited; and to the desert sands, which he conjectures are derived from the waste of the "Punna" or Vindhyan sandstone. The lavas projecting here and there from among the sandhills are considered to be the same Punna sandstones "in its concrete or metamorphosed forms;" and the quartzites of the Aravallis are also referred to the same formation.[3]

1861. Dr. H. J. Carter.

In the same Journal, Vol. VI, Dr. Carter notes the discovery by Dr. Impey during a journey from Rohri across the Jaisalmir desert to Jodhpur, of ammonites at Kuchri [4] in Jaisalmir, referred to A. opis, *Sow.*, a Jurassic (Cutch) species; and of fossil wood in the sandstones of Lathi, between Jaisalmir and Pokaran. The "specimens of clay strata, brick coloured and green, which had evidently been baked by heat, sent by Dr. Impey from Jodhpur, were probably fragments of the Malani lavas occurring near that place.

[1] *Loc. cit.*, p. 190.
[2] *Ibid*, p. 202.
[3] *Ibid*, p. 231.
[4] *Loc. cit.*, p. 161.

In the Journal of the Royal Geographical Society, Vol. XL, Sir H. Bartle Frere gives an account of the physical geography of the Runn of Cutch and its neighbourhood, in which he discusses the origin of the sandhills of the Indian desert. After rejecting the theory that they are built up of blown sand he ascribes them to the action of earthquakes, and compares them to the Allah Bund, said to have been thrown up in the Runn by the earthquake of June 10th, 1819.[1] This theory was subsequently discussed and refuted by Mr. W. T. Blanford in a paper read before the Asiatic Society of Bengal.[2] It should be remarked, however, that Sir Bartle Frere's theory is applied to the longitudinal sand ridges along the border of the Indus alluvium in southern Sind, and not to the transverse sandhills of Marwar, and that Mr. Blanford confesses that he does not quite understand how the former could have been formed by the prevailing south-west winds.

1870.
Sir H. B. E. Frere.

It is to Mr. Blanford that we are indebted for the first precise information regarding the geology and physical features of the Indian desert. Mr. Blanford journeyed from Sehwan on the Indus through Umarkot and Barmer to Jodhpur and returned to Rohri in Upper Sind through Jaisalmir. He thus crossed the whole width of the desert in two directions. The observations made by him were published in two papers, one on the geology of the country, published in Vol. X of the Records of the Geological Survey of India, and the other on the physical geography, including notes on the fauna and flora of the desert, read before the Asiatic Society of Bengal on 5th July, 1876.[3]

1876.
W. T. Blanford.

In the former paper Mr. Blanford gives the following list of the formations met with during his journey:—[4]

9. Blown sand	Post Tertiary.
8. Alluvial deposits	

[1] *Loc. cit.*, p 191.
[2] Journ. As Soc. Beng., Vol. XLV, Pt. 2, p. 86.
[3] Journ. As Soc. Beng., Vol. XLV, Pt. 2, p. 86.
[4] Rec. Geol. Surv. Ind., Vol. X, Pt. 1, p. 17.

7. Nummulitic limestone	Tertiary.
6. Ammonitiferous beds of Kuchri . . .	Jurassic.
5. Jaisalmir limestones and sandstones . .	Jurassic.
4. Barmir sandstones	Jurassic.
3. Jodhpur sandstones	? Vindhyan.
2. Shales and boulder bed of Lowo and Pokran	?
1. Malani felsite, porphyries, syenite, etc. .	?

Each of these formations is described in detail. The name of Malani, from the district of Marwar in which they were first met with, is given to the volcanic series of porphyritic lavas and ash beds, which have since been found to be the most widespread rocks in Jodhpur territory. The occurrence of fragmentary plant remains in the Barmer sandstones is noted, and these rocks are correlated with similar sandstones containing fragments of silicified wood occurring beneath the marine Jurassic beds of Jaisalmir. A list of fossils from the latter beds is also given.

In the second paper Mr. Blanford gives an account of the physical characteristics of the desert, with especial reference to the sand-hills, which he shows are entirely due to the movement of the sands driven before the prevailing south-west winds, and discusses the probabilities of a former extension of the sea over a part of this area, in order to account for the production of the sand.

1880.
C. A. Hacket.

Of the papers communicated by Mr. Hacket to the Records of the Geological Survey there are three which deal to some extent with the geology of the area now described, or its economic resources. The first of these, published in 1880,[1] is a discussion of the mode of occurrence and origin of the salt which is the characteristic product of Western Rajputana. Mr. Hacket thinks that the accumulation of the salt may be accounted for by the present operation of drainage and evaporation, but finds a difficulty in attributing to these causes its local concentration in such places as the Sambhar Lake, and seems inclined to account for such

[1] Rec. Geol. Surv. Ind., Vol. XIII, Pt. 3, p. 197.

cases by the (entirely hypothetical) existence of deposits of rock salt of Vindhyan or more recent age concealed beneath the alluvium.

In the same number of the Records[1] Mr. Hacket gives a list of useful minerals occurring in the Aravalli region, but the only mineral mentioned as being found in Marwar is the well known marble of Makrana, and of Sarangwa, near Desuri in Godwar.

The third paper, published in 1881,[2] describes the geology of the Central and Eastern Aravallis, and of the country lying between the Aravalli range and the meridian of Jodhpur. Mr. Hacket includes the whole of the granitic rocks found to the west of the Aravallis under the comprehensive term "gneiss". In reality there is no true gneiss in this area, but there are two protrusions of granite of different ages, differing widely in texture and composition.

After describing the sections in the neighbourhood of Sojat, where upper Vindhyan sandstones are seen resting with total unconformability on the upturned edges of Aravalli schists, Mr. Hacket proceeds to describe the Malani lavas near Jodhpur and their relations to the Vindhyan sandstones resting upon them. The existence of a conglomerate of rolled pebbles of the lavas at the base of the Vindhyans is mentioned, and the former are referred doubtfully to the lower Vindhyan period. A section in the hills north of Chanod is described in which Malani lavas are seen resting upon some red slates, supposed to be Aravallis. I have visited this section, which is the only one where Malanis are found actually in contact with any rocks older than themselves, and convinced myself that the slates belong to the Aravalli system and that the relation is one of complete unconformability. This section will be again referred to subsequently.[3]

1886.
R. D. Oldham.

Two papers were published by Mr. Oldham in Vol. XIX of the Records, giving the results of a traverse of Jaisalmir territory undertaken in 1885 with a

[1] Rec. Geol. Surv. Ind., Vol. XIII, Pt. 3, p. 243.
[2] *Ibid*, Vol. XIV, Pt. 4, p. 279.
[3] *Infra*, p. 19.

view to ascertain the probability of Gondwana coal measures being in existence there. Mr. Oldham identified the boulder beds of Pokaran, already described by Mr. Blanford, and those at Bap, with the Talchirs, and points out that as the sandstones underlying the Jurassic limestones of Jaisalmir are probably of Mahadeva age, there is a possibility of the coal-bearing Gondwana beds occurring in the intervening area. The actual presence of these beds can only be ascertained by boring, and Mr. Oldham recommends that borings should be put down in the country west of Bap. Subsequently in 1887 Mr. Oldham revisited this ground and came to the conclusion that the boulder beds of Bap were overlaid unconformably by sandstones, probably of upper Gondwana age, and that any search for coal in Jaisalmir would be purely speculative.[1]

In his other paper Mr. Oldham gives an account of the geology of the country he passed through, with a sketch map and list of the formations.[2] None of these are found in Marwar, though the lowest, the Lathi group, containing plant remains and fragments of silicified wood, was supposed by Mr. Blanford to correspond to the plant bearing sandstones of Barmer. The group in which the "Ammonite bed of Kuchri" of Mr. Blanford occurs is re-named the Abur group by Mr. Oldham, since the stone is locally known by that name.

1886. Col. McMahon.

In the same volume of the Records Colonel McMahon published a description of the microscopical characters of some specimens of Malani lavas, etc., collected by Mr. Blanford at Barmer, and compared them with the felsites of Tusham hill, on the northern border of Bikanir, described in a previous paper.[3] This is the only information yet available on the petrography of these interesting lavas.

[1] Rec. Geol. Surv. Ind., Vol. XXI, Pt. 1, p. 30.
[2] *Ibid*, Vol. XIX, Pt. 3, p. 157.
[3] *Ibid*, Vol. XVII, Pt. 3, p. 101.

1893.
Manual, 2nd Edition.

In the second edition of the Manual of the Geology of India several references will be found to the geology of this region, summarizing the information given in the foregoing papers. The rocks referred to are the—

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CHAPTER II.—PHYSICAL FEATURES.

The chief physical characteristic of the country under review is that of a vast sandy plain, in which except when rain is actually falling, no running water is to be seen, diversified only by the rounded forms of sandhills, or by isolated knolls and groups of hills composed of solid rock, whose rugged and barren slopes rise abruptly from the sea of sand surrounding them. Arid and barren as the country may seem, however, especially to the traveller who only visits it during the dry months of the winter and spring, it is not altogether a desert in the strict sense of the term. Wherever water can be obtained from wells, and whenever, as occasionally happens, there are favourable rains, excellent crops of wheat and millet are raised, and the whole country is clothed with a luxuriant crop of grass, affording pasturage to large herds of cattle and sheep. The "desert" thus supports a large population, taught by experience to make the most of their means of subsistence, precarious though they may be, and to store up the superabundant harvests of the good years for use during less favourable seasons.

The largest and most lofty group of hills in the country is found in the Siwana district, to the south of the great bend of the Luni, where they reach an altitude of over 3,000 feet above the sea. A study of the map will show that the hills are arranged in irregular groups of individually isolated peaks or ridges, separated by broad expanses of sand, in such a manner as to suggest that what we now see are the highest points of continuous hill ranges, partly buried in sand. Indeed the hills, viewed from an elevation, resemble nothing so much as a number of rocky islands forming the crests of a mountainous tract submerged beneath the sea, and it requires no great stretch of the imagination to picture this region in some former age as one of flowing rivers and fertile valleys, before some change of climate reduced the power of the rivers to sweep back the ever increasing encroachment of sand from the south.

Although running water may in those far off times have played the chief part in determining the configuration of the hills and ridges, it is certain that now and for a long time past it must have exercised a very subordinate influence, and the principal agents of denudation at the present time are the intense heat of the sun, or rather the great alternations of temperature that affect the superficial layers of the rocks during the day and night, and the violent winds that sweep over the country during the greater part of the year, aided by the sand they bear with them. The operations of these agents of denudation have been fully described and explained by Dr. Johannes Walther in his work "Der Denudation in Der Wüste",[1] illustrated by many examples from the Egyptian desert. Insolation, or the action of the sun's heat, is explained at page 19 of the work cited, and is shown to be due to the alternate expansion and contraction of the outer layers of the rock surface, while the inner layers remain at a more equable temperature, and do not therefore change in volume. In Rajputana the results of this action are as conspicuous as they are in Egypt, and the fragments, especially those of the compact lavas, are everywhere traversed by fine cracks, the "halbgesprungene kiesel" of Walther, due to the same cause, so that when struck with the hammer they break up into a number of small sharp-cornered fragments, and it is often very difficult to obtain a good hand specimen. The peculiar half-shattered condition of the boulders of this lava and other crystalline rocks in the boulder bed of the Salt Range, which renders them liable, however solid they may be in appearance, to fall to pieces at a blow from a hammer, may be due to the same cause.

Deflation, or the action of sand laden wind, is described in Chapter I, section 5, and Chapter IV, section 1, of the same work. The peculiar character of the rock sculpturing due to this cause has been described by Mr. R. D. Oldham[2] who draws attention to the difference between the polished surfaces and striæ produced in this

[1] Königl. Sächsischen Gesellschaft der Wissenchaften, Vol. XVI, No. III, 1898.

[2] Rec. Geol. Surv. Ind., Vol. XXI, Pt. 4, p. 159.

way and the results caused by moving ice. Examples of this rock sculpturing may be seen on the crests of any of the rocky hills in Marwar exposed to the prevailing winds, and especially clearly on the smooth surfaces of the glassy Malani lavas (Pl. I, fig. 1) The process, in the case of the more highly porphyritic lavas, is assisted by the decomposition and weathering out of the felspars, whereby a pitted surface, giving the rock a vesicular aspect, is formed, affording the sand blast a continually renewed, roughened surface to work on.

The undercutting and polishing of isolated masses of granite is another instance of the effects of deflation (Pl I, fig. 2), and the large hollows frequently seen in the cliffs of granite and lava may be partly due to the same cause; but these hollows probably owe their origin more to the weathering out of concretionary masses in the case of the granite, or, in the case of the lavas, to the presence of large gas pores. In both cases the hollows are probably only enlarged and polished by the wind. The hard bands of sub-recent conglomerate often found in the river beds are sometimes affected in a curious way. Where they rest upon softer sands the latter are cut away from under them by the wind, leaving oblong masses of the conglomerate, which are frequently tumbled about at all angles (Pl. I, fig. 3). If these masses were subsequently covered up with silt or sand and the whole consolidated and afterwards denuded, the geologist of the future might have some difficulty in understanding how such large masses of apparently transported conglomerate came to be heaped together in a bed of sandy silt, and if he were a glacialist, might be strongly tempted to call them erratics, and ascribe their position to the agency of floating ice or glaciers!

Acting as they do on rocks of varied composition and texture, these agents of denudation produce results of very different appearance. The highly inclined schists and quartzites of the Aravalli system are formed into long hog-backed ridges with an equal slope of talus on either side; the undulating sheets of Malani lava form conical hills or long ridges with steeply scarped sides and rugged contours, with a talus of exceedingly sharp angular fragments at the foot of the scarps (Pl. III, fig. 1); the more homogeneous bosses of intrusive granite have their outer surface stripped off in concentric layers and form hummocky domes with steeply sloping smooth sides, while since the granite fragments are quickly broken up by the action of the weather into a loose gravelly sand, little or no talus is formed at the foot of the hills composed of this rock (Plates VI-VIII); and lastly the almost horizontal sandstones are carved into level plateaux, surrounded by almost vertical scarps, wherever they rise to any appreciable height above the plain. It is thus possible to form an opinion of the character of the rocks of which any particular hill consists, even from a considerable distance, by observation of its form and the appearance of the talus slopes at its foot.

A peculiar feature in several parts of the country, especially in those where the blown sand is not in great quantity, is the occurrence at the base of each isolated rocky peak or knoll of a gently sloping "glacis" extending to a distance of a mile or more from the foot of the hill. Sections of these "glacis" are exposed in great numbers in the numerous water-courses, dry except during an actual fall of rain, which radiate in all directions from the hill, and cut deep channels in the deposit. Their substance is seen to consist principally of a calcareous tufa or "kunkur" frequently consolidated into bands of considerable thickness, mingled with sand and fragments of the rock composing the hill, in fact, a natural concrete. The kunkur gradually diminishes in thickness towards the outer edge of the "glacis" and the slope gradually fades off into the surrounding plain. The sand on the level is also frequently impregnated with nodular kunkur, as may be seen in the wells, but except near the hills this accumulation of calcareous matter does not rise above the general level, and the formation of the "glacis" is evidently connected in some way with the presence of the hill. I shall refer to the source of the carbonate of lime from which this kunkur is formed later on in the chapter dealing with the blown sand.[1]

[1] *Infra*, p. 41.

Little need be said here about the process of formation of the sandhills, which has often been described and explained.[1] I have not had an opportunity of seeing the longitudinal type of sandhill, found along the western edge of the desert in the Thar and Parkar district of Sind, but many of those that occur in the parts of the desert visited by me are of an intermediate type. Several of these are well shown on the one-inch maps of the neighbourhood of Balotra.[2] They appear to have been formed from hills of the transverse type by wind denudation, the wind having scooped out furrows along the windward slope of the dunes. In the Barmer desert the sandhills are all of the transverse type and well illustrate the tendency that dunes possess of remaining permanent when they have reached a certain height, for these dunes are all large, rising to 150 or 200 feet above the plain, and have evidently, judging from the size of the trees growing on their leeward slopes, remained in their present position for many years. Further to the north-east, to the west of Jodhpur and in Bikanir, the sandhills are not so high, and are constantly in motion during the monsoon, but I have had no opportunity of studying their motion during that period.

The rivers of this region play a very subordinate part in moulding the surface features of the country. None of them, even near the hills, contain perennially running water, and the beds of all of them are so choked with sand, that the water, when floods do occur, exercises little or no eroding action on the solid rock. The Luni is the principal river, taking its rise in the Ana Sagar at Ajmere and traversing the whole of Marwar till it loses itself in the sands at the head of the Runn of Cutch. It receives many tributaries from the Aravallis to the south-east of its course, but none of any size from the more sandy country to the north.

[1] Blanford. Journ. As. Soc. Beng., Vol. XLV, Pt. 2, p. 86.
Walther. Denudation in der Wüste, Chapter V.
Vaughan Cornish. Journ. Roy. Geo. Soc., Vol. IX, p. 288.

[2] Rajputana Survey, Sheets 71, 72.

It seems not improbable that the depression in which the salt deposits of Pachpadra are collected is a portion of an old bed of the Luni. Near the town of Pachpadra and again lower down where the Luni makes a sudden bend to the south there are traces of the bed of a large river indicated on the one-inch map,[1] and even now when the river is in flood it spills over the northern bank above Tilwara and flows towards the Pachpadra depression, but is prevented from flooding it by sandhills.

There seems little doubt that within quite recent times the flow of water down these rivers must have been much greater than it is now, and that the change is due to an alteration in the climate. Nearly all the rivers contain masses of subrecent conglomerate, formed of well rolled pebbles and boulders of various crystalline rocks embedded in a calcareous sandy matrix. The conglomerate is always in horizontal layers, exposed in the banks and beds of the rivers and sometimes filling cracks and fissures in the older rocks. These pebbles and boulders must have been transported at a time when the flow of water was much greater than it is now, for the present rivers, even in times of flood, are able to move little more than fine sand and gravel, and only just round off the corners of such fragments of rock as do find their way into them.

If the sand that now chokes the lower courses of the rivers were cleared out, the velocity of the water in the rivers would no doubt be increased, and its power of erosion and of rounding pebbles and transporting them would be proportionally enhanced. At the same time the sea would occupy a large portion of the valleys, the Runn of Cutch, for instance, even without any subsidence of the valley floor. This change would no doubt have a great effect on the climate and the rainfall inland would be greatly increased. A gradual silting up of the river valleys, combined with the progressive encroachment of the blown sand, would account for the change to the present arid condition of the country.

[1] Rajputana Survey, Sheet 71.

CHAPTER III.—STRATIGRAPHICAL FEATURES.

(CRYSTALLINE ROCKS.)

With the exception of the schists and quartzites of the Aravalli system, which are only found along the eastern border of the area under discussion, and are everywhere vertical or highly inclined to the horizon, the rocks met with have suffered very little disturbance since they were first formed, a circumstance which adds considerably to the difficulty of working out their relations with each other, for many of the isolated exposures exhibit only one variety of rock, entirely cut off from all visible contact with those that may be associated with it, by the surrounding sand. As before mentioned, nearly the whole of the rocks seen are crystalline, and can only be distinguished from each other on petrological and stratigraphical grounds. The only fossiliferous rocks in the whole of Marwar are the sandstones of Barmer, and the age of these even is a matter of doubt, since the fossils, which almost without exception are plant remains, are in so fragmentary a condition that it is difficult to form any definite conclusions from them.

It is impossible in the present state of our knowledge of the crystalline formations of India to identify the crystalline rocks of Marwar with those of other localities, and just as the region is sharply cut off by its climate and aspect from the remainder of India, so the geology must be regarded for the present as peculiar to this area. In fact, the most widespread formation that occurs here, the volcanic lavas and tuffs of the Malani series, are so far as is yet known, confined strictly to this part of the country, and have no representatives in other parts of India.

The formations represented are given in the following table, the

Jodhpur area including the whole of the country between the eastern edge of the Barmer desert and the Aravallis :—

PERIOD.	Jaisalmir (Oldham).	Barmer.	Jodhpur.
Recent	Blown sand and alluvium.	Blown sand and alluvium.	Blown sand and alluvium.
		...	River conglomerate.
Sub-recent	Amir shingle beds		
Teritary	Nummulitic limestone		
Mesozoic	Abur group Parihar sandstone Bedesir group Jaisalmir group Lathi group	Barmer sandstone (? cretaceous).	
	Unconformity.	*Unconformity.*	
Palæozoic	Boulder beds of Bap and Pokaran (Talchir).		Boulder beds of Bap and Pokaran (Talchir).
	Unconformity.		*Unconformity.*
	Sandstone (Vindhyan)		Limestones, Sandstones } Vindhyan.
			Unconformity.
		Malani Volcanic series.	Malani Volcanic series.
			Unconformity.
			Schists and quartzites (Transition).
		Intrusive rocks.	
		Siwana granite, Jalor granite	Intrusive in Malani series.
		Erinpura granite.	Intrusive in transition schists.

1. Schists and Quartzites (Delhi System ?).

The schists and quartzites, already mentioned as occurring only in the eastern portion of the region under review, are very poorly represented, and the outcrops they furnish are so isolated and fragmentary that it is impossible to form a definite opinion as to the order of succession of the strata. So far as I am able to express an opinion, judging from the published descriptions, they appear to belong to the Delhi system as restricted in the second edition of the Manual.[1] They consist of dark grey micaceous schists, or schistose slates, with thick lenticular beds of white or bluish white quartzite, the latter often forming hills of considerable size, in which the quartzite is the only rock visible. The strike of the whole series is from north-east or north-north-east to south-west or south-south-west, parallel to the main range of the Aravallis, and they are always very highly inclined or vertical. Along the foot of the Aravalli range, in the district of Godwar, these rocks contain bands of calcareoue schist which, when in contact with intrusive granite, has become altered into a white crystalline marble. A large mass of this occurs at the village of Sarangwa, about four miles west of Desuri, and is largely quarried for building purposes. The marble rests upon a large dome-shaped boss of granite, a portion of the large spread of that rock which occupies the ground between the base of the hills and Erinpura. A lenticular fissure containing large rhombohedral crystals of calcite or Iceland spar was recently discovered among the calcareous schists in the hills about seven miles south-east of Sadri, near Desuri in Godwar. Some of the crystals are fairly transparent, but none are without flaws, and the bulk of them are too opaque to be of any value.

The famous marble quarries of Makrana are situated in exactly the same position as regards the range, but are about 140 miles to the north-west of Sarangwa. Here the marble forms bands very constant in width, in micaceous and calcareous schists with a north-north-east—south-south-west strike and very high easterly dip. The rocks form a series of low ridges parallel to each other, separated by level stretches of blown sand. There may be only one band of marble repeated by folding. The bands of marble alone are worked

[1] Manual, Geology of India, 2nd edition, p. 68.

out, leaving, in the centuries that have elapsed since the quarries were first opened, a series of deep narrow chasms, partly filled with débris and sand. The marble varies a good deal in texture, some portions being fine grained and translucent, while the grain of other portions is much coarser. The beauty of the carved work fashioned from this marble is well known. Here also the alteration of the rock into marble is apparently due to the intrusion of a coarse granite, veins of which penetrate the schists in the direction of the strike.

2. Erinpura Granite.

To the west of the main range of the Aravallis, in the district of Godwar, the low ground is occupied by a great spread of an exceedingly coarse granite, which stretches as far west as the hills north of Erinpura, but is not found further west than this. To the south it extends into Sirohi, and may be easily recognised along the railway to the south of Erinpura by the rounded hummocky knolls into which it has weathered (Pl. VIII). The felspar crystals in this granite are frequently three, or four inches in length, and the other constituents, quartz and mica, are in proportionally large crystals. Where the granite is in contact with the schists, it assumes a gneissose character and is foliated along lines parallel to the junction, but that it is really intrusive is proved by the irregularity of the boundary, by the fact that the granite throws off veins into the schists, that it includes fragments of the latter, and that in some cases, as for instance the marble of Sarangwa referred to above, the rocks in contact with it have been altered. Near the junction with the schists the included masses of the latter have been rolled out into lenticular patches and add to the foliated appearance of the granite; the large felspars are drawn out into lenticular " eyes " surrounded by films of mica and the rock has the appearance of a true gneiss. But at a distance from the boundary, the felspars are arranged in no definite direction, and possess well defined prismatic outlines, and the granitic nature of the rock is apparent.

The eastern boundary of this spread of granite runs along the foot of the main scarp of the Aravalli range in the district of Godwar and it does not appear to extend into the hills. The boundary is probably a faulted one, but it is always concealed by débris from the hills. It was mapped by Mr. Hacket as gneiss, but he seems to have been in some doubt as to its true character and relations with the true gneiss of the Aravalli system.[1]

3. The Malani Volcanic Series.

After the intrusion of the coarse granite of Erinpura just described, a considerable length of time must have elapsed during which both the schists and granites were folded under enormous pressure and afterwards largely denuded before the next series of rocks was deposited upon their upturned edges. Only one instance has yet been discovered of a visible junction between the schists and the overlying bedded lavas.

The section is exposed in a valley lying about two and a half miles to the south-west of the village of Miniari and seven miles north of Chanod in the district of Pali[2] It is mentioned by Mr. Hacket, who says that "a small thickness of red shales dip under the Malani porphyries; but I am unable to say if they are Arvalis or not. These hills are quite isolated in the plain; the nearest hills of gneiss are at Kaunla, about eight miles to the south, and the nearest Arvalis about eighteen miles to the south in the large hills north of Erinpura."[3] A diagrammatic representation of the section is given in fig. 4, Pl. I.

