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Palaeomagnetism of Khairmalia Volcanics, south of Chittorgarh – implications related to the basal age of the Proterozoic Vindhyan Supergroup

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Palaeomagnetic studies were carried out on the basal Khairmalia volcanic rocks of the Proterozoic Vindhyan Supergroup. Two hundred and ten specimens prepared from 30 oriented block samples from 10 sites near Khairmalia, south of Chittorgarh, Rajasthan were studied. They are characterized by mean characteristic remanent magnetization $D = 8°$ and $I = 9°$ ($\alpha_{95} = 16.3$; $k = 23.11$). Virtual geomagnetic pole is estimated at 68.6°N; 231.3°E ($dp = 8.3$ and $dm = 16.4$). Plot on the Proterozoic apparent polar wander path[1] indicates that the volcanics may have erupted ca. 1800 Ma.

Keywords: Chittorgarh, Khairmalia andesites, palaeomagnetism, Vindhyan Supergroup.

THE Vindhyan Supergroup consists of about 4200 m thick sedimentary and volcanic rock sequence. In the western part, the rocks of the Vindhyan Supergroup largely occur in Chittorgarh, Bhilwara, Bundi, Kota and Sawai Madhopur districts of southeastern Rajasthan. Lava flows and volcaniclastic rocks known as Khairmalia volcanic rocks occur south of Chittorgarh. They constitute the basal formation of the Vindhyan Supergroup in southeast Rajasthan. In this communication we report the results of palaeomagnetic studies of these rocks. This work has been taken up to find out the apparent polar wander path (APWP) for the Indian subcontinent during the late Palaeoproterozoic, which is an important period when sedimentation of the Vindhyan Basin began. Recent studies[1–3] show that the age of the lower Vindhyan supergroup is as old as 1601 m.y. We examine the results of palaeomagnetic studies of the volcanics whose age is known through geochemical studies[4].

Khairmalia volcanic rocks occur in a 50 km long linear belt south of Chittorgarh. They are well exposed near Khairmalia, Katai-Madhopur, Madhur Talab and along Jakham river near Kharveri. Figure 1 shows the geological map of the area. Good outcrops are seen between Until and Khairmalia east of Katai-Madhopur, east of Dholapani,

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around Patia-Untakhera and further southwest of Jambuwella. The flows are about 40 m thick near Khairmalia, but are over 100 m thick further south in Untakhera-Madhuratalab area. Between Ratanpura and Pindri about 15 m thick pyroclastic rocks, including tuffs occur in the lower part of the flows. The tuffaceous rocks also occur 1.5 km southeast of Kanauj and south of Dhanet on the southern bank of River Berach. The individual flows are 2–12 m thick with amygdaloidal tops, varying from a few centimetres to 5 m in thickness. The number of flows varies from section to section. There are nine flows near Khairmalia and 20 flows east of Katai-Madhopur and further south. There is a general thickening of the volcanic sequence towards south.

The Khairmalia volcanic rocks are mainly fine-grained and dark purple, pink, greenish and greenish-brown in colour. Specific gravity of the rocks ranges from 2.65 to 2.80 (ref. 5). Amygdales are generally circular or ellipsoidal, ranging in size from millimetres to centimetres and filled with a dark green chlorite, calcite, siderite or quartz. Specks of chalcopyrite and encrustation of malachite have also been noticed in the amygdales. The pyroclastic rocks are dirty green to brown, fine to coarse-grained and compact, often showing indistinct or crude stratification. Just southwest of Pindri, greenish andesitic rocks overlie ~ 1 m thick tuff which in turn rests on pinkish medium-grained Berach granite. Khairmalia volcanics range in composition from theoliitic basalt to andesite[4,6].

Thirty oriented block samples from 10 sites (on average 3–4 samples per site) were collected to the west and south of Chittorgarh.

