Palaeomagnetic dating of Sankra dyke swarm in the Malani Igneous Suite, Western Rajasthan, India

G. V. S. Poornachandra Rao, S. B. Singh and K. J. Prasanna Lakshmi

Palaeomagnetism Laboratory, National Geophysical Research Institute, Uppal Road, Hyderabad 500 007, India

The Malani Igneous Suite is a heterogeneous suite comprising acid lava flows and intrusions divided into three phases of igneous activity, the youngest of which consists of all dykes identified within the Sankra pluton. The dykes in the Sankra pluton have been divided into five sub-phases on which radiometric dates are not available. Hence the sequence of magmatic emplacement is not known. We have undertaken a palaeomagnetic study of four dykes, namely the aplite, granite porphyry, dolerite and gabbro types representing the first, third and fifth sub-phases. The characteristic remanent magnetic (ChRM) directions of these dykes have been recovered by detailed laboratory studies using AF and thermal demagnetization methods on the oriented samples collected from these dykes. The virtual geomagnetic poles of these dykes, when plotted on the apparent polar wander path of the Indian subcontinent, assign their ages between 750 and 60 Ma. The ChRM direction in the aplite dyke is similar to that of the Malani Rhyolite and a granitoid body from Seychelles Islands. Thus, these three results indicate the formation of a tectonic trio with Madagascar towards the western side of the Neoproterozoic Rodinia supercontinent, and also confirm the age of the aplite dyke.

WESTERN Rajasthan presents an intriguing geological terrane due to an extensive sand cover and poses many difficulties in the deep geoscientific probing to obtain the tectonic, geochemical and geophysical characteristics of the region. However, the geology of the Aravalli mountain belt in Rajasthan provides an almost continuous record of basic and acid magmatism with assigned ages ranging from 3500 to 750 Ma, and in the Trans-Aravalli region the record continues up to the Palaeocene[1]. Heron[2] and Gupta *et al.*[3] have described regional geology of the Aravalli mountain ranges in Rajasthan. Bhushan[4,5] and Bhushan and Khullar[6] have suggested three phases (I, II and III) of igneous activity in the Malani Igneous Suite (MIS). The several phases of igneous intrusion, if identified chronologically, would help in establishing the evolutionary history of the region. In the absence of systematic radiometric dating of these igneous activities, a palaeomagnetic study of rocks in the area might help in identifying the magmatic history of the area through palaeomagnetic directions recorded in them. With differences in their periods of emplacement the palaeomagnetic directions would differ, making it possible to unravel the magmatic history of the area. Phase III of magmatic activity of the MIS, which includes all the dykes in the area, is divided into five sub-phases (I, II, III, IV and V) that range in age from Neoproterozoic to Palaeocene[5,6] on the basis of field mapping, cross-cutting relationships and aerial photo evidences. We have carried out palaeomagnetic investigations on four dykes from these sub-phases belonging to Phase III of the igneous activity in the MIS. Our palaeomagnetic study of these dykes identified a sequence of magmatic activities and the results of these studies are presented in this communication.

A group of rocks, both intrusive and extrusive, occurring within an area of about 50,000 km^2 in western Rajasthan to the west of the Aravalli mountain range is named the MIS. These rocks extend for about 255 km from the south of Sirohi to the north of Pokaran, and for about 296 km from the east of Jodhpur to the International border with Pakistan in the west. The MIS, although often identified with the Malani Rhyolites, is a heterogeneous suite comprising igneous rocks ranging from acid plutonic to basic volcanic groups. The Sankra pluton is in the heart of the Thar desert, where the outcrops are mostly peneplained. The MIS has been divided into three phases of igneous activity (Table 1)[4–6].