The floor of the valley is occupied by reddish slates or shales which are either vertical or have a very high dip to the south-east. The

[1] Rec Geol. Surv. Ind., Vol. XIV, Pt. 4, p. 298.
[2] Rajputana Survey, Sheet 115.
[3] Rec. Geol. Surv. Ind., Vol. XIV, Pt. 4, p. 302.

lavas are bent up into an anticlinal, the axis of which runs north and south, and the flows rise in steep scarps on either side of the valley On the west side, at the base of the scarp, a band of conglomerate some 20 feet thick is interposed between the lavas and the slates, resting on the upturned edges of the latter. The boulders and pebbles in this are frequently well rolled and consist of quartzose grit, quartz, schist and slate, evidently derived from the underlying slaty series. The strike of the slates is fairly steady, from north-east to south-west, the lavas and associated beds passing transgressively across their edges, and the evidence of unconformability is very complete. On the east side of the valley the slates appear to dip beneath the lavas and the conglomerate is not visible, but the ground is covered with talus and thorny scrub. The angle of dip of the two series of rocks is however quite different, and at the north end of the valley on this side the lavas are again found resting directly upon the upturned edges of the slates. I found several exposures of micaceous schist with exactly the same strike as these slates, in the plain to the east of this section, and I have no doubt that the slates do belong to the Aravalli series.

At one or two places to the north of this, *viz.*, on the western edge of the group of hills at Khairla, a station on the Jodhpur railway to the north-west of Pali, and again at Rajpura on the left bank of the Luni, about half way between Khairla and Jodhpur, nearly vertical slates are seen within a few hundred yards of outcrops of the Malanis, and in these instances the lava sheets are quite unconformable both in dip and strike to the older rocks. Mr. Hacket says that the schists at Khairla are " undoubted Arvali rocks."

The lavas of the Malani series are for the most part rhyolites of a highly acid type, varying greatly both in colour and texture. The most common variety is of a rich brown colour tinged with red or purple, with a stony texture and studded with porphyritic crystals of pink or flesh coloured felspar and minute blebs of quartz. Other colours, such as bright red, blue, green, dark grey or black are common, and a few are white or light grey. Sometimes the porphyritic crystals are altogether absent. The lavas are all highly siliceous and so hard that the unweathered surface cannot be scratched by a knife. In spite of the great age of these rocks, and of any alteration they may have undergone, there is clear evidence that when originally formed they were true volcanic ejectamenta, spread out over the surface of what was probably dry land or the shores of a shallow lake or sea. All the well known characteristics of glassy lavas can be observed in them. Some of the flows show beautifully developed flow-structure, and in many the original glassy texture has hardly undergone any alteration, so that a thin slice remains almost dark under the microscope between crossed Nicols. Perlitic structure, one of the most certain indications that the rock was originally a true glass, can be detected in a few cases, and sphærulitic structure is very common, ranging from the most microscopic examples up to nodules an inch or more in diameter. A vesicular structure is not often met with, but it does occur in some of the flows ; the vesicles are often filled with secondary minerals, forming amygdales.

In many places the lavas are interstratified with thick beds of tuff and breccia formed out of the dust and fragments of the lavas themselves, and evidently due to volcanic explosions. Some of the tuff beds show signs of having been rearranged under water. But the most conclusive evidence for the subaerial character of the volcanoes is afforded by the presence of bands of conglomerate, formed of well rolled pebbles of the lavas, intercalated between the flows in many places. These bands have all the appearance of ordinary river gravels, and prove that at certain times during the period of volcanic activity subaerial denudation was acting upon the lava flows already solidified.

The lavas and associated rocks cover a very large area in Jodhpur territory, extending from a little east of the meridian of Jodhpur to the edge of the desert between Barmer and Sind, or 145 miles from east to west, and from Pokaran in the north to Jalor in the south, a distance of 120 miles. The area over which they are found thus amounts to about 17,000 square miles. They have hitherto not been identified with certainty beyond the limits of the Jodhpur State, though there is no doubt that rocks closely resembling them occur in other parts of India. Some similar rhyolites, occurring at Tusham hill, about 240 miles to the north-east of the nearest outcrop of the true Malanis near Jodhpur, have been described by Colonel McMahon.[1]

The conditions under which the lava sheets are now exposed, in isolated hills and ridges often separated by miles of sand-covered ground, render it impossible to make out any regular sequence among them, nor can any estimate be formed of the total thickness of the volcanic series. There are no indications whatever of the presence of the vents from which the lavas were poured out, except in one doubtful instance which will be referred to subsequently.[2] The slight amount of disturbance they have undergone has not been sufficient to bring the base of the series to the surface except in one locality,[3] and the vents, whether these were in the form of fissures from which the lavas welled out and consolidated on either side, or pipes of the Vesuvian or Puy type, are buried beneath the accumulation of lava, or may perhaps be concealed beneath the sand. If the vents were filled towards the close of the volcanic period with loose material, it is quite likely that they would have suffered denudation more rapidly than the hard sheets of lava surrounding them, and their sites would be covered with alluvium and sand. With regard to the nature of the vents, there does not appear to be any concentric arrangement of the lava sheets, such as, even in the fragmentary state in which they are exposed to view, we might expect to find if they had been ejected from a centre of eruption, and it is therefore more probable that they were of the fissure type.

[1] Rec. Geol. Surv. Ind., Vol. XVII, Pt. 3, p. 101. Vol. XIX, Pt. 3, p. 101.
[2] *Infra*, p. 51.
[3] *Supra*, p. 19.

That the eruptions were accompanied by explosive outbursts is proved by the intercalation of tuffs and bands of breccia, produced by the shattering of previously consolidated flows, among the bedded lavas.

The viscid character of such acid lavas as these, when they were in a liquid state, is often well exhibited by the uneven and scoriaceous aspect of the surface of the flows, and by the abrupt manner in which they frequently die out. Some of the sheets are of considerable thickness and extend without any alteration in appearance for several miles, but very often a scarp can be seen to be built up of a number of thin sheets, differing from each other in colour and texture. A columnar structure is frequently well developed in them, and also serves to distinguish the different sheets, building up a scarp, from each other.

There are indications that during this period the eruptions were not altogether of an acid character. In several places sheets of igneous rock of a more basic type, containing plagioclase felspar and no free quartz, are interbedded with the rhyolites. It is difficult to say whether these are truly interbedded lavas or whether they are sills thrust in between the sheets of rhyolite after the consolidation of the latter. The material of which they are composed is much more subject to decomposition than that of the rhyolites, and as a rule their relations with the latter are obscured by soil and débris. They sometimes appear to be intrusive, but in other cases the appearance of interstratification is quite as clear. On the whole I think that the balance of evidence is in favour of their being intrusive.

The tuffs and breccias associated with the lavas are quite subordinate in amount to the latter, so far as can be seen from the limited exposures now visible. It is quite possible that a great part of the sandy plains between the hills of lava may be underlaid by these softer rocks, which are as a rule exposed only in the slopes at the base of the scarps formed of the harder lavas. The tuffs are usually distinctly stratified, but the breccias are generally found in small patches only, enclosed between sheets of lava. The bands of pebbly conglomerate intercalated in places between the lava flows are sometimes associated with tuffs, but elsewhere they are sandwiched in between two flows of lava without the intervention of any finer material.

4. Granites associated with Malani Series.

Closely connected with the outpouring of the lavas there are other signs of volcanic activity in the intrusion, both into the Aravalli schists and the lavas themselves, of great masses of granite. The granite is generally coarse grained, but not nearly so much so as the Erinpura granite described above, and is lithologically of two varieties. One of these contains quartz in abundance, pink or white felspar, and hornblende, but no mica. This is the "syenite" of Mr. Blanford. The other variety contains the same minerals, but with the addition of mica. The latter, which I have named the Jalor granite, since it is well developed in the neighbourhood of that town, which is built at the foot of an enormous boss of this granite, is confined to the eastern edge of the volcanic area, where it forms a succession of large bosses, either surrounded by highly inclined Aravalli schists, or in a few cases in contact with the lavas, in which it is seen to be intrusive. The other variety, without mica, is confined to the interior of the volcanic area. It forms the greater part of the enormous mass of the Saora range, south of Siwana, rising to over 3,000 feet above the sea, and several other bosses formed of it are found in that neighbourhood. I have, therefore, named it the Siwana granite. It also forms several hills in the Barmer area, and it is found to the south-west of that district on the borders of the Runn of Cutch, in the Kalinjur hills of Nagar Parkar, where it has been described by Mr. Wynne.[1] In the Barmer area the relations of the granite to the lavas are not so clear as elsewhere, for although there is evidence that the granite was intrusive in the lava sheets in contact with it, the former is also traversed by dykes of a rock indistinguish-

[1] Mem. Geol. Surv. Ind., Vol. IX, Pt. 1, pp. 48, 98.

able from the lavas, which must have been injected after the consolidation of the granite. The granite must have been intruded after a sufficient depth of lava had accumulated to allow of the crystallisation of the material in a coarse grained form, but before the extrusion of the lavas had ceased. The granites may, therefore, be considered as strictly contemporaneous with the lavas, and it is not at all improbable that they mark the approximate sites of some of the vents or fissures from which the latter were poured out.

5. Basic dykes.

The volcanic period was succeeded by the intrusion into the complex of lava and granite of a number of basic dykes, the material of which is an altered olivine dolerite or diabase consisting of plagioclase felspar, olivine and augite with a small amount of biotite. The interval that elapsed before the intrusion of these dykes cannot be ascertained, but it must have been sufficient to allow of the development in the lavas and granites of joint planes, since the dykes usually follow such planes. The majority of the dykes run north and south, but another system crosses these almost at right angles. There does not seem to be any difference in composition between the rocks of each system. They appear to have been injected before the deposition of the overlying Vindhyan sandstones, since they have not been found traversing these, but as it happens, none of the dykes were observed, even among the lavas, in that part of the country where the remnants of the sandstones are now visible, and it is quite possible that the dykes are of post-Vindhyan age. Mr. Blanford mentions an outburst of "basalt" in connection with the Talchir boulder beds of Pokaran, but he says that the relations of the rocks are not clear.[1]

[1] Rec. Geol. Surv. Ind., Vol. X, Pt. 1, p 13.

CHAPTER IV.—STRATIGRAPHICAL FEATURES.

(SEDIMENTARY ROCKS.)

6. Vindhyan sandstones and limestones.

The relations between the Vindhyan sandstones and the schists of the Aravalli series is, as might be expected, one of complete unconformability. A section of the junction occurs at Sojat, where Mr. Hacket thus describes it.[1] "The Sojat hills are formed, at base, of nearly vertical Arvali slates, capped by about 10 to 20 feet of a conglomerate composed of small pebbles of quartz, very nearly horizontal, or with a dip of 3° to north, passing up into a fine white and reddish sandstone, of which there may be about 100 feet in thickness. On the northern side of the hills are some beds of chert resting upon the sandstone, and which in the large hills a mile to the north passes up into a thick limestone. The sandstone resembles very closely the Kaimur sandstone, and doubtless the whole, from the conglomerate upwards, may be referred to the Upper Vindhyan series."

Still further north, at Khatu, a similar section of the unconformable junction between the schists and sandstones is exposed, but here there is another band of conglomerate with overlying sandstones between the Kaimur sandstone and the limestone. This second band of sandstone is referred by Mr. Hacket to the Bhander subdivision, and is stated to be upwards of 200 feet thick. The middle (Rewa) group of the Upper Vindhyans is absent.

After the eruption of the Malani lavas a considerable period of time may have elapsed before the sandstones of the Vindhyan system were deposited upon them. The evidence of unconformability is not so clear as in the case of the junction between the schists and sandstones, for as it happens the sandstones are never seen in contact with the lavas in places where the latter have been disturbed, but wherever the two formations occur together they are both nearly hori-

[1] Rec. Geol. Surv. Ind., Vol. XIV, Pt. 4, p. 300.

zontal. On the other hand there is clear evidence that the lavas were subjected to a long period of erosion and weathering before the deposition of the sandstones. In the scarps north of the city of Jodhpur numerous sections of the junction are exposed, in which the sandstones are seen to rest upon a very uneven floor of the lavas. This in itself would not be evidence of unconformability, for the surface of the lava flows was probably originally irregular and hummocky, as is usual with such viscous lavas as these, but the sandstones can sometimes be seen banked up against denuded and scarped edges of the flows. Moreover, at the base of the sandstones there is frequently a layer of varying thickness in which large blocks of the lava are imbedded in silt and grit (Pl. II, fig. 1). These are not waterworn boulders, transported from a distance, but are always of the same variety of lava as that composing the sheet immediately underlying them, and they have evidently been weathered out *in situ*, and then quietly buried in silt. Again, the upper portion of the lava flows, where they are exposed beneath the scarps of sandstone, is usually found to be weathered to a considerable depth, so that the lava has become quite soft and rotten. This weathering of the surface of the lavas is not observed where they are not protected by the sandstone, and evidently took place before the latter were deposited, and judging from the effects of atmospheric agencies on the lavas at the present time, it must have taken a very long period to produce the results noted on such slowly altered rocks as these. Lastly, in a few places patches of true conglomerate, containing waterworn and well rolled pebbles and boulders of the lavas, mingled with pebbles of other crystalline rocks, and transported from a distance, are found occupying hollows in the uneven surface of the lava flows, and underlying the sandstones. These are associated with beds of fine red and green shales also of quite local occurrence.

Whatever may have been the length of the interval separating the period of the emission of the lavas from that of the deposition of the

Vindhyans there is no doubt that an entire change of conditions took place during it, and that from this time onwards this region, which had in former times been the scene of intense volcanic activity, became subjected only to those slow changes of level which have resulted in the gradual accumulation of a series of sedimentary rocks. The oldest of these are sandstones, passing upwards into impure cherty limestones, and the whole group from its resemblance to the Vindhyan sandstones and limestones on the eastern side of the Aravalli range has been referred to that period. The position of the group with reference to the undoubted Talchir boulder beds of Bap and Pokaran renders it impossible that it can be other than Vindhyan.

At Jodhpur the thickness of the sandstones does not exceed 200 feet, but they have been subjected to great denudation, and the upper portion of the beds has been everywhere removed. In this neighbourhood they dip very gently towards the north, and gradually disappear beneath the plain, and the isolated groups of hills further north probably consist of higher beds of the same series. At Pokaran, where they are exposed close to the Talchirs, but not visibly in contact with them, the boundary is probably a faulted one.

The sandstones consist of rapid alternations of more or less fine grained gritty material, generally tinged with red, but sometimes grey or white. Strings of waterworn pebbles of quartz, none of which are of large size, frequently occur, especially in the higher portion of the beds, and with the presence of current or false bedding, which is very conspicuous in the artificially scarped cliffs near Jodhpur, and the numerous examples of ripple marking, which is beautifully developed on the surface of some of the finer beds, indicate that the sandstones were laid down in shallow water. Some of the finer beds make a most excellent building stone, universally employed in Jodhpur and the neighbourhood. Not only are the walls of the houses built of it, but pieces of sufficient length in proportion to their thickness are obtained and used as beams for the roof, while thinner slabs are used for the ceilings. Thus except for doors and windows no wood whatever is employed in the construction of the houses, no slight advantage in a country where wood fit for timber is so scarce. The same stone is also capable of being fashioned into the beautiful carved work with which the larger houses and palaces in Jodhpur are embellished, the soft reddish colour of the stone adding greatly to the effect of the delicate tracery of the window screens and other ornaments. No one who has seen the interior of the Fort at Jodhpur will readily forget the impression made at once by the massive character of the buildings and the delicacy of the carved screens and cornices so lavishly employed in their ornamentation, and it is difficult at first to realise that the same material can be turned to such different uses.

The occurrence of two bands of conglomerate in these sandstones near Sojat and Khatu, already referred to,[1] points to the existence of a shore line in the direction of the Aravalli range at the time of their deposition. Mr. Oldham has already pointed out [2] the resemblance between the relations of these beds to the Vindhyans on the eastern side of the Aravallis and those of the recent deposits on the northern flanks of the Himalayas with the Indo-Gangetic alluvium. There was apparently no connection whatever between the basins of deposition on either side of the range, and in the absence of fossil evidence it is only on lithological grounds that we can correlate the successive beds in these separate areas with each other. All we can say is that towards the end of the Vindhyan period a local depression was formed in the western side of the Aravallis, in which these sandstones and limestones were deposited. It is impossible to say how far this basin extended in a north-westerly direction, for the rocks on that side are concealed beneath the Jurassics of Jaisalmir and the sands of the desert. To the south and south-west it did not extend apparently as far as Balotra or Barmer, for in that direction sandstones of much later age rest directly upon the Malani lavas. But

[1] *Supra*, p. 26.
[2] Manual, Geology of India, 2nd Edition, p. 106.

to the north-east, parallel to the Aravalli range, the basin extended, at least at intervals, as far as Khari, 40 miles to the north-east of Bikanir, and 150 miles from the present southern limit of the sandstones near Jodhpur.

So far these rocks have yielded no traces of indubitable organic remains, but in the neighbourhood of the village of Osia, 30 miles north of Jodhpur, I found on the lower surface of some of the fine grained sandstone beds at a particular horizon, certain markings which I find it difficult to reconcile with any other than an organic origin. They are evidently casts of grooves on the upper surface of the underlying beds, but the latter appear to have been of a soft clayey nature and all trace of the actual grooves has disappeared. The casts are in the form of straight or curved ridges, occasionally duplicated, with a rounded cross section, very slightly raised above the surface of the slabs on which they occur and about one-eighth of an inch in width. They are sometimes parallel, but frequently cross each other in all directions. The resemblance of the straight ones especially when they tail off gradually at the ends, as they often do, to mechanically formed striæ, is very striking, and it is possible that they may have been produced by some mechanical means, but it is very difficult to conceive what the agent can have been. They are certainly not worm tracks; they are not such markings as would be made by large grains of sand or small pebbles, besides no such pebbles are to be found in the beds in which they occur. Floating vegetation just grazing the bottom; the tips of fronds of algae or reeds sweeping to and fro under the influence of gentle currents in shallow water; or possibly the fins of fish swimming within a short distance of the bottom are explanations that have suggested themselves to me, but none of them are satisfactory, especially because if the markings were due to either of these causes we should certainly find traces at least of the vegetation or of the fish preserved in these fine grained sandstones, and a diligent search has revealed absolutely nothing of the kind. For the present, therefore, the origin of these mysterious markings must remain undecided.

7. Boulder beds of Bap and Pokaran (Talchir).

The next group of beds in succession to the Vindhyans has already been alluded to several times; these are the boulder beds exposed at Bap, Pokaran and other places on the eastern borders of Jaisalmir. I have not met with these beds in any part of the area surveyed by myself, but they are described by Mr. Blanford as consisting of "green, red and variously coloured shales, occasionally soft, but often hard and even porcellanic. Some are fine, others are coarse and sandy, and contain grains of pink felspar, and of a green mineral resembling epidote; some beds being composed throughout of one or the other of these minerals. In places, pebbles and boulders of the Malani porphyries and syenite are found towards the base of these shales; the boulders being occasionally from three to four feet in diameter, whilst remains of much larger blocks, which had fallen to pieces, but which could not have measured less originally than twelve to fifteen feet in diameter, were seen about Lowo. These boulders appear to have been brought from a distance, and there is some reason for supposing that they may have been transported by ice, as the underlying surface of the Malani porphyries near Pokaran was in one instance found to be grooved and striated."[1]

These beds were supposed by Mr. Blanford to underlie the Vindhyan sandstones, and Mr. Oldham was at first of the same opinion, but 40 miles to the north-east of Pokaran, near the village of Bap, exactly similar beds are seen, but containing, in addition to boulders of the Malani lavas, pebbles derived from the Vindhyan limestone, which must therefore have been indurated and metamorphosed before the accumulation of the boulder beds.[2] The difficulty

[1] Rec. Geol. Surv. Ind., Vol. X, Pt. 1, p. 17.
[2] Rec. Geol. Surv. Ind., Vol. XIX, Pt. 2, p. 123.

of supposing that two exposures of such similar beds, separated by so short a distance horizontally, should belong to such different periods as pre and post-Vindhyan, makes it almost certain that the boulder beds at Pokaran are faulted down against the Vindhyans. The sandstones of the latter formation form a scarp rising above the low ground in which the boulder beds are exposed, and the apparent superposition of the sandstones on the Talchirs may be due to masses of the sandstone having slipped bodily down the scarp.

Mr. Oldham describes the boulder beds of Bap as consisting of "a matrix of fine grained marl through which fragments of felsite, syenite, limestone, gneiss and granite of all sizes from a few inches to in one case over 10 feet across, are scattered; and many of these are smoothed and striated in the peculiar manner characteristic of glacier work."[1] These beds extend from Shekasar to Nokra, both villages near the eastern boundary of Jaisalmir, a distance of about 35 miles.

Another instance of a boulder bed of probably the same age may be mentioned here, since it contains boulders of the Malani lavas and granites, though it occurs far beyond the limits of the area now dealt with. This is the well-known boulder bed of the Salt Range in the Punjab, which has been shown to be of upper Palæozoic age and to rest unconformably and transgressively on all the older Palæozoic strata of the range.[2] Mr. Middlemiss has described microscopically several specimens of the boulders from this bed, and though he could not specifically identify any of his specimens with the few examples of Malani rocks available, he notes the existence of a certain family likeness between them.[3] These boulders were probably carried across from what must have been the high glacier covered land of the Malani area by floating ice.

[1] *Loc. cit.*

[2] Manual, Geology of India, 2nd Ed., p. 120. Rec. Geol. Surv. Ind., Vol. XXIV, Pt. 1, p. 22.

[3] *Ibid.* Vol. XXV, Pt. 1, p. 29.

8. Barmer Sandstones.

The only strata of later age than the Talchirs, excepting recent deposits, that occur in the area I have personally examined, are the plant bearing sandstones of Barmer, mentioned by Mr. Blanford.[1] These rocks consist of whitish and grey sandstones locally indurated and breaking with a conchoidal fracture, but sometimes soft and veined or blotched with purple or red. At the base is a thick band of conglomerate, the pebbles in which are well rolled and are all derived from the underlying Malani lavas. Some of the sandstones are locally slightly calcareous. The beds dip to the north-east at angles of 20° to 25° and near the town of Barmer form a narrow fringe along the margin of the hills of lava. A small outlier of the conglomerate occurs at the top of a conspicuous conical peak about a mile north-west of the town, rising to about 500 feet above the plain and 1,387 feet above sea level. Patches of a similar sandstone, surrounded by sand and alluvium, occur at intervals for about 18 miles to the north and there are others on the eastern side of the Barmer desert not far from the Luni. Here they rest directly upon an uneven floor of the lavas. At Barmer the sandstones are extensively quarried for millstones and building purposes.

The upper limit of the sandstones is concealed by the alluvium of the plain, and nothing can be seen of the overlying beds. A fine unctuous clay or fuller's earth, which may overlie the sandstones, is found at Kapuli, a village about 12 miles to the north of Barmer, and is quarried for sale as "Multani mitti." It may be of lower Tertiary age, for the same substance is found and quarried to the north-east in Jaisalmir and Bikanir territory and is there associated with nummulitic limestones.

I spent several days at Barmer in attempting to collect more well preserved fossils from the sandstones than had hitherto been obtained. It is impossible to get perfect specimens as the sandstones will not

[1] Rec. Geol. Surv. Ind., Vol. X, Pt. 1, pp. 11, 18.

split along definite bedding planes, and all the fossils I obtained are in a more or less fragmentary condition. One specimen appears to be part of the cast of a *Unio* shell, but the hinge is absent; I also found another small fragment of a bivalve shell, which may be a *Cardium*. The most interesting plant remains obtained are two impressions of veined leaves, which are undoubtedly dicotyledonous angiosperms and, so far as they go, indicate that the beds are not older than cretaceous. But, further to the north-east on the borders of Jaisalmir, there is a group of sandstones containing fossil wood and plant remains which Mr. Blanford considered to be on the same horizon as the Barmer sandstones, and which Mr. Oldham found to underlie the marine Jurassic beds of Jaisalmir. Mr. Blanford distinctly states that these sandstones, named the Lathi group by Mr. Oldham, contain *dicotyledonous* fossil wood, and we must either suppose that in this region dicotyledonous plants appeared at an earlier stage of geological history than they do in Europe, or that the sandstones of Lathi do not really underlie the Jurassic strata of Jaisalmir but are faulted against them, or that the latter are not really Jurassic, but belong to a higher stage among the Mesozoic strata. So little is as yet known of the palæontology of these Jaisalmir rocks that the question must be left unsettled for the present. It should be stated, however, that among the fossils collected by Mr. Blanford from the Jaisalmir limestones, the group supposed to overlie the Lathi sandstones, several were determined by Dr Feistmantel, who found that they were characteristic Jurassic forms, occurring in the Chari group of the Cutch Oolites.[1]

9. Mesozoic and Tertiary strata of Jaisalmir.

The strata of Mesozoic and Tertiary age succeeding the Talchir boulder beds in Jaisalmir have been described by Messrs. Blanford and Oldham, but their relations and palæontology have not been

[1] Rec. Geol. Surv. Ind., Vol X, Pt. 1, p. 19.

worked out in detail. Except the Barmer sandstones with their fragmentary plant remains, none of these newer rocks occur in the area I have examined myself. No large scale maps of Jaisalmir territory have been published, even the sheets of the Atlas of India being as yet a blank as regards that part of the desert, and in the absence of such maps, especially where the exposures of rock are so isolated, no detailed work can be done. Mr. Oldham has given a sketch map of part of the country lying to the north of Jaisalmir, and divides the rocks into the following groups[1]:—

Period.	Name of groups.	Description.
Recent . .	Alluvium and Blown sand.	
Sub-recent .	Amir shingle beds . .	Patches of rolled pebbles of local origin; possibly marine littoral deposits.
Tertiary . .	Nummulitic . . .	Limestones with nummulites and beds of Fuller's earth (Multani mitti).
Mesozoic	Abur group . . .	Sandstones, shales and fossiliferous limestones, the latter weathering dark red ("Ammonite bed of Kuchri"). *Am.* (*Stephanoceras*) *opis*, Sow., *Arca*, etc.
	Parihar group . .	Soft white felspathic sandstones, occasionally calcareous and sometimes ferruginous, locally hard and glassy, weathering into a clean sugary sand.
	Bedesir group . .	Purplish and reddish sandstones with thin layers of black vitreous ferruginous sandstone; a bed of red calcareous sandstone contains fossils resembling Katrol (Cutch) forms.
	Jaisalmir group .	Thick bands of compact buff and light brown limestone interstratified with grey, brown and blackish sandstone with some conglomerate. Probably equivalent to the Chari (Cutch) group, *Am.* (*Stephanoceras*) *fissus*, Sow., *Nautilus Kumagunensis*, Waagen, *Terebratula biplicata*, Sow., *Corbula lyrata*, Sow., *C. pectinata*, Sow., etc.
	Lathi group . . .	White, grey and brown sandstones interstratified with numerous bands of hard black and brown ferruginous sandstones and grit. Towards the base soft argillaceous sandstone, streaked and blotched with purple Fragmentary plant remains and pieces of dicotyledonous wood.