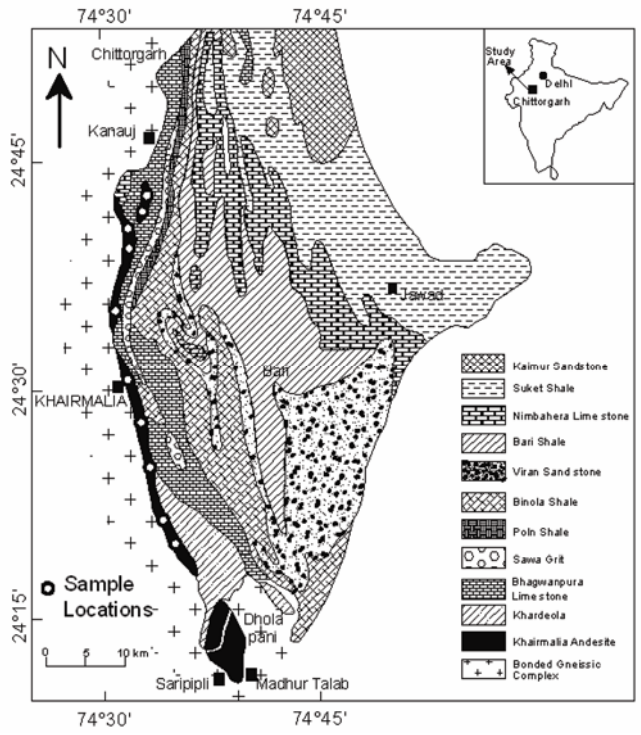

Figure 1. Geological map of the Khairmalia andesite showing sampling sites for palaeomagnetic studies[4].

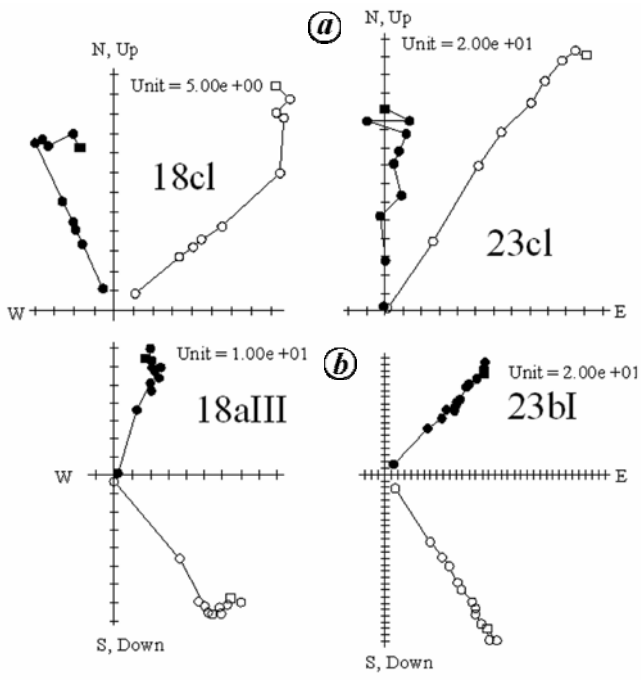

Figure 2. Vector behaviour during (***a***) step-wise alternating field demagnetization and (***b***) progressive thermal demagnetization. Solid circles are projections onto the horizontal plane and open circles are projections onto the vertical plane.

