The Pre-Vindhyan Geology of Rajputana.

By A. M. Heron,
*Geological Survey of India.**

SINCE 1907 a geological survey of Rajputana and the States of Bombay which adjoin it to the south in Gujarat has been in progress. Its results have been presented from time to time in papers by the author and his colleagues Mr. C. S. Middlemiss, Dr. A. L. Coulson and Mr. B. C. Gupta, and several other publications are in preparation. As, however, it may be some time before the main description dealing with the work done in central Rajputana since the Great War can appear, it has been thought advisable to submit a brief sketch of the results obtained. A somewhat fuller account of this has appeared in the *Transactions of the National Institute of Sciences of India*, Vol. I, No. 2.

The rocks below the Vindhyans and the Malani volcanics have been arranged in four groups, separated by three erosion unconformities, all of which are in places clearly shown by basement conglomerates accompanied by other evidences of discordance, and are in addition well displayed in the mapping by the trend of the boundaries of the formations. The unconformity most distinctly seen, that at the base of the Delhi system, has been traced for something like five hundred miles along the edges of the synclinorium, which is almost exactly coincident with the limits of the Delhi system, for outside of it representatives of the Delhis are insignificant and somewhat uncertain. It appears to have been the successor to a geosyncline in which the Delhis were accumulated; on either side of it are found the older formations—the Raialo series, the Aravalli system and the pre-Aravalli gneisses.

The succession is shown in the annexed table.

In view of the presence in Rajputana of four distinct Precambrian and Archæan formations, separated by important unconformities each denoting a period of diastrophism and erosion, and of the immense thicknesses of strata involved, it is reasonable to infer that the *Bundelkhand gneiss* and the banded gneissic complex at the base of this long sequence are among the oldest rocks which occur anywhere upon the earth's surface. If the Vindhyans are also placed in the Precambrian, neglecting the doubtful evidence of obscure markings which are held by some palæontologists to be primitive Cambridge brachiopods and by others to be vegetable remains, the sequence is still further lengthened and the oldest rocks are pushed farther down in the Archæan.

Unfortunately we can say nothing definite regarding the relationship of the banded gneissic complex and the Bundelkhand gneiss, as their mutual junction is everywhere concealed by a broad syncline of Aravallis resting on both of them unconformably. In a recent paper in *Current Science*[1] by Mr. W. D. West, it is stated that they are thought to be equivalent. This, however, is the case only in the sense that both are overlain unconformably by the Aravallis, for they are entirely different lithologically. The Bundelkhand gneiss is a true granite, unfoliated except in its extreme western extension, non-porphyritic, and remarkably uniform over all its wide area of outcrop; it is traversed by intrusive dykes of dolerite and great reefs of quartz. The banded gneissic complex, on the other hand, was originally a sedimentary formation, predominantly argillaceous, but showing by two anticlinal inliers of massive bedded quartzites that its oldest visible strata were arenaceous. Over most of its extent, however, especially in the south, its sedimentary character has been obscured by the intrusion of multitudes of acid and basic rocks in great variety of texture and of different ages, giving rise to a complex of banded and foliated gneisses. In the north the banded character is on the whole less strongly marked and the intrusions are more in the form of large bosses of a dark porphyritic biotitic granite, usually strongly foliated, with its cognate pegmatite and aplite veins forming composite gneisses, and masses of basic rocks.

To the north-west of the synclinorium a third type of gneiss, a fine-grained and usually homogeneous granite, is present at

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[1] *Current Science*, 1934, 3, 138.