[1] Rec. Geol. Surv. Ind., Vol. XIX, Pt. 3, p. 157.

10. Sub-recent conglomerates.

These conglomerates have already been described in a previous chapter.[1] They evidently belong to a period when the drainage of the country followed the same lines as it does now, but when the conditions of climate were such that the flow of water in the rivers was much greater than it is at present. The conglomerates are found in the channels of the Luni and of all its tributaries from the Aravallis, but only in patches, as they have undergone a considerable amount of denudation by winds and floods.

[1] *Supra*, p. 14.

CHAPTER V.—RECENT DEPOSITS.

1. Blown sand.

The most widespread and important of the recent formations of Western Rajputana is undoubtedly the blown sand with which so large a portion of the country is covered. Driven by the south-westerly gales which blow across the desert for several months in the year, and unimpeded in its advance by streams of running water, it has encroached upon the land until no district is entirely free from it, except those lying immediately at the foot of the Aravalli range, where the numberless watercourses descending from the hills, although they contain running water for only short periods, are able to sweep back the sand blown into them.

The dunes that are formed in the open plain are all of the transverse type, that is, they present a broad gently sloping face to the south-west, and a steep slope, corresponding with the angle of rest of the sand, to the north-east. A plain covered with these sandhills, such as that to the north-west of Pachpadra, presents a curious aspect when viewed from the top of one of the rocky hills to the east, in the evening, when the sun is sinking towards the western horizon. The steep face of each sand dune casts an intensely black shadow, while from the elevation on which one is standing the lower ground appears as a uniform level, so that the country presents the appearance of a yellow plain crossed by a number of black bars, parallel to each other, the cause of which is not at the first glance very evident.

Where, as is often the case, the sandhills are formed under the lee of one of the rocky knolls, they form long ridges extending in a north-east direction. The sand is also banked up against the windward side of the hills, and sometimes rises to a great height, over 800 feet in the case of those at the western end of the Saora range, above the plain. But as a rule they do not actually reach the slopes of the hills, but are separated from them by a deep ravine kept clear by the drainage from the hill-sides, and probably to some extent also by eddies of wind. When, however, the drainage is thrown off to either side by a rocky spur, the sand runs up to the rock and forms a gently sloping ramp on which one may climb the hill without having to scramble over the loose angular talus with which the lower slopes are covered. These sloping ramps of sand perform a certain amount of work in distributing the rock débris falling from the hill sides, the creep of the sand carrying the fragments outwards and downwards. Thus they are sometimes transported to considerable distances from the hill, much in the same way that a moraine is carried by a glacier.

The sand of which the dunes are formed presents several features of interest. That which is found in the dunes out in the plain, where the sorting action of the wind has had full play, is very uniform in grain, the diameter of the individual grains averaging about one-fifth of a millimetre, though much of the sand is still finer than this. But on the lee side of outcrops of solid rock, especially of the sandstones and granites, a greater variety of size is observed. For example, on the north side of the broad plateau of sandstone north-west of Jodhpur, in the neighbourhood of the village of Teori, the ordinary fine yellowish buff sand of the dunes is mingled with grains derived from the sandstones, easily distinguishable from the former by their bright red colour. Owing to their size and weight these grains have a tendency to collect along the crests and in the furrows of the ripple marks formed by the wind, and their strongly contrasting colour gives a peculiar streaky appearance to the surface of the ground.

The composition of the sand, judging from numerous samples collected from widely separated localities, appears to be very uniform. Quartz grains predominate, and flakes of hornblende and felspar, as well as chips of the lavas are common. All of these might be derived from the rocks locally present in the desert, and it is a significant fact that flakes of mica are very rare and appear to be almost confined to those samples which were collected near the eastern margin of the desert where there are outcrops of micaceous schists and granites. The rocks in the interior of the desert, on the other hand, the Malani lavas and Siwana granite, do not contain mica, and its absence from the sand, contrasted with the presence in abundance of the minerals that are found in these rocks, is almost complete proof that the sand has mainly been derived from local degradation of the rocks, and has not, or at any rate the bulk of it, been transported from outside the desert area.

At the same time there is very good evidence that the sand is not entirely of local origin, but that some of it has travelled from a considerable distance. In all the samples that I have collected, including localities so far apart as those south of Barmer and north-east of Bikanir, there is an appreciable quantity of particles of carbonate of lime which cannot have been derived from any of the local rocks. Their amount varies from less than one per cent. in the sand from Bikanir to as much as ten per cent. by weight in some of the samples from the south-west, or from 25lb to over 3 cwt. per ton of sand. But the most interesting point about these particles is that many of them are casts of the shells of minute foraminifera, and this fact affords a clue to their origin. I found that they were not the shells of recent foraminifera blown up from the coast, but that they are in a fossilised condition, for when they are immersed in weak acid on a glass slip beneath the microscope, they dissolve away gradually, becoming smaller and smaller till at last nothing is left, and it is evident that they are solid all through. I then examined a few specimens of Tertiary limestones that had been collected in Cutch by Messrs. Wynne and Fedden, and found similar foraminifera in some of them, especially in a limestone almost entirely made up of fragments of nummulites and other foraminifera, labelled as occurring "North of Kannai, north-east of Teyrah, probably on the horizon of the Gaj (Miocene) group of Sind." The specimen in the museum from this bed (No. 3·285)[1] is coloured a bright yellow by iron oxide, and many of the foraminifera found in the sand have a similar colour. Most of these interesting little fossils are flatly coiled shells probably belonging to the genera Rotalia or Pulvinulina, but they have not yet been accurately determined. I think that there can be little doubt that these particles of carbonate of lime have actually been carried by the winds from Cutch and distributed over the desert. The most distant locality to which I have traced them is Khari, 40 miles to the north-east of Bikanir and 500 miles from Cutch. Here they are exceedingly minute and are not recognisable as foraminifera, but that is not to be wondered at, considering that they have travelled so far in company with hard grains of quartz and other minerals.

I found, on examining samples of the sand from several localities with the microscope, that the great majority of the grains show little or no signs of attrition, and are in fact for the most part as sharp and angular as when they were broken off the parent rock. The contrast between the effects of water and wind action is well brought out in the sample from Teori, referred to above, in which the ordinary dune sand is mingled with grains derived from the plateau of Vindhyan sandstone to the south. The latter are easily recognisable under the microscope by their bright red colour, and are all well rounded, having been derived from an aqueously formed sandstone, whereas the grains of dune sand are mostly quite angular. Such sand as this could never form beds of sandstone with well rounded grains, like the "millet seed" Triassic sandstones in England, which have been attributed to the action of wind.[2] No doubt the fact that the grains of sand, when driven by the wind, are all moving in the same direction with a more or less uniform velocity, coupled with the minuteness of the grains, which must make the effect of any collisions that may take place

[1] This number refers to the entry in the Rock Register of the Indian Museum.

[2] See the discussion on a paper by Mr. Vaughan Cornish. "On the formation of sand dunes." Geographical Journal, Vol. IX, p. 302.

between them while in the air very slight, accounts for the small amount of attrition that they undergo. The persistence of the particles of carbonate of lime and foraminifera among grains of hard material like quartz to such great distances as I have indicated also shows that the amount of attrition that goes on must be very small.

2. Kunkur.

I have already mentioned[1] the almost universal occurrence of thicks bed of calcareous tufa or kunkur among the desert sands, and shown how they are apt to collect round the bases of the isolated rocky knolls scattered over the country. At first sight the source of the lime in these deposits was not at all obvious, for the lavas, granites, and other crystalline rocks round which they collect do not contain lime in any appreciable quantity. But the discovery of the particles of carbonate of lime and foraminifera in the sand at once afforded an explanation of the origin of these deposits. Occasional showers of rain falling upon the sand dissolve these particles and, since the moisture is quickly evaporated, the lime is soon re-deposited as tufa. Naturally this process goes on most rapidly where the rain water is collected on a rocky surface and flows off into the surrounding sand; and thus the gently sloping "glacis" at the bases of the knolls, described in Chapter II, are formed.

3. Origin of the Salt.

It is a well known fact that the sand and alluvium of the Rajputana desert is more or less impregnated with salt. Except after heavy rain the water that lingers in a few pools here and there along the course of the Luni is intensely salt, and large quantities of it, of immense commercial value, are obtained from brine pits situated in various depressions in the general surface of the plain, the largest of which occurs near Pachpadra, or from salt lakes like those at

[1] *Supra*, p. 12.

Sambhar and Didwana. The water of wells that are sunk in the sand without reaching the rock beneath is also brackish as a rule, and sometimes decidedly salt. Mr. Blanford conjectured that the salt may have been derived from an arm of the sea which, he supposed, formerly extended up the valley of the Luni,[1] but there are considerable difficulties in the way of accepting this theory. In the first place there is no evidence whatever of a recent submergence and re-elevation of the desert area, such as would bring the Sambhar lake down to sea level, and back again to its present position 1,184 feet above the sea. This objection was pointed out by Mr. Blanford himself. Again, if the sea only extended as a gulf up the lower portion of the Luni valley, this would not account for the presence of salt higher up the valley; and in any case such a gulf, if it ever existed, would be filled up by ordinary silt brought down by the rivers from the hills, and not more likely to contain salt in larger quantities than similar sediments elsewhere.

It seems to me that instead of our being compelled to speculate on former extensions of the sea or great changes of level, no evidence of which is to be found, in order to account for the presence of the salt, a simple explanation presents itself in the peculiar conditions of the country as regards drainage and evaporation. The rain water flowing from the hills is evaporated long before it reaches the sea, owing to the porous nature of the sand and the dryness of the atmosphere, and the salt it contains, which would under ordinary conditions be carried by rivers into the sea, and help to swell the amount of salt already there, is deposited among the sand grains, and in process of time has thoroughly impregnated the soil with salt. The process is in fact exactly similar to that which, it is universally admitted, accounts for the presence of the salt in the sea itself. Wherever depressions in the general level of the country occur, as at

[1] Journ. As. Soc. Beng., Vol. XLV, Pt. 2, p. 96. Rec. Geol. Surv. Ind., Vol. X, Pt. 1, p. 21.

Pachpadra, Sambhar, and other places, the drainage from the surrounding higher ground concentrates the salt, until in course of time the accumulation has become so great as to be commercially valuable.

It is perhaps not improbable that as particles of carbonate of lime are distributed over the desert by winds blowing from the south-west, and in time form beds of kunkur, so also particles of salt may be blown up from the sea shore and help to increase the amount of salt contained in the sand.

4. Gypsum.

In several places in the desert, on low lying ground surrounded by sandhills, beds of impure gypsum of considerable extent are found. A large deposit of this kind occurs on the plains about half way between Barmer and Madpura, on the Balotra-Barmer railway. It probably owes its origin to a process similar to that which has resulted in the accumulation of the salt, being gradually leached out from the sand and deposited when the water dissolving it evaporates. The gypsum is locally known as "Kuddi" and is extensively used as a cement for lining the interior of wells.

CHAPTER VI.—DETAILED DESCRIPTIONS OF ROCKS.

When the exposures of the rocks are so isolated from each other as they are in Western Rajputana, the usual method of describing their relations in detail, by following the belts of outcrops of the various strata across the country, is hardly practicable, and I have thought it more convenient to take each quarter sheet of the atlas of India on the scale of 4 miles to the inch, covering the area surveyed, separately, and describe the rocks found in it, noticing any points worthy of remark in the sections exposed.

1. Quarter sheet 19 S. E.

The greater part of the area included in this quarter sheet is covered by blown sand and alluvium. At the western edge about Lawa (Lowo) the Talchir boulder beds are exposed, along the foot of a scarp of Vindhyan sandstone. Several detached outcrops of the Vindhyans occur between this place and Teuri near the south-east margin of the map. They either just show above the surface of the ground between the sandhills or rise into scarped hills and plateaus of no great height. Several large groups of these hills occur in the neighbourhood of Osia, about 12 miles north of Teuri. The sandstone scarps rise abruptly to a height of 100 to 150 feet above the plain, and the base is always concealed by sand. The peculiar striæ-like markings described in Chap. IV, p. 30, were found among these hills between one and two miles south-east of Osia, near a small village named Basin, not marked on the map.

Several small inliers of the Malani rhyolites occur among the sandstones forming the plateau west of Bastua, near the southern edge of this quarter sheet, and others are isolated among the sandhills near Ketu, to the west of the same plateau. The largest of these inliers occurs in a narrow gorge immediately above the southern village of Bastua. The lava has the appearance of a ridge or hummock that has been gradually buried by the sandstones, which are quite horizontal. There is no conglomerate at the junction.

2. Quarter Sheet 20 N. E.

Along the northern margin of this quarter sheet the Vindhyan sandstones form several plateaus of considerable extent, the largest of which stretches for several miles to the north and west of Jodhpur. To the west they are found as far as the neighbourhood of Shergarh, where they gradually disappear beneath the sand. At Balasar, 11 miles north-east of Shergarh, the sandstones rest horizontally upon a very uneven surface of the Malanis, and the junction can be traced along the scarps to the north and south of the village. Here also there is no conglomerate at the base of the sandstones. The junction is also exposed along the scarps to the north of Chaunda, 16 miles north-west of Jodhpur, and is of a similar character.

The former extension of the sandstone plateau over the whole area is well shown by the number of detached conical flat topped knolls scattered over the plain. Several good examples of these "witnesses" (*Zeugen*) may be seen near the village of Ghoriala, a few miles east of Balasar (Pl. II, fig. 2).

At Jodhpur the Malani lavas form a large flattened dome-shaped mass extending for about five or six miles to the west of the city and surrounded by scarps of the Vindhyan sandstones. Patches of true conglomerate containing rolled pebbles and boulders of granite and other crystalline rocks, are exposed at the base of the sandstone in a shallow valley west of Chopasni, about five miles west of Jodhpur, at the base of Masuria hill about a mile south-west of the city, and at the base of a scarped outlier about half a mile to the south-west of the old Residency at Sursagar. Here it is associated with some finely laminated purple shales, containing globular patches of a white substance resembling kaolin, which give a peculiar mottled appearance to the surface of the laminæ. This substance is apparently derived from the decomposition of grains of felspar imbedded in the shales. Markings resembling the casts of rain prints also occur on some of the laminæ. The boulders are sometimes imbedded in the shales, which are then contorted on a small scale. None of the boulders in the conglomerate are of very large size, but some of the granite blocks reach a foot in diameter. There is nothing to indicate that they may not have been deposited by ordinary fluviatile action in a hollow on the lava surface. The thickness of conglomerate exposed here is from 20 to 25 feet at the most. At the base of Masuria hill there are about 40 feet of red shales at the base of the sandstones.

The psuedo conglomerates mentioned in Chap. IV, p. 27, are well exposed along the scarp to the north-east of Sursagar and again to the north of Mandor, four miles north of Jodhpur. The blocks of lava in these always correspond in composition and texture with the lava of the sheet immediately beneath them. Where this has a tendency to weather into rounded concretions the boulders are also rounded (Pl. II, fig. 1), but elsewhere they are quite angular.

From the village of Baorli, 19 miles to the west of Jodhpur, a series of detached hills of Malani lavas runs in a south-west direction as far as the village of Thob, 12 miles north-west of Pachpadra, a distance of about 30 miles. The highest of these rise to an elevation of between 900 and 1,000 feet above the sea, and about 300 feet above the general level of the plain. Between them the ground is usually at a slightly higher level than the sandy plain to the east and west, and is covered in many places with a fine angular gravel, derived *in situ* from the weathering of the lavas. The chain of hills is probably, therefore, composed of the highest points of a continuous ridge of lavas, the lower portions of which have been smothered in sand.

The hill at Baorli is composed of earthy looking brownish red rhyolite, with porphyritic crystals of pink felspar, mostly kaolinised. There seem to be several flows, one of which, forming the crest of a low ridge immediately south of the village, consists of a light green and pink compact rhyolite without porphyritic felspar, but containing numerous minute grains of quartz. The flows have an undulating westerly dip of about 10°.

The greater portion of the groups of hills at Agolai, eight miles south-west of Baorli, is composed of a strongly porphyritic rhyolite, dark grey or reddish brown in colour, with rather fresh looking crystals of felspar and numerous grains of quartz, in fact the most common type of Malani lava. Some of the flows exhibit a fairly well marked columnar structure, especially at the base of the peak (912 ft.) close to the village of Dugar. Flow-structure is not uncommon, and is especially well developed in a small hill at the south-west end of the group, the upper part of which consists of a rock strongly resembling pitchstone. This flow is inclined to the south-east at about 32°. The usual dip of the beds in this group of hills is to the north or north-east, at angles varying from horizontality up to 45°. At the south-eastern edge of the group is a bed of vesicular lava also exhibiting flow-structure, associated with some greenish ash beds dipping N. E. at 10°. Another variety of rhyolite is seen in the low hills near Agolai on the western edge of the group; this is a compact greyish red rock, with very few porphyritic crystals. Near the top of the peak close to Dugar, on the north side, a patch of breccia is intercalated with the rhyolites, consisting of angular fragments of rhyolite imbedded in a dark coloured matrix. Some other brecciated beds are seen on the slopes along the southern edge of the group, but these appear to be flows of rhyolite broken up *in situ*, probably by movements in the mass when partly solidified, and re-cemented; the fragments only show on the weathered surface of the rock and are not visible in section.

Between Agolai and Korna, six miles to the south-west, there are several low rises consisting of the reddish brown porphyritic rhyolite and covered with angular gravel derived from the disintegration of the rock *in situ*. At Korna there are three or four small hills, the upper portion of which consists of thick flows of rhyolite dipping at a low angle in a northerly direction. Flow-structure is well developed in this rock and is very conspicuous on the weathered surfaces. The edges of the flows present a steep scarped face to the south and exhibit a well defined columnar jointing, at right angles to the surface of the flows. The rhyolites rest upon a series of buff coloured felsitic tuffs and ash beds, which are exposed on the slopes of the hills below the scarps, and also dip slightly towards the north. Some of these beds are distinctly fragmental, the fragments being imbedded in a glassy felsitic paste. Others have a bright green colour mottled with specks of red hæmatite and are apparently largely composed of chloritic mud.

The large hills, rising to 902 feet, about four miles to the south-west of Korna, are mainly composed of strongly porphyritic rhyolite, with a dark purplish colour. A small knoll at the northern end of the group consists of compact glassy rhyolite with well developed flow-structure, containing fragments, sometimes up to three or four inches in diameter, of a previously consolidated flow of a similar rock, but darker in colour.

A short distance further to the south-west, in the neighbourhood of Nagona, an interesting series of rocks is exposed. The large hill, 937 feet high, immediately to the south of the village, is composed of a glassy looking rhyolite, which splits up easily along vertical plains, which are seen to be lines of flow, causing the rock to be almost as fissile as ordinary slate. On the top of the hill these divisional planes are seen in plan to pursue a wavy direction, generally about north-west to south-east and sometimes flowing round an included mass of more massive porphyritic rock. In the surrounding hills patches of a similar fissile rock are frequently met with, among the nearly horizontal flows of more porphyritic rhyolite of which the main mass of the hills is composed, and rise through the latter after the manner of an intrusive dyke. There is nothing to indicate that there has been any great disturbance of the rocks since they were poured out, or that the fissile rock was originally horizontal; and it seems therefore very probable that the vertical character of the flow-structure is due to pressure, from the sides of a great fissure through which the rock was erupted, and that this may be the site of a vent. The fissile rock extends over an area of about six miles in its longer diameter from N. W. to S. E., but it may extend to a greater distance beneath the sand and alluvium beyond the edge of the hills; the width seems to be very irregular, from two to three miles.

At the south-west extremity of this group of hills a thick lava flow shows a strongly developed columnar structure, with lines of flow running transversely to the columns. A section across the end of a spur formed by this flow shows that the columns are arranged in a roughly radial fashion, lying nearly horizontally towards the side of the spur and inclined at various angles towards the centre, like the radial structure so often seen in dykes of basic rock. Some of the columns are traversed by joints showing a cup and ball structure.

In the dry watercourses at the western edge of these hills a breccia occurs formed of clips and fragments of glass imbedded in a glassy matrix. The process of devitrification in the imbedded fragments is very well exhibited (Pl. XI, figs. 4, 5). This bed can be traced for about three miles along the edge of the hills.

A band of sphærulitic rhyolite, in which the sphærulites are sometimes as large as hazel nuts, is exposed in a ridge running west from the hill with a survey mark about three miles south-west of Nagona and can be traced for some distance along the side of the ridge between two flows of the porphyritic rhyolite. A beautiful perlitic structure is also developed in portions of the rock (Pl. X, fig. 6); and the same structure occurs in a flow forming a ridge running south from the village of Madli, about two miles to the north of Nagona.

About eight miles to the south-west of Nagona another group of isolated hills occurs extending from the village of Tesingri (Tringri of map) in a westerly direction for about 10 miles to near Patodi. Those at Tesingri consist of compact dark coloured rhyolites, with well developed flow-structure and columnar jointing, with a general dip at low angles to the south or south-west. These rocks are very fresh looking and seem to be scarcely, if at all altered, the crystals of orthoclase which they contain having remarkably well defined outlines.

Further to the west in the neighbourhood of Thob, the prevailing rock is of the common strongly porphyritic type of rhyolite, with dark grey and red colours. Seen from the north-west side in profile the large hill (837 feet) appears to be built up of successive flows dipping to the south-west at various angles up to 45°, each flow being marked by columnar jointing. Some breccias and fluidal rhyolites are exposed in the low ground about three quarters of a mile to the north of the village, apparently dipping beneath the porphyritic rocks.

In the group of hills between Thob and Patodi, still further west, a regularly stratified series of beds is exposed in a scarp facing north-east, the beds dipping to the south-west. Red, slightly porphyritic rhyolite is exposed at the base; above this comes a band of an almost black rock, crowded with quartz grains and weathering with a shaly structure, probably an ash bed. Then there is another band of the red porphyritic rhyolite, and above this a light greenish tuff, with a sandy texture and somewhat shaly. With this are associated some more coarsely fragmental beds studded on the surface with small nodules resembling lapilli. Above this there is a band of a dark grey amygdaloid rock which looks like a contemporaneous flow of basic rock, and is greatly decomposed. Finally, forming the crest of the ridge, is a thick flow of compact blue rhyolite, with well marked flow-structure, and containing fresh looking crystals of felspar. The rock is traversed by a system of fine black veins, probably coloured with iron oxide, and roughly following the lines of flow. This series of beds is about 150 feet in thickness and can be traced for a considerable distance along the scarp. The main mass of the hills to the south-west of the scarp is composed of a thick flow of dark grey and red porphyritic rhyolite, like that forming the hills near Thob, with a roughly columnar structure. This flow forms a dip slope gradually descending to the level of the plain on the south-west.

Considering the chain of hills, extending from Baorli to Thob, as a whole, it is worthy of notice that, speaking generally, the rocks to the north-east of Nagona dip towards the north-east while those to the south-west are inclined in the opposite direction. Moreover, we have seen that about the centre of the chain, in the large block of hills surrounding Nagona, there is some evidence of the presence of one of the vents through which the lavas were poured out. It seems at least possible therefore that this chain of hills represents the remnants of an ancient volcanic cone. The inclination of the lava flows on either side of the central area, and the form of the scarps, which points to a large amount of denudation having taken place, is not inconsistent with the supposition of the former existence of such a cone ; but the enormous extent to which the surrounding rocks are covered up by sand, leaving only the merest fragments of what must have been thick flows of lava, extending over large areas, now visible, renders it impossible to say with certainty whether the lavas were erupted from a single vent, forming a cone of the Vesuvian type, from a number of fissures, or from smaller vents of the Puy type scattered over the surface of the country.

