GEOLOGY OF THE AREA AROUND PHALODI DISTRICT SAWAI MADHOPUR (RAJASTHAN)

DISSERTATION
IN PART FULFILMENT OF THE REQUIREMENTS
FOR THE AWARD OF
M. Sc. Tech. DEGREE IN APPLIED GEOLOGY

SUBMITTED BY

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1966-67

C E R T I F I C A T E

CERTIFIED that the dissertation entitled "GEOLOGY OF THE AREA AROUND PHALODI, DISTRICT SAWAI-MADHOPUR, (RAJASTHAN)", being submitted by Shri SATISH CHANDRA SHARMA in partial fulfillment for the award of the Degree of M.Sc. Tech., in Applied Geology of University of Roorkee is a record of student's own work carried out by him under my supervision and guidance. The matter embodied in this dissertation has not been submitted for the award of any other Degree or Diploma.

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ACKNOWLEDGEMENTS

It is my pleasant duty to thank Dr. R.S.Mithal, Professor and Head of the Department of Geology and Geophysics, University of Roorkee, Roorkee, for providing all the facilities and encouragement during the present investigation.

My grateful thanks are due to Dr. B.B.S.Singhal, Reader, Geology and Geophysics Department, University of Roorkee, for kindly suggesting this problem and giving his valuable guidance throughout the course of the present study.

I am deeply indebted to Dr. V.K.S.Dave, Reader in the Department of Geology and Geophysics, for his guidance during the course of the chemical analysis.

I wish to particularly acknowledge my gratitude to Dr. K.K.Singh, Dr. V.D.Choubey and all other staff members of the Department of Geology and Geophysics, for their constructive criticism and help at various stages during the course of this study.

Dated : 6th May, 1967. (S.C.SHARMA)

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CHAPTER I

INTRODUCTION

LOCATION

The area under investigation by the present author forms a part of Survey of India toposheet No. 54C/NW. It covers an area of 30 square kilometres which lies within the latitudes $25^{\circ}45'$ and $25^{\circ}55'$ and longitudes $76^{\circ}18'$ and $76^{\circ}26'$.

MEANS OF COMMUNICATION

The investigated area is situated at a distance of about 24 kms. south of Sawai Madhopur Railway Station, which is about 400 kms from Delhi and lies on the Delhi - Bombay line of Western Railways. This area can be approached by train upto Rawanjna-Dungar Railway station. From there it is 6 kms. and is connected with a motorable road between Sawai Madhopur old town and Phalodi quarry. Limestone quarries in the area are connected by a four mile long Railway siding to the South-east of the Rawanjna - Dungar Railway Station.

DURATION OF FIELD WORK

The field work was done for 14 days during the month of June-July 1966. It was visited again for 7 days during August 1966. For the third time field work was carried out for 20 days in November 1966. Thus a total of 41 days field work was done covering an area of 30 square kilometres.

NATURE AND SCOPE OF THE PRESENT WORK

Geological mapping of the area was done on the scale two inches to a mile from which the accompanying geological map is prepared.

Representative samples of various formations were collected for study in the laboratory. Thin section of some rocks were prepared for study under microspope. Microscopic description of the igneous rocks, sandstones, quartzites and limestone is given in Chapter III & IV.

Samples of Lower Bhander limestone were collected across the strike and their variation in composition, color, shale content were noted, Chemical analysis of these limestones was also carried out and it is given in the Chapter IV.
An attempt has also been made to classify the limestones on the basis of their chemical composition.

Grain size analysis of the sandstones from various horizons was carried out with the help of thin sections. On the basis of these grain size data, the various statistical parameters such as Median, Inclusive Graphic Standard Deviation, Sorting, Kurtosis and Skewness are determined. Modal analys of sandstone was also done and the data have been utilised in classifying the sandstones.

An attempt has also been made to determine the provenance of the sandstones with the help of grain size, modal and heavy mineral data.

The pattern of sedimentation has also been interpreted on the basis of stratigraphic sequence and sedimentary structures.

PREVIOUS WORK

The first observer in this area seems to have been C.A. Hacket who referred to this region in the following three papers :

"Geology of Gwalior and Vicinity", Rec.Geol.Surv.India Vol. III, p. 40 (1870).

"Aravalli series in north-eastern Rajputana " Rec. Geol. Surv. India Vol. X, p. 84 (1877).

"On the Geology of Aravalli region, central and eastern" Rec. Geol.Surv. India XIV, p. 279 (1881).

Some work has been done by Mallet who published his observation alongwith those of Hacket's in Mem.Geol.Surv. India", Vol. VII (1871).

Although every credit is due to Hacket as the first investigator of the geology of the area, his condensed and generallised published reports do not throw much light on the details of the geology of the area.

In 1913 - 1914, the area was again resurveyed by A.M. Heron.

Heron mapped the area structurally and lithologically in detail and his detailed published reports about the area are available in the following memoir :

"Mem. Geol.Surv. India", Vol 45 (1918).

In this published report Heron has described the structure in detail - various lithological units have been described separately for their field chabacters as well as for their petrography.

An attempt was made by Heron regarding the assignment of age to different series present in the area and to correlate them with other areas. He classified the low metamorphosed rocks of this region i.e. quartzites into Gwaliors and unmetamorphosed sediments into Vindhyans. In 1935, Heron revised his views regarding their grouping into the Gwaliors and he regrouped these low metamorphosed rocks into the upper parts of the Aravalli as mentioned in the article entitled.

"Synopsis of the pre-Vindhyan Geology of Rajputana" Transactions of the National Institute of Sciences of India Vol. I No. 2 p. 25 (1935).

Since Heron's work no published account of the geology of the area is available.

PHYSIOGRAPHY AND GEOMORPHOLOGY

CLIMATE

Although the present area is situated in Rajasthan which is typically semiarid to arid, the climate of this region is exceptionally good. Rainfall is quite good which may be due to presence of high hills of Aravalli and Vindhyan ranges which help in the precipitation. The annual rainfall in this area is at an average of 50 inches.

WEATHERING

The most important weathering agents active in this region can be named as rain, wind, variation in temperature (both seasonal and daily). Out of these factors seasonal rain plays a major role and also the wind action.

SOIL

The soil cover and mantle present in the narrow strike valleys and vast plains is mostly due to the erosion of shales which are interbedded with Vindhyan sandstone and Aravalli quartzites. In the shaly and phyllitic region of Aravallis and Vindhyans the soil is finer and more clayey. The mantle of the soil is not very thick, but it is quite fertile. The best soil closely resembling the famous black cotton soil of the Deccan traps, locally called "Mooram", is found near the outcrops of the dolerite due to their weathering as seen near Rawanjna Dungar Railway Station.

VEGETATION

The climatic conditions as mentioned earlier are quite good in this region. The area is densely vegetated and has got many reserve forests within which game sancturies are located. Dip slopes of the Vindhyans are more thickly vegetated in comparison to those of Aravalli ridges and this is supposed to be a good criteria in differentiating these rock types.

Trees are of "tendu" (Diosphyros melanoxylon) "pipal" (Fiscus religioea) "banyah"(Fiscus Bengalnsis) "dhak" or "pilas" (Buta frondosa and "ber" (Zizyphus jububa) etc.

The low but very dense small trees (shrubs) which cover the hills is mainly "dhao" (Anogeissus pendula and latifolia). The top of the hills are dominated by "salar" (Boswillia thurifera) and "tendu".

Agriculture is quite normal here. Almost all seasonal crops are grown like wheat and maize etc.

INDUSTRY

The only major industry in the area is a cement factory belonging to Jaipur Udyog Limited. This factory is situated about half km. from Sawai Madhopur Railway Station. The upper Vindhyan limestone for this cement work is supplied from the Phalodi quarry.

INHABITANTS

The people of this area are Mewaries, Rajputs and Jats. Some people from other provinces have also settled here.

GEOMORPHOLOGY

The rocks exposed as the part of Aravalli system and of the upper Vindhyan system, show distinctive geomorphological characters. The various geomorphologic units are related with the lithology and structures of the rocks present in the area. The upper Vindhyan formations like sandstones are interbedded with soft shale and similarly Aravalli quartzites are interbedded with shales and phyllites.

The evolution of the present topography of the area is a result of the inherent properties of the rock types present within Vindhyans and Aravalli system. The area ranges in elevation from 130 metres to 528 metres. The difference in the resistance to erosion of various rocks has given rise to the geomorphological features like plains, valleys, mounds and ridges.

The topography of the area can be illustrated by plate No. 1Photograph No. 1.

PLAINS

As mentioned above, the shales of great thickness present in the area interbedded with Aravalli quartzites and upper Vindhyan sandstone form plains of vast extent. Vast plains are present south-east of Great Boundary Fault.

RIDGES

Aravalli quartzites and upper Vindhyan sandstone outcrop as a strike ridges in the area with a general NE - SW trend. Vertical escarpments are seen due to the presence of vertical joints as shown in plate No. 3 photographs No. 1 These escarpments are prominently seen south of Mandrehri in lower Bhander Sandstone and in Upper Rewa Sandstone near Jhojha-ji Temple. These bold vertical cliffs rise abruptly upto a height of 510 metres above the ground surface. At the foot of these ridges talus of Aravalli shales is seen near Handwar village. The north-west side of the strike ridges slopes with an angle of $20^{\circ} - 30^{\circ}$ which is nearly equal to the dip of the rocks whereas south-western side has the vertical escarpments.

VALLEYS

A wide valley between the upper Rewa sandstone hill and lower Bhander Sandstone strike ridge and occupies a large area. In the valley Gunurgarh shales have been weathered giving rise to a thick mantle of soil. Similarly a wide valley is present between the Lower Bhander sandstone ridge and Aravalli quartzites ridge in which Phalodi village is situated. There is also a wide valley north-west of Great Boundary Fault.

DRAINAGE

There is neither any particular drainage pattern present in the area, nor any important river flows through it. During rainy season small nalas are developed which show dendritic pattern. The water flows along the slope of the hills and gets accumulated in nalas on the hill slopes which finally flows into the valley.

CHAPTER II

REGIONAL GEOLOGICAL SET-UP

The first stratigraphic succession of the Pre-Cambrian rocks in this region was given by A.M. Heron (1918) who mapped this area geologically. Following is the stratigraphic succession proposed by Heron :

Recent and Subrecent deposits

Upper Bhander Sandstone	Detwa series	Bhander
Sirbu Shales		
Lower Bhander Sandstone	Havelli series	
Bhander Limestone		
Gunurgarh shales		
Upper Rewa sandstone	Tons series	Kaimur
Jhiri shales		
Lower Rewa sandstone		
Panna shales		
Kaimur sandstone		
Kaimur conglomerate		
Lower Vindhyan: Tirohan breccia	Son series	
Tirohan limestone		
Conglomerate and sandstone		

Gwalior system - quartzite, shales, slates, jaspers and dolerite

Aravalli system - Impure limestone and amphibolite

In 1935 stratigraphic succession in this region was again revised by A.M.Heron which was supported by Pascoe (1964) and is incorporated by M.S.Krishnan (1960) in the book "Geology of India and Burma".

In the revised succession Heron regrouped the earlier called Gwaliors into Aravallis and thus the revised position of Gwalior system and Upper Vindhyan formations has been shown here with respect to standard stratigraphic column.

The lower Vindhyans are absent from the present area, therefore only the Gwaliors i.e. Aravallis and Upper Vindhyans are considered here.

Series	Som Valley	Phalodi area
	Upper Bhander sandstone	
	Sirbu shales	Sirbu shales
	Lower Bhander sandstone	Lower Bhander Sandstone
Bhander series	Lower Bhander limestone	Lower Bhander limestone
	Gunurgarh shales	Gunurgarh shales
	~~Diamond Bearing unconformity~	no unconformity
	Upper Rewa sandstone	Upper Rewa sandstone
	Jhiri shales	Jhiri shales
Rewa series	Lower Rewa sandstone	Lower Rewa sandstone
	Pampa shales	Pampa shales

<u>Delhi System</u>

Raialo series	(upper quartzites	Upper quartzites	
Aravalli System -	(shales and phyllites	shales and Phyllites.	Great Boundary Fault.
	(basal quartzites and grits.	Basal quartzites with chert veins	

Banded Gneissic Complex

Aravalli System

In the investigated area of the Sawai Madhopur region, Aravalli system consists mainly of quartzites which are found interbedded with grits, shales and phyllites. The shales grade upwards into quartzites and also at places shales have developed phyllitic character. Although these rocks were earlier classified by Heron into Gwaliors, but there seems to be no relation between them and the Gwaliors of the type area. Hence they were regrouped into Aravalli system. Around the vicinity of Great Boundary Fault of Rajasthan Aravallis are unaltered or little altered. Formation to the east of fault have been given the name Ranota shales (24° 32', 34°34')

The interbedded shales and intrusive dolerite were also included in the Gwaliors by Heron. In the present area these rocks of the Aravalli system are to the north-west of the Great Boundary Fault. The quartzites are brought against the Sirbu shales and lower Bhander Sandstone. The quartzites are interbedded with shales and phyllites.