Jodhpur. Memoir, Geological Survey of India, XXXV, Pt 1. Records, Geological Survey of India, LXV, Pt. 4.	*Mewar, Ajmer-Merwara* (Main Syncline).	Unmetamorphosed rocks of *Chitor, Nimbahera* and *Sadr.*			*Jaipur.* Records, Geological Survey of India, XLVIII, Pt. 4 and LIV, Pt. 4.	*Alwar.* (North-Eastern Rajputana), Memoir, Geological Survey of India, XLV, Pt. 1.
Vindhyans of Western Rajputana.		Upper Vindhyans.				
Malani volcanic series.		'Semri Series' (Lower Vindhyans).				
	Delhi System. 'Calc-gneisses.' 'Calc-schists.' Biotite-schists.				Ajabgarh series.	Ajabgarh series. Hornstone breccia. Kushalgarh limestone.
	Delhi System. Quartzites. Basement arkose grits.	Sawa shales and grit.	Fault	Jiran, sandstone	Alwar series.	Alwar series.
Raialo (Makrana) marble, limestones of Ras. Unconformity not seen.	*Raialo Series.* Garnetiferous biotite schists. Raialo (Rajanagar) marble. Local basal grit.	Raialo (Bhagwanpura) limestone.	Boundary			Raialo limestone. Raialo quartzite.
Shales (Sojat). Schists of Godwar.	*Aravalli System.*	Khardeola and Kanoj grits, Badesar quartzites. Vague unconformity.				
		Ranthambhor quartzites. Shales and cherty limestones.	Great	Binota shales.	Quartzites and schists of Baonli—Awan ridge and Bechun, Biana and Lalsot hills. Volcanics of Basi. Schists of Rajmahal.	Limestones and schists of Baswa and Rajgarh. Quartzite and conglomerate of Rewasa.
Unconformity not seen.	Phyllites, cherty limestones, quartzites and composite gneisses. Basal quartzites, grits and local conglomerates. Local thick volcanic series.	Basal quartzites and grits.				
Grey homogeneous gneiss.	Banded gneissic complex.	Bundelkhand gneiss.			Gneissic granite of Karela and Ganor.	

the edge of the Marwar plain, but is much obscured by the Erinpura granite intrusive in it, and by alluvium. It is clearly older than the Delhis but the Aravallis have not been seen in association with it.

The Aravalli system consists predominantly of an immense but immeasurable thickness of phyllites, in certain zones of which impure limestones and fine-grained quartzites occur. Its base is marked by a thin grit resting on the underlying gneisses, and in two widely separated areas thick basic amygdaloids and pyroclastics have been accumulated near the base, in one case passing up into a great series of conglomerates, and these again into massive quartzites.

A feature of great interest is the occurrence, south of Chitor in south-eastern Mewar, of a tract in which the Aravallis have undergone hardly any metamorphism, being still shales with low rolling dips. As they are followed across the strike from east to west, in the direction of the ancient belt of mountain-folding and igneous intrusion of the synclinorium, dips steepen and they become successively slates, phyllites and ultimately mica-schists with small garnets, magnetite, staurolite, chiastolite and kyanite. The intruded dolerite becomes epidiorite and hornblende-schist.

At the top of the little-altered Aravallis are several quartzite and grit formations, of very limited extent and somewhat obscure relationships, to which have been given local names. Some of them (the Badesar quartzites, the Kanoj and Khardeola grits) appear to be slightly unconformable upon the Aravallis; others, the Ranthambhor quartzites, which are found in eastern Jaipur as well as in south-eastern Mewar, are conformable with the Aravallis.

The suggestion is made that the Gwaliors may also be unaltered Aravallis, like those just mentioned, which, like them, have escaped metamorphism owing to their distance from the protaxis of diastrophism now represented by the Aravalli range and by the protection of the solid mass of Bundelkhand gneiss upon which they rest.

Intrusive igneous rocks in the Aravallis are scarcer than in the pre-Aravalli gneisses and in the Delhi system. In the unaltered Aravallis they comprise the dolerite mentioned above, which may perhaps be the hypabyssal equivalent of the Khairmalia amygdaloid at the base of the Khardeola grits, and in the metamorphosed Aravallis to the west they are granite and ultra-basic rocks. The granite, acid, fine-grained and almost devoid of mica, forms several bosses near Udaipur City; on their margins intrusive relations with the Aravalli limestones are excellently shown, and the granite, by *lit-par-lit* injection of the mica-schists, gives rise to a broad band of composite gneiss which runs south-east from Udaipur City[2] for many miles. The ultra-basics are talc-serpentine-chlorite rocks occurring near Rakhab Deo[3] and at other places. The post-Delhi Erinpura granite also invades the Aravallis south-east of Salumbar.