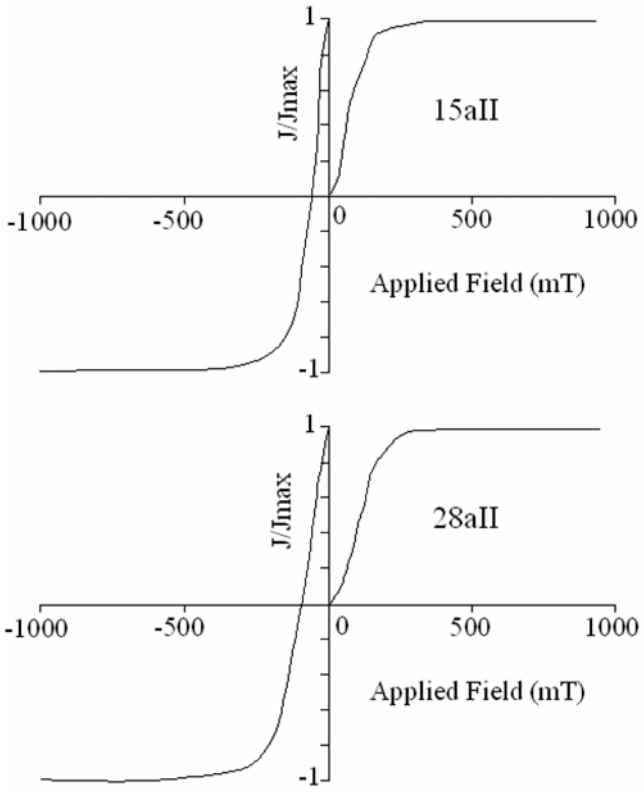

Figure 3. Selected isothermal remanence acquisition studies of Khairmalia andesites.

Table 1. Palaeomagnetic results of the Khairmalia Andesites, south of Chittorgarh, Rajasthan

Site no.	*Dm*	*Im*	α_{95}	*k*	plat	plong
Site 1	349	43	–	–	–	–
Site 2	354	–40	19.6	10.45	42.11	262.34
Site 3	350	–45	19.8	8.80	38.12	265.80
Site 4	32	33	19.7	12.49	37.36	215.54
Site 5	12	22	14.7	13.25	72.36	211.82
Site 6	352	7	26.6	5.31	67.42	276.34
Site 7	20	–6	16.6	17.17	56.27	216.80
Site 8	19	4	19.7	16.02	60.90	213.09
Site 9	358	19	28.6	6.45	74.98	260.89
Site 10	24	47	34.9	3.13	68.06	150.27
Mean of five sites (5–9)	8	9	16.3	23.11	68.68	231.32

Dm, Mean declination; *Im*, Mean inclination. α_{95}, Circle of cone of confidence at 95% probability level; *k*, Precision; plat, Pole latitude; plong, Pole longitude.

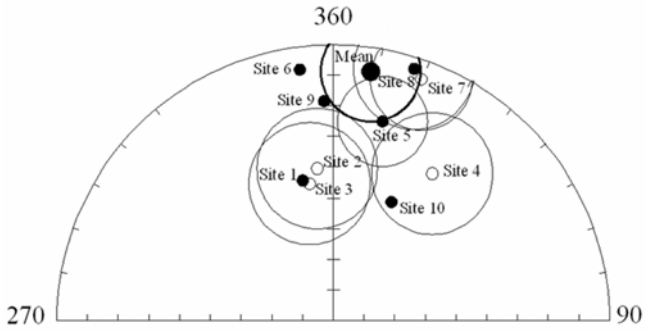

Figure 4. Site mean characteristic remanent magnetization directions along with mean direction of the Khairmalia andesites with circle of confidence at 95% probability level.

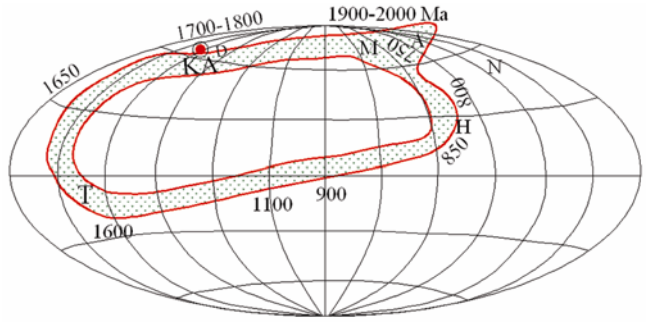

Figure 5. Palaeomagnetic pole of the Khairmalia andesites in comparison with the Proterozoic polar wander curve of India[9]. A, Agali; D, Dharmapuri; T, Tiruvannamalai; N, Northern Kerala; H, Harohalli Dykes; M, Malani rhyolite; KA, Khairmalia andesite.

