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MAGNETIC AND PETROGRAPHIC ANALYSIS OF ANDESITE ROCK BODIES, KHAIRMALIA, SOUTH OF CHITTOURGARH, RAJASTHAN

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Abstract: Thirty oriented fresh block samples were collected from ten suitable sites of the outcropping andesite rock formation to study their Petrographical characteristics and Magnetic properties. The analysis of these rocks around Khairmalia shows that the magnetite crystals are fresh and are in perfect shape. These crystals are present in sufficient quantity i.e. measured as 10 to 20% in various rocks in the area. The measured values of the natural remanant magnetization (NRM), magnetic susceptibility (MS) and Koenigsberger (Qn) Ratio shows typical variations in their values. Their limits states that the beginning of the Vindhyan Supergroup crustal formation during Palaeoproterozic Period was of oscillating and disturbed type.
Key words: Vindhyan Supergroup, Khairmalia Andesites, Petrography, Palaeomagnetism.

INTRODUCTION

The Indian shield is characterized by the presence of several non-linear Proterozoic sedimentary basins, which are collectively referred as Purana Basins (Soni et al., 1987). The largest one is the Vindhyan basin (Raza et al., 2009). The Vindhyan basin covers a larger part of the Peninsular India, an area of about 1,04,000 sq km. Vindhyan basin started evolving during the late PaleoProterozoic with the effusion of Khairmalia andesite formation and deposition of sedimentation (Sankaran, 2008). The mode of occurrence of Vindhyan rocks shows unconformable relation with the basement rocks of granitic composition. The western margin of the Vindhyan basin is marked by the presence of

synsedimentary mafic volcanics, among these the andesitic rocks described as Khairmalia andesite. The margins of the Vindhyan basin are very much disturbed due to the oscillating nature of basin conditions affected by reactivation of fundamental fractures, which resulting ultimately in the Great Boundary Fault towards the close of the Vindhyan sedimentation (Prasad, 1984).

Geology and Sampling

Khairmalia Andesite rocks occurring over the Berach granite is a synsedimentational with the Khardeola sandstone and locally conglomerate also present. The Khairmalia andesite outcrops are exposed in South and Northwest of Khairmalia ($24^0$29'; $74^0$22') along road side and are continuing towards North. Nearly 5 km strike length of andesitic body has been sampled and shows little variation in color of the rock. Thickness also varies from 25 to 75 meters. The unconformity is marked by amygdaloidal andesitic flows, Conglomeratic beds and difference in grade of metamorphism is seen. It is maintaining continuity and parallelism with adjoining rock formations.

The basement for the Vindhyans is pre-Aravalli rocks, referred to as the Bhilwara Supergroup, which comprise shale, slate and phyllite intercalated with dolomite / limestone and quartzite. The contact between two sequences (Ray et al., 2003) is that of distinct composite unconformity marked by Khairmalia amygdaloidal Andesite, Khardeola Conglomerate or Bhagwanpura Conglomerate or by a mega-lineament called Great Boundary Fault (GBF). The Vindhyan sedimentation started with Khairmalia volcanic activity. The lower part of the Basal Satola Group a) Khairmalia Andesite and pyroclastics b) Khardeola and Kanoj Sandstone and shale (Raza et al., 2002) which represent the coastal facies and the upper part of this group Bhagwanpura limestone with conglomerate represent the tidal flat deposits. The basement rocks, earlier included into the Aravalli system are found to be the part of the pre-Aaravalli sequence and are named now "Bhilwara Supergroup". The age of the base of the Vindhyan is obtained from the radiometric age of Khairmalia Andesite is 1250 Ma (Crawford and Compston, 1973) and the species of stromatolites (Carmichael, 1961) found in the Bhagwanpura Limestone

which indicate Lower to Middle Riphean age (1000 Ma to 1300 Ma) and also making the unconformity (Prasad, 1984).