The Raialo series is the thinnest and simplest of the four formations discussed, consisting of a thin, occasionally conglomeratic quartzite at the base, which, however, is more often than not missing, then about two thousand feet of white crystalline limestone, with at the top of the sequence but exposed in one area only, in the core of the syncline (see below) near Kankroli, an unknown thickness of garnetiferous biotite-schist.

A correlation has been made between the widely separated exposures of massive white crystalline limestone which are believed to belong to this series, near Raialo on the frontier between Jaipur and Alwar States, a great syncline running out from below the base of the Delhis past Nathdwara and Kankroli and extending as long narrow synclinal outliers beyond Bhilwara to the Jahazpur and Sawar hills near Deoli, the celebrated Makrana marble in Jodhpur State, with other outcrops along the strike to the south-west and, in the south-eastern Mewar area of unaltered Aravallis, the "Bhagwanpura limestone". In the Makrana and other occurrences to the north-west of the Delhi synclinorium the limestone is a calcium carbonate rock, in those to the south-east of the synclinorium it is dolomite.

The limestone is very free from igneous intrusions, only a few dykes of the post-Delhi pegmatite penetrating it, but the garnetiferous biotite-schists which overlie it give excellent examples of how various types of gneiss arise from the injection of one original rock. Starting from biotite-schist intruded by large definite dykes of pegmatite, these may become so numerous that they crowd into each other leaving little schist, or they may take the form of

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[2] *Mem. Geol. Surv. India*, 1934, **65**, pt. 2, 152-153.

[3] *Rec. Geol. Surv. India*, 1933, **68**, pt. 4, 453.

clusters of sills, ending in the schist being intimately and uniformly permeated by multitudinous interfoliar veins, forming a banded composite gneiss often highly contorted. There is no evidence that the Raialos were invaded by any igneous rocks of post-Raialo but pre-Delhi age.

The rocks of the Delhi system are exposed in a great synclinorium which extends throughout Rajputana from north-east to south-west, disappearing beneath the Indo-Gangetic alluvium at the one end at Delhi, and under the alluvium of the Gujarat plain at the other, in Idar State. The north-western flank of the synclinorium is a straight line but its south-eastern side is a great curve; in the medial portion of this, for about forty miles along its length, the synclinorium is a simple syncline about six miles wide but to north and south of this it widens greatly by the development of numerous isoclinal folds.

In the southern portion the base of the Delhi system is exposed as a simple curve without re-entrants, as the present surface of erosion cuts only the higher portions of the folds and therefore the upper formations only, in the synclinorium itself. In the northern portion, however, the basal beds are repeated in great curves running athwart the general direction of the axes of folding, the anticlines pitching to the north-east. We find that the uppermost divisions of the Delhi sequence are more fully preserved in the southern part of the synclinorium than in the northern.

South-west of Ajmer the synclinorium consists of two synclines of Delhis separated by a tongue of the pre-Aravalli banded gneissic complex. They are brought together to the south-west by a thrust-fault, and beyond their point of meeting the north-western of the two synclines is so much intruded by epidiorite and Erinpura granite that it is ultimately obliterated at about where the other, south-eastern, syncline becomes the sole component fold of the synclinorium and so persists, as I have said, for a distance of about forty miles along its length, with a breadth of some six miles. This decrease in width is in part due to the smoothing out of minor folds and in part to the Alwar series at the base of the Delhis having almost died out for a space, to reappear again to the south.

South of the constriction the synclinorium widens again owing to additional folds appearing, to the coming in again of the Alwar series in force and also to deeper plunging synclines bringing in the highest beds of the central core. Here also igneous intrusion, principally the Erinpura granite, increases towards the south-west, obliterating the component formations *en echelon* from west to east until in Idar State only the Alwar quartzites are left where the synclinorium disappears below the alluvium of Gujarat.

In the northern part of the synclinorium both the strong quartzites and the basement grits of the Alwar series are in force, the latter becoming coarse conglomerates with strangely flattened and elongated cobbles at Barr and Srinagar. As a rule the basement beds here are arkose, the felspar being derived from the abundant granitic material in the pre-Aravalli gneisses upon which they rest unconformably.