Beyond the southern end of the chain of hills just described, no rocks occur in the plain until the river Luni is reached at Jasol, about 20 miles to the south-west of Thob. Here on the south bank of the river are one or two isolated hills of rhyolite, and here the first instance occurs of rocks of a different age being associated with the rhyolites. On the southern side of the large hill close to Jasol, which consists of a dark purplish porphyritic rhyolite, two broad vertical dykes of basic rock (olivine dolerite) are intruded into the lavas. The dykes are 50 and 30 feet broad respectively, parallel to each other and striking W. 30° N. Branches are thrown off into the surrounding rocks, and at one point a dyke about 15 feet broad connects the two, running diagonally from one to the other. The material of the dykes is dark green in colour, consisting mainly of plagioclase felspar, serpentinised olivine and hornblende. It decomposes much more rapidly than the rhyolites, and is usually very rotten in texture so that it is difficult to procure a good hand-specimen. Owing to this difference in weathering the rhyolites generally stand up on either side of the dykes in the form of vertical walls, and the eye can easily follow the course of the dykes along the hill side.

About four miles to the south-west of Jasol is a very large mass of hills, extending for about seven miles from east to west and rising at its highest point to an altitude of 1,354 feet above the sea. The village of Nagar is situated at the base of the range on the north side, at about its centre. The whole of this range is composed of the Malani rhyolites, in great variety, interbedded in places with breccias and tuffs, and traversed by numerous dykes of dolerite.

Towards the eastern end of the range the rhyolite is of the common dark grey or reddish brown porphyritic variety, but towards the western end, and in the detached ridge to the south-west, the prevalent rock is a dark green highly porphyritic rhyolite with very conspicuous flow-structure. Where the lava sheets are not horizontal they are inclined to the south or south-west at various angles up to about 30°. Some brecciated beds occur on the crest of the range a little to the south-east of the survey mark near its western end, associated with tuffs. These beds are also exposed on a low pass close to the western end of the range, where they are brought down by the south-westerly dip. The most conspicuous is a band of light yellow colour containing scattered angular fragments of a dark brown rhyolite. A band of breccia beneath this is dark coloured, containing in places large blocks of rhyolite up to a foot in diameter. These breccias underlie the dark green porphyritic rhyolites at the western end of the range.

Breccias are also exposed at the base of the range, about a mile east of Nagar. The matrix of these includes small fragments of rhyolite as well as large blocks up to three feet in diameter. They appear to have undergone some denudation before being covered up by the overlying flow of rhyolite, as they occur in patches like heaps or mounds surrounded by the lava. They may possibly be the remnants of an ancient neck filled with agglomerate. The rhyolite immediately surrounding them has an altered appearance, yellow and earthy looking, perhaps due to the passage of heated vapours through the body of the rock.

The rocks comprising the range are traversed by numerous dykes of basic rock, of a dark green colour, consisting principally of a plagioclase felspar with a good deal of augite and olivine. These dykes run along the joint planes of the rhyolites, the most usual direction being due north and south, another system cutting these at right angles. Generally their course is well marked by a depression in the surface, since the material of which they are composed weathers more rapidly than the rhyolites. A large chasm formed by the weathering out of one of these dykes is seen in the hillside immediately to the south of Nagar village (Pl. V, fig. 1); this dyke is 18 feet wide. About a mile and a half to the east of Nagar is a narrow pass through the range, the bottom of which is occupied by a broad dyke, 155 feet wide, to the weathering out of which the formation of the pass is due. Another pass close to the east end of the range has been formed in a similar manner. Again, near the western end of the range, on the northern slope beneath the survey mark, are two broad dykes crossing each other at right angles, and bounded by lofty vertical walls of rhyolite. The north-south dyke is 45 feet and the other 30 feet wide. Some of the dykes split up into a number of narrow parallel branches, running in among the rhyolites; one of these, on the hillside a little to the east of Nagar, is altogether about 90 feet wide, and includes about a dozen alternations of dolerite and rhyolite. The latter has lost its colour, but does not appear to be otherwise altered.

About eight miles to the south-east of Jodhpur, near the village of Rassida, and again at Salawas, 12 miles south of the city, a coarse granite is exposed forming bosses rising abruptly from the surrounding sand. It is composed of quartz, pink felspar, mica, hornblende and a bright greenish yellow mineral, probably epidote; it weathers into rounded exfoliating masses and shows no traces of foliation, though it is traversed by roughly parallel joints which give it a certain appearance of being bedded. Included in it are numerous rounded patches of a darker coloured rock, measuring up to 6 inches in diameter, some of which appear to be fragments of schist. They are always more fine grained than the surrounding granite, but some of them contain the same ingredients, with a larger proportion of small crystals of mica or hornblende, which give them their darker colour, and these may be concretionary in origin, being merely the result of an abnormal arrangement of the constituents of the granite. Exactly similar patches are described by Mr. J. Arthur Phillips, as occurring in many of the granites of the United Kingdom, in a paper "on Concretionary Patches and Fragments of other Rocks contained in Granite,"[1] where the author comes to the conclusion that some are of concretionary origin, while others, generally schistose in character, are foreign fragments derived from the rocks through which the granite has forced its way.

Seven miles to the east of Salawas, on the right bank of the Luni river near the village of Rajpura, a large spread of Malani lavas occurs, forming a low rise extending for some two miles along the river bank. All the rocks exposed are lavas of different varieties, some strongly porphyritic, and others exhibiting good flow-structure. Mr. Hacket says that he found some very much decomposed olive green schists in the bed of the Luni almost in contact with the lavas, but that no junction between the two was exposed. These schists were covered by the sand of the river at the time of my visit, and I could not find them.

Two small hills, both composed of rhyolites, occur isolated in the plain a few miles to the south and south-west of Salawas. The

[1] Quart. Journ. Geol. Soc., Vol. XXXVI, p. 1.

larger of these, near the village of Phinch, rising to an altitude of 1,001 feet, consists of red or purple rhyolite without porphyritic crystals, dipping to the south-east at between 25 and 30 degrees. In places the rock has an ashy look and contains imbedded fragments of rhyolite.

The large group of hills near the railway station of Khairla, about 11 miles north-west of Pali, is mainly composed of a coarse granite similar to that above described at Salawas, and like it containing rounded patches up to a foot in diameter of a darker coloured more fine grained rock, some of which may be included fragments. On three sides of the granite schists and slates are exposed, but in no case are they found actually in contact with it. They are usually vertical and much contorted, with a somewhat variable strike, the prevailing direction being N. E. to S. W. The slaty beds are badly exposed in the shallow watercourses on the western side of the large hills close to the railway station, and may be traced across their strike over the low ground to the north-west to within a few hundred yards of a low ridge of Malani rhyolites, the flows in which dip due west at from 45 to 50 degrees. These probably rest unconformably on the edges of the slates, but the actual junction is not seen. The rhyolite here is a dark purplish variety, sometimes porphyritic and with well developed flow-structure, the lines of flow coinciding with the dip. The granite hills rise quite abruptly from the plains, and there is little doubt that they are intrusive bosses, although the contact with the surrounding schists and slates is concealed.

At Samdari on the north bank of the Luni, 23 miles above Jasol, there is an isolated hill of rhyolite, reddish yellow in colour, with flesh coloured porphyritic crystals of felspar and the usual quartz grains. One or two small hills of a similar rhyolite occur lower down the river, and at Mongla, six miles from Samdari, there is one consisting of a dark green porphyritic rhyolite similar to that in the western end of the Nagar range.

Proceeding southwards from this point one is struck on approaching the hills near Meli, about three miles from the river, with their rounded aspect as compared with the usual rugged character of the hills composed of rhyolite, and on reaching the hills one finds that this difference in appearance is due to a radical change in the composition and texture of the rocks. The ridge which runs in a north-westerly direction for about six miles from the village of Deora is in fact mainly composed of a coarse granite, the microscopic constituents of which are quartz, felspar and hornblende *and no mica*. This rock weathers into rounded, exfoliating masses and frequently assumes somewhat fantastic forms. The fragments that fall from the sides of the hills formed of it are quickly broken down into a coarse sand, and the bare sheets of granite rise abruptly from the plain, with no covering of talus, such as is found on the slopes of the hills of rhyolite.

The relations of the granite with the rhyolite are well seen in the ridge immediately north-west of Meli, on its northern side. The rhyolite occurs in patches at the base and here and there on the flanks of the hill, sometimes running up to the crest, and generally dipping to the north at angles corresponding with the slope of the surface of the granite, as though the latter had been forced up from beneath as a dome or boss, and thrust aside the sheets of lava above. The boundary between the two is always perfectly abrupt, and the granite is evidently intrusive. It sends off narrow veins into the rhyolite ramifying in all directions through the latter. The granite of the veins is frequently a coarse pegmatite, containing well shaped crystals of hornblende an inch or more in length. Near the junction the joint planes of the rhyolites are often covered with a thin glaze of granite, the latter having evidently been forced in among the rhyolites under great pressure and in a very fluid state. The rhyolites here do not appear to have been altered by the intrusion, but in other localities, to be noted later on, signs of alteration are not wanting. Along the southern side of the ridge the rhyolites are not exposed, probably having been denuded and covered up with sand. To the west the granite ridge slopes very gradually down to the plain, the end of it being rounded off on either side like the crown of a dome.

3. Quarter Sheet 20 S. E.

The ridge just described forms the northern edge of a very large group of hills, about the centre of which is situated the town of Siwana at the foot of a steeply scarped hill on which is built an ancient fort. From about a mile south of the westerly termination of the granite ridge, two others run more or less continuously for about 10 miles in a west-south-west direction to near the village of Thapan. Both of these are steeply scarped to the north, but present sloping surfaces, corresponding to the inclination of the rhyolite flows composing them, to the south.

At the base of the more northerly of the two ridges, near the east end, a dark grey vesicular rock, very trap-like in appearance, is exposed, and seems to be intrusive along the strike of the rhyolites. The relations of this rock with the lavas are, however, somewhat obscure. In one place, about a mile from the end of the ridge, it is certainly intrusive, being thrust up vertically through the rhyolites which stand up on either side of it like a wall, and a little further to the west it runs in among them in narrow bands and appears to alter them. Further west again the same rock seems to be interbedded with the rhyolites, and is associated with dark grey ashy looking beds.

Towards the east end of the ridge the rhyolites forming the upper part of it are a dark brown variety with large crystals of red felspar often in strings drawn out in the direction of flow, dipping to south-south-west at about 20°. Further west a thick band of rhyolite with well developed flow-structure, frequently vesicular in its upper part, crops out in places beneath the porphyritic variety. In one place a narrow dyke of rhyolite in which the lines of flow are vertical runs from east to west through these rocks. The upper lava flows dip to the south or south-south west and form a bare dip slope on the southern side of the ridge inclined at an angle of about 20°. Nearer the western end the dip curves round to south-south-east at about the same angle, and the rhyolites both above and below the trappoid band are of the ordinary grey or reddish brown porphyritic variety.

A dyke or boss of dolerite rises through the rhyolites on a low pass to the east of the road through the ridge from Siwana to Pachpadra. It is 70 feet wide and runs from north-west to south-east, but is only exposed for a short distance on either side of the pass. The material is very much decomposed; at the edges it has caught up large fragments of the rhyolite, which weather out in rounded ellipsoidal masses, each surrounded by concentric shells of dolerite.

The southern ridge, when looked at from a distance, appears at first sight to be a repetition of that to the north, but on closer inspection the rocks composing it are found to be quite distinct. The detached hills at the east end are all porphyritic rhyolite of the ordinary type, with some vesicular bands dipping to the south-south-west at 30 to 35 degrees. The upper portion of the main ridge is of similar rhyolite, but at the base on the northern side, which is steeply 'scarped, some very different beds are exposed. These are sandy and gravelly, containing rolled pebbles of rhyolite, and form a band from 20 to 30 feet thick with sheets of rhyolite above and below. Further to the west, at a pass due north of the village of Kuip, and on the west side of the peak marked 1,319 feet, these beds are better seen, and are altogether about 100 feet thick, consisting of pebble beds interstratified with breccias and felsitic tuffs. In the uppermost pebble bed rolled fragments of other crystalline rocks, gneiss and quartzite, as well as the rhyolites, are found. One of the rhyolite pebbles found was a variety containing large red crystals of felspar similar to that in the northern ridge. At the pass these beds are broken through by a dyke of strongly porphyritic rhyolite, 60 feet wide, running directly across the ridge; near the contact with this dyke the pebble beds are highly indurated. The pebble beds and tuffs extend along the base of the ridge to the west of the pass through which the road to Pachpadra runs, but in that direction they are more or less concealed by sand-hills. The rock below them crops out about a mile beyond the pass and is a red porphyritic rhyolite. Above the pebble beds come thick sheets of a very dark grey variety of rhyolite only slightly porphyritic. The pebble beds and the sheets of rhyolite above and below are quite conformable to each other, dipping to south-south-east at about 25°. The southern side of the ridge is a steep dip slope formed of bare sheets of rhyolite.

In the hill rising to 1,634 feet, about three miles west-south-west of the village of Kuip, some greenish ash beds, about 30 feet thick, are exposed near the base of the spur on the north-east side, dipping to the south at about 20°. These are pierced by a dyke or rather boss of red rhyolite forming a low dome surrounded on all sides by the ash beds. The latter are succeeded above by thick flows of vesicular rhyolite, and these by successive sheets of the ordinary variety of porphyritic rhyolite, forming the mass of the hill, and steeply scarped on all sides, rising above each other like the steps of a staircase (Pl. III, fig. 1). Towards the south side of the hill these flows become nearly horizontal.

The large scarped hill rising to 1,601 feet to the south of that last described, and about two miles north of Garah, is also composed entirely of rhyolite. The main mass of the hill at its western end consists at the base of brick red rhyolite full of porphyritic crystals of red felspar, extending for about 300 feet up the scarp. This is succeeded by thick flows of red rhyolite without porphyritic crystals. The junction between the two is quite abrupt, and they are evidently distinct flows. Towards the east the rocks are inclined to east-south-east and the non-porphyritic rhyolite is brought down to the level of the plains. Here a well developed flow-structure is seen in some portions of the rock.

The small detached group of hills between this and the hill at Siwana also consists of the brick red non-porphyritic rhyolite, with a small quantity of porphyritic rock with red felspar crystals exposed at the base.

The lower part of the scarped hill on which the fort at Siwana is built is composed of tuffs of various colours, pink, buff, purple and green, with thin bands of rhyolite interbedded among them. At the base they are conglomeratic, containing rolled pebbles of rhyolite, and rounded blocks a foot or more in diameter. These beds are about 40 feet thick on the southern side of the hill, resting on red rhyolites without porphyritic crystals, and are overlaid by a thick flow of dark brown rhyolite, with a roughly columnar structure, on which the fort is built. The tuff beds extend all round the hill at the foot of the scarp below the fort, and on the north side are from 80 to 100 feet thick, dipping in slightly towards the hill on all sides. On the west side they are either banked up or faulted against the rhyolites of which the western portion of the hill is composed. The tuffs have every appearance of having been laid down under water.

Beneath the high peak at the western end of the hill a bed of conglomerate, consisting entirely of well rounded pebbles of the rhyolites, is intercalated between the flows. This band is from 20 to 30 feet thick. It does not appear to correspond with the conglomerate band below the fort, for the tuff beds are wanting. Some sandy looking ash beds are exposed immediately above the conglomerate band on the southern face of the peak, and are hollowed out into a deep gallery running horizontally along the hillside beneath the scarp. The conglomerate band dies out before reaching the western end of the hill, and is replaced by ash beds and thin bedded rhyolites. The rhyolites above and below are of the red or reddish brown non-porphyritic variety. They dip, with the conglomerates, at 20° to the north.

The structure of the large hill, 1,790 feet high, to the north-east of Siwana, is very similar to that of the hill already described to the south-west of Kuip. The beds are inclined to the south, dipping on the north side at 27 or 30 degrees, and becoming more horizontal towards the south. The lowest beds exposed on the north side are brick red non-porphyritic rhyolites, similar to those in the hill west of Siwana. These are succeeded by reddish ochrey porphyritic rhyolites, which form a spur, steeply scarped on the north face, running out towards the west. In the depression between this spur and the main mass of the hill is a thick band of ash beds, which runs diagonally up the slope to the north of the rhyolite cliffs forming the crest of the hill, and down to the plains on the east side. On this side there appears to be two bands of ash beds separated by a thick flow of rhyolite, but this apparent doubling of the band may be due to faulting or to slipping of the beds forming the scarp. The total thickness of the ash beds is about 250 feet. They are succeeded by brownish red rhyolites which are very slightly porphyritic, forming the crest and the whole of the southern portion of the hill.

In the plain to the east and north-east of the hill last described are several small knolls all of rhyolite, of the ordinary type. At the northern edge of one of these, close to the village of Bijli, are two small outcrops of the coarse hornblendic granite, one of which is in contact with the rhyolites, and throws off veins into them. The same granite forms a large mass of hills to the east between Balu and Phulan, but although it is surrounded by exposures of rhyolite, one, immediately north of Balu, of considerable area, the two rocks are nowhere seen in contact. On the south side the rhyolites dip steadily away from the granite at an angle of 30° to south-west, while in the small exposure to the east, between the granite hill and the village of Raki, the dip is from 30° to 35° to the east. Here again the granite seems to have been forced as a dome shaped mass or laccolite among the rhyolites, and to have tilted them up on either side.

To the south-west of this group of hills another area of granite is found in the hill between Ajiana and Ludrara, and here the relations between the granite and rhyolite are well displayed. The central portion of the hill consists of rhyolites which dip to the north-west at about 30°, away from the large mass of granite forming the eastern portion of the hill towards Ludrara. The granite and rhyolite are here in contact, the former as usual sending off numerous veins into the latter. The rhyolites are of the ordinary porphyritic type, occasionally containing large crystals of red felspar. Close to the granite on the north-west side a thick band of pebble beds and breccias is interstratified with the rhyolites. The contact of these beds with the granite is concealed by sand.

Another exposure of the pebble beds occurs in a small hill rising to 927 feet, close to the village of Siner, about 10 miles to the west of Siwana. At the base are some rhyolites with flow-structure succeeded by strongly porphyritic rhyolite. These are exposed at the south-west side of the hill close to the village. Upon them rests a bed of a dark greenish rock of basic type, portions of which are amygdaloidal. Then comes a band of conglomerate in which the pebbles are well rolled, consisting of rhyolites of various types, some showing good flow-structure, and a few of quartz. This band is about five feet thick and is succeeded by a band of highly vesicular rhyolite of a dark greenish colour, and on top of all a thick flow of rhyolite of the ordinary porphyritic type. All these beds dip to the north-east at an angle of about 35°. A diagrammatic section of the hill is given in fig. 1, Pl. IV. The pebble bed can be traced all round the western side of the hill, and appears again in a smaller hill about a quarter of a mile away to the north. Here besides the pebbles of rhyolite and quartz it contains a few, also well rolled, of a micaceous gneiss or gneissose granite.

A dyke of rather coarse grained dolerite, 30 feet wide, breaks across the larger hill through the rhyolites and conglomerate band, striking from south-east to north-west. On the southern side of the hill it runs parallel to the bedding of the rhyolites and conglomerate for a short distance, just beneath the latter, and divides into two branches as shown in the section. It also appears on the same strike in the smaller hill to the north.

To the north of the hill at Siner there is another large mass of the hornblendic granite, in the range a short distance west of the village of Indrana. On the south-west side of the range the rhyolites are in contact with the granite, but here the former dip directly towards it, that is to the east-north-east at an angle of about 30° (Pl. III, fig. 2). The junction of the granite and rhyolite is very well snown on the western slope of the hill beneath the survey mark (1,346 feet). The granite abuts vertically against the rhyolite and has thrown off numerous veins into it; in addition the granite has torn off large blocks of the rhyolite and included them. The rhyolite, near the contact with the granite and in the included blocks, is considerably altered; and is full of small nests of hornblende. The granite of the veins is usually very coarse in texture, especially towards the middle of the vein, where the hornblende crystals are frequently from 3 to 4 inches in length. A good instance of the manner in which the granite veins penetrate the rhyolites is seen at the western end of a detached mass of granite to the south of the range (Pl. IV, fig. 3). A dyke of dolerite 12 feet wide runs through the rhyolites from north to south, a short distance from the boundary between the granite and rhyolite and parallel to it.

The range a few miles further to the west and parallel to the Indrana range is entirely composed of rhyolites. At the southern end they exhibit good flow-structure and dip to the north east at about 25°. Further north are red rhyolites only slightly porphyritic. In the midst of these there is a well defined band of breccias about 20 feet thick, which can be traced to near the northern end of the range. Here the beds are inclined to the east at about 30°. In a small detached hill to the east of the middle of the range a thick band of much decomposed diabase, apparently interbedded with the rhyolites, is exposed; it is overlaid by green rhyolites with porphyritic crystals of bright red felspar.

Some five or six miles to the south of Siwana is a very large mass of hills, extending for nearly 17 miles from east to west and about 6 miles across in its broadest part, rising to an altitude of 3,199 feet above the sea at its highest point, or about 2,500 feet above the plain.

This is the largest continuous mass of rock to the west of the Aravallis. On the map it is named Saora, but among the natives this name seems to be confined to the portion, including the highest point, immediately south of the village of Golia, situated about midway of the range on the north side. By far the greater part of the hill, including all the higher portion, is composed of the coarse hornblende granite which appears to be everywhere identical in texture except that it is frequently traversed by broad veins of a finer grained rock, or eurite, of the same composition as the surrounding granite. Occasionally these veins contain large porphyritic crystals of pink felspar, and the material then resembles the Malani rhyolites to some extent, but is easily distinguished from the latter by its lighter colour and its less glassy texture. The rhyolites are found in contact with the granite on the spurs all along the northern side of the range, but except for a very short distance near the west end, they do not occur at all on the southern side, where the boundary between the granite and the rhyolites forming the hills further south is everywhere concealed by sandhills.

At the western end of the range a large area of rhyolite extends from a narrow ravine immediately south of the small village of Jhika, or about four miles to the west. The rhyolite in the whole of this area is very homogeneous in texture, and almost holocrystalline in appearance from the large number of felspar crystals and quartz grains which it contains. It weathers into rounded exfoliating masses, so that at a distance it is difficult to distinguish it from the granite. The contact between this rock and the granite is exposed in the ravine south of Jhika. The line of junction runs N. W., S. E., and is quite abrupt and vertical, but it does not appear to be faulted. The bedding of the rhyolites is either horizontal or undulating, but towards the west they dip to the north and north-east at angles varying from 20 to 30 degrees. A detached ridge to the north consists of dark red rhyolite with few porphyritic crystals, dipping to the north-east. Near the south-east end of this ridge a band of strongly porphyritic rhyolite, with large crystals of pink felspar, crosses it, apparently interbedded with the less porphyritic rock; and still further in the same direction a band of diabase, vesicular in places, is badly exposed above the porphyritic rhyolite and is also apparently interbedded. A small patch of granite is exposed at the base of the ridge close to this end on the north side. The veins running into the rhyolites from this are very coarse in texture, with crystals of hornblende up to three inches in length.

Along the northern side of the main range the patches of rhyolite exposed on the spurs apparently form the remains of a dome arching over the granite, the relics of what were once continuous sheets, rising into jagged peaks easily distinguishable at a distance from the more rounded contours of the granite. Occasionally, however, the rhyolites are seen to strike directly towards the granite, and it appears as though the latter had partly invaded and remelted the rhyolites, absorbing and replacing them, and had partly forced up the sheets of rhyolite from beneath. Large masses of the rhyolite have been broken off and included in the granite, and sometimes the edges of these masses have been altered, the porphyritic crystals visible in the interior of the mass having disappeared. Veins of granite, sometimes fine and at other times coarse grained, are nearly always to be found intrusive in the rhyolites near the boundary (Pl. IV, fig. 4).

In a ravine about half a mile to the south of Golia a band of breccias and tuffs occurs in the rhyolites close to the granite boundary and strikes directly towards it. Here the band is not altered where it is in contact with the granite, but further to the east, at the head of a broad valley due east of Golia, where a similar band of breccias and tuffs, probably the same, is again exposed, the tuffs on approaching the granite are altered into a porcellanous rock with a conchoidal fracture. Some of the fragments in the breccia beds are water worn pebbles.

Less than two miles to the south of the Saora range another large mass of hills runs parallel to it, extending for about 14 miles from east to west and about 5 miles from north to south, and rising to an altitude of between two and three thousand feet above the sea. This is entirely cut off from the Saora range by a broad belt of level ground covered with sandhills. The rock composing it is mainly a strongly porphyritic rhyolite exactly similar to that forming the large area at the western end of the Saora range, and like it, weathering into rounded masses closely resembling the granite. Some less porphyritic black and red rhyolites, the former exhibiting flow structure, are exposed at the east end of the range, underlying the porphyritic rhyolites, and with these are associated thin beds of breccia. The inclination of the flows is generally northerly, and the hills present precipitously scarped faces to the south. Near the top of a pass immediately to the south of Dhira is a band of a peculiar reddish coloured rhyolite containing large spherical concretions or sphærulites an inch or more in diameter. The same rock is found at the base of the range on the southern side near Gogoji-ka-Than and extends for some distance to the west. Here also some breccias are interstratified with the rhyolites.