The "Khairmalia flow" referred by Heron as "Khairmalia amygdaloid" within the Aaravalli System, is as mentioned, found to be at the base of Vindhyan and the andesitic rock composition on petrographic studies and as such the formation has been named as "Khairmalia Andesite" with pyroclastic / tuffs as member. This overlies unconformable of the Berach Granite or the pre-Aravalli slate and is synsedimentational with the succeeding Khardeola Sandstone. The representative of Khairmalia Andesite near Kanauj is a tuff which is succeeded by Kanauj Sandstone. Such tuffaceous rock is also found at the base of Bhagwanpura formation on west of Chittorgarh on the southern side of river Berach. The Khairmalia volcanics, through patchy due to basement irregularities, are having distinct lithology. They represent a significantly major break, indicating disturbances and fissure effusion along a deep seated ancient fracture. The Khairmalia Andesite, Khardeola Sandstone including Kanauj Sandstone and Bhagwanpura Limestone have been grouped into Satola Group after the village Satola, where they have well developed. The generalized Stratigraphic sequence of Vindhyan basin in Chittorgarh is given in Table- 1.

Table-1: Generalised Stratigraphic Sequence of Vindhyan Basin in Chittorgarh Area.

WEST VINDHYAN BASIN in CHITTORGARH

		CHITTORGARH-BUNDI AREA			
ERA	**SUPERGROUP**		Group	Formation	Thickness(m)
	V I N D H Y A N S	UPPER VINDHYANS	BHANDER	Deccan Trap **- - Unconformity - -**	
			REWA		
			KAIMUR-QUARTIZITIC SANDSTONE		
		LOWER VINDHYANS	SEMRI	Suket shale Nimbahera Limestone Nimbahera shale Khorip-Malani sandstone Binota shale Sawa grit Bhagwanpura limestone Khardeola sandstone/grit Khairmalia andesite	165 150 60 50 160 150 250 160 70

				---Unconformity---	
Archean	**Pre-Aravallis**				

Khairmalia Andesites

The Khairmalia intermediate amygdaloidal andesitic flows (Figure 1) including pyroclastics occur unconformably over the Berach Granite (Bundelkhand Gneisses) or in a few places over the pre-Aravalli metamorphites grouped into Bhilwara Supergroup (Heron's Aravalli) and have an inter-beds of quartzitic sandstone. The flows are well exposed between Uthail and Khairmalia, east of Katai - Madhopur, east of Dholapani, around Patia-Untakhera and further south-west of Jambuwella.