The block samples were drilled in the laboratory and 2.5 cm diameter × 2.2 cm height specimens were prepared. Rock magnetic and palaeomagnetic measurements were carried out on these specimens. Two hundred and ten specimens have been obtained from 30 oriented block samples. Natural remanent magnetization of all the specimens was measured on minispin Molspin magnetometer. Intensity of magnetization ranges from 0.06 to 300.08 A/m. Magnetic susceptibility was measured on MS-2 Bartington Susceptibility System. The susceptibility values range from 1.00 to 9.95 S.I. Koenigsberger ratio calculated is > 1.

In a pilot study both step-wise alternating field (AF) and thermal demagnetization were carried out on representative samples. Figure 2 presents the orthogonal projections of the vectors during step-wise AF and thermal demagnetization[7]. The linear curve passes through the origin in most of the specimens and the directions are stable at higher temperatures with high blocking temperatures.

Based on the pilot study, at least four specimens from each site are subjected to blanket cleaning in three different fields at 20, 30 and 40 mT in AF and at three different temperatures 450°C, 500°C and 540°C in thermal demagnetization. Sample and site mean directions were calculated statistically isolating characteristic remanent magnetization (ChRM) directions[8].

Some specimens were imparted magnetization in steps from 15 to 1000 mT. Figure 3 gives the isothermal remanent magnetization (IRM) curves which show that most of the specimens saturate (*Hs*) at 160–250 mT, suggesting magnetite as the chief magnetic carrier. A few samples do not saturate even at 3000 mT, suggesting that haematite is also present. Back-field study on a few samples indicates coercivity force (*Hc*) of 80–100 mT.

The site mean directions for the Khairmalia andesites are shown in Figure 4. The overall mean direction is calculated at *Dm* = 8°, *Im* = 9° (α_{95} = 16.3 and *k* = 23.11). Virtual geomagnetic pole is estimated at λ_p = 68.6°N: L_p = 231.3°E (Table 1).

The palaeomagnetic pole of the Khairmalia volcanics is plotted over the Proterozoic polar wander curve for India given by Radhakrishna and Joseph (Figure 5)[9]. The obtained pole for the Khairmalia volcanics (λ_p = 68.6°N: L_p = 231.3°E) falls close to 79.7°N, 101.1°W pole position[9] reported for the 1855 ± 9 Ma Dharmapuri dykes[10] of southern India. Age of basal volcanics from the Vindhyan basin inferred from palaeomagnetic pole position is older than what has been reported by geochronological studies.

As the Khairmalia volcanic rocks are at the base of the Vindhyan Supergroup, they may mark volcanism at the time of formation of the Vindhyan sedimentary basin. Based on geochemical studies on Khairmalia and Jungel volcanics, Raza *et al.*[4] linked the volcanism to the initiation of the Vindhyan Basin coinciding with ~ 1.8 Ga collisional events in the Aravalli–Delhi Fold belt and the Central Indian Suture Zone (CIS)[4,11]. Therefore, it may be suggested that rifting and initiation of the Vindhyan basin might have begun ca. 1.8 Ga.

Geochemical studies led Poornachandra Rao *et al.*[12] to further suggest that the Khairmalia andesites have evolved in a tectonic environment transitional between oceanic and continental tectonic settings.

Palaeomagnetic studies on the Khairmalia volcanic rocks of Chittorgarh provide a new pole position for the basal Vindhyan Supergroup at 68.6°N, 231.3°E (α_{95} = 16.3). On the Proterozoic APWP curve, the pole position falls between 1800 and 1700 Ma and is close to the pole position of 1855 ± 9 Ma Dharmapuri dyke of southern India[10]. The 1.8 Ga age assigned by palaeomagnetic approach is in agreement with a suggestion of linking the volcanism to the initiation of the Vindhyan Basin formation ca. 1.8 Ga, coinciding with collisional events in the Aravalli–Delhi Fold belt and the CIS[11]. Further geochronological studies may constrain the age of initial rifting that marked the onset of the Proterozoic Vindhyan basin.

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