Granite was found in only two places among the rhyolites of this range, and in each case the outcrop is very small. One of these is at the base of a spur a mile or so to the south-east of the village of Kundal, and the other in a large valley to the south-west of Selo, about two miles south-south-east of the Kundal outcrops. This granite is more fine grained than the hornblende granite of the Saora range and differs from it in containing mica. A similar granite but more coarse in texture forms a detached hill about two miles west of the main range, close to the village of Kanki, where it is also in contact with a small patch of rhyolite. This micaceous granite is similar to that of which the large hill at Jalor, several miles to the south-east, as well as many of the smaller hills in that neighbourhood, is composed.

A few miles to the north of the town of Chanod a range of hills runs in a north east to south-west direction for about 25 miles, broken through in the centre by the Sukri river, which runs north-west from the Aravallis to join the Luni near Samdari. The range attains its greatest elevation almost due west of Chanod where it rises to an altitude of 2,172 feet above the sea, or about 1,500 feet above the plain. The elevation of the portion of the range north of the Sukri is much less. The greater part of it is built up of flows of Malani rhyolites of various types with occasional bands of tuff and breccia. The prevailing type in the northern portion of the range is a compact rhyolite with well developed flow-structure, sometimes containing vesicles drawn out in the direction of flow. The usual dip is westerly or south of west at angles varying between 25 and 30 degrees. Some angular fragments of a light greenish hornstone occur in places imbedded in these rocks; they are probably fragments of the underlying slates that have been caught up by the ascending lava and highly altered.

The only instance yet discovered of a visible junction between the Malani lavas and the underlying Aravalli rocks occurs among these hills in a valley lying about two and a half miles to the south-east of the village of Miniari and 7 miles north of Chanod. The section exposed here has already been described in Chapter III.[1]

A peculiar band of nodular rhyolite occurs among these hills in the detached portion lying to the north of Miniari. The rock is crowded with nodular concretions up to six inches or so in diameter, some of which are almost perfect imitations of fossil shells. The matrix in which they occur is a compact flinty rock with a reddish colour. Some of the nodules contain cavities filled with crystalline quartz and a little calcite. This is the only instance I have met with in which carbonate of lime is associated with the lavas, except the crust of recent origin, which is often formed on the surface of fragments of the lava imbedded in the sandhills.

A nodular bed also occurs in the isolated hill at Bhaori, about 4 miles to the north-west of Miniari, where it is associated with nearly white slaggy lavas in which scattered blocks of rhyolite are imbedded. A small patch of a friable rusty looking rock with fragments of rhyolite, some of which appear to have been rolled, also occurs among the white

[1] *Supra*, p. 19.

lavas. The dip of the whole series is to north-north-west at various angles up to 45°.

About the centre of the range, where the Sukri river breaks through it, a large area of granite is exposed in the bed of the river and its tributaries to the south. This granite is rather coarse grained, containing pink felspar and mica, and is therefore of the Jalor type. It does not rise above the general level of the country as in the case of all the other bosses met with, but is exposed only in the bed and banks of the streams. It is in contact with the rhyolites at one point only, in the bed of the Sukri about a mile south of the village of Darri, and is there clearly intrusive, sending off veins into the lavas and including blocks of them. A small patch of Aravalli schists occurs a little higher up the same river, near the village of Bhaonagar, but is not seen in contact with either the granite or the rhyolites. The schists have the usual north-east south-west strike, and are nearly vertical.

The southern portion of the range, to the south of the Sukri, consists mainly of a compact black rhyolite with porphyritic crystals of white felspar. It often exhibits beautiful flow-structure. Bands of breccia and agglomerate also occur, and some of the flows are amygdaloidal. The dips are very varied and it is sometimes impossible to make out any bedding in the rock. It looks as though it had welled out from a fissure parallel to the length of the range; at the base of the hill, on the east side, about a mile south of the village of Malgarh, the lines of flow are vertical, as though the lava had been subjected to lateral pressure while it was being poured out.

The southern slope of the detached hill north of Chondrai, which appears to be on the continuation of this range, consists of the same black porphyritic rhyolite with a southerly dip. Beneath this, forming the whole of the lower portion of the slope on the north and east sides, a boss of coarse granite containing mica forms a rounded dome supporting the rhyolites. Along the line of contact it is clearly intrusive in the latter, throwing off narrow veins into them, and in one place a sill occurs running parallel with the bedding of the flows a short distance above the junction with the granite. Near the boundary it sometimes includes blocks torn from the rhyolites, and I found one fragment of a dark coloured schistose rock imbedded in it, probably derived from the underlying schists. Close to the plane of contact the granite sometimes has a foliated appearance, and this is very conspicuous in some of the veins which traverse the rhyolites.

The large mass of hills at Kaonla village, 7 miles south-west of Chanod, is entirely composed of a similar granite, traversed by thick veins of a fine grained eurite. These hills furnish a good example of the characteristic dome shaped weathering of the granite bosses (Pls. VI, VII).

The rhyolite of the main range near its southern end is traversed by several dykes of diabase which strike across the hills in a north-westerly direction. They are generally found in depressions on the crest of the range, the diabase weathering more rapidly than the rhyolite. A small dyke of the same kind occurs at the base of the large hill at Kaonla cutting through the granite, and at the same time piercing a vein of eurite which also traverses the granite.

In the isolated hill at Pati, 18 miles north-west of Chanod, an interesting section is exposed. The lower portion of the hill on the southern side is composed of sandy pebbly beds, purple and greenish yellow in colour. These extend up to the foot of a precipitous scarp of rhyolites which form the whole of the crest and northern slope of the hill, and rest conformably upon the sandy beds, the whole dipping to the north-west at about 40 degrees. In places the sandy beds show distinct current or false bedding and have evidently been laid down under water. At the top of these beds, at the foot of the scarps, is a band containing rolled pebbles of rhyolite up to six inches in diameter. The upper part of this band is highly indurated, apparently by the heat from the overlying flow of lava. About 200 feet of the sandy beds are exposed, but their base is concealed by talus, and to the south-east they are covered by alluvium; one or two small patches of the rhyolite which probably underlies them occur in this direction about two and a half miles away on the banks of the Sukri.

A few miles to the west of Pati a considerable range of hills runs due north and south for about 11 miles, rising to an altitude of 2,112 feet above the sea at its highest point close to the town of Bhadrajun, which lies in a narrow ravine on the eastern side of the range near its southern end. The whole of this range consists of various types of rhyolite. To the north of the village of Goendla, about the middle of the range, the prevailing rock is a strongly porphyritic dark coloured rhyolite, with white or red crystals of felspar, with a general westerly dip. At the base on the east side some nodular and sphærulitic flows are exposed in places, and near the village of Bakhal, at the north end of the range, is a highly concretionary bed, the concretions in which reach a diameter of at least two feet (Pl. V, fig. 2). At Goendla itself some ashy beds containing small lapilli of rhyolite as well as rounded blocks up to 10 inches in diameter, associated with fine grained reddish tuff, are exposed in a watercourse at the foot of the hills. Above these come some strongly porphyritic rhyolite, and then thick flows of compact dark grey rhyolite, forming precipitous scarps facing east. These are succeeded by the porphyritic rhyolite continued southwards from the northern end of the range, the whole of the slopes on the western side being formed of this rock. To the south the compact rhyolites rise into the high craggy hills above the town of Bhadrajun and form the greater portion of the southern end of the range. Some of the flows exhibit very well developed flow-structure. Brecciated beds occur on the southern side of a pass through the range south of Bhadrajun, and are intercalated with the rhyolites. The whole of the rocks dip at various angles in a westerly direction.

About four miles to the west of this range another chain of small hills runs parallel to it for about six miles from north to south. These hills all consist of the coarse micaceous granite, but are quite isolated, and the granite is not seen anywhere in contact with the rhyolites. A number of small isolated hills of a similar granite occur scattered over the plain to the south-west in the direction of Jalor. In one of these, near the village of Sakarna, 5 miles east of Jalor, a large mass of rhyolite is seen running through the granite like a dyke, and at first sight apparently intrusive in it. It is, however, traversed by veins from the granite, and is evidently a mass of rhyolite that has been split off and imbedded in the granite. The rhyolite has apparently been partially remelted at the edges, for a fluidal structure following the irregularities of the boundary has been developed in it and it has lost its dark colour for about half an inch from the junction.

The granite of these hills is sometimes traversed by dykes of diabase running from west-north west to east-south-east. One of these, at the southern end of the hill at Godhan, near Sakarna, is about 50 feet wide.

The large hill on which the fort at Jalor is built, and the greater portion of the hill called Roza, to the west of the fort, is formed of the same granite. The western part of Roza hill, however, consists of Malani rhyolites, which rest upon the granite and dip away from it. The boundary between the two is everywhere concealed by talus and scrub jungle, but it appears to run nearly north and south along the ridge, rising to 2,118 feet on the west side of Roza hill. The rhyolite also appears in the two isolated hills west of Tarwa, about seven miles west of Jalor, and in the more northerly of the two is in contact with granite. Here the latter is clearly intrusive, sending off large dyke-like masses among the rhyolites. A small hill of rhyolite also occurs to the north, on the right bank of the Joai river, near the village of Saparo. It seems likely that the rhyolites underlie most of the plain, and may extend to the north-west to the large mountains south of Siwana, and that the granite forms bosses protruded through them. Except where these isolated hills appear above the plain, however, the ground is entirely covered with blown sand.

In the neighbourhood of Jalor the granite is traversed by several large dykes of olivine dolerite. One of these, which is quite 200 feet wide, may be traced at intervals along the base of the hill to the south of Jalor town. The dolerite is greatly decomposed, and weathers more easily than the granite, so that the latter stands up like a wall on either side of it. Several dykes also run through the granite of the hill itself, their course being marked by deep chasms weathered out. Another very large one occurs in the pass between Jalor fort and Roza hill. The dolerite in this is in a better state of preservation, and in the centre of the dyke is rather coarse grained. At the northern end of the pass this dyke splits up into a number of smaller parallel dykes, and in contact with the granite the dyke rock becomes very fine grained and has a vertical platy structure parallel to the walls. All the dykes run in a north-north-west, south south-east direction.

The large hills to the south and south-east of Jalor were surveyed and mapped by Mr. Hacket. They lie for the most part in the State of Sirohi and are not included in the area which I surveyed. To the north of Erinpura, however, there is a considerable mass of hills lying in Jodhpur territory, and as the conclusions I came to regarding the rocks exposed in them differ somewhat from those of Mr. Hacket, it is perhaps worth while to give such information as I can about them.

The relations of the rocks composing these hills are well seen in the detached hill at Sanderao, a village about 13 miles north-east of Erinpura, on the old road from Ahmedabad to Ajmere. The main mass of the hill consists of quartzite with schistose bands, nearly vertical and striking in a general north-east, south-west direction. On the east side of the hill a large mass of gneissose granite is exposed, which was evidently originally intrusive, since it sends off veins into the quartzites. The intrusion must have taken place prior to the disturbance and folding of the quartzites, for the granite has become foliated, and the fragments of schist included in it, which are very numerous in places near the boundary, have been rolled out into lenticular patches. The granite of some of the veins is also foliated, especially where they run parallel to the bedding of the quartzites.

Several dykes of dolerite run through the rocks, traversing both the quartzites and the granite veins. The largest of these occurs in a ravine at the north-east corner of the village; the rock is coarse grained and a good deal decomposed, forming a dyke about 12 feet wide striking north and south. A few yards up the ravine it sends off a branch to the north-west. Several granite veins occur in the same ravine, cutting across the strike of the quartzites and in turn cut through by the dolerite.

The whole of the northern portion of the large mass of hills between Sanderao and Erinpura, extending from near Khadalo station on the Rajputana-Malwa railway to the Joai river, about five miles below Erinpura, consist of dark coloured Aravalli schists with bands of quartzite. The strike varies between north-north-east, south-south-west, and east-north-east, west-south-west, but is generally in the latter direction. Over the low ground to the south of these hills an exceedingly coarse granite crops out, forming low hummocks scattered over the plain, and occasionally rising to a greater height, as in the hill at Khidara and in the long ridge to the south of this village running parallel to the road. This rock is not often seen in contact with the schists, but where it is visible the junction is very irregular, and the granite sends off veins among the schists and includes fragments of them. As at Sanderao the granite near the boundary is generally strongly foliated, and the veins which traverse the schists are sometimes contorted, showing that the granite must have been injected before the folding of the schists took place (Pl. IV, fig. 2). This granite is therefore far older than the granite associated with the Malani rhyolites to the north and west. It also differs from that granite lithologically, being exceedingly coarse grained and containing crystals of whitish felspar often three inches or more in length. Among these hills a few dykes were met with, generally running in a west-north-west, east-south-east direction or at right angles to the strike of the schists, and traversing both these and the coarse granite.

This granite also forms the large hills to the east of Erinpura Road

Station, where the usual "granitic" mode of weathering is well displayed (Pl. VIII), and extends for many miles to the north along the base of the Aravallis, in Godwar.

4. Barmer Area.

Rajputana Survey, 1 inch = 2 miles, sheet $\frac{38}{39}\frac{53}{54}$.

The quarter sheet of the Atlas of India that would include the Barmer desert has not yet been published, but very nearly the whole of the solid rock that appears above the sand in this area is mapped in the half inch sheet of the Rajputana Survey cited above, and I shall use that in describing the geology of the district.

On the eastern side of the desert, after leaving the rocky hills south of Jasol, solid rock is first met with on the right bank of the Luni, near the village of Dandali. Here there are two or three conical hills, the highest rising to 1,038 feet above the sea, consisting of a coarse grained hornblendic granite without mica. These hills are quite isolated, but a short distance to the south there are a few low hills composed of Malani rhyolite, a dark grey variety with numerous white crystals of felspar and quartz grains. The granite is traversed by narrow dykes of a fine grained dark grey eurite running north and south parallel to each other. This rock is very similar to the rhyolites in appearance, but it is impossible to say whether the dykes are connected with the flows.

About seven miles to the west of these hills there are three outliers of the Barmer sandstones, of no great height or extent, resting upon an uneven platform of the rhyolites, which are exposed on either side of them. The most northerly of these outliers occurs to the west of the village of Nausar, where there are a few small outcrops of the rhyolites. The sandstones are rather coarse grained with numerous strings of small well-rolled pebbles of white and yellow quartz, and a very few derived from the rhyolites. I could find no fossils anywhere in these sandstones, but they resemble the sandstones of Barmer so closely that there is little doubt that they belong to the same group. The sandstone of the two outliers to the south, near the villages of Sanpa and Sarnu, is precisely similar. They all dip at low angles, from 7 to 10 degrees, in an easterly direction. On the east side of the Sarnu outlier there is a large boss composed of a dark grey basic rock containing ægerine-augite, sanidine and sodalite with perhaps nosean, resembling a tinguaite from the neighbourhood of Montreal,[1] and is thus quite different from the material of which the ordinary basic dykes traversing the rhyolites are composed. From its position it appears to be intrusive in the sandstones, but the actual junction between the two rocks is concealed by sand.

Thirteen miles to the north of Nausar, near the village of Khatu, there is a chain of small hills running from south-west to north-east for a distance of about seven miles. These are all composed of rhyolites, a reddish brown highly porphyritic variety with numerous crystals of pink felspar.

To the west of the outliers near Nausar the country for a distance of about 25 miles is entirely covered with sandhills, among which there are no outcrops of solid rock. Beyond this again, to the west of Barmer, there is a larger area, extending from Bonthia in the north to Chotan in the south, a distance of 40 miles, and from Barmer westwards to the edge of the map, a distance of about 27 miles, in which numerous rock islets are scattered about protruding from the undulating surface of the sand in a manner which suggests the summits of a large mountainous island partly submerged beneath the sea. By far the greater portion of these hills are composed of the Malani rhyolites, and these do not present so great a variety as those occurring on the eastern side of the desert about Jodhpur and Siwana, but consist for the most part of compact dark grey, sometimes black, glassy or pitchstone like lavas containing porphyritic crystals of white or

[1] Rosenbusch. Mikr. Phys. Mass. Gest., 1896, p. 483.

pink felspar and grains of quartz. Flow-structure is frequently met with among them, and some of the flows are sphærulitic. A reddish brown, more strongly porphyritic rhyolite is found in places, especially in the neighbourhood of Barmer itself.

There do not appear to be any beds of tuff intercalated with the lava flows, and it is generally impossible to make out any regular bedding among them. They seem to have been erupted from a network of fissures and to have been heaped together without any definite arrangement. No trace of anything like a vent is to be seen anywhere. Near the village of Jesai, about ten miles west of Barmer, a thick bed of conglomerate, consisting of well rolled pebbles of the rhyolites imbedded in an ashy matrix, is interstratified with the flows. The bedding of this is inclined to the west-south-west at an angle of 30°.

The western portion of the large hill at Jesai, rising to an altitude of 2,073 feet above the sea, consists of a rather coarse hornblendic granite without mica, similar to the granite of Siwana. The relations of this granite to the rhyolites are not so clear as they are in the Siwana country, for no sections were found in which the granite could be seen to throw off veins into the rhyolites, while on the other hand the latter in a few places appeared to be intrusive in the granite. I have already pointed out [1] that the granite of this area was probably intruded into the lavas before the period of volcanic activity came to an end, and thus it came to be pierced by dykes of the rhyolites.

The same granite occurs again in the hill west of Taratra, ten miles south of Jesai, and clear sections of the junction with the rhyolites are exposed at the head of a ravine just west of the village. Here the granite is distinctly intrusive, sending off veins and tongues into the rhyolites; it also includes masses of the latter. The western portion of the hill is composed of rhyolite dipping away from the granite towards the north-west.

[1] *Supra*, p. 24.

The large hills at Chotan, which is situated just outside the south-western corner of the map, are all composed of a similar granite, traversed by numerous east and west dykes of basic rock. A few masses of rhyolite are seen in contact with the granite of the hill north-west of Chotan, and are apparently included in it.

The isolated hill at Radhana, 27 miles west of Barmer, is also composed of this coarse grained granite. Here it is broken through by several broad dykes of a dark coloured eurite indistinguishable in appearance from the rhyolites.

The mode of occurrence of the Barmer sandstones at Barmer itself has already been described.[1] A clear section showing the unconformability between the sandstones and rhyolites is exposed in a small hill at Lunu, about five miles north west of Barmer. Here the sandstones dipping to the north-east at 26° are banked up against and cover up an old ridge of the rhyolites, which runs from north to south through the middle of the hill. The sandstones are also exposed in several places on the plain to the north. At Bhadres they form a low rise entirely covered with blown sand, but the sandstone is found in wells. At Sondri and Bonthia they rise above the sand into low scarped hills dipping in an easterly direction at low angles.

[1] *Supra*, p. 33.

CHAPTER VII.—PETROGRAPHICAL NOTES.

1. Malani Rhyolites.

I have not yet been able to work out in detail with the microscope the large mass of material collected during my three seasons' field work in Western Rajputana, but I think that I have examined a sufficient number of specimens to give a general idea of the composition and structure of the rhyolites.

That these rocks were exceedingly siliceous was noticed by Mr. Blanford, the hardness of fresh specimens being often equal to that of quartz, so that they are not scratched by a knife. The siliceous character is confirmed by microscopic examination, the groundmass always consisting to a great extent of free quartz. The groundmass consists essentially of an intimate mixture of felspar and quartz, with as a rule a good deal of magnetite in minute grains, and dusty matter. Hornblende in the form of minute rods or acicular crystals and grains also occurs in the groundmass of many specimens. Augite perhaps occurs in one or two, but owing to its generally decomposed condition, I have considerable doubt in identifying it; and a yellowish green chloritic mineral is common. I have not found mica in any of the lavas, but magnesian mica occurs in minute flakes in the matrix of one of the tuffs (No. 11·500)[1]. Apatite is also sometimes present in small quantity. Phenocrysts of quartz and felspar occur in nearly all the lavas, but are in a few cases entirely absent.

The forms of structure exhibited by the groundmass are very various. Fluidal, perlitic and sphærulitic structures are common, those in fact that are peculiar to rocks that have flowed in a molten condition at the surface. Vesicular structure is sometimes met with, but is not very common, probably because such acid lavas as these were in a very viscid condition when molten; and some of the flows

[1] These numbers refer to the entries in the Rock Register of the Indian Museum.

have a very scoriaceous appearance. The different structures of the groundmass will be described more in detail further on.

The colours of the lavas also vary to a great extent. A rich brown, often with a reddish or purplish tinge, is perhaps the most common, but many are bright red, blue, green or almost black, and a few are white or light grey. The colour appears to be due in most cases to the presence of oxides of iron, but in the green and yellow varieties to the abundance of hornblende or chloritic minerals they contain. The tuffs are generally light coloured, in various shades of pink, buff, and green.

The specific gravity of the rhyolites varies from 2·42 in the softer altered specimens to about 2·76 in unaltered varieties. That of some of the tuffs ranges as low as 2·33 and very rarely rises above 2·40. An analysis of the values found for 167 specimens, including tuffs, gives the following results:—

Specific Gravity.		
Below 2·5	23 specimens	or 13·7 per cent.
2·5—2·55	32 „	19·1 „
2·55—2·6	28 „	17·0 „
2·6—2·65	41 „	24·6 „
2·65—2·7	29 „	17·3 „
Above 2·7	14 „	8·3 „

From this it appears that the greater number of the specimens approximate in specific gravity to that of quartz, 2·65.

The quartz phenocrysts in many cases possess very perfect crystalline outlines in the form of hexagons and octagons, but more frequently the original shape has been destroyed by corrosion. This frequently results in the production of fantastic forms, inlets, or tongues (Einbuchtungen) of the groundmass projecting far into the interior of the crystal (Pl. IX, fig. 1). In some cases the corrosion has taken place more rapidly along zones concentric with the outer boundary of the crystal; a very perfect example of this is shown in fig. 2, Pl. IX. Occasionally the included portions of the groundmass, without visible connection with the surrounding magma, have a more or less well defined, hexagonal outline, but in most cases their outlines are rounded and they are evidently sections of inlets.[1] In one or two cases the quartz crystals appear to have been partially melted and drawn out into strings along the lines of flow (Pl. IX, fig. 3).

A very beautiful and interesting phenomenon is exhibited by the quartz phenocrysts in several specimens, and is illustrated by figs. 4, 5 and 6, Pl. IX. This consists in a growth of the crystal to a greater or less distance into the surrounding groundmass, either during or subsequent to the consolidation of the rock. In all cases the secondary quartz surrounding the original phenocryst is in optical continuity with it, and extinguishes simultaneously with it between crossed Nicols. Sometimes the secondary quartz forms irregular patches, looking like small tufts of cotton wool, only partially surrounding the phenocryst. In this particular instance the hexagonal outline of the original crystal is very distinct. In other cases these patches are united into a continuous area surrounding the crystal sometimes with irregular boundaries as in fig. 4, and sometimes following the outlines of the crystal pretty closely as in fig. 5. In one example the crystal appears to have been broken into two halves, lying in a slightly different optical relation to the plane of polarised light traversing them, so that they give slightly different colours between crossed Nicols; each portion has its concentric area or "court" enclosing it, each polarising in the same colour as the portion of the crystal it surrounds, and the two "courts" meet along a line about midway between the two halves of the crystal. With a high power the details of the structure of these "courts" can be easily examined. The secondary quartz ramifies out from the edge of the

[1] It appears to me that the hexagonal inclusions of the groundmass may also be sections of "inlets" that have corroded the crystal along zonal lines, and that their presence does not afford a convincing argument for the contemporaneous formation of the phenocrysts, as suggested by Zirkel (Rosenbusch. Mikr. Phys. Massig. Gest., pp. 52, 99).

phenocryst in among the minute crystals of felspar forming the remainder of the groundmass, giving rise to a minutely micropegmatitic structure as in fig. 6. This structure appears to me to throw some light on the question of the origin of the groundmass of rhyolites and quartz porphyries and will be referred to later on in the discussion of the groundmass.

Inclusions of various kinds are tolerably numerous in the quartz phenocrysts. They include gas pores, which are often arranged in lines parallel to the cracks traversing the crystals ; and glass inclusions, usually with a fixed bubble. These latter sometimes possess hexagonal outlines, but are more usually rectangular with rounded corners. Occasionally a faint asterism is perceptible in them. Cavities containing liquid are also not rare, and these generally contain a movable bubble, which when the cavity is of sufficiently small dimensions, and the bubble is also small, may be seen under a high power to be in constant spontaneous motion. The inclusion of portions of the groundmass in the quartz phenocrysts has already been alluded to.

The felspar phenocrysts do not as a rule show signs of corrosion, but frequently have well defined crystalline outlines; this suggests that the felspars may be phenocrysts in the true sense of the word, that is, that they have been formed *in situ* in the molten magma, while the quartz phenocrysts may have been floated in from some deep-seated coarsely crystalline mass, pierced by the rhyolites, and undergone corrosion in the process. In the phenocryst shown in fig. 2, Pl. X, the felspar possesses perfect crystalline outlines, while the quartz is apparently merely the skeleton of a previously formed crystal. I have never found any trace of secondary growth at their edges, such as is so often exhibited by the quartz grains. Sometimes the felspars possess well defined simple twinning or consist of aggregates of interpenetrating individuals, a structure that is very distinctly brought out in polarised light (Pl. X, fig. 1). The great majority of them are undoubtedly orthoclase, and many have the "glassy" appearance of sanidine. Very often, however, a more or less distinct striated twinning is developed in them somewhat similar to the twin structure in microcline, but without its reticulated appearance. The striæ sometimes lie parallel to the direction of schillerisation of the felspars, and it is possible that their development is of secondary origin and is connected in some way with the decomposition of the mineral. In one case (No. 11·556) some of the felspars consist of undoubted oligoclase.