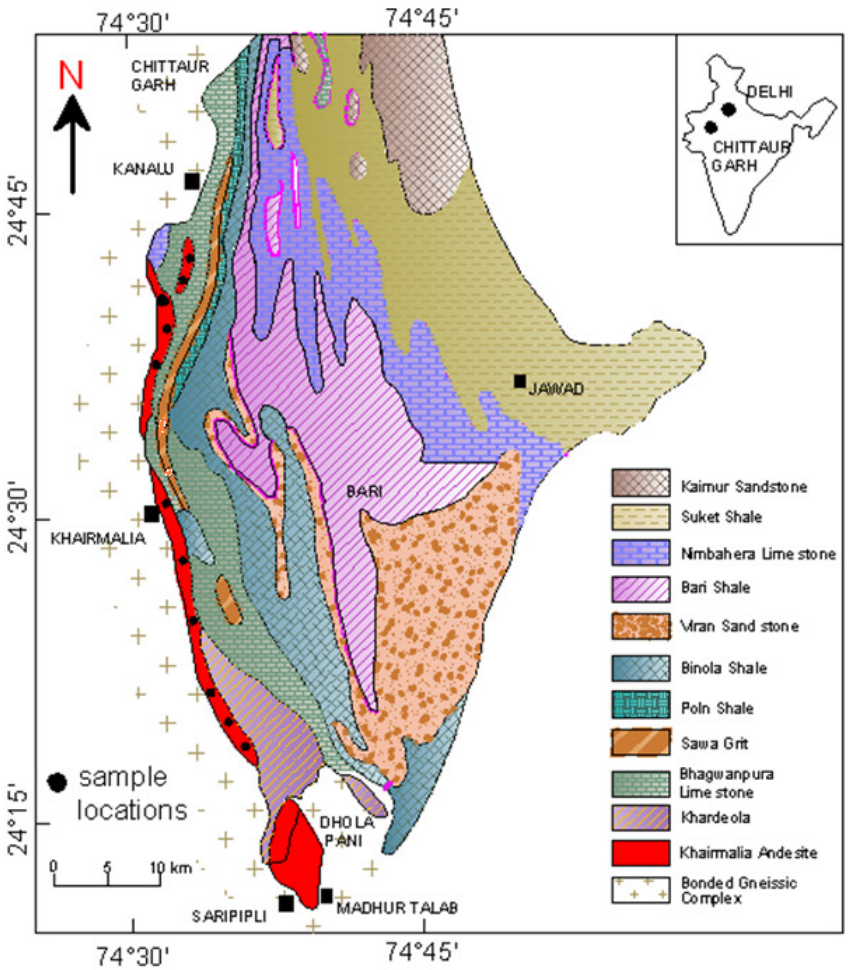

Fig. 1: Geological map of part of Vindhyan basin in Chittorgarh, SE Rajasthan showing the palaeomagnetic sites near Khairmalia (modified after Raza et al., 2002).

The flows are about 40 m thick near Khairmalia, but are over 100 m in thickness further south in Untakhera – Madhuratalab area. Between Ratanpura and Pindri about 15 m thick pyroclastics including tuffs are seen in the lower part of the flows. The tuffaceous rocks are also seen 1.5 km south-east of Kanauj and south of Dhanet on southern bank of river Berach. The individual flows are 2 – 12 m thick with amygdaloidal tops, varying from a few cm to 5 m in thickness. The number of flows seen in any section is variable. There are 9 flows near Khairmalia, 20 flows east of Katai-Madhopur and further south, and thus there is a general thickening towards south.

The Khairmalia andesitic rock is mainly fine grained and dark purple, pink, greenish and greenish brown in colour. It is, when fresh, hard and break with a subconchoidal fracture. Its Sp. Gravity ranges from 2.65 to 2.80. Amygdales are generally circular or ellipsoidal, ranging in size from mm to cm and filled with a dark green silicate-chloritic mineral, calcite, siderite, chert or quartz; (a) quartz around amygdales of chlorite, (b) pyrite around amygdales of quartz, (c) siderite around amygdales of calcite are seen. Specks of chalcopyrite and encrustation of malachite have also been noticed. The pyroclastics are dirty green to brown, fine to coarse-grained and compact, often showing indistinct or crude stratification. Just south-west of Pindri, greenish andesitic rocks are followed downwards by a metre or so tuffaceous rock resting on pink medium grained Berach Granite occupying the bottom parts. The rock is mainly an andesite but varies to trachy-andesite or basaltic-andesite at places (Prasad B, 1984).

The Khairmalia andesitic flows mark the western edge of the Vindhyan basin and their generation must be related with the basin tectonics responsible for initiation of Vindhyan sedimentation and reactivation of associated basement fractures at the margin. Some evidence in this respect may also be found in its association for a major part with the Berach granite.

Sampling and Methodology

The study area is located nearby Chhotisadri, which is at south of Chittorgarh, Rajasthan. Traverse has been taken all along N-S of the exposed andesitic bodies. Figure 3 shows the field photographs of the andesite rock bodies. Thirty oriented block samples from ten sites were collected for magnetic and petrographic studies. The oriented block

samples were made as standard specimens (25 mm diameter x 22 mm length) for laboratory measurements and thin sections were prepared for petrographic analysis. The magnetic studies (Radhakrishnamurthy and Deutsch, 1974) comprise of measurement of the remanent intensities and susceptibilities using Molspin mini spin Magnetometer and Kappa Bridge (MFK–1, Brno, Czechoslovakia) at Palaeomagnetism laboratory of National Geophysical Research Institute and petrographic studies are carried out under the refraction and reflection microscopes (Nikon) at petrological laboratory, Udaipur.