The complete absence of limestone indicates that the beds represent a shallow water phase of deposition.

The rocks of the Aravalli system present in the region appear to represent a shallow water facies of Aravallis which due to its great distance from the main axis of disturbance has for the most part escaped the metamorphism suffered by the more central Aravalli tracts.

THE VINDHYAN SYSTEM

The term Vindhyan was first suggested by Oldham (1856) to designate the great sandstone formation of Bundelkhand and Malwa. Through-out a large proportion of its border, this great sandstone formation is unconformably related to the ancient Archaen gneisses or the Dharwars (Bijawars or Gwaliors) but, along the eastern extension of its outcrops in Bundelkhand and Son Valley, as well as in the neighbourhood of Chittor at the western corner of the basin, it rests with no visible discordance, except in the case of one or two outliers, upon deposits of a much younger character. The latter, called alternatively the Semri series (Meddlicott, 1860) or the Son series (Vredenburg, 1906), were soon realised to be nearly related to the great formation they underlay and for this reason, were included as a lower division of Vindhyan systems; the overlying succession comprising the Kaimur, Rewah, and Bhander series, thus becoming the "Upper Vindhyan".

The shape of the great Vindhyan basin is that of an axe, with its cutting edge coinciding with the boundary of the Archaen exposure of Rajputana and its haft curving eastwards along the Narbada and Son Valleys.

To the north, the Vindhyans obviously disappear beneath the alluvium of Ganges and Jamuna continue even under it to the Extra Peninsula (Krishnan, 1959).

The Upper Vindhyans are found in an almost continuous but irregular outcrop from Chittor in the west to Sasaram in east. A large and roughly square area - the blade of the axe some 250 miles across its diagonal and having its four corners at Achenera to the north (west of Agra), Chittor on the west, the Narbada Valley opposite the Dhar state to the south and a point north of Narsinghpur in the Central provinces on the east, is all presumeably occupied by Vindhyan deposits.

The Upper Vindhyans exposed in the region forms the most northernly extension of the great Vindhyan Plateau but separated from the main expanse by the Valley of the Chambal.

The Upper Vindhyan outcrop covers a very much larger spread of the country than the lower and in a general way, is made up of several thick masses of sandstone and alternations of shale, the calcareous element is deficient. The general composition and arrangement of the Upper Vindhyan rocks is strikingly uniform.

In eastern Rajputana along the northern corner of the Vindhyan basin, every division of Upper Vindhyan is represented here and can be distinguished from other divisions.

Although made up chiefly of sandstones, deposits typical of the coarser kinds of detritus - the general fineness of the sediments which make up the formation is a remarkable feature.

REGIONAL STRUCTURE

The regional structure of the area is characterised by two parallel faults running in NE-SW direction. These are 18 km. apart. The eastern one was named as the Great Boundary Fault by Hacket (1877). It is considered to be a reversed fault and on this assumption the hade of the fault would be to the North - West. Pascoe (1959)pp.556) has mentioned that a ferruginous breccia sometimes marks the position of the fault in Karauli (26° 29' 77° 5') and crushing and brecciation are often seen along its line, where the Aravalli quartzites are brought into juxtaposition with the Sirbu shales, the throw of the fault must be at least 1400 metres. The throw decreases from SW to NE and becomes zero some kms. North of TEWANGARH (26°43', 77°19').

Near Budal (25°56', 76°29') there are indications that the Great Boundary Fault divides and includes between its branches part of Upper Vindhyans which are folded in an anticline.

In the present area, North-west of the Great Boundary Fault, Aravalli formations are exposed while to the South-east of this fault Upper Vindhyans are seen.

The general trend of these formations in the area is NE - SW with varying amount of dip (5° - 35°) due NW.

CHAPTER III

THE ARAVALLI SYSTEM

ARAVALLI SYSTEM

The rocks which have been regrouped by Heron (1935) in this system are exposed in the north and north-west of the Great Boundary Fault of Rajputana.

Extent

The outcrops of these rocks occur in the form of strike ridges and valleys from Amli Railway Station, through Phalodi, upto Handwar village. They are also exposed near Rawanjna - Dungar village and Rawanjna Railway station and ~~xxxx~~ have an approximate thickness of 1,000 metres.

The general trend of the formation is NE-SW with varying dip from 5° - 35° due NW.

The Aravallis are represented in this area by the following succession :

Upper Quartzites
Shales and Phyllites
Basal Quartzites

Basal Quartzites

Field Characters

These quartzites are pinkish and reddish in color and are banded in nature. They are more compact and quartzitic than the Vindhyan sandstone, for which the author has given the name protoquartzite. The basal quartzites are abundantly and irregularly jointed and are of medium thickness.

The Aravalli Basal Quartzites are brought against the Lower Bhander sandstone at Phalodi due to Great Boundary Fault (Fig. No. 1c). These quartzites are of pinkish color with medium thickness and are exposed near Balapura village and on a ridge near Phalodi quarry (Typical Aravalli quartzites in appearance).

The quartzites are overlain by shales and phyllites near Mandwar. Jointing in the quartzites is quite common. Prominent joints are the strike joints, dip joints and bedding joints. The orientation of various types of joints have been noted and are given on page No. 22. Vertical joints having a general trend of north-east- south-west have given rise to vertical escarpments.

About ~~...~~ .4 km. north of Balapura village a China clay band occurs alongwith the Aravalli basal quartzites. Heron (1918) has given the origin of this China clay due to leaching of feldspars present within the quartzites. The vast occurrence of China clay in the form of a persistent band along the strike and about 7 - 8 metres wide outcrop does not seems to support Heron's view. It might have been formed due to the alteration of shale band interbedded with quartzite.

Shale with Phyllite

The Aravalli shales which are underlain by Aravalli basal quartzite and overlain by Aravalli quartzites occur as a distinct unit extending right from Shivpura village N of Great Boundary fault upto Handwar village.

In general the Aravalli shales are dark greenish to black in color and are less friable and fissile than upper Vindhyan's shales. At places, near Dalapura, in a nala under the railway track, shales have developed phyllitic character and show complex folding. The minor folds are inverted chevron fold, symmetrical, assymmetrical anticlines and syncline. The direction of plunge is N 225° with varying amount i.e. 10° - 30°. The nature of these minor folds is shown in plate No. 10 Photo No. 2.

Near Handwar village the shales show hematitic character. The various primary sedimentary structures like ripple marks, flow cast and load cast are beautifully preserved. Here the shales are folded and thrown into anticline and syncline. The shales are exposed on the Handwar hill alongwith quartzites.

Due to the presence of prismatic and rectangular joints in the shales, they break into sharp edged brick or tile like fragments and are used by local people for building purposes.

The general trend of the Aravalli shales and phyllites is NE-SW. The amount of dip varies from 20° - 35° due NW. At Handwar hill the shales have dip of 30° due N 60°.

Upper Quartzites

Field Characters

The quartzites exposed all around the Ravanjna Dungar village and Ravanjna Dungar railway station can be distinguished from basal quartzites due to their more reddish color and less compaction. Moreover in these quartzites we get well preserved sedimentary structures such as cross bedding, ripple marks, flow casts, flute casts and load casts. These quartzites seem to be more coarse grained than the Basal quartzites. Characteristic feature of these quartzites is the occurrence of interlayer of shale bands which are complexly deformed. These are exposed on the kuchha midway from Ravanjna Dungar railway station to Ravanjna Dungar village. These interlayers of shales separate the different thick bands of quartzites. The direction of plunge of the axis of minor folds in the inter layer shale is N 200 and N 280 with a plunge of 5° to 20°. The shales being of incompetent character are folded while more competent quartzite layers are not affected. Near Ravanjna

Dunger railway station an igneous intrusion within the Aravalli quartzites in the form of a dyke is seen. At contact quartz-epidote rock has developed.

The ripple marks found in the quartzites are of oscillation type and therefore the direction of palaeocurrent could not be determined. The quartzites are well jointed. The common joint direction is NW-SE. The various measurements regarding joints are given in table on page No. 22

The direction of current measured from the cross bedding structure is from SW and SSW.

Igneous Intrusion

Field Characters

In the present area the only igneous intrusion ~~which has taken place~~ is of a dolerite dyke within the Aravalli quartzites as seen near Ravanjna Dunger railway station. The dyke occupies an area of about 400 square metres and is almost rounded in shape having one or two offshoots. The sharp contact between the quartzite and dolerite intrusion could not be traced out due to the thick coverage of alluvium.

At the extreme boundary of the dolerite dyke, band of about 2.3 metres width of quartz - epidote rock is seen which is quite persistent along the boundary for a considerable distance. Further moving towards the centre of the dyke another rock type (basalt) is exposed. This rock also occurs as thin band of about one metre width. It is very fine grained and greenish black in color. It resembles basalt but does not show the presence of vesicles.

The main dolerite rock is more coarse grained at the margin than in the centre.

It appears that the rocks are in the form of multiple intrusions.

Differential weathering has produced boulders of dolerite which have been rolled down on the slope. Disintig-ration product of dolerite has produced a soil which resembles the black cotton soil.

The fresh exposures of dolerite are blackish in color and coarse crystalline. Small white plagioclase laths and greenish pyroxene mineral can be observed with naked eye.

The effect of the intrusive on the quartzites is not very much interesting from the point of view of minera-logical changes except the baking affect at the contact.

Heron (1918) suggested that some of the dolerite sills and dykes traversing the Aravallis may be hypabyssal equivalents of the Khairmalia amygdaloids.

STRUCTURE

Aravalli formations are exposed to the North-west of the Great Boundary Fault of Rajputana. Near the fault plane these formations are thrown into minor folds.

They show a general trend of NE - SW. The amount of dip varies from 5° - 35° due NW.

FAULTS

The Great Boundary Fault, as has been discussed under Regional structure is the only major fault in the area.

FOLDING

Folding is very commonly observed in the Aravalli shales which is found interbedded with Aravalli quartzites. The complex folding in the shales and phyllites can be accounted due to the incompetent character of these formations. Although no any large scale folding has been observed in the Aravalli formations, but several minor folds in Aravalli shales near Handwar, Ravanjna Dungar village and Amli station are seen.

The direction and amount of plunge for these minor folds are as follows :

Locality	Rock type	Amount of plunge	Direction of plunge
1	2	3	4
On the kuchha road, midway between	Shale	5°	N60

1	2	3	4
Ramonjna Dungar Railway station to Rwonjna Dungar village	interbedded with quartzite	8° 9° 14° 10° 18° 12°	S60 W N82 E N50 E N35 E N42 E S40 N
North-East of Amli Railway station in a Nala under the Railway track	shales and phyllites	27° 18° 24° 32° 35° 12° 26°	N75 E due W N87 W due W N80 W N50 E N76 W
Handwar	shales	25° 20° 18°	N46 E N50 E N60 E

JOINTS

Aravalli quartzites are well jointed. The following types of joints are most commonly observed in these formations:

1. Dip joints
2. Strike joints
3. Bedding joints
4. Oblique joints

Oblique joints

Amount	Direction
90°	N55 W
87°	N48 E
85°	N60 W
48°	S40 W
90°	N70 W
10°	S35 W
85°	S45 W
45°	N20 E
90°	N10 E

PETROGRAPHY

Basal Quartzites (6/123, 6/124)

In hand specimen the quartzites are pinkish white in color. They are fine grained, hard and compact with will developed joints.

In thin section the rock is medium to coarse grained and equigranular. It shows blastopsammitic texture. The grains are cemented together with siliceous cementing material which has recrystallised and shows secondary over-growth around the detrital quartz grains. Grains are quite tightly or closely packed. The rock is traversed at places by chert veins.

Mineralogically quartz is the most dominant mineral alongwith little chert, rock fragments and cementing material.

Quartz occurs as colorless anhedral grains, sub-rounded in shape. The individual grains are cemented with re-crystallised siliceous material. Recrystallization of siliceous cementing material has given rise to authigenic growth to quartz grains. Quartz shows low relief and low birefringence. Polari-sation colors are of 1st order greys. Some quartz grains show turbid nature and few grains have inclusions.

Chert occurs in veins in the form of cryptocrys-talline mass. The veins do not have any particular orientation and appears due to the filling of shearing cracks.

Rock fragments are also present which occur in between the quartz grains.

Heavy minerals present are tourmaline and zircon. In one thin section 3 to 4 tourmaline grains can be seen which are bluish colored and are strongly pleochroic. Tourmaline grains are subrounded in shape. Under crossed nicols it shows second order colors.