Very commonly the whole of the felspar phenocrysts have been converted into white powdery kaolin, which has hardly any action on polarised light. In other cases they are much clouded by dusty matter and lines of inclusions, the products of schillerisation. The inclusions are sometimes arranged in zones parallel to the edges of the crystal.

Phenocrysts of hornblende occur in a few specimens, principally from the range south of Jasol. They are generally in the form of irregular patches consisting of aggregates of minute microlites, but some show well defined crystalline outlines. They are generally associated with much opaque magnetite, and are frequently altered into a light yellow chloritic mineral.

The slide cut from specimen No. 11·564, from the range south of Jasol, contains a well defined crystal giving brilliant colours in polarised light, and with a high angle of extinction, which may be augite.

At first sight in many cases the groundmass of these lavas appears to be entirely glassy and homogeneous, but the application of polarised light shows that it is always crystalline, though the size of the crystal varies greatly, from the most minute grains, such as can be detected only with a very high power, to an almost granitic holocrystalline structure. In the most common varieties the quartz appears to have acted as a matrix, in which minute crystals of felspar are imbedded, sometimes irregularly, giving rise to a structure similar on a small scale to the ophitic structure of some basic rocks; in other cases more or less parallel to each other, forming an extremely minutely grained micropegmatite (Pl. IX, fig. 6); or again arranged in radiating fibrous aggregates or sphærulites. The minute microlites of felspar are often well shaped and have evidently grown freely in the surrounding magma, but they are usually too small to allow of their species being determined, though most of them are probably orthoclase. Occasionally one may be found which shows striated twinning.

In many of the specimens the groundmass breaks up on the application of polarised light into a more or less irregular mosaic of light and dark areas (Pl. IX, figs. 4, 5), in which, when in a position of extinction, the felspar microlites appear as dim points of light. That the matrix of each of these areas consists of crystalline quartz is evident when they are in contact with the quartz phenocrysts, for it is then seen that the quartz of the phenocryst is in optical continuity with the substance filling the interstices between the felspar microlites. The original quartz of the phenocryst and the "secondary" quartz of the groundmass extinguish simultaneously, the latter forming the closed areas or "courts" surrounding the phenocryst, already described. It is possible that each of the areas forming this "quartz mosaic," as it may be called, has been built up round a previously existing granule of quartz, introduced, like the larger phenocrysts, from outside, though such a central granule is not always visible in the slide, owing to the direction the section has taken. The size of the areas appears to depend upon the number and distribution of these granules; where they are numerous and close together the mosaic will be proportionally fine grained. The quartz composing any individual of the mosaic appears to have grown outwards until its development was arrested by contact with the surrounding individuals. Thus, in cases where the mosaic is composed of small areas, the "court" surrounding a quartz phenocryst, even though the latter is a large one, is proportionately narrow. Conversely, a small phenocryst may be surrounded by a broad "court" if the mosaic composing the groundmass consists of large individuals.

It is a question whether this mosaic of quartz grains was formed at the time of consolidation of the rock, or whether it is a result of secondary devitrification of an originally glassy magma. I am strongly inclined to think that it is an original feature, otherwise it would be difficult to account for cases where the secondary quartz does not surround the whole phenocryst. If this growth had taken place after the consolidation of the rock, there seems to be no reason why it should not have spread through the whole of the groundmass, as it has done in some instances (Pl. IX, figs. 4, 5). In other cases also, for instance, No. 11·537 (Pl. IX, fig. 2), there is no sign of such a growth round the quartz phenocrysts and yet there is no reason to suppose that these flows have been subjected since their consolidation to different conditions. There is no evidence of their having been greatly disturbed or folded to such an extent that some of them might have been acted upon by great heat and pressure, to which others were not subjected. I have observed that some of the flows which show no trace of the formation of a "mosaic", bear evidence in the shape of included fragments of rhyolite probably showered down upon them from above, that at the time of their eruption they were at once exposed to the atmosphere, and therefore presumably cooled more rapidly than the flows which do not contain such fragments, but which do possess the mosaic structure. Thus the formation of this structure seems to have depended to some extent at any rate on the conditions under which the rock solidified. For this reason, although I have called the quartz of the "courts" surrounding the phenocrysts "secondary," I do not consider that it is "secondary" in the sense of having been produced by devitrification subsequently to the consolidation of the rock, but merely that it was of secondary growth in comparison with the original quartz of the phenocrysts.

It is difficult to say why the groundmass of some of the lavas should present the appearance just described, while in others instead of the "quartz mosaic" we have a microcrystalline aggregate composed of minute but perfectly distinct crystals of quartz and felspar. Probably this variation in the character of the groundmass is due to some difference in the conditions and rate of cooling, or perhaps, in the microcrystalline variety, to the absence of the foreign particles of quartz which appear to have started the growth of the "quartz mosaic."

A consideration of the appearances presented by the fluidal structures so beautifully developed in several of these rhyolites (Pl. X, figs. 3—5) seems to me to lead to the same conclusion that I have deduced from a study of the "quartz mosaic," that is to say, that the rocks at the time of their consolidation were not in the condition of a homogeneous glass, which has become crystalline by subsequent devitrification. In all the slides which exhibit this structure we find alternate bands of exceedingly fine grained, and more coarsely crystalline matter. The coarse grained bands are never continuous for any considerable distance, but are always lenticular, while the fine grained bands stream round these lenticular areas just as they do round the phenocrysts. If the coarse grained lenticles are closely examined, it will be seen that the crystals composing them have grown inwards from either wall, and that there is a well marked line along the centre, where the crystals from either side meet; in fact the structure is exactly similar to that of an ordinary mineral vein. In some cases, as in No. 11·565 (Pl. X, fig. 3), the substance filling the central space of the lenticle is hornblende, and in others, it appears to be either magnetite or a mixture of magnetite and hornblende. The crystals projecting from the walls are also frequently hornblende, sometimes in rod shaped microlites and sometimes in radiating bunches of delicate needles (Pl. X, figs. 3, 4). It appears therefore that the magma filling these lenticles contained a larger amount of ferromagnesian material than the body of the rock, and was presumably in a more liquid condition. This would account for the more perfect growth of the crystals in these areas, just as the growth of the crystals in a cavity filled with concentrated mineral solution is generally more perfect than in the surrounding rock. On the other hand, on the assumption that the rock was originally a homogeneous glass, it would be difficult to account for the presence of these lenticles.

That they were formed, or in process of formation, while the surrounding magma was in a more or less viscous condition is proved by the manner in which this "flows" round them; and their dimensions preclude the idea of their having been originally cavities, which have been subsequently filled with minerals leached out from the surrounding rock, for they are sometimes several inches long and half an inch or more in width. If they had been cavities, we should expect to find spaces in the centre of them unfilled with mineral, and I have so far not found anything of the kind. True cavities filled with chalcedony or other secondary mineral do occur sometimes, but they present an appearance very different from the lenticular bands in the fluidal rocks.

Some few of the specimens I have examined exhibit a very well defined perlitic structure. This is especially well developed in No. 11·494 (Pl. XI, figs. 1, 2), from a flow in the neighbourhood of Jodhpur, and is associated with minute sphærulites. No. 11·530 also shows this structure very clearly. In No. 11·532 (Pl. X, fig. 5) the perlitic cracks are concentric with the quartz phenocrysts and sometimes extend into them from the groundmass. The perlitic structure in all of these is of the ordinary kind, but the beautiful variety shown in portions of No. 11·523 (Pl. X, fig. 6), merits a further description. In this case the cracks have opened to a small extent, and are lined on either side by minute crystals of quartz, projecting inwards, and meeting along a well defined line in the middle of the fissure. The spaces between the cracks are filled with granular quartz, sometimes clear, but usually stained a deep brown. This structure is identical, so far as can be determined from the description, with that described by Rosenbusch in the pyromeride of Wuenheim in Upper Alsace.[1] This specimen, which was collected in the hills to the west of Nagona, about 33 miles west-south-west of Jodhpur, also contains large brown sphærulites, some of them as large as a hazelnut.

Sphærulitic structures are of very common occurrence in these rocks

[1] Rosenbusch. Mikr. Phys. Massig. Gest., p. 83.

and often very beautiful in appearance. In some, as for instance No. 11·578, the sphærulites are isolated globules, scattered about in the body of the rock and giving a dark interference cross between crossed Nicols. In others, the different individuals forming the "quartz mosaic" each contain in their interior a radiating bunch of minute crystals, so that between crossed Nicols a number of little black crosses make their appearance revolving as the Nicols are rotated like so many minute wheels. In these cases the mineral forming the radiating aggregates is felspar. In some others again minute needles of hornblende are intercalated among the felspar crystals, giving rise to the beautiful sphærulites seen in No. 11·563 (Pl. XI, fig. 3). In this specimen, where the sphærulites abut against a quartz phenocryst, the quartz filling the interstices between the hornblende and felspar needles is, for a short distance from the edge of the phenocryst, in optical continuity with it. A sphærulitic structure of this kind also occurs along the edges of the more coarsely crystalline bands in those rocks that possess flow-structure (Pl. X, figs. 3, 4), and in the latter specimen perfect globular sphærulites occur in the middle of the broader bands. The large sphærulites in the specimen No. 11·523, described in the last paragraph, are often broken across, and fragments of them lie scattered about in all directions in the body of the rock. In this rock they generally have a quartz grain at the centre.

Among the specimens collected in the Boulder bed of the Salt Range by Mr. Middlemiss and described by him in the Records of the Geological Survey [1] there is one which corresponds very closely in appearance with some of the rhyolites of Western Rajputana. This is No. 8·473, which is almost identical with No. 11·512 from my collections from the group of hills near Agolai. The variable structure of the groundmass, which is strongly fluidal, described by Mr. Middlemiss is exactly repeated in my specimen, and the boulder from the Salt Range might have been broken off a portion of the same flow. It is

[1] Rec. Geol. Surv. Ind., Vol. XXV, Pt. 1, p. 29.

also very similar to Nos. 11·508 and 11·532, the first of which is from the same group of hills, and the other from the neighbourhood of Thob, at the south-western end of the chain of hills in which the Agolai group is situated.

The felsites of Tusham hill described by Col. McMahon,[1] and compared by him with the rhyolites of Barmer and Pokaran collected by Mr. Blanford,[2] differ from the latter in containing mica among the constituents of the groundmass, and although the structure is very similar, the presence of this mineral makes it more than doubtful whether the Tusham rocks are identical with the Malanis.

Through the courtesy of Dr. Callaway, who has devoted much time to a study of the pre-Cambrian rocks of Great Britain, I have been enabled to compare these rhyolites with a few slides cut from the ancient devitrified pitchstones and perlites of the Wrekin in Shropshire, which were microscopically described by Mr. S. Allport.[3] The similarity in the structure of the groundmass in the two sets of rocks is very remarkable, and indeed it would be difficult, if not impossible, if the specimens from the two localities were mixed together, to pick out those from the Wrekin from among the Rajputana rocks. The identity is especially striking in a specimen from Lyd's Hole, which shows the peculiar structure of the groundmass that I have designated by the name of "quartz mosaic." The sphærulitic and other structures too in other slides are exactly similar, but perhaps they are more clearly defined in the Rajputana specimens, since these have not been subjected to so great an amount of disturbance and crushing as the Wrekin rocks. It would of course be rash to conclude that this similarity implies any strict contemporaneity between the volcanic outbursts in two localities so widely separated; but when we consider that the Malani rhyolites were poured out in pre-Vindhyan times, it is probable that there is no very great disparity in age between them.

[1] Rec. Geol. Surv. Ind., Vol. XVII, Pt. 3, p. 108.
[2] *Ibid*, Vol. XIX, Pt. 3, p. 161.
[3] Quart. Journ. Geol. Soc., Vol. XXXIII, p. 449.

2. Tuffs and Breccias.

The tuffs associated with the rhyolites are easily distinguishable from them in the field mainly by reason of their lighter colours, their mode of weathering, and their undoubtedly bedded aspect. In many cases the larger fragments and lapilli they contain stand out conspicuously on the weathered surface of the rock. Under the microscope the matrix is hardly to be distinguished from the groundmass of some of the rhyolites, and they are evidently formed of the same material, blown into dust and subsequently consolidated by pressure. The presence of fragments and lapilli of quartz and other minerals as well as fragments derived from previously consolidated flows is sufficient proof of their clastic origin. One of the tuffs, No. 11·500, contains numerous flakes of brown mica ; this is the only instance in which I have found this mineral associated with any of the Malani rhyolites.

The breccias usually occur in lenticular bands intercalated with the lava flows. They consist of irregularly shaped angular fragments of various sizes derived from previously consolidated flows imbedded in a more or less opaque paste. The condition of the fragments affords further argument in support of the contention that the crystalline structures developed in the groundmass were original, that is, formed at the time of consolidation, and are not due to subsequent processes of devitrification ; for in one and the same hand specimen of breccia fragments may be found which exhibit each of the structures I have described, "quartz mosaic", microcrystalline and flow-structure, which must have been developed in them before they were broken up and included in the breccias. In one case, however, in a bed of breccia extending over a considerable area in the low ground west of the group of hills near Nagona, the included fragments possess a structure, which may be due to devitrification developed in them after they were included in the matrix. The fragments are mostly rectangular and triangular or wedge shaped chips of glass, in which bundles of delicate fibres have been developed, projecting inwards from the edges and at right angles to them, not meeting in the centre but leaving a clear space along which there is usually a line of black granules (Pl. XI, figs. 4, 5). Some of the chips contain minute globulites round which the fibres curve as shown in fig. 5. The structure is exactly similar to that developed in a piece of artificial glass exposed after its first consolidation to great heat, an example of which is given in Professor Bonney's anniversary address to the Geological Society of London in 1885.[1] The matrix of this breccia, No. 11·524, is a fine grained microcrystalline rhyolite, and there is no doubt that it was molten when the chips of already solidified glass from another flow were showered into it, and that they were then partially devitrified by the heat of the surrounding molten mass.

The volcanic ash, No. 8·480, described by Mr. Middlemiss in the paper above referred to, from one of the boulders in the Salt Range boulder bed, is very similar to one of the tuff beds at Korra, No. 11·501.

3. Granite.

The granites associated with the Malani rhyolites do not present many features of particular interest under the microscope. The Siwana granite contains an abundance of actinolitic hornblende, usually of a bright green colour but sometimes with a bluish tinge; the pleochroism is usually very strong. It is commonly interstitial, but occasionally occurs in idiomorophic crystals, especially in the veins and dykes protruded from the main mass into the surrounding rhyolites. The felspar and quartz frequently form a micropegmatitic intergrowth or granophyric structure of great beauty, and the rock is then indistinguishable from the specimen No. 8·472 described by Mr. Middlemiss in the paper

[1] Quart. Journ. Geol. Soc., Vol. XLI, p. 92.

above cited on the Boulder bed of the Salt Range. There seems to be a singular dearth of accessory minerals in this granite ; even magnetite is rare.

At the contact between the granite and rhyolite there is usually a considerable development of hornblende in the latter. At times this takes the form of a growth of comparatively large nests of hornblende which have apparently included portions of the groundmass. Along the actual line of junction a row of small hornblende crystals projects into the granite, evidently formed before the mass of the latter began to solidify (Pl. XI, fig. 6).

The Jalor granite differs from that just described mainly in containing mica as the principal ferromagnesian constituent instead of hornblende. There is also a fair proportion of plagioclase felspar as well as orthoclase. The mica is of two kinds, muscovite and biotite The former predominates in a specimen from Manpur near Pali, No. 12·258, while biotite alone occurs in the granite of Jalor hill, No. 11·716.

4. Basic Dykes.

I am indebted to Mr. Holland for the following description of the specimens collected from the dykes in the area surveyed. The ordinary dykes traversing the rhyolites and granites, when unaltered, like the rock composing the large dyke to the south of Jalor (No. 11·715) are olivine dolerites or diabases, and consist of "plagioclase felspar, a "basic variety giving extinctions near labradorite (bytownite) ; olivine "in isolated crystals and in clusters partially serpentinised, but without 'reaction borders' at their junction with the plagioclase ; pale "red brown augite, forming sub-ophitic intergrowths with the felspar "and olivine ; apatite in numerous well shaped prisms ; opaque black "iron ores in large lumps with crystalline shapes, and a small quantity "of brown biotite often associated with the iron ores." The rock is medium or coarse grained in the centre of the dykes, but near their edges passes into an extremely fine grained selvage, often quite glassy in appearance. Where it has been much decomposed, as in No. 11·548, the olivines have almost entirely disappeared and the augite is to a great extent replaced by hornblende. The specific gravity varies from 3·14 in No. 12·312, which contains a large amount of unaltered olivine, to 2·72 in the most altered varieties. About half of the specimens examined have a specific gravity of 3·00.

The rock from the dyke or boss mentioned on p. 75 as probably intrusive in the Barmer sandstones near the village of Sarnu, on the eastern edge of the Barmer desert, is very different in composition from that just described and evidently belongs to quite a different period of volcanic activity. Mr. Holland says: "Macroscopically this rock "(No. 13·803) is grey, with porphyritic crystals of sanidine and ægerine "augite, sometimes reaching (in the former case) about ½ inch across "but more often ¼ inch, ⅛ inch, or less. The weathered surface shows the "characteristic pitted surface of these rocks by removal of the soluble "felspathoids. The constituents are idiomorphic ægerine augite, "sanidine, sodalite (and? nosean), sphene, apatite and melanite in a "fine grained matrix of sanidine and nepheline.

"*Felspar*. Sanidine in porphyritic crystals, fairly fresh and as "numerous lath shaped crystals in the groundmass. Often in Carlsbad "twins. Irregularly shaped inclusions of a colourless isotropic decom-"posable mineral are common.

"*Pyroxene*. Ægerine augite variety in porphyritic crystals and "as smaller granules. Zoned with zonal extinctions and hour-glass "structure between crossed Nicols. Pleochroism strong, 𝔞 green, 𝔟 "yellowish brown, 𝔠 greenish yellow. Extinction 31° (c : 𝔞) : or 59° "(c : 𝔞) ; occasionally twinned. Margins often rugged and of different "colour.

"*Sphene* in numerous well shaped colourless crystals, twinned.

"*Melanite*. Rugged brown lumps, very few in number.

"*Sodalite* (and? *nosean*). Well shaped crystals; dirty brown and "darkened at borders, isotropic, often decomposed with formation of "fibrous zeolites; rectangular meshwork of dust lines occasionally "shown.

"Rounded masses of tufted zeolites with clear apatite crystals "probably represent patches where sodalite was once concentrated. "The products of decomposition include *calcite*.

"Much of the colourless groundmass is decomposed by hydrochlo-"ric acid with formation of gelatinous silica in which the insoluble "granules (ægerine, etc.) are imbedded. Treatment of the powdered "rock with nitric acid is attended with effervescence, and the solution "gives reactions for chlorine (strong), sulphuric acid (very faint), "alumina (strong), and phosphoric acid (strong).

"Opaque iron ores present only in very small quantities and as "very minute grains.

"The rock appears to resemble a tinguaite from the neighbourhood "of Montreal. (Rosenbusch, Mass. Gest., 1896, p. 483)."

The specific gravity of the rock is 2·69.

At the same locality is found a dense nearly black basaltic rock (No. 13,804), containing plagioclase felspar, pale red brown augites and a large amount of iron ore. The specific gravity of this rock is 3·23. It approaches some of the Deccan traps in composition. The relations of this rock with the tinguaite could not be made out, as the junction is concealed by sand.

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LIST OF ILLUSTRATIONS.

PLATE VIII.

PLATE IX.

PLATE X.

PLATE XI.

Surface of Malani Rhyolite, grooved & polished by action of wind

Fig 1.

Granite block undercut by wind. Near Chotila.

Fig 2.

Sub-recent Conglomerate, Bed of Sukri R. near Darri

Fig 3.

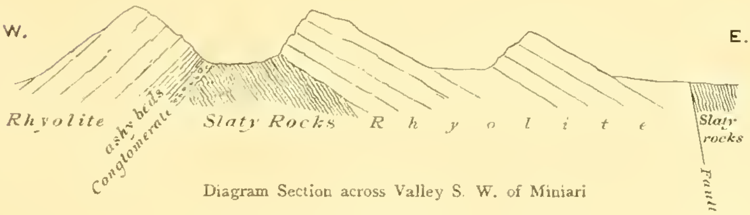
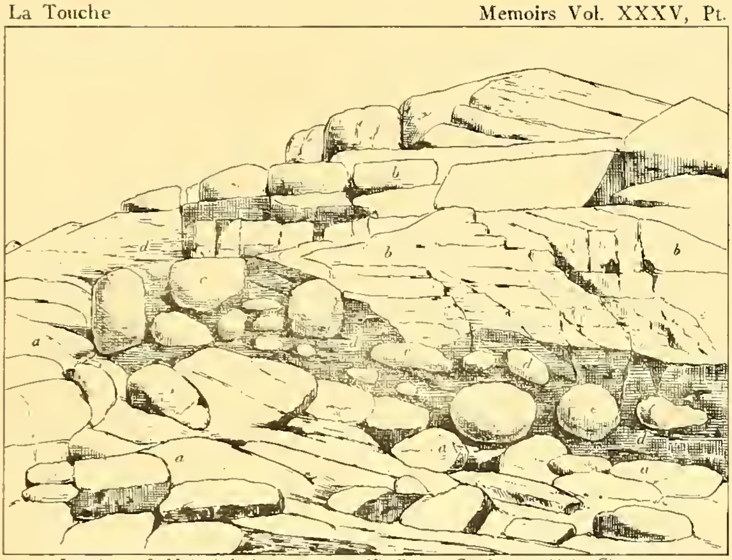


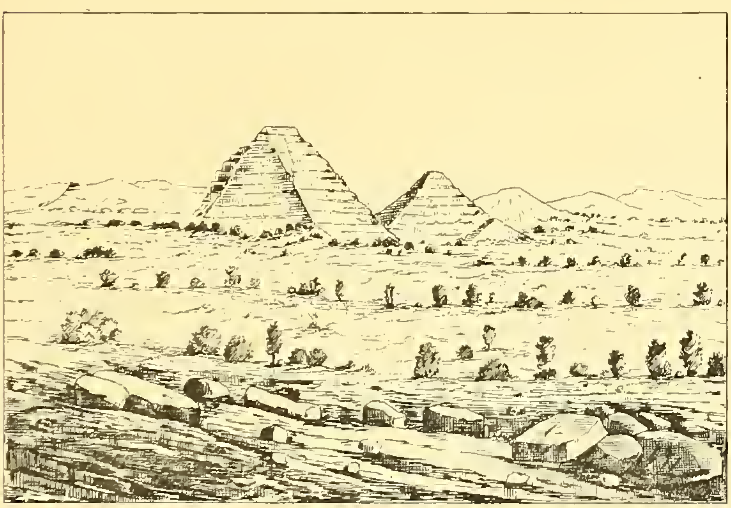
Diagram Section across Valley S. W. of Miniari

Fig 4.



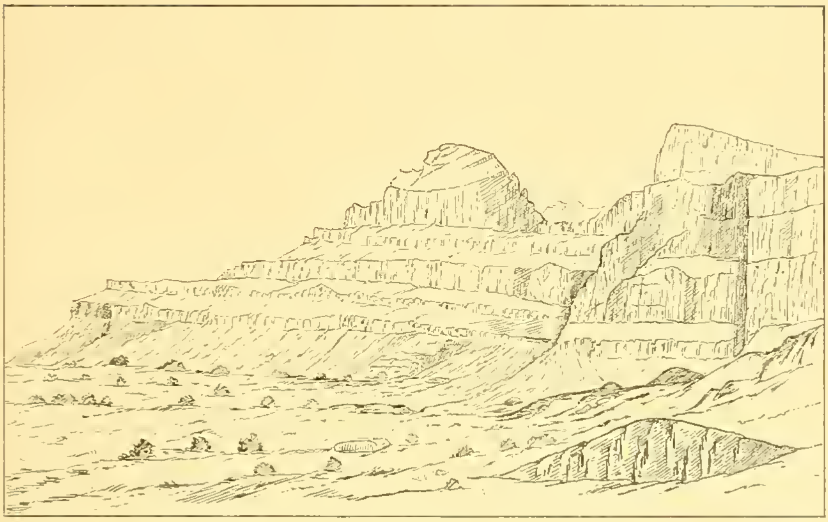
Junction of Malani beds (a,a) and Vindhyan Sandstones (b,b) Showing rounded blocks of Malanis c,c embedded in silt d,d, forming a pseudo-conglomerate. N. E. side of scarped hill S. W. of Sur Sagar, Jodhpur.

Fig 1.



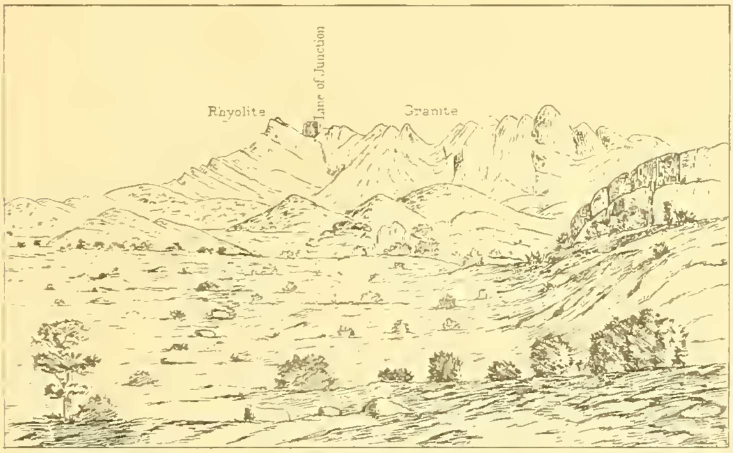
SCARPED OUTLIERS (ZEUGEN) OF SANDSTONE NEAR GHORIALA, MARWAR.