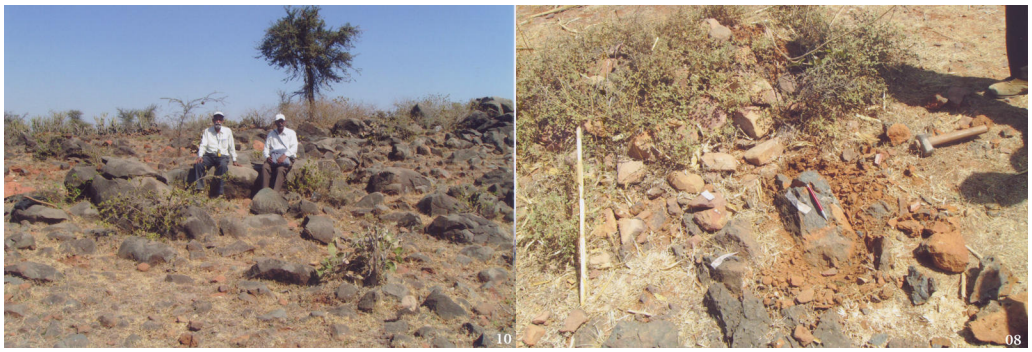

Fig. 2: Field photographs showing andesite outcrops and in-situ marked oriented block sample.

Magnetic Analysis

The magnetic analysis is carried out to find out the magnitude (intensity) of the natural remanent magnetization, Susceptibility and Qn-ratio. NRM intensity was measured for all the specimens on Molspin minispin Spinner Magnetometer and values varied from 0.05 to 388.34 A/m. The Magnetic Susceptibility was measured for all specimens on Kappa Bridge System. The values varied from 1.00 to 9.95 SI units. The Koenigsberger Ratio (Qn), which is the ratio of natural and induced magnetic intensities has been computed by using the measured intensity and susceptibility values for all specimens by assuming a value of 0.05 mT for the inducing field that is equivalent to that of the Earth's magnetic field value. The computed value varies from 1.82 - 4.15**.** As all the values of the specimens are having > 1 value indicating that the samples are good enough and suitable for palaeomagnetic investigations. Figure 4 (a, b and c) show the histograms of the Intensities, Susceptibilities and Koeningsberger Ratio respectively. The variations in values of site-wise maxima and minima are given in Table 2.

Petrography

Khairmalia andesites are showing well preserved amygdaloid structure and pisolitic structure evident of volcanicity (Balasubrahmanyan, 2006)**.** Andesite generally described as the surface equivalent and having intermediate composition. Quartz is less and predominantly occurs in matrix and mixed with feldspar that are hardly distinguished. Diorite contains more silica than most of the andesites. The essential minerals of andesite are plagioclase and one or more of the mafic minerals, hypersthene, clinopyroxene, hornblende, biotite and olivine.

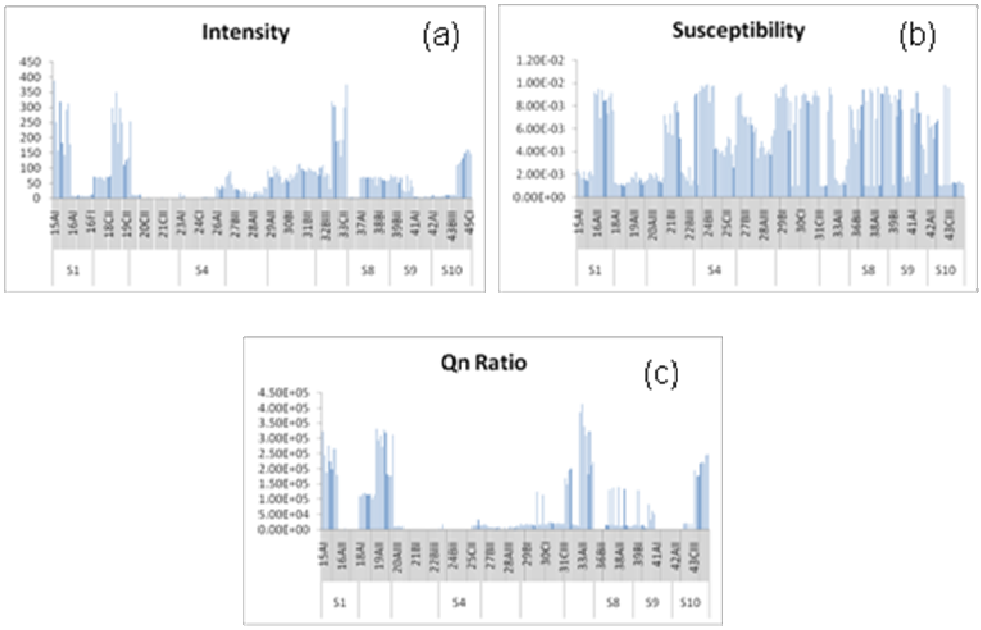

Fig. 3: (a) Histogram of NRM intensity (b) magnetic susceptibility (c) Qn – Ratio.