Zircon shows well developed fractures and occurs as prismatic colorless grains. Under crossed nicols it shows high birefringence. Polarisation colors are of 2nd and 3rd order i.e. blue, red, green.

Upper Quartzites (Rewanjna Dungar) (4/602, 4/603, 4/604)

In hand specimen these quartzites appear to be coarse grained and pinkish red in color. Pinkish white variety is also common. It is quite hard and compact.

In thin sections rock is coarse grained, equigranular. Quartz grains are cemented together with the recrystallised siliceous cementing material. The quartzites show blastopsammitic texture.

Quartz is the main constituent mineral around which overgrowth has taken place. The secondary enlargement is due to the recrystallisation of cementing material around the quartz grains. Quartz grains occur as colorless, anhedral grains with low relief. These grains are packed very tightly and show polarisation colors of first order i.e. grey and yellows. Turbid nature of the quartz grains is an important property. Some of the quartz grains show wavy extinction.

Few quartz grains have inclusions of rock fragments. Some of these quartzites have muscovite in abundance. Muscovite occurs as colorless, and small flakes. It shows polarisation colors of second order and straight extinction.

Zircon and tourmaline are quite prominent. Zircon occurs as colorless mineral and subrounded in shape. Relief is high. Fracture quite common. Under crossed nicols shows polarisation colors of second order.

Tourmaline occurs as a bluish mineral and is strongly pleochroic. Polarisation colors are of second order.

The microscopic difference between the upper quartzites and the basal quartzites as described earlier is the occurrence of chert veins in the latter, while former are more coarse grained.

BASIC INTRUSIVES IN THE ARAVALLIS

Olivine dolerite (4/682, 4/686)

Megascopically the rock is dark gray in color and coarse grained. The visible mineral constituents under naked eye are dark colored fero-magnesium minerals and grayish feldspars.

In thin sections the rock shows coarse grained, holocrystalline and inequigranular texture. The chief constituent minerals i.e. augite, plagioclase and olivine, are subhedral. The plagioclase laths form the bulk of the groundmass. The plagioclase laths are within augite grains thereby showing characteristic ophitic texture.

The modal percentage of plagioclase felspars is 58.3. At places the plagioclase is altered into sericite. They show twinning on albite and Carlsbad laws. Interference colors are first order grays. The maximum extinction angle measured on the albite twin planes is 33° and hence the composition will be Ab_{42} An_{58} i.e. labradorite.

Augite mostly occurs as subhedral grains which are colorless to purplish brown. Both prismatic and basal sections are present. Basal sections show two sets of cleavage intersecting at an angle of 87°. At some places boundaries of augite crystals have become irregular due to penetration of plagioclase laths. Some crystals of augite show alteration into antigorite which is greenish in color and is more prominent at the margins of the augite grains. Interference colors vary widely from first order gray to second order, blue, red, yellow etc. The extinction angle ranges from parallel to 33°. The low angle of extinction and low order of polarisation colors may be due to their orientation parallel to one of the optic axis. Polysynthetic twinning is exibited in some grains. Augite forms about 33.4% of the total rock.

Olivine occurs as rounded or polygonal grains. Fracture in olivine grains are quite characteristic. Grains are quite fresh, but at some places alteration into serpentine and magnetite is observed. Olivine grains appear to be embedded within pyroxene crystals. Polarisation colors are dark second order, blue, red, green, yellow etc.

Biotite is brownish in color and is characteristically phochroic from light shade of brown to dark brown. It occurs as small plates developed at the boundary of the augite grains. Interference colors are of second order and extinction is straight.

Magnetite is not uniformly distributed in the rock. It forms 1.3% of the total rock mass. Most of the magnetite grains are anhedral.

The modal composition of the two thin sections as determined by Leitz cylinder stage counter is as follows :

Constituent minerals	Rock specimen No. 4/682	Rock specimen No. 4/686
Plagioclase (Labradorite)	60.2 %	58.40 %
Augite	33.5 %	32.42 %
Olivine	4.8 %	7.84 %
Magnetite	1.5 %	1.34 %

Epidote-Quartz rock (6/161)

The rock commonly occurs along the margin of the dolerite intrusives. It is medium grained and dark greenish grey in color. Fine epidote crystals and quartz grains can easily be recognised in the hand specimen.

In thin section the rock is coarse grained, holocrystalline and mostly equigranular. It is mainly composed of anhedral grains of epidote and quartz traversed by thin veins of epidote with well developed crystal outlines.

Epidote, the most abundant mineral, is yellowish to colorless. It occurs in euhedral to anhedral grains of prismatic shape. It shows high relief and strong birefringence with bright second order colors i.e. yellow, green violet and red. Extinction is parallel to the cleavage.

Quartz is colorless with low relief and low birefringence. Polarisation colors are gray and yellow of first order. Some chert is also present in the form of veins.

Quartz and epidote together make up the bulk of rock mass. This rock is at time traversed by the epidote veins which show well developed crystals of epidote.

Porphyritic Basalt (4/680)

In hand specimen rock appears to be blackish green in color and is very fine grained similar to basalt. It also occurs near the margin of the dolerite.

In thin section the groundmass of the rock is very fine grained and is difficult to recognise. There are few big grains of plageoclase feldspars and augite embedded within the fine grained groundmass. Thus the texture of the rock can be named as porphyritic.

The main constituent minerals are augite, plagioclase feldspars. Most of the pyroxene and plagioclase is distributed in the form of fine grained groundmass except the few phenocrysts of plagioclases and augite.

Plagioclase occurs as colorless laths. It shows low polarisation colors of first order. Albite law twinning is commonly observed in them. The extinction angle measured on the albite law twin planes is 32°. Thus the composition of the plagioclase is Ab_{42} An_{58} i.e. labradorite.

Phenocrysts of augite are colorless to light yellow and occurs in prismatic shape. One set of cleavage is quite prominent. Under crossed nicols it shows second order polarisation colors and 32° extinction angle.

<u>Accessories Minerals</u>

Magnetite occurs as anhedral grains and is opaque.

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SEDIMENTARY STRUCTURES

Primary sedimentary structures are quite commonly seen in the Aravalli formations near Rawanjna Dungar Railway station and Handwar village. These structures are observed in the Aravalli quartzites and shales. Although the Vindhyans are supposed to show varities of sedimentary structures, but in the present area sewral types of well preserved sedimentary structures are present in the Aravallis instead of in the Vindhyans. There is no earlier account of these structures from this area.

Firstly, the sedimentary structures from the area have been tabulated with respect to their occurrence in the field.

A general classification of sedimentary structures is also given as proposed by Potter and Pettijohn (1963).

The various sedimentary structures are described alongwith a note on their origin.

TABLE SHOWING THE LOCATION OF VARIOUS SEDIMENTARY STRUCTURES IN THE ARAVALLIS

([illegible])

Structures with respect to their position in bed.	Rock type	Locality
1	2	3
1. Structures on the base of the bed (Sole markings)		North-West of Rawanjna Dungar Rly. Station and Handwar Village.
(a) Flute Casts	Shales	
(b) Groove Casts	Quartzites	

1	2	3
2. Structures within beds		
(i) Cross bedding (ii) Forset lamination	Quartzites	Rawanjna Dungar Village
3. Structures on top of beds		
(i) Assymmetric ripple marks (ii) Symmetric ripple marks	Quartzites	Rawanjna Dungar Railway Station & Rawanjna Dungar Village.

Sedimentary Structures on the base of bed

The sedimentary structures under this group are a product either of

(i) the current or

(ii) the objects or load propelled by the current.

CLASSIFICATION AND ORIGIN OF SUBSTRATAL LINEATIONS (After Potter and Pettijohn,1963)

Agent	Process	Name of Structure
Produced by Current	Current scour	Flute Casts
	Engraved by moving objects (a) Drag (b) Saltation (c) Rolling	Groove Casts Bounce, Brush and Prod Casts, Roll marks.
Produced by gravity	unequal loading slump or slide marks	Load Casts Slide marks, Slump folds, faults.

Flute Cast

The structures to which the name Flute Cast is commonly given has been referred by earlier workers as 'Flow marks' (Rich, 1950), 'Lobate rill marks' (Shorck, 1948), 'Scour Cast' (Kingma, 1958) and 'Scour finger' (Bokman, 1953)

Now-a-days the term flute cast is generally accepted.

Crowell (1955) has described Flute Casts as sharp subconical welts, one end of which is rounded or bulbous where-as other end flares out and merges gradually with the botton surface. In the present area flute casts are seen in Aravalli quartzites near Rawanjna Dungar Railway station and in Aravalli shales near Handwar village (Plate No. 14 Photograph No. 1&2). Despite the general conformity in their pattern, Flute Cast vary in shape and size. In the present area the length of subconical welts varies from 1 mm. to 4 cm. Some are deltoid while others are elongated. A few have exaggerated relief which is perhaps a result of modification by load casting.

Flute Casts in the present area are closely related with groove and striation casts.

Origin

According to Potter and Pettijohn (1963) Flute Casts are a result of current scour.

Rucklin (1938) clearly explained the origin of these features as product of erosion in mud by vortices, such scour pits being preserved by subsequent filling with silt or sand.

Crowell (1955) on the basis of thin section studies of these structures has found out that the coarsest grains in the bed are concentrated at the bottom of the Casts in the undistorted laminated bed. This feature has been cited has an evidence of sedimentary origin. After the scouring the Flute was just filled with the coarsest grains dropped by a turbidity current. These are the product of filling of scour pits generated by current eddies.

Flute casts are one of the wide spread of sole marks used as a guide to determine the direction of flow and are most characteristic of flysch facies.

<u>Groove Casts, Bounce Casts, Brush Casts, Prod Casts.</u>

These sedimentary starructures are also seen in the area alongwith Flute casts about .3 km north-west of Rawan-jna Dungar Railway station and near Handwar village.

Groove casts are charactarised by their straightness and uniformity of height and great length.

The term Bounce cast is proposed by Wood and Smith (1957) for rather short ridges which fade out at either end.

A Brush cast is of similar shape and origin and differs only in that it has a slight crescentic depression at one end (Plate No. 14 Photograph No. 2).

A Prod cast as termed by Rgdomski(1958) is a term applied to short ridge which has one blunt end and fades out in the other direction.

Origin

According to Potter and Pettijohn the above mentioned sedimentary structures are made by objects which function as engrooving tools and are in continuous contact with bottom.

Load Casts

This sedimentary (structure) feature has also been observed in the Aravalli quartzites near Rawanjna Dungar Railway Station and in the shales near Handwar village.

The load casts appears as swellings varying from slight bulges deep, or shallow rounded sacks, knobby or highly irregular protruberances. They can be distinguished from Flow casts structures by their much greater irregularity of form and distinct up and down current ends. They generally show no alignment. Load cast on the same bedding plane tend to be of the same general size and character. In some cases they are much flattened in other they exibit a striking mamillary or papliform appearance. Some are highly irregular. In few cases they are highly assymmetrical.

Load cast in the area do not vary much in diameter (from 1 cm to 3 cm.).

Origin

Regarding their origin Shrock (1948) believed that soft hydroplastic sediments if unequally loaded with sand or gravel yield to the weight of the super incumbent load by flowing. These are indicative of no particular environment. The only requirement of their formation is deposition of a bed of sand on a water saturated Hydroplastic layer.

This feature has been cited by Kuenen (1953) as an evidence of sedimentary origin.

STRUCTURES WITHIN BEDS

Cross Bedding

Cross bedding is seen in the Aravalli quartzites near Handwar village and Rawanjna Dungar village.

Cross bedding has been defined as a sedimentary structure confined to a single sedimentation unit (Otto 1938) consisting of internal bedding called foreset bedding inclined to the principal surface of accumulation.

Cross bedding has been classified by sub internal properties as shape of its foreset beds, whether they are concave, convex or straight in vertical section as well as angle of inclination.

The cross bedding that have sensibly planar contact are essentially tabular bodies and those that have curved contact are trough shaped bodies (Fig. No. 3).

Origin

This structure is developed in bodies of granular sediments by currents of wind and water that build the deposit forward by successive addition of sediments on down current side.

Current Direction

The predominant current direction shown by cross bedding is from SSE, but at places it has been observed from SW. At places the laminae of foreset are 1 cm. in thickness. The whole bed extends for about 10 metres in length and 20 cms. in width (near the Raunjna Dungar village). There is a variation in the dip of laminae from 15° to 60° (Fig. No. 8).

STRUCTURES ON THE TOP OF BEDS

Ripple Marks

In the present area Ripple marks are seen in the Aravalli quartzites near Hendwar village and Raunjna Dungar Railway Station.

Ripple marks are referred to as rhythmic or periodic undulations that occur on bedding planes. They may be classified in a number of ways, by appearances in plan, whether assymmetric or symmetric, whether crests are straight or curved, continuous or discontinuous, by either wavelength, amplitude or by ripple index or by presumed hydrodynamic conditions of origin.