Fig 2.



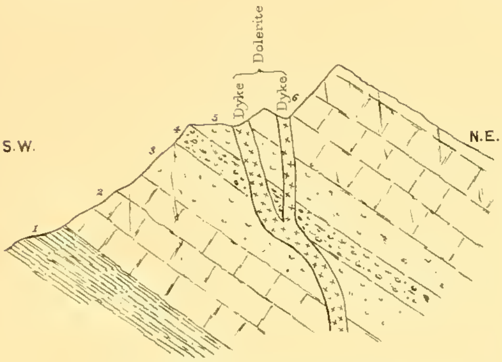
HILL (1634 ft.) W. S. W. FROM KUIP, FROM THE NORTH

Fig 1.



JUNCTION OF MALANI RHYOLITE AND GRANITE, HILL W. OF INDRANA. FROM S.

Fig 2.



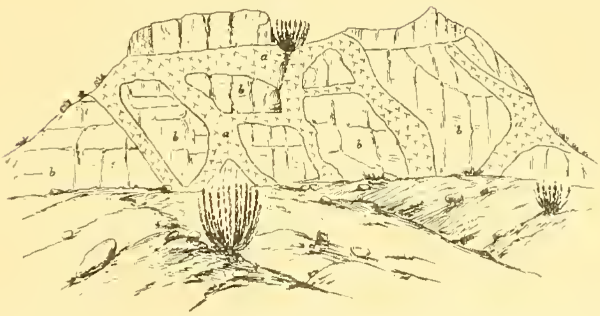
SECTION OF HILL AT SINER.

1. Fluidal rhyolite. 2. Porphyritic rhyolite.
3. Dark greenish basic rock with amygdales
4. Conglomerate. 5. Vesicular rhyolite.
6. Porphyritic rhyolite.
7. Dyke Dolerite.

Fig 1

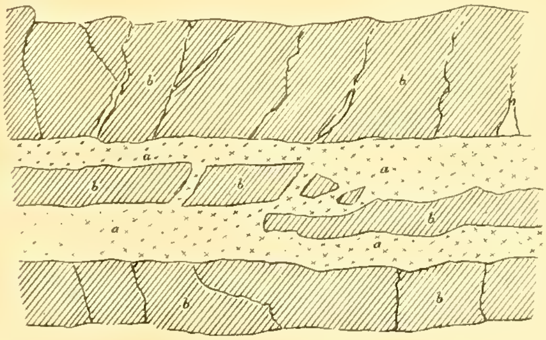
Contorted Granite Veins in Schist Hill W. of Pomao, near Erinpura.

Fig 2.



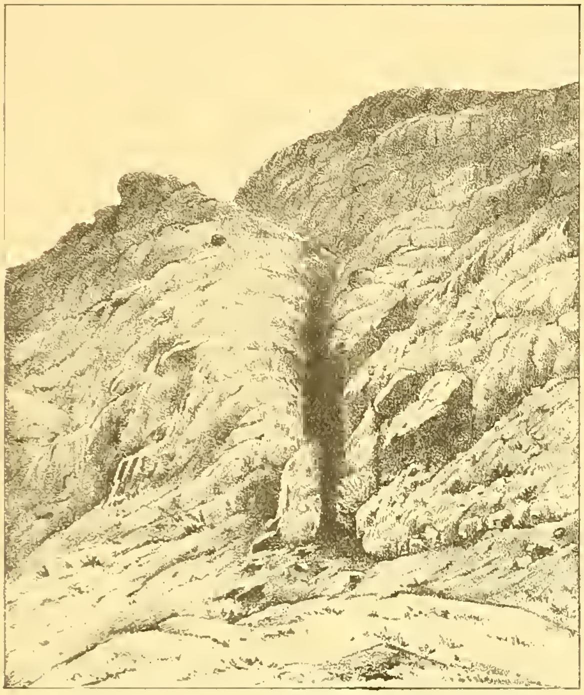
Veins of Granite (a,a) penetrating Rhyolite (b,b) S. end of range W. of Indrana.

Fig 3.



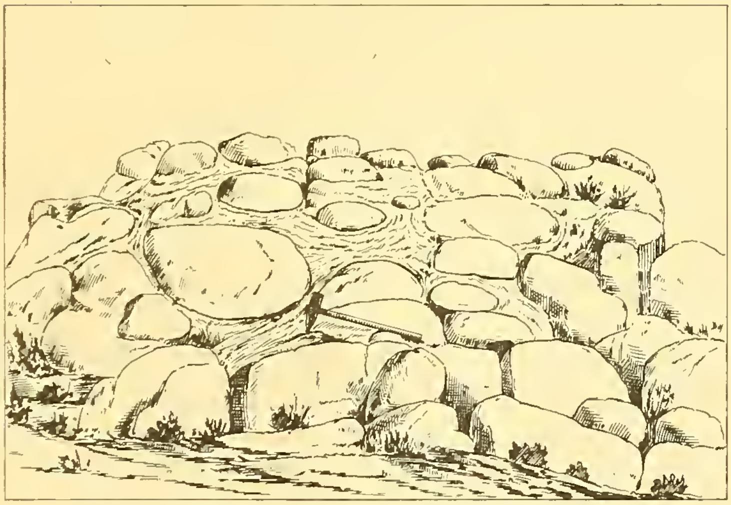
Vein of Granite (a,a) intrusive in Rhyolite (b,b) Ravine S. of Golia, Saora Range.

Fig 4.



CHASM FORMED BY WEATHERING OUT OF INTRUSIVE DYKE IN RHYOLITES. HILL SIDE S. OF NAGAR.

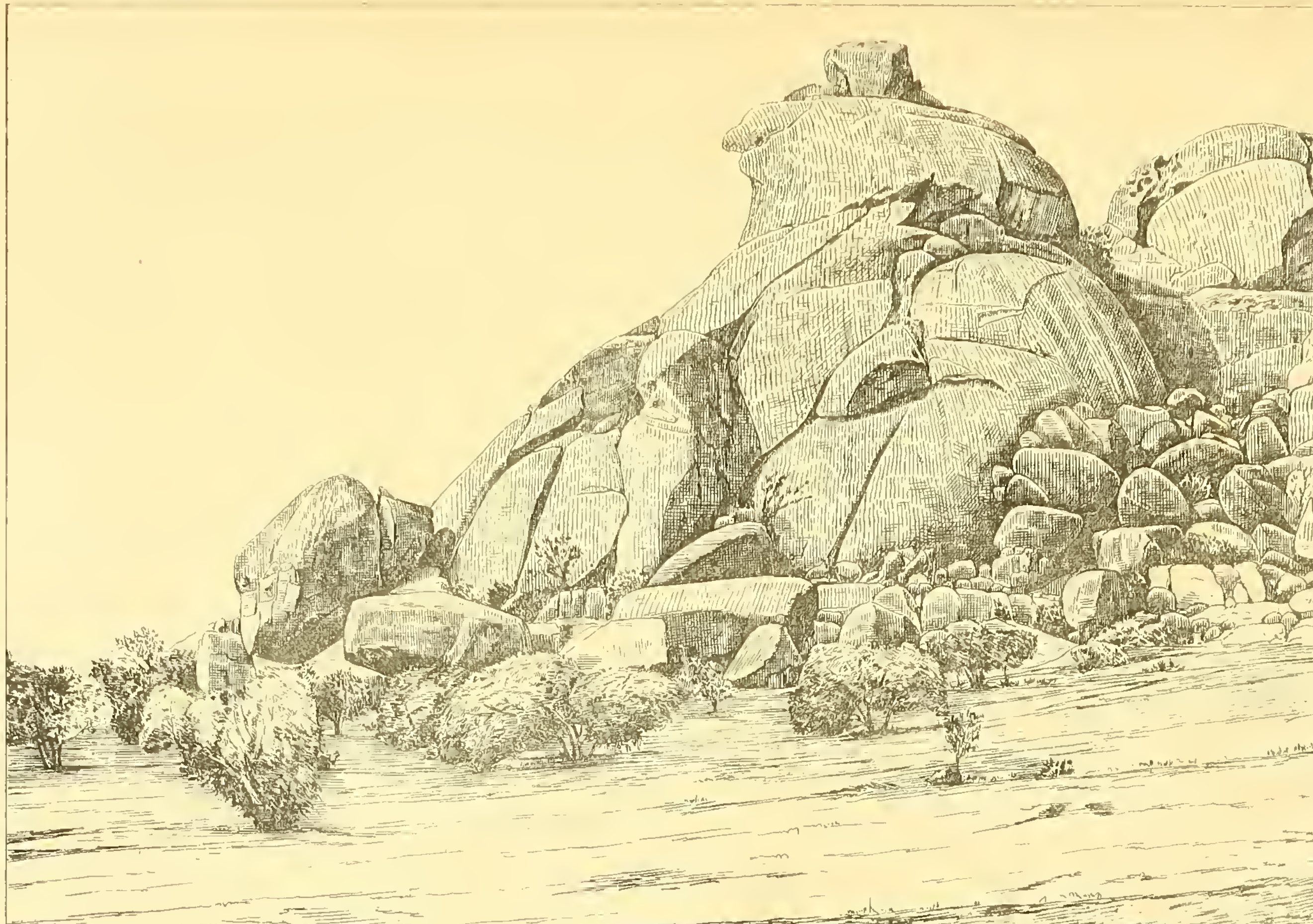
Fig 1.



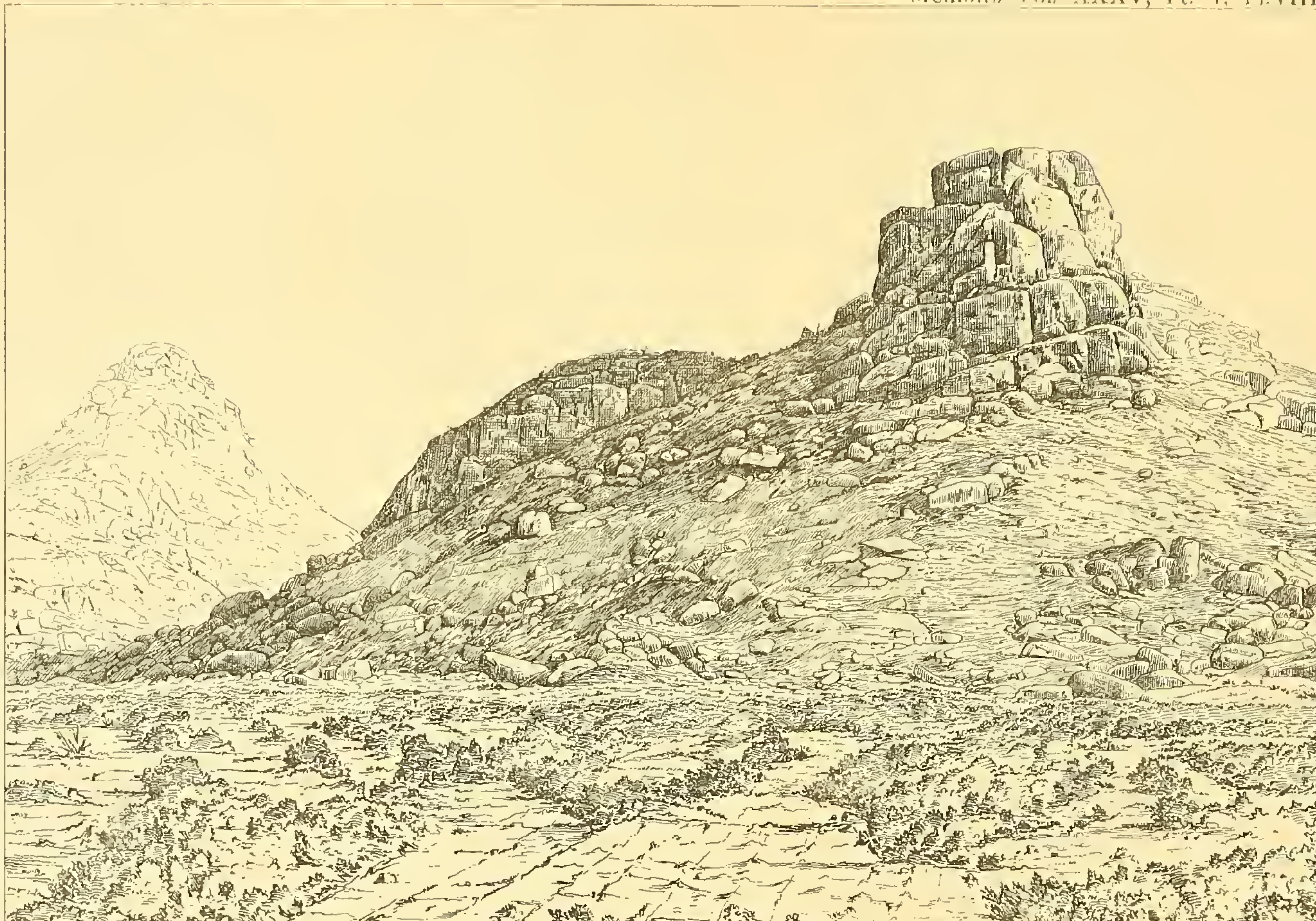
NODULAR RHYOLITE NEAR BAKHAL, BHADRAJUN RANGE.

Fig 2.

GRANITE HILL AT KAONLA.



GRANITE AT KAONLA.



HILL OF GRANITE NEAR ERINPURA ROAD Stn. R. M. Ry.

FIG. 1.

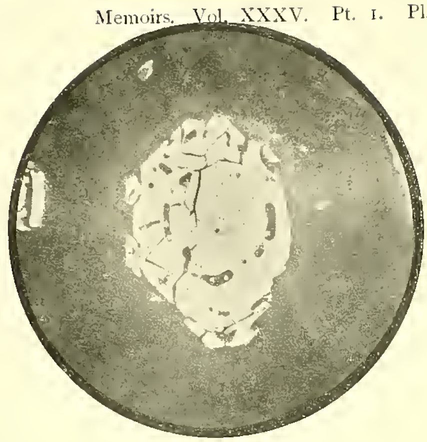


FIG. 2.

FIG. 3.

FIG. 4.

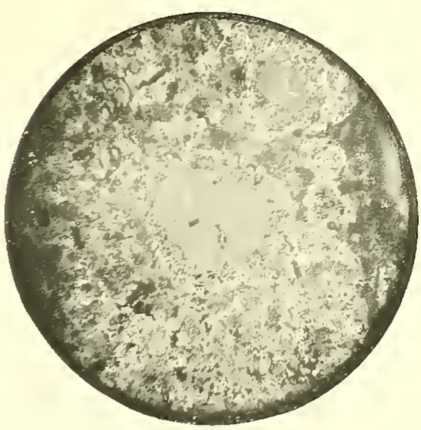


FIG. 5.

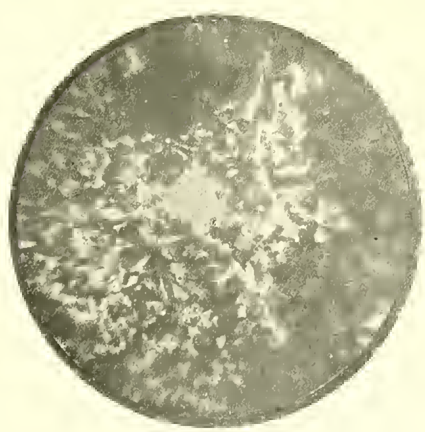


FIG. 6.

BEMROSE & SONS, LIMITED, DERBY, LONDON & WATFORD.

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BEMROSE & SONS, LIMITED, DERBY, LONDON & WATFORD

FIG. 1.

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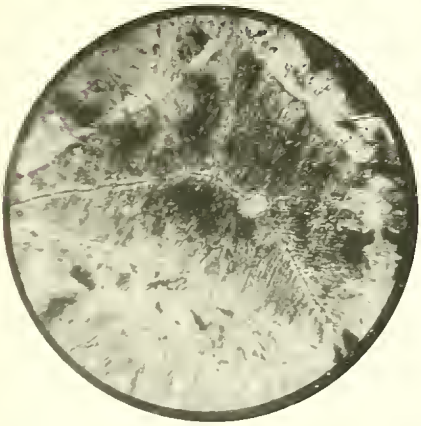

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FIG. 6.

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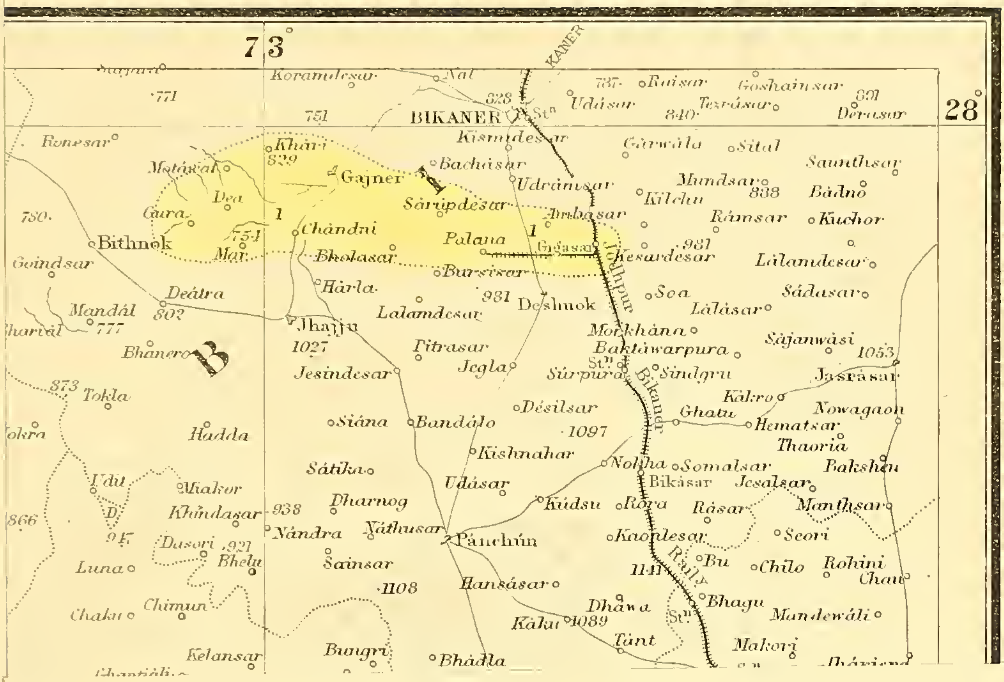
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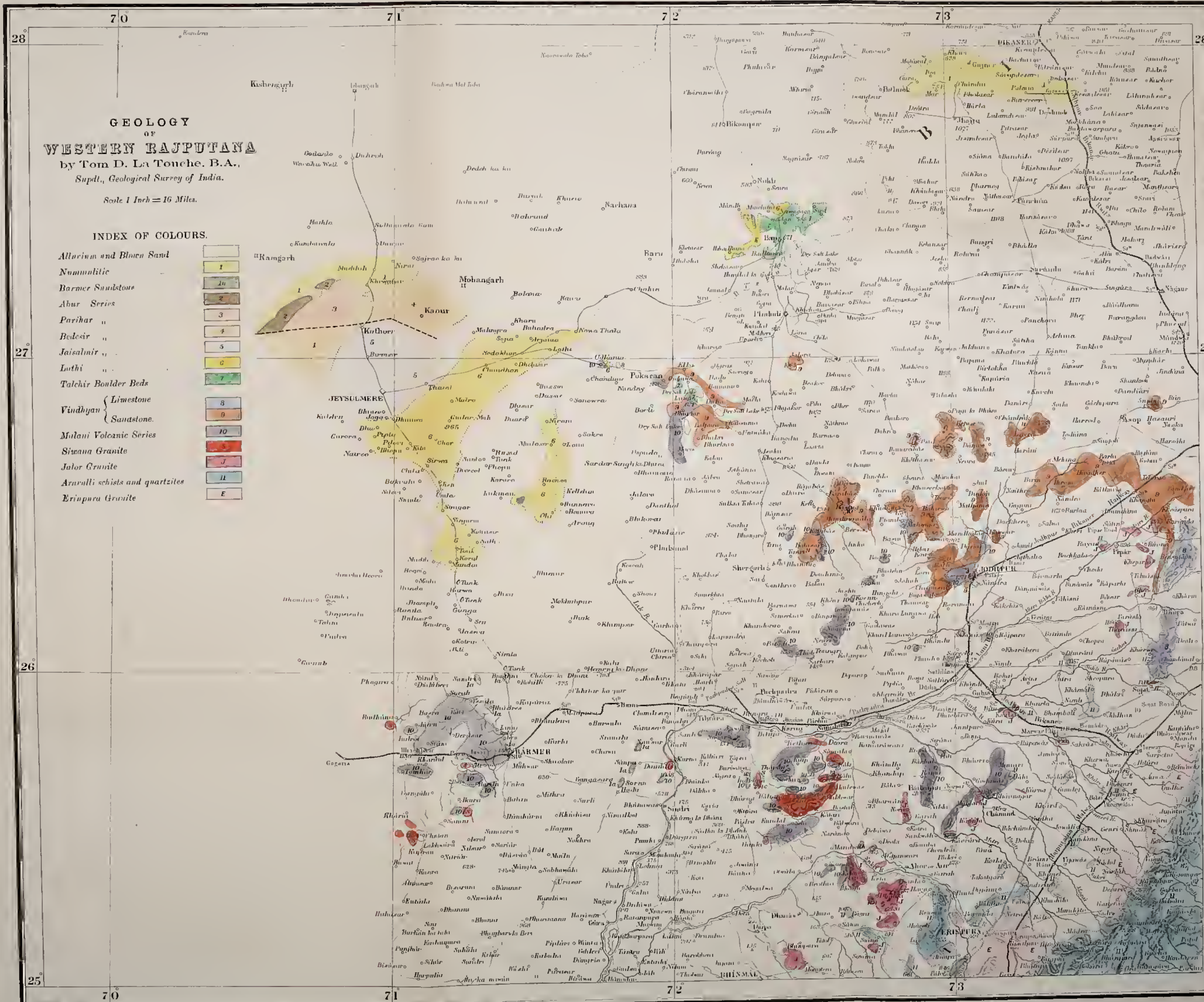
GEOLOGY
OF
WESTERN RAJPUTANA
by Tom D. La Touche. B.A.,
Supdt., Geological Survey of India.
Scale 1 Inch = 16 Miles.
INDEX OF COLOURS.
Alluvium and Blown Sand
Nummulitic 1
Barmer Sandstone 1a
Abur Series 2
Parihar „ 3
Bedesir „ 4
Jaisalmir „ 5
Lathi „ 6
Talchir Boulder Beds 7
Vindhyan { Limestone 8
Vindhyan { Sandstone 9
Malani Volcanic Series 10
Siwana Granite S
Jalor Granite J
Aravalli schists and quartzites 11
Erinpura Granite E
JEYSULMERE
BARMER
JODHPUR
BIKANER
ERINPURA
Pokaran
Phalodi
Mohangarh
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Part 3.—Note on the progress of the gold industry in Wynaad, Nilgiri district. Notes on tbe representatives of the Upper Gondwana series in Trichinopoly and Nellore-Kistna districts. Senarmontite from Sarawak.

Part 4.—On the geographical distribution of fossil organisms in India. Submerged forest on Bombay Island.

VOL. XII, 1879.

Part 1.—Annual report for 1878. Geology of Kashmir (third notice). Further notices of Siwalik mammalia. Notes on some Siwalik birds. Notes of a tour through Hangrang and Spiti. On a recent mud eruption in Ramri Island (Arakan). On Braunite, with Rhodonite, from near Nagpur, Central Provinces. Palæontological notes from the Satpura coal-basin. Statistics of coal importations into India.

Part 2.—On tbe Mohpani coal-field. On Pyrolusite with Psilomelane occurring at Gosalpur, Jabalpur district. A geological reconnaissance from the Indus at Kushalgarh to the Kurram at Thal on the Afghan frontier. Further notes on the geology of the Upper Punjab.

Part 3.—On the geological features of the northern part of Madura district, the Pudukota State, and the southern parts of the Tanjore and Trichinopoly districts included within tbe limits of sheet 80 of the Indian Atlas. Rough notes on the cretaceous fossils from Trichinopoly district, collected in 1877-78. Notes on the genus Sphenophyllum and other Equisetaceæ, with reference to the Indian form Trizygia Speciosa, Royle (Sphenophyllum Trizygia, Ung.). On Mysorin and Atacamite from the Nellore district. On corundum from the Khasi Hills. On the Joga neighbourhood and old mines on the Nerbudda.

Part 4.—On the 'Attock Slates' and their probable geological position. On a marginal bone of an undescribed tortoise, from the Upper Siwaliks, near Nila, in the Potwar, Punjab. Sketch of tbe geology of North Arcot district. On the continuation of the road section from Murree to Abbottabad.

VOL. XIII, 1880.

Part 1.—Annual report for 1879. Additional notes on the geology of the Upper Godavari basin in tbe neighbourhood of Sironcha. Geology of Ladak and neighbouring districts, being fourth notice of geology of Kashmir and neighbouring territories. Teeth of fossil fishes from Ramri Island and the Punjab. Note on the fossil genera Nöggerathia, Stbg., Nöggerathiopsis, Fstm., and Rhiptozamites, Schmalh., in palæozoic and secondary rocks of Europe, Asia, and Australia. Notes on fossil plants from Kattywar, Shekh Budin, and Sirgujah. On volcanic foci of eruption in the Konkan.