Typical andesites are almost without exception porphyritic and Khairmalia andesites also shows porphyritic to non porphyritic and ophitic texture. These may be categorized as basaltic andesites on the basis of colour index and composition (Poornachandra Rao et al., 2004). The determination of the plagioclase composition by optical means can be determined near approximate and in Khairmalia andesites their presence are as phenocrysts crystals which are perfect in shape, trivial, fresh, not ground, not altered and possible composition can be determined by plagioclase grain count per unit volume. The typical characteristic oscillatory zoning exhibits the compositional variation

in plagioclase is not present in Khairmalia andesite. In these andesites the plagioclase phenocryst shows freshness and uniform composition.

Table- 2: Min. and Max. of Site-wise values for Intensity, Susceptibility and Qn ratio

Site	N	n	Intensity		Susceptibility		Qn Ratio	
			Min	Max	Min	Max	Min	Max
S1	2	20	4.30	388.34	1.43E-03	9.55E-03	9.01E+02	3.23E+05
S2	2	18	59.46	352.12	1.03E-03	2.26E-03	1.04E+05	3.33E+05
S3	3	25	0.05	255.32	1.08E-03	8.43E-03	1.82E+01	3.13E+05
S4	4	23	0.12	43.01	1.10E-03	9.93E-03	2.54E+01	3.27E+04
S5	2	21	2.38	89.81	3.48E-03	9.19E-03	9.65E+02	1.95E+04
S6	3	24	49.92	112.99	1.03E-03	9.95E-03	1.29E+04	1.26E+05
S7	3	16	32.04	376.20	1.01E-03	9.64E-03	1.25E+04	4.15E+05
S8	3	21	1.40	72.45	1.00E-03	9.74E-03	4.65E+02	1.41E+05
S9	3	21	2.27	78.05	1.14E-03	9.45E-03	6.13E+02	1.30E+05
S10	3	20	5.18	161.16	1.03E-03	9.87E-03	1.69E+03	2.48E+05
Min / Max			**0.058**	**388.34**	**1.00E-03**	**9.95E-03**	**1.82E+01**	**4.15E+05**

The plagioclase present in Khairmalia andesites are high temperature plagioclases, anhedral in form, mostly rectangular laths with albitic composition [0 – 10 % $(CaAl_2Si_2O_8)_2$] showing albitic twinning (Moorhouse, 1984). Most of plagioclase crystals are twinned following albite lava. Most of the crystals are homogeneous relatively calcic plagioclase showing uniform conditions setup of paleo-conditions. The stresses associated with recrystallization would facilitate the rich development of twinning (Tuttle, 1952). The accurate identification of the plagioclases is perhaps the most valuable single determination.

Index of refraction in thin sections is sodic plagioclases upto An_{20}, have an index less than that of Canada balsam. Pyroxene is also present as ferromagnetism constituent of andesite. Orthopyroxene i.e. generally hypersthene and clinopyroxene i.e. diopside and pigeonite, are both present in andesites (Figure 5). The petrological characteristics of the studied samples are shown in the Table 3.