TYPES OF RIPPLE MARKS OBSERVED

Two main types of ripple marks have been observed in the present area

(1) Current ripple marks (Assymmetrical type)

(2) Oscillation ripple marks (symmetrical type)

Current ripple marks (Transverse type or Assymmetrical type)

These are confined to the Aravalli quartzites and shales. The ripple index varies accordingly to the rock type as well as within the same rock type.

In the case of shales ripple index varies from ½ to 1 whereas in case of quartzites the ripple index varies from 3 to 4. (fig. 5 & 6)

The direction of current during the deposition also appear to differ. The most prominant direction appears to be from SE. Others are from North 125 and N 90 as shown in the accompanying geological map.

Origin

Assymmetrical ripple marks are certainly the product of current action. Below a certain critical velocity ripples do not form and above a critical velocity they are destroyed.

Such ripples develop when a current either of water or of air, moves across sand.

Oscillation ripple marks (Symmetrical type)

These are found only in the Aravalli quartzites. A characteristic feature found in the Aravalli quartzites is the presence of oscillation ripple marks on one surface of the bed and the flow casts on the opposite surface.

Direction of paleocurrent could not be determined due to its oscillatory character.

Origin

Oscillation ripples form in bodies of standing water. Whenever waves disturb the upper surface of the body of water, the individual water particles move in vertical orbits that are nearly circular. Although the wave form moves across the water, the individual particles do not. The motion of the particles is transmitted downward with decreasing intensity. The sand on the bottom is affected by the same motion and is thrown into ripples.

SEDIMENTATION

The well preserved sedimentary structures in the Aravalli formations like cross bedding, ripple marks indicate that these formations were deposited under shallow water conditions.

Sedimentary features and structures like Flute cast, Load cast, Prod cast and other linear current structures are due to the action of turbidity currents. These features can be related with turbidites facies as mentioned by Daniel J stanley and Arnold H. Bouma(1964).

CHAPTER IV

THE UPPER VINDHYAN SYSTEM

UPPER VINDHYAN SYSTEM

The rocks belonging to the Upper Vindhyans in this area are Rewa and Bhander series. These formations are exposed to the South and South - east of the Great Boundary Fault.

Extent

Outcrops of these formations are seen extending from Dolara to Dumeda village and from Amli Railway station, through Phalodi upto Dumeda village.

The general strike of the rocks is NE - SW. The amount of dip varies from 5° - 30° due NW.

The following stratigraphic succession can be given for this area :

Bhander series	-	Sirbu shales Lower Bhander Sandstone Lower Bhander Limestone Gunurgarh shales
Rewa series	-	Upper Rewa Sandstone

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STRUCTURE

Structurally, the Upper Vindhyan formations are not much disturbed in the area. The general trend of the rocks is NE - SW with locally varying dip. The angle of dip varies from 6° - 30° due NW.

Great Boundary Fault

The most significant structural feature of the area is the Great Boundary Fault which separates the Upper Vindhyans from the older Aravalli rocks to the North. This persistent fault, with another parallel to it (as mentioned earlier under the Regional structure) has been traced to the North - east of the area by Heron. Great Boundary Fault enters in this area near Amli Railway station. It has brought the Sirbu shales (Upper Vindhyan) in contact with the Aravallis. To the North-east of the Bhatpura village Lower Bhanders are brought against the Aravallis as shown in the section No. 10 . Minor displacement in the dolomitic limestone band has been observed near Amarkund.

Folding

The Upper Vindhyan formations in the area show little folding except South-west of Mandrehri, where a large asymmetric anticline is seen. Minor folds in Lower Bhander sandstone are seen near Mandrehri hill top. Similarly Lower Bhander limestone also shows minor folding near Amarkund, Sadakund, Dumoda and Phalodi quarry. Such minor folds are shown in Plate No. 6. Photo. No. 1.

Joints

Three sets of prominent joints have been observed in the Upper Vindhyan formations. The Lower Bhander limestone and Lower Bhander sandstone show the following three types of joints :

1. Bedding joints,
2. Strike joints, and
3. Dip joints.

In addition to the above mentioned type of joints Lower Bhander sandstone show vertical joints also as shown in Plate No. 3 Photo. No. 1.

Upper Rewa Sandstone

Field Characters

The upper Rewa sandstone is underlain by Jhiri shales and is overlain conformably by Gunurgarh shales (Fig. No. 10). They are light pinkish in color and are quite hard and compact. They appear in hand specimen very similar to lower Bhander sandstone. These sandstone are fine grained and well jointed. The general trend of the formation is NE - SW with angle of dips varying between 5^o - 20^o due NW. They extend all along the strike from Deopura to Bhairopura exposed on the top of the hills. The total thickness of the rocks in this area is about 70 metres.

The prominent primary sedimentary structures like ripple marks and cross bedding are quite common in the sandstones and were observed by the author while taking traverse from Phalodi quarry to Jhoja-ji temple. The current direction measured from these primary structures is from N 50^oE.

Strike joint, bedding joint and dip joint are mostly common in the upper Rewa sandstone.

Gunurgarh Shales

Field Characters

The Gunurgarh shales which are very soft, greenish red and yellow in color form the lowest division of the Bhander series. It is exposed in the large valley East of Phalodi quarry temple. The weathering product is a highly fertile soil of great thickness.

Its total thickness in the type area is 120 metres but in the present area it is only 70 metres.

The general trend of the Gunurgarh shales is NE - SW. The amount of dip varies from 5^{0} - 20^{0} due NW.

Good sections of Gunurgarh shales with typical buiscuit weathering are exposed in the midway between Dolara to Mandrehri. The Gunurgarh shales in this area seem to overly conformably over upper Rewa sandstone without any intervening of conglomerate or breccia. The shales are conformably overlain by Lower Bhander Limestone.

The Gunurgarh shales are found interbedded with sandstone (thin layer of about 10') which are exposed about 1½ km from Phalodi quarry temple in the north-east direction. The sandstone is quite coarse grained and white in color. In the dip direction Gunurgarh shales grades into Lower Bhander Limestone.

Near Bhagwanpura village Gunurgarh shales are found interbanded with sandstone band as revealed from the well cuttings. Perennial nalas are developed in the Gunurgarh shales which have caused deep cuttings.

Lower Bhander Limestone

Field Characters

The lower Bhander limestone is the most important economic unit of the area. It occupies a large area in the valley from south - west of Deopura to Dumoda village and is exposed on the Phalodi quarry hill in arcuate shape. The limestone outcrop has taken a right angle turn at about .2 kms. south of Mandrehri.

The total thickness of limestone horizon is about 150 metres in the present area. The lower 20 - 30 metres thick horizon is marly.

The limestone is conformably underlain by Gunurgarh shales and conformably overlain by shale band of about 40 metres for which no separate name has been given. This inturn is overlain by a 13 metres thick Dolomitic limestone band above which Lower Bhander sandstone are exposed forming the top of the hill range (Fig. No. 10).

The general trend of the limestone is similar to the regional strike of the upper Vindhyans i.e. NE -SW. Dip varies from nearly horizontal to 25^{o} due NW.

The lower Bhander limestone is fine grained and thickly laminated. It is predominantly of two colors, brownish red and bluish gray, but due to various impurities it shows, purple red, grey, bluish gray, greenish red etc. It is commonly interstratified with thin brown layers of high magnesia limestone and shale (about 1 cm in thickness). This inter-and intrastratification of shale band which commonly occur within 3 metres or more of thick limestone bed has imparted a characteristic feature of non-uniformity to the composition of limestones at places.

Another characteristic feature of the Lower Bhander limestone is the irregular occurrence of intraformational breccia which has elongated lensoid pebbles of limestone embedded within the fine groundmass of limestone. The cementing material as well as pebbles are made up of calcitic material. The pebbles do not follow any particular orientation and might represent the earlier precipitated product adjusted by penecontemporaneous deformation.

The purple red colored limestone is more or less confined in the lower horizon. The bluish gray color limestone commonly occurs in the middle and upper horizon of the section as shown in (Fig. No. 11)

The lowest 20 metres thick limestone of purple color is of high grade overlain by 80 metres thick red shaly limestone of low grade which inturn is followed (and overlain by) by a 50 m. thick bluish gray limestone of high grade. As already mentioned, above, this bluish gray limestone occurs 40 metres thick of greenish soft shale and these are overlain by 5 metres thick band of dolomitic limestone.

As described earlier, compositionally the Lower Bhander limestone is marly at places and elsewhere contains only 60% carbonated. This low CO_3 percentage is due to their inter-stratification with red shales which is difficult to separate. Thus grade of the limestone is lowered and has become a broblem for the cement manufacturers. At certain outcrops the total carbonate percentage of the limestone is more than 90%. Generally the bluish gray colored high grade limestone gives a total carbonate perdentage upto 88%. This bluish gray high grade limestone occurs in Dumeda area and is more than 70 metres thick as proved by drilling by the quarry geologists.

The limestone in the area shows typical elephant skin weathering, plate No. 8 photo. No. 2.

Local warping (penecontemporaneous deformation) is quite a common feature in the limestone near Sadakund and Amarkund areas of Phalodi quarry and is shown in plate No. 6 Photo. No. 1 . The similer deformation in the limestone has been observed in the Dumeda area.

The limestone shows in general layered structure which is present everywhere. It also shows minor slips, minor folds and monoclines. A monocline in the limestone has been noted in the Sadakund area. The bedding joints, dip joints, strike joints are quite prominent in the limestone.

Lower Bhander Sandstone

Field Character

The Lower Bhander Sandstone is the most dominant member of the upper Vindhyan system in the present area. They extend from SW of Deopura along the arcuate Phalodi hill range upto Dumeda and forms the hill tops at both the places. The sandstone are exposed in the valley also in between Phalodi village and Dumeda village.

The sandstones conformably overly dolomitic limestone band and are inturn overlain by Sirbu shales. The total thickness of this unit in the present area is approximatly 100 metres.

The lower Bhander sandstone is pinkish white and pinkish red or brown in color and is quite hard and compact. In the field it appears to be quite fine grained and at places shows local recrystallisation changing into quartzite like rock and is white in color. Quartz seems to be the main constituent mineral with very little ferruginous and clay matrix.

The sandstones are well jointed and show three prominent joints i.e. strike joints, bedding joints and dip joints. Vertical joints are also common, Plate No. 3 photo. No. 1.

The general trend of the formation is NE - SW dipping with 5° to 25° due NW. The vertical joints which are at right angles to each other have been noted near Mandrehri top.

The most characteristic sedimentary feature observed by the author, while taking traverse from Sadakund area to Bhatpura village, is cross bedding. The foreset laminae are quite thick and dip due SW indicating palaeocurrent direction from NE. The cross bedding observed here is of tabular type and shows that the beds are right side up.

Ripple marks are seen in the sandstone and are of assymmetric type. Paleocurrent direction inferred from this is from N 40^{0}

<u>Sirbu Shales</u>

<u>Field Characters</u>

Sirbu shales are exposed over the large area in the valleys near Bhatpura village and Amli village. Weathering product of the shales have given rise to good mantle of the fertile soil in the valley. The shales outcrops were also found in the well cuttings near Phalodi village. Its total thickness in this area is about 130 metres.

Usually the Sirbu shales are very thinly cleaved with a good cross jointing. These are ferruginous, but Gunurgarh shales are more ferruginous.

To the north of Amli village Sirbu shales are in contact with Aravalli quartzite along the Great Boundary Fault. Near Amli railway station minor folding has been noted in the shales.

General Trend of Sirbu shales is NE - SW with varying amount of dips (from 5° to 25°) due NW.

PETROGRAPHY

Upper Rewa Sandstone (4/132, 4/111)

In hand specimen the upper Rewa sandstone is pinkish white in color. It is fine grained, hard and compact.

In thin section, the upper Rewa sandstone is fine grained. Quartz grains are subrounded in shape. The individual grains are cemented together with siliceous matrix. Siliceous cementing material at places has recrystallised around the quartz grains and shows overgrowth.

Chief constituent minerals are quartz, feldspar with little siliceous matrix and zircon, and tourmaline (heavy minerals).

Quartz occurs as subrounded grains which are colorless, show low relief and low birefringence; few thicker grains show bright lower second order color. Quartz grains are of three types :

(a) Quartz grains of turbid nature.

(b) Quartz grains with inclusions

(c) Clear quartz grains.

At places secondary authegenic growth is common.

Feldspar grains occur colorless, and show good one set of cleavage. It shows polarisation colors of first order i.e. grays. Extinction angle is

Zircon occurs as colorless and prismatic in shape with well developed cleavage. Under crossed nicols it shows polarisation colors of second order i.e. blue, red and green.

Tourmaline is bluish in color, strongly pleochroic from light blue to dark blue. Polarisation colors of second order are seen.