South of the constriction the basement beds of the main synclinorium are fine-grained quartzites with intercalations of biotite-schist, as they are derived from the underlying Aravalli phyllites, which yield on disintegration no coarse felspar and no pebbles. Out to the east, however, is a line of faulted outliers of the Alwar series, in which arkose conglomeratic grits are strongly developed, as they rest upon the granite-intruded pre-Aravalli gneisses.

The Kushalgarh limestone[4] and the closely associated Hornstone Breccia, which in Alwar State separate the Alwar series from the Ajabgarh series, are not found outside Alwar.

In the country now described, *i.e.*, from the Sambhar Lake southwards, the lowest division of the Ajabgarhs is typically a great thickness of biotite-schists intruded with pegmatite in massive dykes and sills, and with aplite in veins and *lit-par-lit* injection; as a rule there is as much igneous material present as sedimentary, and excellent examples are seen of the transition from phyllite through biotite-schist to composite gneiss formed by the interfoliar permeation of biotite-schist with aplite.

The middle division, the "calc-schists," in their least metamorphosed phase are calcareous shales and impure limestones, seen only in two narrow synclines folded into the Alwar quartzites in the extreme south. These form the Mundeti series[5] of Middlemiss. Except in these two narrow

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[4] *Mem. Geol. Surv. India*, 1917, **45**, pt. 1, 56-72.

[5] *Mem. Geol. Surv. India*, 1921, **44**, pt. 1, 53-61.

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synclines and the isolated exposures of the 'Mundeti series" in Idar, the "calc-schists" attain a higher degree of metamorphism, and have a surprisingly uniform character throughout their great length of outcrop. They are straightly banded, flaggy rocks, the banding being certainly the result of the original stratification and is now due to the alternation of dark layers rich in biotite and actinolite with pale layers of felspars, tremolite and diopside. The amount of igneous intrusion is generally less than in the case of the biotite-schists, and it occurs more as large sills and dykes of pegmatite, *lit-par-lit* injection being scarce.

The upper division of the Ajabgarhs, the "calc-gneisses," in its less altered phase in the north-east is a series of dark, banded biotitic and siliceous limestones, passing gradually along the strike to the south-west into "calc-gneisses". In these the banding, which is essentially the same as the banding in the original limestones, is broader and more variable in composition and in width than in the "calc-schists" and is more irregular, often being characterised by extraordinary contortion. In the "calc-gneisses" bands composed largely of carbonates (calcite and dolomite) alternate with bands rich in silicates (felspars, diopsides and amphiboles), the former being more soluble than the latter, which stand out in relief on weathering. In both "calc-schists" and "calc-gneisses" the present banding is essentially the same as the original stratification but metamorphosed; this consisted of alternating layers of calcareous sediment with argillaceous and ferruginous sediment.

The earliest intrusives in the Delhi system are epidiorites and hornblende-schists, originally basalts and monzonites, which are in particular abundance along the north-western flank of the synclinorium. Ultra-basic rocks are represented by talc- and chlorite-schists and by a group of small plugs of unfoliated talc-limonite-serpentine-magnesite rock, probably much younger than the former schists.

The principal post-Delhi intrusive is the Erinpura granite, in bodies of all sizes, and with wide variations of texture and degree of foliation. Its earliest forms were probably aplite veins and foliated granite sheets, followed by stocks and batholiths of larger sizes, composed of granite coarser in grain, more biotitic and often unfoliated; the last manifestation was the widespread pegmatite swarms.

Later than the Erinpura granite and earlier than the Malani volcanic series is a suite of basic and ultra-basic rocks found by Coulson[6] in Sirohi State, comprising picrite, pyroxenite, gabbro, dolerite and basalt. It also includes a sodalite-syenite; this is quite distinct from the soda-syenites[7] of Kishengarh State at the other end of the Aravalli range, which are probably pre-Delhi in age.