Part 2.—Geological notes. Palæontological notes on the lower trias of the Himalayas. On the artesian wells at Pondicberry, and the possibility of finding such sources of water-supply at Madras.

Part 3.—The Kumaun lakes. On the discovery of a celt of palæolithic type in the Punjab. Palæontological notes from the Karharbari and South Rewah coal-fields. Further notes on the correlation of the Gondwana flora with other floras. Additional note on the artesian wells at Pondicherry. Salt in Rajputana. Record of gas and mud eruptions on the Arakan coast on 12th March 1879 and in June 1843.

Part 4.—On some pleistocene deposits of the Northern Punjab, and the evidence they afford of an extreme climate during a portion of that period. Useful minerals of the Arvali region. Further notes on the correlation of the Gondwana flora with that of the Australian coal-bearing system. Note on reh or alkali soils and saline well waters. The reh soils of Upper India. Note on the Naini Tal landslip, 18th September 1880.

VOL. XIV, 1881.

Part 1.—Annual report for 1880. Geology of part of Dardistan, Baltistan, and neighbouring districts, being fifth notice of the geology of Kashmir and neighbouring territories. Note on some Siwalik carnivora. The Siwalik group of the Sub-Himalayan region. On the South Rewah Gondwana basin. On the ferruginous beds associated with the basaltic rocks of north-eastern Ulster, in relation to Indian laterite. On some Rajmahal plants. Travelled blocks of the Punjab. Appendix to 'Palæontological notes on the lower trias of the Himalayas.' On some mammalian fossils from Perim Island, in the collection of the Bombay Branch of the Royal Asiatic Society.

Part 2.—The Nahan-Siwalik unconformity in the North-western Himalaya. On some Gondwana vertebrates. On the ossiferous beds of Hundes in Tibet. Notes on mining records, and the mining record office of Great Britain; and the Coal and Metalliferous Mines Acts of 1872 (England). On cobaltite and danaite from the Khetri mines, Rajputana; with some remarks on Jaipurite (Syepoorite). On the occurrence of zinc ore (Smithsonite and Blende) with barytes, in the Karnul district, Madras. Notice of a mud eruption in the island of Cheduba.

Part 3.—Artesian borings in India. On oligoclase granite at Wangtu on the Sutlej, North-west Himalayas. On a fish-palate from the Siwaliks. Palæontological notes from the Hazaribagh and Lohardagga districts. Undescribed fossil carnivora from the Siwalik hills in the collection of the British Museum.

Part 4.—Remarks on the unification of geological nomenclature and cartography. On the geology of the Arvali region, central and eastern. On a specimen of native antimony obtained at Pulo Obin, near Singapore. On Turgite from the neighbourhood of Juggiapett, Kistnah district, and on zinc carbonate from Karnul, Madras. Note on the section from Dalhousie to Pangi, *viâ* the Sach Pass. On the South Rewah Gondwana basin. Submerged forest on Bombay Island.

VOL. XV, 1882.

Part 1.—Annual report for 1881. Geology of North-west Kashmir and Khagan (being sixth notice of geology of Kashmir and neighbouring territories). On some Gondwana labyrinthodonts. On some Siwalik and Jamna mammals. The geology of Dalhousie, North-west Himalaya. On remains of palm leaves from the (tertiary) Murree and Kasauli beds in India. On Iridosmine from the Noa-Dibing river, Upper Assam, and on Platinum from Chutia Nagpur. On (1) a copper mine lately opened near Yongri hill, in the Darjiling district; (2) arsenical pyrites in the same neighbourhood; (3) kaolin at Darjiling (being 3rd appendix to a report on the geology and mineral resources of the Darjiling district and the Western Duars). Analyses of coal and fire-clay from the Makum coal-field, Upper Assam. Experiments on the coal of Pind Dadun Khan, Salt-range, with reference to the production of gas, made April 29th, 1881. Report on the proceedings and result of the International Geological Congress of Bologna.

Part 2.—General sketch of the geology of the Travancore State. The Warkilli beds and reported associated deposits at Quilon, in Travancore. Note on some Siwalik and Narbada fossils. On the Coal-bearing rocks of the valleys of the Upper Rer and the Mand rivers in Western Chutia Nagpur. On the Pench river coal-field in Chhindwara district, Central Provinces. On borings for coal at Engsein, British Burma. On sapphires recently discovered in the North-west Himalaya. Notice of a recent eruption from one of the mud volcanoes in Cheduba.

Part 3.—Note on the coal of Mach (Much) in the Bolan Pass, and of Sharag or Sharigh on the Harnai route between Sibi and Quetta. New faces observed on crystals of stilbite from the Western Ghâts, Bombay. On the traps of Darang and Mandi in the North-western Himalayas. Further note on the connexion between the Hazara and the Kashmir series. On the Umaria coal-field (South Rewah Gondwana basin). The Daranggiri coal-field, Garo Hills, Assam. On the outcrops of coal in the Myanoung division of the Henzada district.

Part 4.—On a traverse across some gold-fields of Mysore. Record of borings for coal at Beddadanol, Godavari district, in 1874. Note on the supposed occurrence of coal on the Kistna.

VOL. XVI, 1883.

Part 1.—Annual report for 1882. On the genus Richthofenia, Kays (Anomia Lawrenciana, Koninck). On the geology of South Travancore. On the geology of Chamba. On the basalts of Bombay.

Part 2.—Synopsis of the fossil vertebrata of India. On the Bijori Labyrinthodont. On a skull of Hippotherium antilopinum. On the iron ores, and subsidiary materials for the manufacture of iron, in the north-eastern part of the Jabalpur district. On laterite and other manganese ore occurring at Gosulpore, Jabalpur district. Further notes on the Umaria coal-field.

Part 3.—On the microscopic structure of some Dalhousie rocks. On the lavas of Aden. On the probable occurrence of Siwalik strata in China and Japan. On the occurrence of Mastodon angustidens in India. On a traverse between Almora and Mussooree made in October 1882. On the cretaceous coal-measures at Borsora, in the Khasia Hills, near Laour, in Sylhet.

Part 4.—Palæontological notes from the Daltonganj and Hutar coal-fields in Chota Nagpur. On the altered basalts of the Dalhousie region in the North-western Himalayas. On the microscopic structure of some Sub-Himalayan rocks of tertiary age. On the geology of Jaunsar and tbe Lower Himalayas. On a traverse through the Eastern Khasia, Jaintia, and North Cachar Hills. On native lead from Maulmain and chromite from the Andaman Islands. Notice of a fiery eruption from one of the mud volcanoes of Cheduba Island, Arakan. Notice.—Irrigation from wells in the North-Western Provinces and Oudh.

Vol. XVII, 1884.

Part 1.—Annual report for 1883. Considerations on the smooth-water anchorages or mud banks of Narrakal and Alleppy on the Travancore coast. · Rough notes on Billa Surgam and other caves in the Kurnool district. On the geology of the Chuari and Sihunta parganas of Chamba. On the occurrence of the genus Lyttonia, Waagen, in the Kuling series of Kasbmir.

Part 2.—Notes on the earthquake of 31st December 1881. On the microscopic structure of some Himalayan granites and gneissose granites. Report on the Choi coal exploration. On tbe re-discovery of certain localities for fossils in the Siwalik beds. On some of the mineral resources of the Andaman Islands in the neighbourhood of Port Blair. The intertrappean beds in the Deccan and the Laramie group in western North America.

Part 3.—On the miscroscopic structure of some Arvali rocks. Section along the Indus from the Peshawar Valley to the Salt-range. On the selection of sites for borings in the Raigarb-Hingir coal-field (first notice). Note on lignite near Raipore, Central Provinces. The Turquoise mines of Nishâpûr, Khorassan. Notice of a further fiery eruption from tbe Minbyin mud volcano of Cbeduba Island, Arakan. Report on the Langrin coal-field, soutb-west Kbasia Hills. Additional notes on the Umaria coal-field.

Part 4.—On the Geology of part of the Gangasulan pargana of British Garhwal. On fragments of slates and schists imbedded in the gneissose granite and granite of the North-west Himalayas. On the geology of the Takht-i-Suleiman. On the smooth-water anchorages of the Travancore coast. On auriferous sands of the Subansiri river, Pondicherry lignite, and phosphatic rocks at Musuri. Work at the Billa Surgam caves.

Vol. XVIII, 1885.

Part 1.—Annual report for 1884. On the country between the Singareni coal-field and the Kistna river. Geological sketch of the country between the Singareni coal-field and Hyderabad. On coal and limestone in the Doigrung river, near Golaghat, Assam. Homotaxis, as illustrated from Indian formations. Afghan field notes.

Part 2.—A fossiliferous series in the Lower Himalaya, Garhwal. On the probable age of the Mandhali series in the Lower Himalaya. On a second species of Siwalik camel (Camelus Antiquus, nobis ex Fale. and Caut. MS.). On the. Geology of Chamba. On the probability of obtaining water by means of artesian wells in the plains of Upper India. Furtber considerations upon artesian sources in the plains of Upper India. On the geology of the Aka Hills. On the alleged tendency of the Arakan mud volcanoes to burst into eruption most frequently during the rains. Analyses of phosphatic nodules and rock from Mussooree.

Part 3.—On the Geology of the Andaman Islands. On a third species of Merycopotamus. Some observations on percolation as affected by current. Notice of the Pirthalla and the Cbandpur meteorites. Report on the oil-wells and coal in the Thayetmyo district, British Bnrma. On some antimony deposits in the Maulmain district. On the Kashmir earthquake of 30th May 1885. On the Bengal earthquake of 14th July 1885.

Part 4.—Geological work in tbe Chhattisgarh division of the Central Provinces. On the Bengal earthquake of July 14th, 1885. On tbe Kashmir earthquake of 30th May 1885. On the results of Mr. H. B. Foote's further excavations in the Billa Surgam caves. On the mineral hitherto known as Nepaulite. Notice of the Sabetmahet meteorite.

Vol. XIX, 1886.

Part 1.—Annual report for 1885. On the International Geological Congress of Berlin. On some Palæozoic Fossils recently collected by Dr. H. Warth, in the Olive group of the Salt-range. On the correlation of the Indian and Australian coal-bearing beds. Afghan and Persian Field notes. On the section from Simla to Wangtu, and on the pterological character of the Amphibolites and Quartz Diorites of the Sutlej valley.

Part 2.—On the Geology of parts of Bellary and Anantapur districts. Geology of the Upper Dehing basin in tbe Singpho Hills. On the microscopic characters of some eruptive rocks from the Central Himalayas. Preliminary note on the Mammalia of the Karnul Caves. Memorandum on the prospects of finding coal in Western Rajputana. Note on the Olive Group of the Salt-range. On the discussion regarding the boulder-beds of the Salt-range. On the Gondwana Homotaxis.

Part 3.—Geological sketch of the Vizagapatam district, Madras. Preliminary note on the geology of Northern Jesalmer. On the microscopic structure of some specimens of the Malani rocks of the Arvali region. On the Malanjkhandi copper-ore in the Balaghat district, C. P.

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Vol. XX, 1887.

Part 1.—Annual report for 1886. Field-notes from Afghanistan: No. 4, from Turkistan to India. Physical geology of West British Garbwal; with notes on a route traverse through Jaunsar-Bawar and Tiri-Garhwal. On the geology of the Garo Hills. On some Indian image-stones. On soundings recently taken off Barren Island and Narcondam. On a character of the Talchir boulder-beds. Analysis of Phosphatic Nodules from the Salt-range, Punjab.

Part 2.—The fossil vertebrata of India. On the Echinoidea of the cretaceous series of the Lower Narbada Valley, with remarks upon their geological age. Field-notes: No. 5—to accompany a geological sketch map of Afghanistan and North-eastern Khorassan. On the microscopic structure of some specimens of the Rajmahal and Deccan traps. On the Dolerite of the Chor. On the identity of the Olive series in the east with the speckled sandstone in the west of the Salt-range in the Punjab.

Part 3.—The retirement of Mr. Medlicott. Notice of J. B Mushketoff's Geology of Russian Turkistan. Crystalline and metamorphic rocks of the Lower Himalaya, Garhwal, and Kumaun, Section I. Preliminary sketch of the geology of Simla and Jutogh. Note on the 'Lalitpur' meteorite.

Part 4.—Note on some points in Himalayan geology. Crystalline and metamorphic rocks of the Lower Himalaya, Garhwal, and Kumaun, Section II. The iron industry of the western portion of the District of Raipur. Notes on Upper Burma. Boring exploration in the Chhattisgarh coal-fields. (Second notice.) Some remarks on Pressure ,Metamorphism, with reference to the foliation of the Himalayan Gneissose-Granite. A list and index of papers on Himalayan Geology and Microscopic Petrology, published in the preceding volumes of the records of the Geological Survey of India.

Vol. XXI, 1888.

Part 1.—Annual report for 1887. Crystalline and metamorphic rocks of the Lower Himalaya, Garhwal, and Kumaun, Section III. The Birds'-nest or Elephant Island, Mergui Archipelago. Memorandum on the results of an exploration of Jessalmer, with a view to the discovery of coal. A facetted pebble from the boulder bed ('speckled sandstone') of Mount Chel in the Salt-range in the Punjab. Examination of nodular stones obtained by trawling off Colombo.

Part 2.—Award of the Wollaston Gold Medal, Geological Society of London, 1888. The Dharwar System, the chief auriferous rock series in South India. On the Igneous rocks of the districts of Raipur and Balaghat, Central Provinces. On the Sangar Marg and Mehowgale coal-fields, Kashmir.

Part 3.—The Manganese Iron and Manganese Ores of Jabalpur. 'The Carboniferous Glacial Period.' The sequence and correlation of the pre-tertiary sedimentary formations of the Simla region of the Lower Himalayas.

Part 4.—On Indian fossil vertebrates. On the geology of the North-west Himalayas. On blown-sand rock sculpture. Re-discovery of Nummulites in Zanskar. On some mica traps from Barakar and Raniganj.

Vol. XXII, 1889.

Part 1.—Annual report for 1888. The Dharwar System, the chief auriferous rock-series in South India. (Second notice.) On the Wajra Karur diamonds, and on M. Chaper's alleged discovery of diamonds in pegmatite near that place. On the generic position of the so-called Plesiosaurus Indicus. On flexible sandstone or Itacolumite, with special reference to its nature and mode of occurrence in India, and the cause of its flexibility On Siwalik and Narbada Chelonia.

Part 2.—Note on Indian Steatite. Distorted pebbles in the Siwalik conglomerate. 'The Carboniferous Glacial Period.' Notes on Dr. W. Waagen's 'Carboniferous Glacial Period.' On the oil-fields of Twingoung and Beme, Burma. The gypsum of the Nehal Nadi, Kumaun. On some of the materials for pottery obtainable in the neighbourhood of Jabalpur and of Umaria.

Part 3.—Abstract report on the coal outcrops in the Sharigh Valley, Baluchistan. On the discovery of Trilobites by Dr. H. Warth in the Neobolus beds of the Salt-range. Geological notes. On the Cherra Poonjee coal-field, in the Khasia Hills. On a Cobaltiferous Matt from Nepál. The President of the Geological Society of London on the International Geological Congress of 1888. Tin-mining in Mergui district.

Part 4.—On the land-tortoises of the Siwaliks. On the pelvis of a ruminant from the Siwaliks. Recent assays from the Sambhar Salt-Lake in Rajputana. The Manganiferous Iron and Manganese Ores of Jabalpur. On some Palagonite-bearing raps of the Rájmahál hills and Deccan. On tin-smelting in the Malay Peninsula. Provisional index of the local distribution of important minerals, miscellaneous minerals, gemstones, and quarry stones in tbe Indian Empire. Part 1.

Vol. XXIII, 1890.

Part 1.—Annual report for 1889. On the Lakadong coal-fields, Jaintia Hills. On the Pectoral and pelvic girdles and skull of the Indian Dicynodonts. On certain vertebrate remains from the Nagpur district (with description of a fish-skull). Crystalline and metamorphic rocks of the Lower Himalayas, Garhwál and Kumaun, Section IV. On the bivalves of the Olive-group, Salt-range. On the mud-banks of the Travancore coast.

Part 2.—On the most favourable sites for Petroleum explorations in the Harnai district, Baluchistan. The Sapphire Mines of Kashmir. The supposed Matrix of the Diamond at Wajra Karur, Madras. The Sonapet Gold-field. Field Notes from the Shan Hills, (Upper Burma). A description of some new species of Syringosphæridæ, with remarks upon their structures, &c.

Part 3.—On the Geology and Economic Resources of the Country adjoining the Sind-Pishin Railway between Sharigh and Spintangi, and of the country between it and Khattan (with a map). Report of a Journey through India in the winter of 1888-89, by Dr. Johannes Walther, translated from the German, by R. Bruce Foote. On the Coal-fields of Lairungao, Maosandram, and Mao-be-lar-kar, in the Khasi Hills (with 3 plans). Further Note on Indian Steatite. Provisional Index of the Local Distribution of Important Minerals, Miscellaneous Minerals, Gem Stones, and Quarry Stones in the Indian Empire (continued from p. 286, Vol. XXII).

Part 4.—Geological sketch of Naini Tal; with some remarks on the natural conditions governing mountain slopes (with a map and plate). Notes on some Fossil Indian Bird Bones. The Darjiling Coal between the Lisu and the Ramthi rivers, explored during season 1890-91 (with a map). The Basic Eruptive Rocks of the Kadapah Area. The Deep Boring at Lucknow. Preliminary Note on the Coal Seam of the Dore Ravine, Hazara (with two plates).

Vol. XXIV, 1891.

Part 1.—Annual report for 1890. On the Geology of the Salt-range of the Punjab, with a re-considered theory of the Origin and Age of the Salt-Marl (with five plates). On veins of Graphite in decomposed Gneiss (Laterite) in Ceylon. Extracts from the Journal of a trip to the Glaciers of the Kabru, Pandim, &c. The Salts of the Sambhar Lake in Rajputana, and of the Saline efflorescence called 'Reh' from Aligarh in the North-Western Provinces. Analysis of Dolomite from the Salt-range, Punjab.

Part 2.—Preliminary Report on the Oil locality near Moghal Kot, in the Sheráni country, Suleiman Hills. On Mineral Oil from the Suleiman Hills. Note on the Geology of the Lushai Hills. Report on the Coal-fields in the Northern Shan States. Note on the reported Namsèka Ruby-mine in the Mainglôn State. Note on the Tourmaline (Schorle) Mines in the Mainglôn State. Note on a Salt-spring near Bawgyo, Thibaw State.

Part 3.—Boring Exploration *in the* Daltongunj Coal-field, *Palamow* (with a map). *Death of* DR. P. MARTIN DUNCAN. Contributions *to the* study *of the* Pyroxenic varieties *of* Gneiss *and of the* Scapolite-bearing Rocks.

Part 4.—On a Collection of Mammalian Bones from Mongolia. Further note on the Darjiling Coal Exploration. Notes on the Geology and Mineral Resources of Sikkim (with a map). Chemical and Physical notes on rocks from the Salt-range, Punjab (with two plates).

VOL. XXV, 1892.

Part 1.—Annual report for 1891. Report *on the* Geology *of* Thal Chotiáli *and part of the* Mari country (with a map and 5 plates). Petrological Notes *on the* Boulder-bed *of the* Salt-range, Punjáb, Sub-recent *and* Recent Deposits *of the valley plains of* Quetta, Pishin and the Dasht-i-Bedaolat; *with appendices on the* Chamans *of* Quetta; *and the* Artesian water-supply *of* Quetta *and* Pishin (with one plate).

Part 2.—Geology *of the* Saféd Kóh (with 2 plates of sections). Report *on a* Survey *of the* Jherria Coal-field (with a map and 3 section plates) (*out of print*).

Part 3.—*Note on the* Locality *of* Indian Tscheffkinite. Geological Sketch *of the* country north of Bhamo. Preliminary Report *on the* economic resources *of the* Amber *and* Jade mines area *in* Upper Burma. Preliminary Report *on the* Iron-Ores *and* Iron-Industries *of the* Salem District. *On the* Occurrence *of* Riebeckite *in* India. Coal *on the* Great Tenasserim River, Mergui District, Lower Burma.

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VOL. XXVI, 1893.

Part 1.—Annual report for 1892. Notes *on the* Central Himalayas (with map and plate). Note *on the occurrence of* Jadeite *in* Upper Burma (with a map). On *the* occurrence *of* Burmite, *a new* Fossil Resin *from* Upper Burma. Report *on the* Prospecting Operations, Mergui District, 1891-92.

Part 2.—Notes *on the* earthquake *in* Baluchistán *on the* 20th December 1892 (with 2 plates) Further Note *on* Burmite, *a new amber-like fossil resin from* Upper Burma. Note *on the* Alluvial deposits *and* Subterranean water-supply *of* Rangoon (with a map).

Part 3.—On the Geology *of the* Sherani Hills (with maps and plates). On Carboniferous Fossils *from* Tenasserim (with 1 plate). *On* a deep Boring *at* Chandernagore. Note *on* Granite *in the districts of* Tavoy *and* Mergui (with a plate).

Part 4.—*On the* Geology *of the country between the* Chappar Rift *and* Harnai *in* Baluchistán (with map and 3 plates). Notes *on the* Geology *of a part of the* Tenasserim Valley *with special reference to the* Tendau-Kamapying Coal-field (with two maps). *On a* Magnetite *from the* Madras Presidency containing Manganese *and* Alumina. *On* Hislopite (Haughton) (with a plate).

VOL. XXVII, 1894.

Part 1.—Annual report for 1893. Report *on the* Bhaganwala Coal-field, Salt-range, Punjab (with map and 2 plates).

Part 2.—Note *on the* Chemical qualities of pertroleum *from* Burma. Note *on the* Singareni Coal-field, Hyderabad (Deccan) (with map and 3 plates of sections). Report *on the* Gohna Landslip, Garhwal (with 5 plates and 2 maps).

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Part 4.—Note on the Geology of Wuntho *in* Upper Burma (with a map). Preliminary notice *on the* Echinoids *from the* Upper Cretaceous System of Baluchistán. *On* Highly Phosphatic Mica-Peridotites intrusive *in the* Lower Gondwana Rocks *of* Bengal. On a Mica-Hypersthene-Hornblende-Peridotite *in Bengal.*

VOL. XXVIII, 1895.

Part 1.—Annual report for 1894. *Cretaceous Formation of Pondicherry. Some* early allusions *to* Barren Island; *with a few remarks thereon.* Bibliography *of* barren Island *and* Narcondam, *from* 1884 *to* 1894; *with some remarks.*

Part 2.—On the importance of Cretaceous Rocks *of* Southern India *in estimating the geographical conditions during* later cretaceous times. *Report on the Experimental Boring for Petroleum at Sukkur from October 1893 to March 1895. The development and Sub-division of the Tertiary system in Burma.*

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Part 4.—On the Igneous Rocks *of the* Giridih (Kurhurbaree) Coal-field *and their* Contact Effects. *On* some outliers *of the* Vindhyan system south *of the* Sone and their relation *to the* so-called Lower Vindhyans. *Notes on a* portion *of the* Lower Vindhyan area *of the* Sone Valley. *Note on* DR. FRITZ NOETLING'S paper *on the Tertiary system in Burma, in the Records of the Geological Survey of India for 1895, Part 2.*

VOL. XXIX, 1896.

Part 1.—Annual report for 1895. *On the Acicular inclusions in Indian Garnets. On the Origin and Growth of Garnets and of their Micropegmatitic intergrowths in Pyroxenic rocks* (with 1 plate).

Part 2.—Notes on the Ultra-basic rocks *and* derived minerals *of the* Chalk (Magnesite) hills, *and other localities near* Salem, Madras (with 2—6 plates). *Preliminary notes on some* Corundum localities *in the* Salem and Coimbatore districts, Madras (with 7—9 plates). *On the occurrence of* Corundum *and* Kyanite *in the* Manbhum district, Bengal. *On the papers by* DR. KOSSMAT and DR. KURTZ, *and on the ancient Geography of* "*Gondwana-land.*" *Note from the Geological Survey of India.*

Part 3.—On some Igneous Rocks *from the* Tochi Valley. *Notes from the Geological Survey of India.*

Part 4.—Report *on the* Steatite mines, Minbu District, Burma. Further notes *on the* Lower Vindbyan (Sub-Kaimur) area *of the* Sone Valley, Rewah. *Notes from the Geological Survey of India.*

VOL. XXX, 1897.

Part 1.—Annual report for 1896. *On* some Norite *and* associated Basic Dykes *and* Lava flows *in* Southern India (with plates I to II). *The reference of the genus* Vertebraria. *On a* Plant of Glossopteris with part of the rhisome attached, *and on the* structure of Vertebraria (with plates III to V).

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Part 4.—On Nemalite from Afghanistan. On a quartz-barytes rock occurring in the Salem District, Madras Presidency (with plate XVIII). Note on a worn femur of Hippopotamus irravadicus, Caut. and Falc., from the Lower Pliocena of Burma (with plates XIX and XX). On the supposed coal at Jaintia, Baxa Duars. Percussion Figures on micas. *Notes from the Geological Survey of India.*

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General Report on the work carried on by the Geological Survey of India for the period ending 31st March 1902.

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