Mostly the cementing material is silica with very little clay and ferruginous material. Siliceous cementing material has recrystallised and shows secondary authegenic growth at places.

Lower Bhander Sandstone (4/630, 4/623, 4/633, 4/634, 4/632)

Megascopically the lower Bhander sandstone is pinkish brown and pinkish white in color. It is fine grained, hard and compact with well developed joints.

Under the microscope the sandstone is fine grained. The grain size varies from .05 mm. to .3 mm. The shape of the grains varies from subrounded to subangulor, the subrounded nature being more common. Sorting is good as inferred from the thin section grain size analyses. The individual grains are so tightly packed that very little siliceous cementing material is present.

Mineralogically the rock is composed of quartz which is more than 90% and chert is less than 5%. Matrix is less than 5% and is mostly siliceous, ferruginous or clayey.

Quartz grains are colorless with low relief and low birefringence, but few thicker grains show bright colors. Quartz grains are of two types. Some grains are very clear and have no inclusion, while other have turbid appearance due to the presente of inclusions. These would have been derived from metamorphic terrain. The quartz grains are bounded with matrix of siliceous and ferruginous material with little clay. Siliceous cementaing material has recrystallised around the quartz grains and thus shows secondary growth (Authegenic growth) which is supposed to be due to diagenetic process. Few quartz grains show wavy extinction.

Under the crossed nicols chert appears to be very fine grained cryptocrystalline granular mosaic mass.

Most of the quartz grains show secondary growth . This overgrowth on the quartz grains is in optical continuity with the detrital grain i.e. the extinction of both the parts is exactly the same. On the boundaries of the original quartz grain, around which the overgrowth has taken place, a ferruginous coating is present which distinguishes the secondary growth from the original grain. The recrystallised siliceous cementing material is observed around this ferruginous coating. About 50% of the quartz grains show secondary growth.

Feldspar grains are only 3 to 4 in the whole thin section.

Heavy minerals present are tourmaline, zircon, muscovite. Tourmaline can be recognised by its yellowish blue color, pleochroic nature and high biregringence.

Zircon can be distinguished by its strong bluish red color with prominent fractures.

Small flakes of colorless muscovite are quite commonly seen which show second order polarisation colors.

Results of the modal analyses of the lower Bhander sandstone are tabulated below :

Constituent minerals	4/634	4/633	4/632	4/630	4/623
Quartz	90.5	90.4	91.0	92.3	92.8
Chert	3.5	3.1	2.9	2.7	2.4
Feldspar	2.4	2.0	2.2	1.5	2.0
Ferruginous clay } matrix	3.6	4.5	3.7	3.5	2.8

<u>Lower Bhander Limestone (4/631, 4/659)</u>

In hand specimen the (brownish red, bluish gray & purple) Lower Bhander limestone shows different colors which may be due to the presence of impurities. These limestone show well developed calcite crystals in few veins and are fine grained.

In thin section the limestone is very fine grained. Calcite is the chief constituent mineral. Calcite occurs as colorless anhedral crystal aggregates. Due to the presence of impurities calcite appears as dirt like mass. Few veins with well developed calcite crystals are seen traversing the fine grained carbonate mass. Calcite shows extreme birefringence and polarization colors are of third order. There is no preferred orientation of the fine grained mass.

Fossils have not been observed in these limestones.

CLASSIFICATION OF SANDSTONES

INTRODUCTION

Various schemes for the classification of sandstones are devised as a practical shorthand method of summarising important descriptive and / or genetic feature. Each of the many classification that has been proposed differs from the others in the kind of the factors on which the classifications are based. None of the proposed classification has been universally accepted as it is impossible to satisfy all the important factors.

Sandstones have three fundamental attributes i.e. composition, texture and structure. Among the recent classification proposed, all utilise mineral composition, several combine mineral composition and texture and two utilize all three attributes.

Classification based on sedimentary structures was first proposed by Grabau (1904) and later on modified by Packam (1954) and Crook (1960). This takes into consideration the genetic factors also. Texture and mineralogical factors were utilised by Dapples, Krumbein and Sloss (1953), Gilbert (1954), Krumbein and Sloss (1963), Pettijohn (1957) and Tallman (1949).

Classifications on the basis of mineralogical attributes were attempted by Folk (1954), Fuchtbauer (1959), Hubert (1960), Krynine (1948) and Van Andel (1958).

The sandstones from the area under investigation are classified with respect to the classification suggested by Pettijohn (1957).

Pettijohn (1957) has taken the following factors into consideration for the classification of sandstones :

1. Percentage of quartz and cementing material.

2. Maturity of sediments as interpreted from the results of grain size analyses.

Pettijohn has classified the sandstones into four groups (Table No. 1). The parameters are "source rock index","maturity index" (ratio of quartz + chert, to feldspar + rock fragment) and "fluidity index", which is the ratio of sand detritus to interstitial detrital matrix.

TABLE 1 (Tectonism - Climate)

Cement or matrix		Detrital matrix prominent to predominant no chemical	Detrital matrix absent or scanty less that 15.% voids filled with chemical cement			
Sand or detrital fraction	Feldspars exceed rock fragments	Feldspathic Graywacke	Arkosic sandstone		ORTHOQUARTZITE	Chert less than 5%
"	Rock fragment exceed feldspar	Lithic Gray Wacke	Lithic sandstone: sub Gray wacke	Proto-quartzite		Chert more than 5%
"	Quartz content	Variable generally less than 75%	less than 75%	more than 75% to 95%		more than 95%

According to the above classification and on the basis of modal analyses given under the petrography of the Upper Vindhyan Sandstone, (Lower Bhander Sandstone), which are interbedded with limestones, can be classified as "proto-quartzites".

GRAIN SIZE ANALYSES OF LOWER BHANDER SANDSTONE

Introduction

Grain size analyses of sediments are primarily made for the purpose of expressing the sorting and sizing of sediments in mathematical terms. Analyses permits precise statement of size distribution and sorting.

Mechanical grain size analyses of sediments requires separation into fractions or grades according to some size ratio. Technique depends upon dimensions and nature of the rock.

Analyses of coarse grained sediments can be done by sieving method. Grain size analyses of fine grained loose sediments involves a complex process. In this method analyses consists of preparing a suspension of the sediment in a dispersed state so that each particles acts as an independent unit in settling.

For hard, compact and fine grained sediments particle diameter may be determined visually with either a microscope, a camera or both. The measurement of large number of particles serves to give an approximation of the average grain diameter. The measurement of maximum diameters of 250 particles is done with the help of microscope provided with a micrometer ocular which is calibrated. A mechanical stage is used in such analyses.

Method of Analyses

As the Lower Bhander Sandstone is very hard and compact, the grain size analyses is carried out in thin sections. Five specimens of these sandstones were selected and thin sections were prepared. Each section was mounted on a microscope fitted with micrometer and mechanical stage. In each slide 250 quartz grains were studied and their largest diameter was measured. The results of this grain size analyses are tabulated in table No. 1.

Plotting of data and statistical parameters

The above data were utilised in plotting the cumulative curves (Figs. No. 1, 2, 3, 4 and 5). The ordinate is an arithmetic scale running from 0 - 100 %, grain size (in phi units) is plotted on the abscissa with coarser particles on the left. In order to indicate the grain size variation in these sandstones phi scale has been used instead of milimetre scale for such plottings.

The following parameters are determined from the cumulative curves :

1. Median ($Md\ \phi$) :- It represents 50% mark on the cumulative curve. It can also be [illegible] in mm.

2. Graphic Mean (Mz) (Folk) :- It is a measure of determining the over all size and this is expressed by the following formula :

$$Mz = (\phi 16 + \phi 15 + \phi 84)/3$$

It is better than Median because it takes into consideration three points on the cumulative curve .

3. Trask's Sorting Coefficient (So) :- It measures only the sorting in the central part of the curve and is given by the formula

$$So = Mm\ 25/Mm\ 75$$

4. Phi Quartile Deviation (QDØ) :- It is a measure of uniformity and is analogous of So (Trask's Sorting Coefficient) . It is given by the formula

$$QDØ = (Ø\ 75 - Ø\ 25)/2$$

5. Inclusive Graphic Standard Deviation (σI) (Folk):- The Graphic standard deviation is a good measure of sorting and is computed as (Ø 84 - Ø 16)/2. However, this takes in only the central two-thirds of the curve and as better measure is the Inclusive Graphic Standard Deviation given by the formula :

$$\sigma I = (Ø84 - Ø16)/4 + (Ø95-Ø5)/6.6$$

6. Phi Quartile Skewness ($Sk_q Ø$):- This is found by

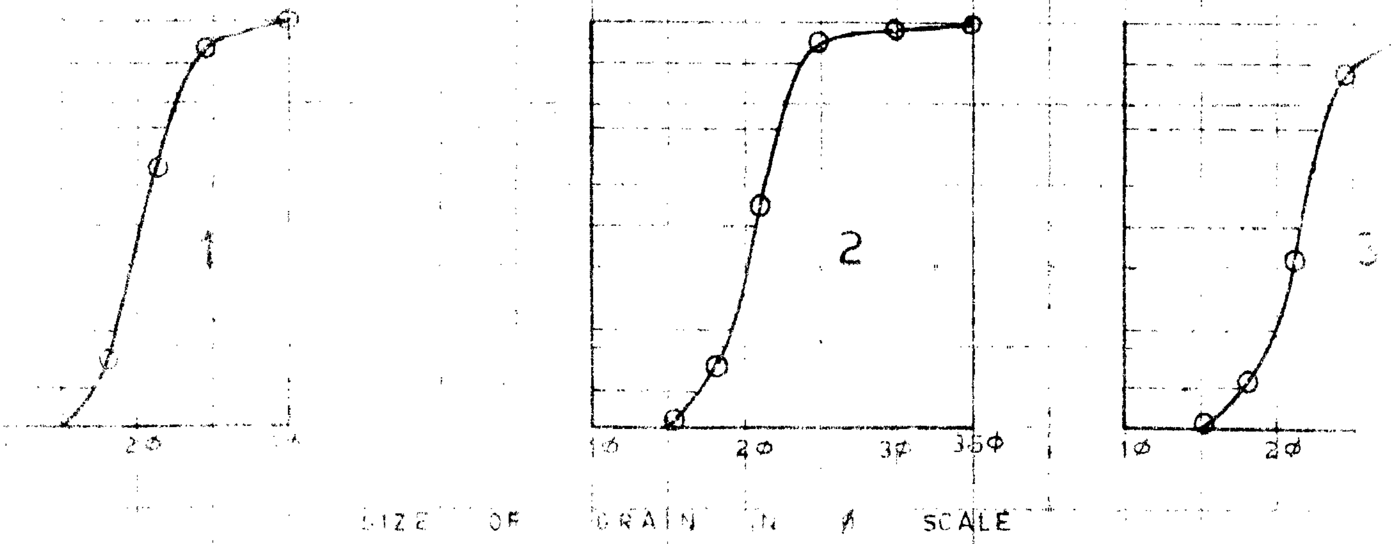
$$\frac{(Ø25 + Ø75 - 2\ (MdØ)}{2} .$$

7. Graphic Kurtosis (KG) (Folk) :- This is given by the formula

$$KG = \frac{Ø95 - Ø5}{2.44\ (Ø75 - Ø25)}$$

The above parameters were determined from the cumulative curves of the Lower Bhander Sandstone in table No.3.