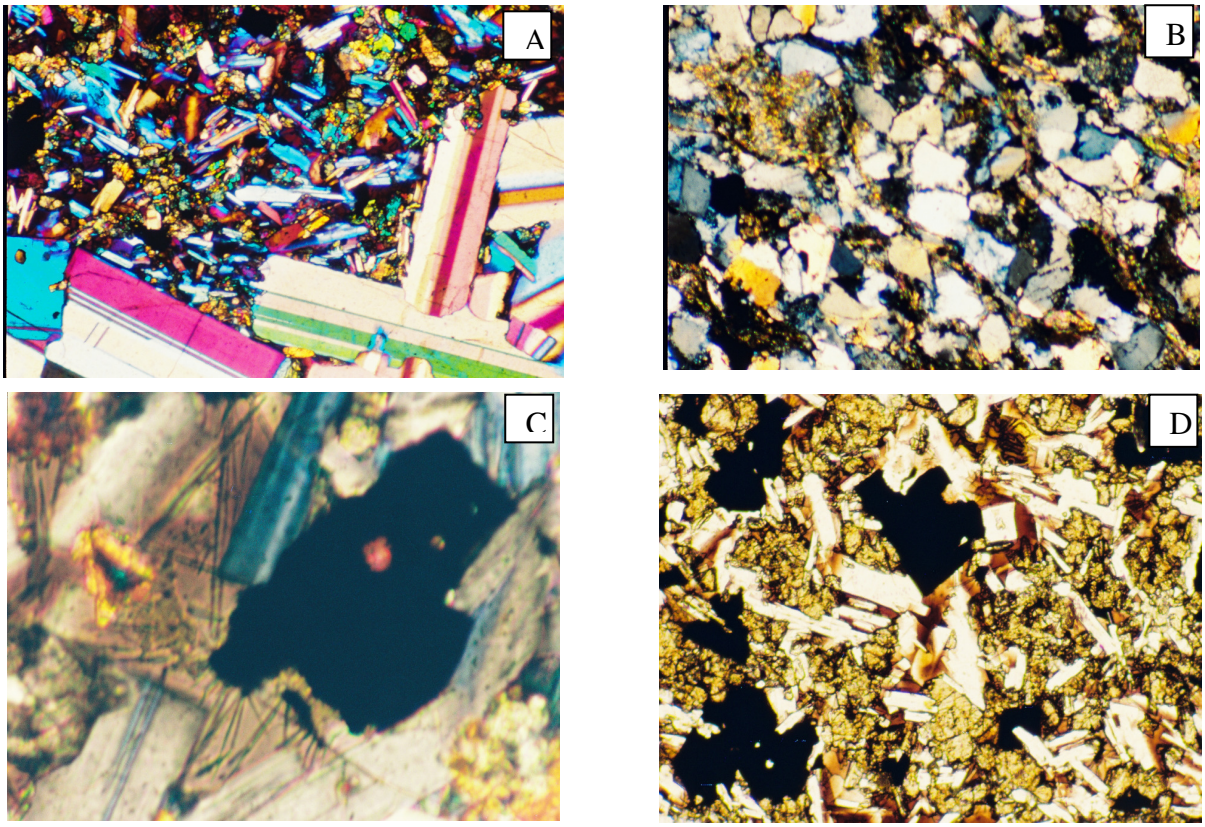

Fig. 4: Photomicrographs showing magnetite crystals (black) (magnification 10x).

Table- 3: Sample location and characteristic particulars of the andesite rock samples

Sample Location	**Characteristics**
South of Khairmalia	Brownish coloured, flows bands visible, amygdaloid present
North of Khairmalia	Light brownish, flow bands visible, amygdaloid present
Near Pindri village area	Yellowish tinge, amygdaloid little filled with minerals
Near Ratanpur village area	Greenish to brownish in coloured.
Unthelkhera	Greenish to brownish in coloured. More weathered.

Discussion

Most of the great volcanic chains of the world are the places of occurrences of andesites including the cascade volcanoes of the Western United States, the Caribbean,

Mexican, and Andean volcanoes, the volcanoes of Japan and East Indies, some Mediterranean volcanoes, as well as many other areas for recent and former volcanism. The great strato volcanoes are also predominantly andesitic. Field relationship of Khairmalia andesite, Khardeola sandstone and diorite leads to the petrographical studies and the geological setting shows that the litho units are marker horizons where the paleomagnetic features are well preserved on the basis of magnetite (Carmicheal, 1961) content makes these rocks are found suitable for paleomagnetic studies (Figure 6). The variation in the values of Intensities and suscptibilities in these rocks is an indicative of geological disturbances i.e. oscillating nature at the beginning of Vindhyan sedimentation as well as configuration of the Vindhyan basin during synsedimentational andesitic flows.

Fig. 5: Khairmalia andesite sample which shows amygdule as spots.

Conclusions

The preliminary studies shows that the **f**ield relationship and regional geological set up is indicative of the significance of the rocks from palaeomagnetic study point of view and it may be referred as paleomagnetic studies marker horizon. Petrographic investigation identifies mineral assemblages rich in iron and mineral magnetite is identified as main magnetic mineral under reflecting light investigation. It is further confirmed by magnetic analysis viz. NRM, Magnetic Susceptibility and Qn Ratio.

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