The Jalor and Siwana granites with their granophyres, porphyries and rhyolites, form the Malani series,[8,9] which has a wide development on the plains to the west of the synclinorium. The Idar granite of Middlemiss,[10] which was formerly supposed to be the same as the Jalor and Siwana (Malani) granites, has at the end of this field-season been traced into continuity with the main Abu-Erinpura batholith of the Erinpura granite, and the outcrops of the Malani series are thus confined to the west of the synclinorium and the Aravalli range.

Youngest of all is the dolerite which cuts the Delhis and the Malanis in a few plugs and dykes and may perhaps be related to a dolerite which intrudes even the Semri series or Lower Vindhyans far to the east in Mirzapur district.[11]

The Delhi system is characterised by a greater variety and abundance of igneous intrusives than either the Aravalli system or the Raialo series and by the fact that its sedimentary rocks usually attain a higher grade of metamorphism, particularly in the south-western part of the synclinorium, than the much older Aravallis outside it. It is believed that the plethora of intrusions was not to any important degree the *cause* of metamorphism but that the rocks of the synclinorium had reached their present metamorphic stage before the almost universal pegmatite, at any rate, had pervaded them. The Erinpura granite has, it is true, in some places produced local extra metamorphic effects on the calc-gneisses, but both calc-gneisses and calc-schists are uniformly in their usual highly metamorphosed

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6 *Mem. Geol. Surv. India*, 1933, **63**, pt. 1, 77-101.
7 *Rec. Geol. Surv. India*, 1924, **56**, pt. 2, 179-197.
8 *Mem. Geol. Surv. India*, 1902, **35**, pt. 1, 19-25.
9 *Mem. Geol. Surv. India*, 1933, **63**, pt. 1, 102-141.
10 *Mem. Geol. Surv. India*, 1921, **44**, pt. 1, 115-126.
11 *Mem. Geol. Surv. India*, 1933, **62**, pt. 2, 191-193.

state over great areas and at great distances from any body of Erinpura granite.

Pegmatite veins were never seen to produce any marginal effects on the calc-gneisses and calc-schists, and in considerable areas free from pegmatite they do not differ from those in tracts riddled with pegmatite. Though not cause and effect, igneous intrusion and metamorphism are doubtless related in both being effects of the same cause,—deep folding by which the rocks were brought within the range of high temperatures and pressures and into contact with rising granite magma.

The Delhis appear to have been deposited in a geosyncline which was subsequently laterally compressed and elevated into a mountain range, the deeply folded roots of which are now laid bare. The two major unconformities, at the base of the Aravallis and at the bases of the Delhis and Raialos respectively, were of sufficient magnitude for the underlying formations to be highly folded and for deep-seated plutonic masses to be laid open by denudation. In the Raialo-Delhi interval similar folding took place but no post-Raialo and pre-Delhi igneous rocks have been detected.

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Additions to the London Zoo.

WE learn that the Prince of Wales presented to the mammalian section of the London zoo a giraffe-like specimen commonly known as the Okapi. This animal is known to the zoologists from a long time and we read that Sir, H. Johnston made a present of the skin, two skulls and the bones of the feet of a new genus of Giraffidæ secured from the Belgian Congo to the Nat. Hist. Society, London, as early as 1900. On examination this turned out to be the new genus *Ocapia johnstoni*. The genus *Ocapia* contains a single species *O. johnstoni*. Peculiarly, however, the animal which is about the size of a Sable antelope, incorporates in itself the striped side skin of the Zebra on its hind and forelimbs and the head of the giraffe *minus* the horns. The body and tail are coloured uniformly reddish brown. Naturalists tell us that he is a very shy creature and exhibits a predilection for choosing the thick recessus of the forests, but always lives in pairs. As regards the position of the animal in the scale of evolution, we know from the study of the skull that it is intermediate between that of the giraffe and that of the extinct Samotherium of the lower Pliocene of Europe.

The rare and proverbial blood-sucking bat—the Vampire—is a native of tropical America. Though small in size, it possesses a sharp set of teeth by means of which it is capable of inflicting painless wounds and then "licks" the oozing blood by means of the tongue with such rapidity that a regular sanguinous stream is seen to enter the mouth. For a long time the use of the long thumb was not known and now after a careful study Ditmar tells that it is used as feet for progression on the ground.