SIZE COMPOSITION OF SANDSTONES REPRESENTED BY CUMULATIVE CURVES



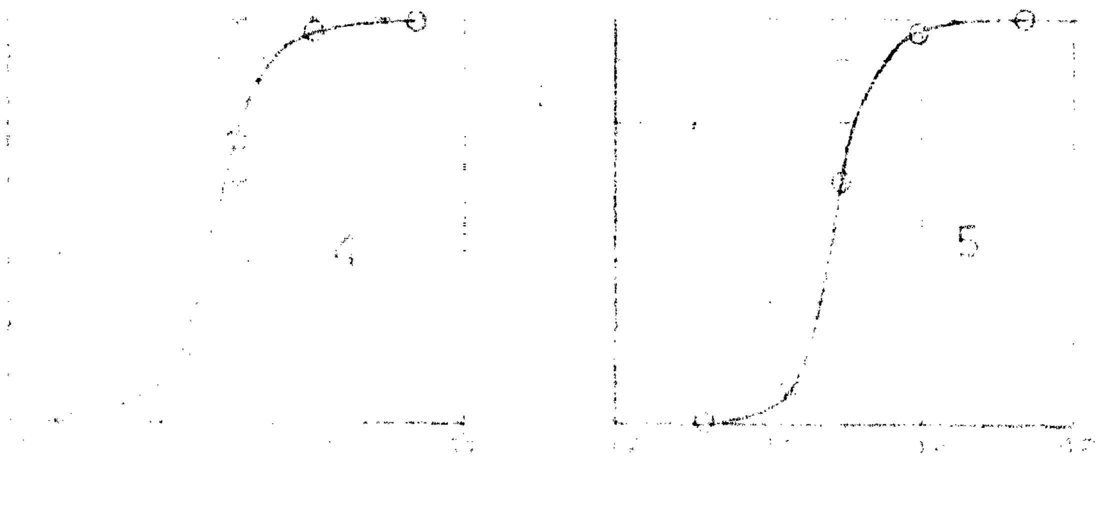


TABLE NO. 1

Range of size in mm.	Average size in mm	4/634		4/633		4/632		4/630		4/623	
		Nos.	%	Nos.	%	Nos.	%	Nos.	%	Nos.	%
.35 - .30	.325	8	3.2	8	3.2	4	1.6	2	.8	-	-
.30 - .25	.275	38	18.4	31	16.6	24	11.2	8	4.0	2	.8
.25 - .20	.225	114	64.0	100	56.6	79	42.8	33	17.2	19	8.2
.20 - .15	.175	80	96.0	98	94.8	114	88.4	132	70.0	129	66.2
.15 - .10	.125	10	100.0	12	99.6	27	99.2	17	99.6	96	98.4
.10 - .05	.075	-	-	1	100	2	100	1	100	4	100

TABLE NO. 2

Slide No.	Ø75	Ø25	Ø5	Ø95	Ø16	Ø84	Md. mm.
4/634	2.25	1.90	1.65	2.55	1.80	2.30	.28
4/633	2.2	1.95	1.66	2.45	1.85	2.30	.26
4/632	2.35	2.00	1.70	2.75	1.90	2.40	.25
4/630	2.55	2.2	1.85	2.90	2.15	2.65	.195
4/623	2.56	2.32	2.05	2.90	2.25	2.70	.182

TABLE NO. 3

Slide No	QDØ	Mz	So mm.	Md Ø	SKq Ø	SKg	σI
4/634	.175	2.06	1.26	2.05	.025	1.05	.261
4/633	.125	2.08	1.17	2.1	-.025	1.32	.233
4/632	.175	2.15	1.28	2.15	.025	2.12	.285
4/630	.175	2.38	1.23	2.35	.025	2.12	.285
4/623	.12	2.41	1.17	2.45	-.6	1.0	.243

As shown in the table No. 2, the sandstones have a median value from .182 mm. to .28 mm. and so they will be blassified as medium to fine grained sandstone.

The Inclusive Graphic Standard Deviation (σ_I) is less than 0.35 and hence sandstone can be classified as very well sorted (Folk, 1957).

Trask sorting coefficient (So) is between 1.17 to 1.28 which also indicates very good sorting.

Sandstone has an excess amount of fines as indicated by three positive values of Phi Quartile skewness.

The value of Kurtosis varies from 1.00 to 2.12. On the basis of Kurtosis following classes can be assigned to different sandstone specimens :

4/634, 4/623	-	Mesokurtic
4/633	-	Leptokurtic
4/632, 4/630	-	Very leptokurtic

—

CHEMICAL ANALYSES OF LIMESTONES

The Lower Bhander limestone is the chief economic deposit in the present area. It is, therefore, essential to know the exact chemical composition and variation in each band of limestone. Such a study will be of great help in utilising the deposit to its maximum.

Specification of Limestone for Cement purpose

According to the British specification No. 12, 1940, which is also the specifications for limestone in India, the limestone suitable for cement should normally contain not less than 40% of Cao and not more than 2.5 % of Mgo. Silica allowed is upto 14 - 15 % depending upon the type of clay used smaller amounts of sulphates (upto 2.75 %), iron oxide and alkalies (upto 1.2%) are not objectionable.

Limestone Analyses

Sixteen samples were selected from different horizons at Phalodi quarry belonging to Lower Bhander Limestone, for the chemical analyses. Out of these five samples were subjected to complete analyses and rest were partially analysed.

The results of complete analyses of five limestone samples are tabulated in the Table No. 1 and the partial analyses results of remaining specimens are given in the Table 2.

TABLE NO. 1

Location	SiO_2	Al_2O_3	Fe_2O_3	CaO	MgO	CO_2
A	13.25	3.04	1.06	45.11	1.05	36.01
B	14.10	3.45	1.48	43.42	1.11	36.43
C	12.65	2.80	1.01	44.81	.98	37.10
D	12.12	3.61	1.82	43.38	1.21	36.82
E	22.50	1.21	2.65	28.24	20.67	25.20

TABLE No. 2

Location No	1	2	3	4	5	6	7	8	9	10	11
CaO	43.4	43.1	43.3	42.8	43.8	40.2	44.0	43.8	41.8	42.6	43.5
MgO	1.05	1.33	1.82	1.66	1.72	1.25	.96	1.16	1.08	1.34	1.11

Locality

A = 200 yds. NW of Phalodi quarry Temple.

B = 100 yds. NW of Phalodi quarry Temple.

C = 100 yds. NE of Phalodi quarry Temple.

D = 200 yds. NE of Phalodi quarry Temple.

E = Dolomitic band at Amarkund.

Specimen No. 1, 2, 3, 4, 5, 6, 7, 8, 9, 10 and 11 are collected at an interval of 20 feet across the strike through Todra as shown in the Geological map.

Results of the chemical analyses of the Lower Bhander Limestone indicate that the limestone is suitable for the manufacturing of cement. Samples from the dolomitic band B gives more than 20 % Mgo and can not be used for cement. An average Lower Bhander Limestone contains more than 40% Cao which is above the limit required for cement. The Mgo percentage is less than 2% which is favourable in making the cement. Other impurities like SiO_2, Al_2O_3, Fe_2O_3 etc. are within the specified range.

<u>Classification of Limestones</u>

Pettijohn (1958) has given the following table for the classification of carbonate rocks which depends on the calcite - dolomite amount.

Percent Calcite: 100–95	95–90	90–50	50–10	10–?0–0
LIMESTONE	Mg. LIMESTONE	Dolomitic Limestone	Calcitic Dolomite	DOLOMITE
0–5	5–10	10–50	50–90	90–100

With respect to this classification Lower Bhander carbonate rocks can be classified as limestones except the dolomitic band underlying the Lower Bhander Sandstone which can be grouped under dolomitic limestone($MgCO_3$ % more than 10%).

Pettijohn has further divided the limestones into Autochthonus and Allochthonus types depending upon their origin.

The limestones which grow in place by biochemical action may be termed accretionary or Autochthonus limestones. It is from these deposits that much or most of the transported or redeposited limestones are derived and named as 'Allochthonus Limestone'.

The limestone present in the area will belong to Autochthonus group, as these are the result of precipitation of carbonate solutions at the site of deposition.

The characteristic feature of Autochthonus limestone is their association with shales and unsorted as to size, which holds to further limestone in this area.

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SEDIMENTARY STRUCTURES

The rocks belonging to the upper Vindhyan system in this area are surprisingly devoid of sedimentary structures in comparison to those described from the type area by R.C. Mishra and N. Awasthi (1962).

The following sedimentary structures are observed in the upper Vindhyan rocks of this area.

1. Cross Bedding
2. Ripple marks
3. Intraformational flat pebble Breccia.
4. Penecontemporaneous deformation.

Cross Bedding

Cross bedding structure has been found in the upper Rewa sandstone and lower Bhander sandstone.

This structure is of tabular type in upper Rewa sandstone and has been noted about .4 km. in south-east direction from Phalodi quarry temple. The corss laminae are very thin having a length of 30 cms. and thickness is about 2.5 cms. and extending for about 60 cms. The direction of current represented from this structure is from N 30°.

The cross bedding structure in the lower Bhander sandstone is seen about .2 km. from the Sadakund top. The thickness of the individual foreset laminae varies from 2.5 cms. to 8 cms. and their length is about 60 cms. The thickness of single cross bedded unit is about 1.5 metre. The current direction is from N 40° (Fig. No. 1).

Ripple Marks

Two types of ripple marks are observed in the lower Bhander sandstone and upper Rewa sandstone. They are oscillation ripple marks (symmetrical type) and transverse ripple marks (assymmetrical type).(Plate No. 5 Photograph No. 2).

Oscillation ripple marks or symmetrical ripple marks are seen in upper Rewa sandstone near Bhagwanpur village. Current direction could not be determined due to their symmetrical nature.

Transverse or Assymmetrical ripple marks are present in the lower Bhander sandstone near Nondrehri top (Hill). The direction of current appears to be from N 10°.

Intraformational Flat Pebble Breccia

This sedimentary structure most commonly occurs only in red lower Bhander limestone and can be seen in different outcrops. It is not confined to a particular horizon. It consists of a assemblage of thin broken flat and elongated pebbles of limestone cemented together with fine grained calcitic material. The orientation of the flat, elongated pebble is irregular. The size of the flat pebble varies from .5 cm. to 3 cm. in length.

Origin

An intraformational breccia is a rudaceous deposit formed by penecontemporaneous fragmentation and redeposition of the stratum (Walcott, 1894; Field, 1916). Such fragmentation and redeposition is but a minor interlude in the deposition of the formation and in some cases may be wholly subaqueous. The debris is always of very local origin, has undergone very little or no transportation and is but slightly worn.

Such breccias are probably in part the product of desiccation and induration of the lime muds and redeposition in a matrix of similar composition and in part the product of subaqueous fragmentation and transport by turbidity flows; (F.J. Pettijohn (1957).

Penecontemporaneous Deformation

This is most commonly observed in the lower Bhander limestone near Sadakund, Amarkund and Dumeda village. The lower Bhander limestone bands show gentle warping in the form of anticline and syncline.

SEDIMENTATION

The environments of sedimentation can be interpretated from the studies of lithologic variation in the stratigraphic sequence, sedimentery features and structures.

The local environment is characterized by both physical and chemical characteristics. The physical factors include current velocity, current stability, water depth, fluidity (viscosity and density) of the depositional medium. The chemical factors are principally, the oxidation, reduction potential (EH), the acidity or alkalinity (pH), the concentration or salinity and temperature of deposition medium.

The tectonic environment is the most basic. Diastrophism is the fundamental geological process and produces the inequalities in relief which set in motion the counteracting process of erosion and sedimentation.

Here an attempt has been made to determine the provenance for the Lower Bhander Sandstone from the study of the grain size and modal analyses data for this rock.

The pattern of sedimentation has been interpreted on the basis of the study of orthoquartzite-limestone association and the sedimentary structures present in the area.

The results of the grain size and modal analyses data (chapter III) of the Lower Bhander Sandstone indicate that the formation is very well sorted with the high percentage of quartz (more than 90%). Good sorting along with high percentage of quartz would indicate high degree of maturity. Further, the study of sandstone shows that the quartz grains are of two types. Some are having turbid appearance and others are quite clear but still show wavy extinction. Wavy extinction and turbid nature of quartz grains indicate that they are derived from metamorphic terrain. The cementing material of the sandstone is mostly siliceous with very little clay and ferruginous matter which would indicate that the parent rock were devoid of clayey material.

The above discussion indicates that the source rock for the Lower Bhander sandstone is Aravalli quartzite which is further supported by the presence of common heavy minerals such as tourmaline and zircon in both the formations. The study of paleo-current analyses also shows that the sediments were derived from North-east direction where Aravallis are exposed(about 2 kilometres).

Although in the earlier discussion on the petrography of sandstone the name "protoquartzites" is given to the Lower Bhander Sandstone, but if we take into consideration the sorting and maturity of the quartz grains they are more orthoquartzitic.

We can, therefore, consider the association of orthoquartzite and limestone in the Upper Vindhyans for interpreting the depositional environments. Shale is also a component even in thicker sections. Carbonates are generally dominant. The sandstones are having matured and rounded quartzites.

Cross bedding and ripple marking are quite common in sand-stone. Flat pebble breccia is common in Lower Bhander Lime-stone. Shales are comparatively rare and follow the carbonate stage of deposition.

The orthoquartzitic has been described by Pettijohn (1959) to be the product of sedimentation marginal to a very low lying stable land surface. The evidence of stability is in the maturity of the sands. Throughout the depositional history the water was shallow and was many times withdrawn. The cross bedding in orthoquartzitic sandstone indicates local zones of turbulence. The flat pebble breccia likewise suggests repeated withdrawls of the water.

The above characters indicate shallow water environments of deposition.

CHAPTER V

ECONOMIC RESOURCES OF THE AREA

Building Stone

The usual building stone of the Upper Vindhyans is the Lower Bhander sandstone and Upper Bhander sandstone, the latter is not present in the area.

The Lower Bhander sandstone is exposed all along the arcuate (hill) Phalodi hill top. It is well jointed and bedded. These two properties help in the quarrying of sandstone. It is locally quarried at various places. A quarry of Lower Bhander sandstone is present North-east of the Bhatpura village. At this quarry big slabs of 5 x 50 x 200 cms. size are taken out and are sold for Rs.60.00 per slab. Although it is too far away from the bigger towns, it is employed as a building stone in nearby villages for roofing and flooring purposes.

Dolomitic limestone is also used locally as building stone in nearby areas.

Aravalli quartzites near Rawanjna Dungar village are also quarried and are used as building stone.

Limestone

The Lower Bhander limestone is the chief deposit of economic interest in the Upper Vindhyans. It is at present being extfnsively quarried at Phalodi for the manufacture of cement by Jaipur Udhyog Limited. The structure of the quarry area is simple. The limestone beds are simple dipping with an amount of 5° - 25° due NW. The sequence is the normal one of Gunurgarh shales, Lower Bhander limestone, Lower Bhander sandstone. The Upper most 65 metres thick bluish gray limestone is of high grade as confirmed by chemical analyses given in chapter II. The intermediate red colored limestone is found interstratified with thin layer of red soft shales, which is very difficult to remove, except by screening. This interstratified shale in red Lower Bhander limestone lowers the grade of limestone and poses a great problem before the cement manufacturers. The lower most horizon of Lower Bhander Limestone is marly.

The Lower Bhander Limestone which is quarried at Phalodi can be traced all along the valley,(Phalodi quarry to Dumeda village).

At Dumeda village a new quarry is under development by Jaipur Udhyog Limited.

The open pit mining methods are employed here. Quarrying is done by making benches of 12 x 12 metres.

China Clay (Kaolin)

It is impure and earthy in color and has been formed by the decomposition of aluminous material (shales). It occurs in the form of a small band .1 km NE of Balapura village and is associated with Aravalli quartzites.

It is locally used as pigment.

CONCLUSION

The field work carried out in the area and the laboratory studies which followed it have led to some conclusion. A brief discription about these conclusions is attempted bblow.

The Upper Vindhyans exposed in the area seem to have been deposited in faulted basin, caused by the Great Boundary Fault. The Aravalli quartzites are the provenance for the Upper Vindhyan Sandstone as is evident from thin section studies.

The sandstones which are interbedded with limestone show a composition in the range of protoquartzites. The texture of these rocks has been influenced by that of Aravalli quartzites.

The results of the chemical analyses of Lower Bhander Limestone indicates that it contains less impurities. Cao percentage is more than 40 and Mgo is less than 2%. Therefore, it is suitable for the manufacture of cement.

The conspicuous absence of sedimentary structures of linear type from the Upper Vindhyan is difficult to explain but the presence of structures due to disrupted bedding is explained as a result of penecontemporaneous activity.

The sedimentary structures of the linear type from the Aravallis have indicated that the paleocurrent were from SW and SSE and the beds dip due NW. This is practically in conformity with the dip of the formations which would indicate that the sediments were inclined during the uplift in the direction of regional slope.

The presence of sedimentary structures like ripple marks and flow cast at the top and base of the same bed point to a very special environment. As mentioned earlier Kuenen believes it to be a typical indication of a turbidity current environment. In order to get further support for such an environment, a greater search is needed for other sedimentary structures like Flute cast, Bounce cast etc. which are typically indicative of turbidity environments.

The Aravallis have been intruded by igneous rocks (dolerite). The quartzite at contact do not show any specific mineralogical changes except local baking effect. The intrusive rock is doleritic in composition as inferred from the thin section studies.

SCOPE FOR FUTURE WORK

Geological account of the area as in the report has indicated the scope of future work.

The presence of wide tracts of unmetamorphosed Aravalli rocks with well preserved sedimentary structures of the linear type afford much scope for further work. Paleocurrent studies on a regional basis would throw much light on the sedimentation history of the Aravallis and reveal evidence on the rocks of the Aravalli system.

The regional control by the Great Boundary Fault on the deposition of the Vindhyans should also be studied in more detail. This may indicate differences in the deposition of the Vindhyans in this area as compared with those of the type area where they are comparatively less disturbed.

Another problem of fundamental interest could be the relation between the orthoquartzites and the control of provenance on the origin of such rocks.

LOCALITY INDEX

-	Latitude		Longitude	
	o	8	o	'
Ahli	25	18	76	21
Bhatpura	25	49	76	23
Balapura	25	20	76	21
Dumeda	25	62	76	24
Hanćwar	25	55	76	24
Manćrehri	25	19	76	24
Phalodi	25	21	76	25
Rawanjna Dungar	25	24	76	23
Todra	25	21	76	26

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PLATE 1

PHOTOGRAPH 1 - A view of the Phalodi Area showing the Aravalli ridges in the Background.

PHOTOGRAPH 2 - Strike ridges of Upper Rewa sandstone.

Locality: East of Phalodi Temple.

PLATE 1

1

2

PLATE 2

PHOTOGRAPH 1 - Steep escarpments and strike ridges of Aravallis.

Locality : Near Handwar village.

PHOTOGRAPH 2 - Dip slope in Lower Bhander Sandstone.

Locality : Near Bhatpura village.

PLATE 2

1

2

PLATE 3

PHOTOGRAPH 1 - Lower Bhander Sandstone showing bedding joints and vertical joints.

Locality : Near Mandrahri Hill top.

PHOTOGRAPH 2 - China clay quarry.

Locality : .2 km. North -east of Bhatpura village.

1

2

PLATE 4

PHOTOGRAPH 1 - Complex folding in Aravalli shales and phyllites.

Locality : North-East of Amli Railway Station.

PHOTOGRAPH 2 - Arvalli shales showing asymmetrical Anticline.

Locality : Near Handwar village.

PLATE 5

PHOTOGRAPH 1 - Closely spaced bedding planes in Upper Rewa Sandstone. Photograph also shows variation in the amount of dip.

Locality : Near Jhojaji Temple

PHOTOGRAPH 2 - Oscillation ripple marks in Upper Rewa Sandstone which are traversed by irregular joints.

Locality : North-West of Dolara x village.

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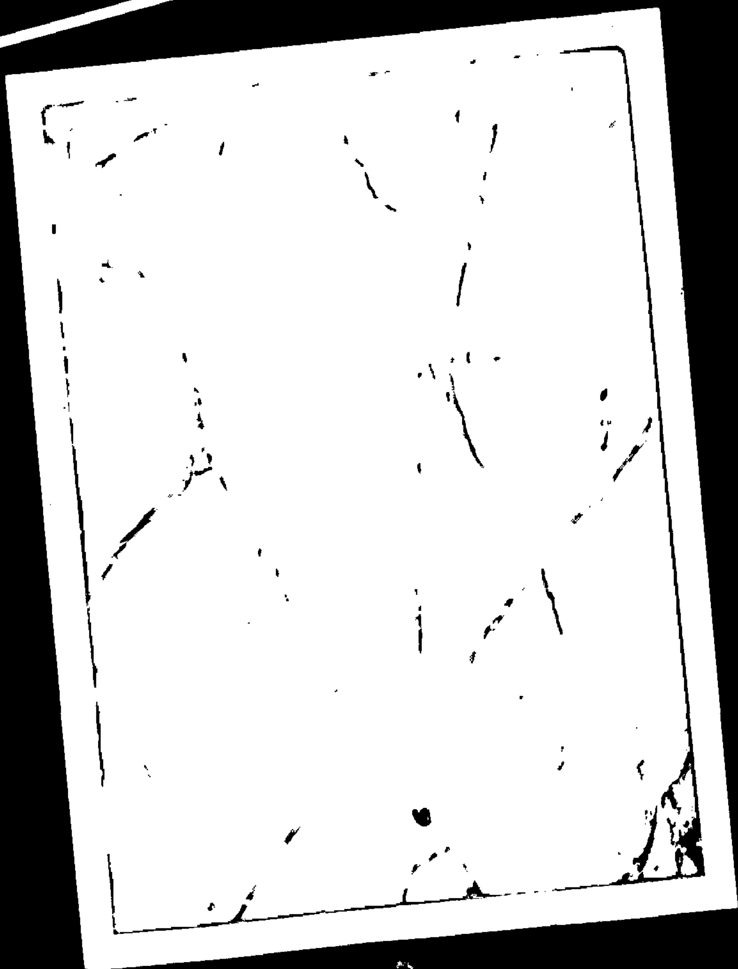

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PLATE 6

PHOTOGRAPH 1 - Lower Bhander Limestone showing Minor folding.

Locality : Amar Kund, Phalodi quarry.

PHOTOGRAPH 2 - Upper Rewa Sandstone showing bedding joints and vertical joints.

Locality : .5 km East of Phalodi Temple.

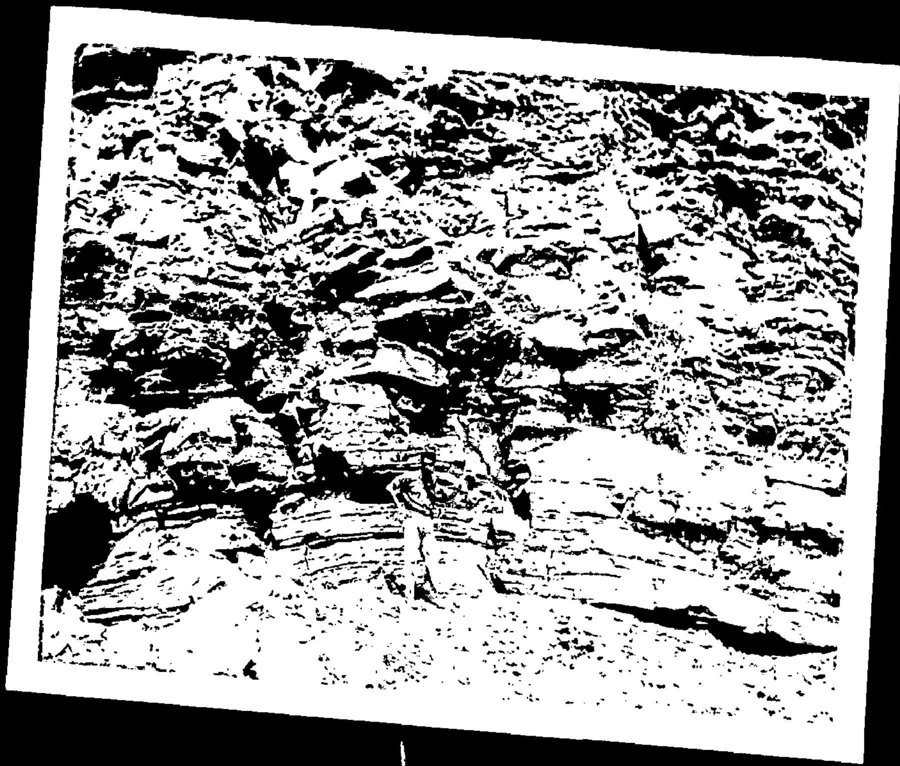


PLATE 7

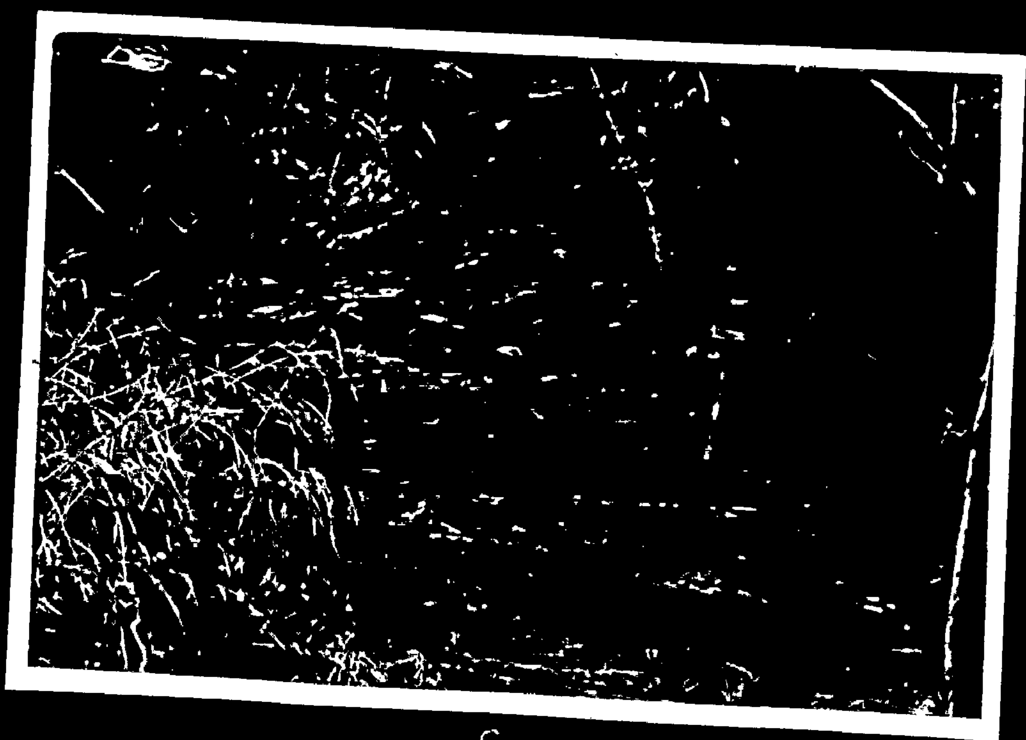
PHOTOGRAPH 1 - Minor Warping in Upper Rewa Sandstone

Locality : .5 km. East of Dumeda village.

PHOTOGRAPH 2 - Warping in Lower Bhander Sandstone .

Locality : South-West of Mandrehri.

1



2

PLATE 8

PHOTOGRAPH 1 - Exposure of Lower Bhander Limestone covered with broken chips which is a result of blasting.

Locality : Sadakund, Phalodi quarry.

PHOTOGRAPH 2 - Lower Bhander Limestone showing typical Elephant skin weathering.

Locality : Phalodi quarry.

PLATE - 8

1

2

PLATE 9

PHOTOGRAPH 1 - Exploratory drilling in Lower Bhander Limestone.

Locality : Phalodi quarry area.

PHOTOGRAPH 2 - Exposure of Lower Bhander Limestone.

Locality : Near Sadakund, Phalodi quarry.

PLATE 10

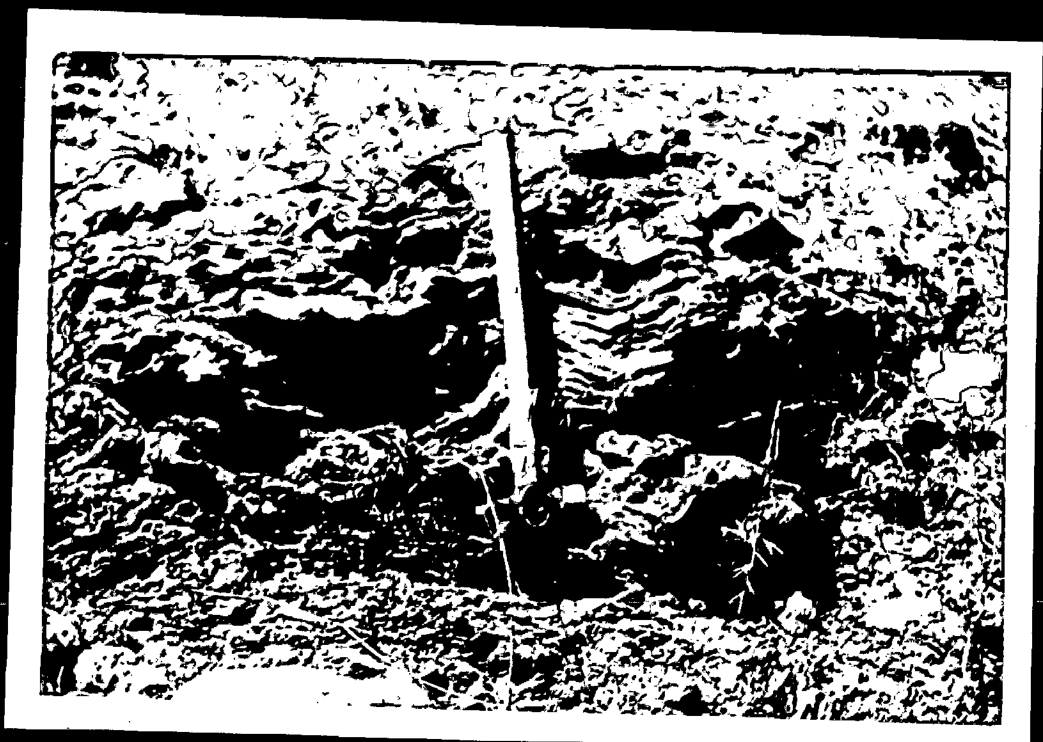
PHOTOGRAPH 1 - Aravalli shales showing major and minor folding.

Locality : Near Handvar village.

PHOTOGRAPH 2 - Minor folding in Aravalli shales.

Locality : .2 km. North of Amli Railway Station.

1



2

PLATE 11

PHOTOGRAPH 1 - Flow cast structure in Aravalli quartzites.

Locality : .2 km. mf North-West of Rawanjna Dungar Railway Station.

PHOTOGRAPH 2 - Ripple marks in Aravalli quartzites. Pencil points in the direction of Paleocurrent.

Locality : Near Rawanjna Dungar Village.

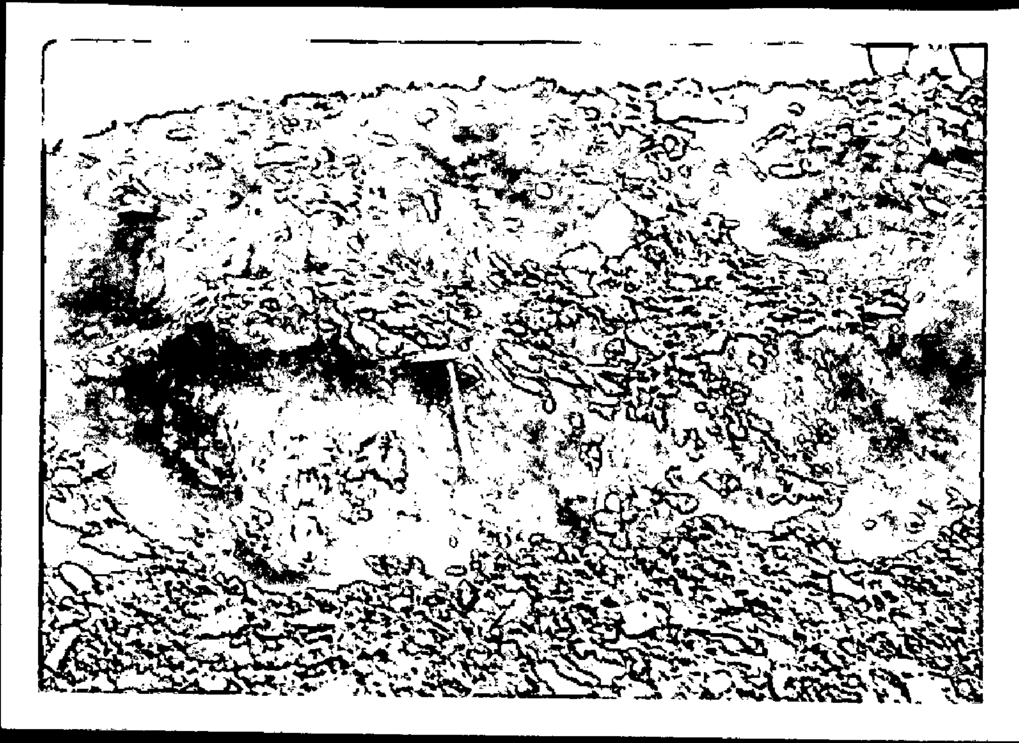
PLATE 12

PHOTOGRAPH 1 - Minor folding in Aravalli shales.

Locality : .2 North-West of Amli Railway Station.

HOTOGRAPH 2 - China clay exposure.

Locality : North - East of Balapura village.



1

2

PLATE 13

PHOTOGRAPH 1 - Folds in Upper Rewa Sandstone.

Locality : .2 km. North-East of Dumeda village

PHOTOGRAPH 2 - Interformation Breccia in Lower Bhander Limestone (Specimen)

Locality : Phalodi quarry area.

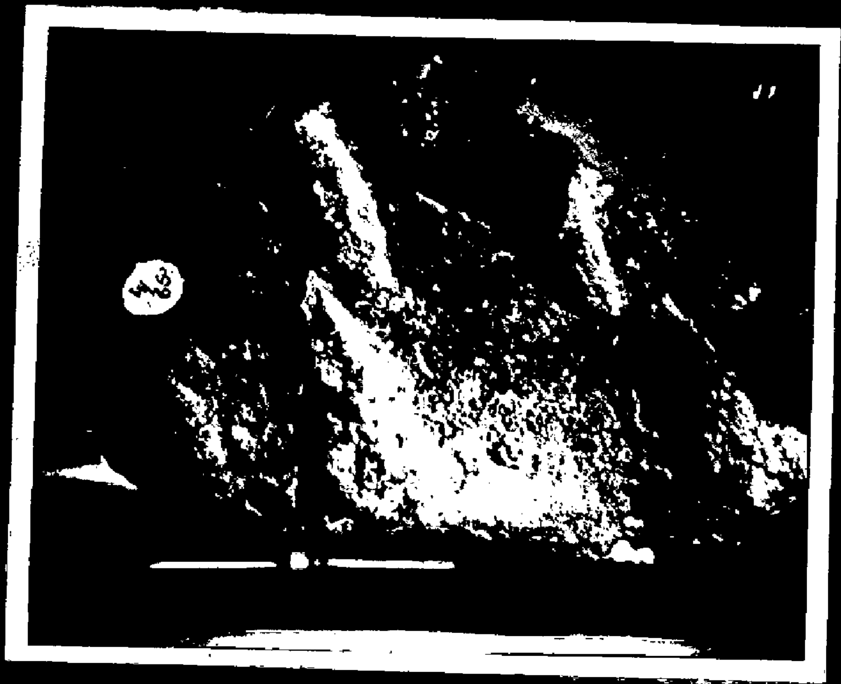
PLATE 14

PHOTOGRAPH 1 - A specimen of Aravalli Quartzites showing flow cast structures.

Locality : .2 km. North-West of Rewanjna Dungar Railway Station.

PHOTOGRAPH 2 - Same structures in another specimen of Aravalli quartzite.

Locality : Same as above.



1

2

PLATE 15

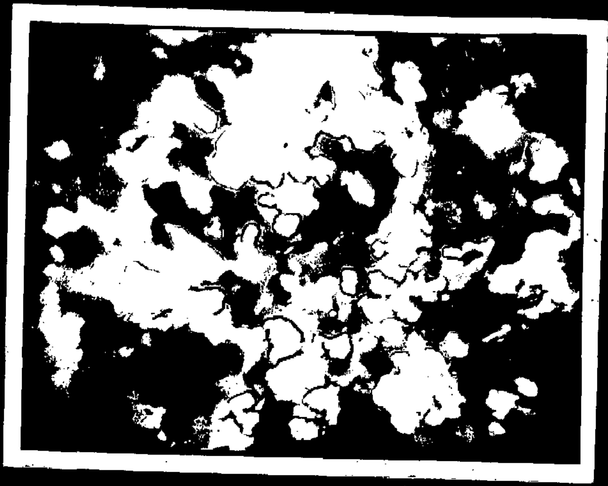
PHOTOMICROGRAPH 1 - Photomicrograph of Lower Bhander Sandstone (4/633). Quartz grains are abundant with little cementing material.

Locality : Phalodi quarry area.

PHOTOMICROGRAPH 2 - Basal Aravalli Quartzites (4/123) showing chert grains in veins.

Locality : Near Phalodi quarry.

PLATE 15



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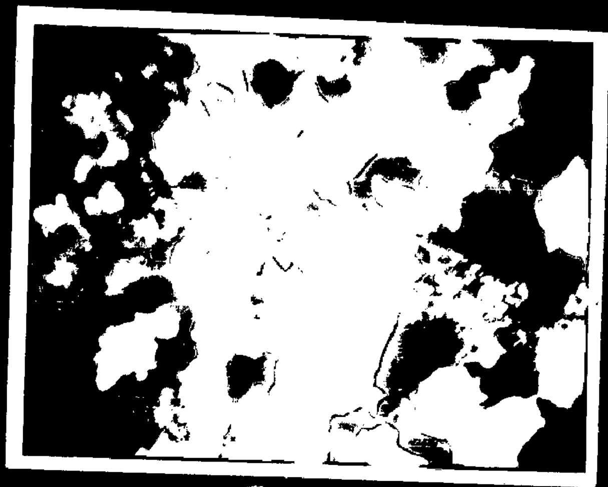

2

PLATE 16

1

PLATE 16

PHOTOMICROGRAPH 1 - Porphyritic basalt. Phenocrysts are either of plagioclase & pyroxenes or of coarse grained basalt embedded in a fine basaltic ground mass.

Locality : Rawanjna Dungar Railway Station.

PHOTOMICROGRAPH 2 - Upper Aravalli Quartzites (4/6607

The interstitial material is recrystallised.

Locality : Near Rawanjna Dungar Village.

PLATE 17

PHOTOMICROGRAPH 1 - Lower Bhander sandstone showing over growth around quartz grains.
Locality : Phalodi quarry

PHOTOMICROGRAPH 2 - Upper Aravalli quartzite (4/680)
showing over growth in quartz grains.
Locality : Rawanjna Dunger village.