Based on cross-cutting relationships, phase III mainly consisting of all dykes in the area, has been further divided into five sub-phases[6]. Most of the dykes stand prominently as linear streaks and ridges due to differential weathering. The geological map[1] of the dyke swarms around Sankra is shown in Figure 1. The Sankra pluton of phase III of MIS covers an area of 2800 km^2 comprising mainly pink granite (Jalore granite), which is further intruded by grey granite covering an area of 100 km^2 around Sankra. The five sub-phases of dykes representing phase III of the MIS are shown in Table 2. Dykes within the Sankra pluton show prominent NNW trend and a weaker NE trend (Figure 1). They extend from 1 to 7 km,

Table 1. Phases of the MIS

Phase III	Acid and basic dykes (intrusive)
Phase II	Alkaline granite and alkali feldspar granites (intrusive)
Phase I	Basic and acid flows (extrusive)

Table 2. Sub-phases of phase III of the MIS

Phase III sub-phases of the MIS	V	Dykes of gabbro, dolerite and basalt
	IV	Rhyolite porphyry and felsite dykes
	III	Rhyolite, rhyolite porphyry and granite porphyry dykes
	II	Quartz trachyte porphyry, andesite and felsite dykes
	I	Granodiorite bosses, plugs and aplite dykes

*For correspondence. (e-mail: gvsprao@rediffmail.com)

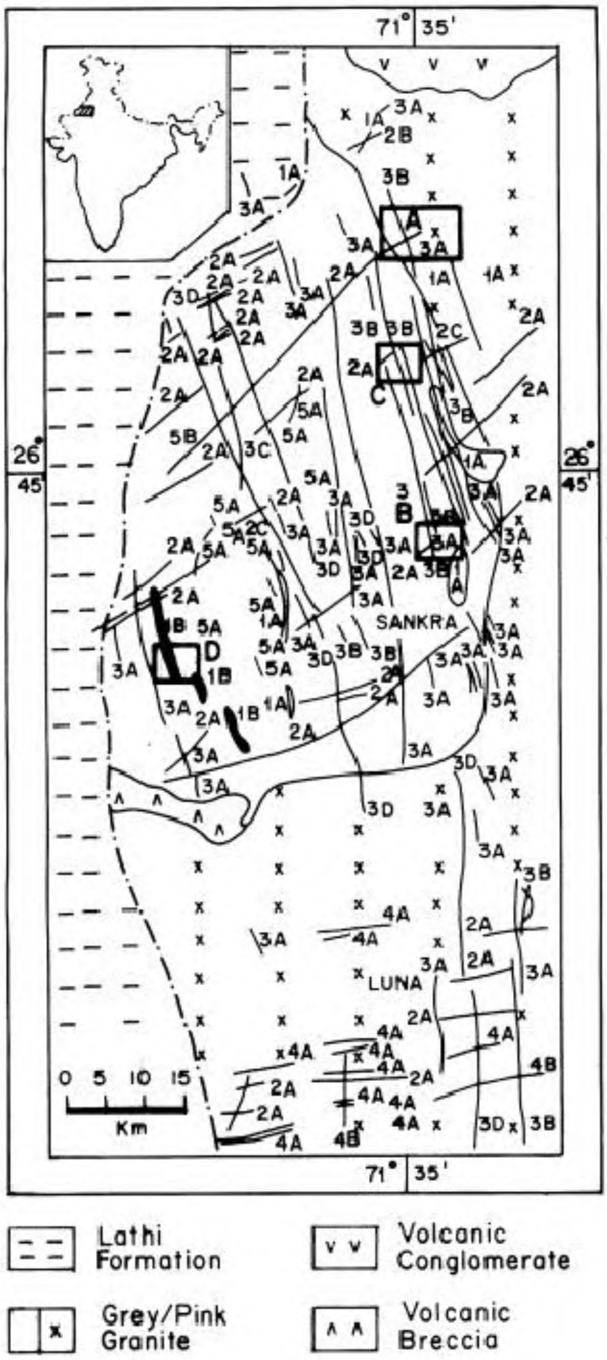

Figure 1. Geological map showing the dyke swarms around Sankra, Jaisalmer district, western Rajasthan (after Bhushan and Khullar[6]). Dykes studied palaeomagnetically are shown by squares indicating their sampling locations. A, Gabbro Dyke; B, Dolerite Dyke; C, Granite Porphyry and D, Aplite Dyke.

with widths varying from a few metres to a few tens of metres. The gabbro and dolerite dykes trend from N10 – 50°E whereas the aplite dyke strikes N 20°W.

The aplite dyke exhibits saccharoidal texture with equidimensional grains of sericitized albite, microcline, quartz, biotite and opaques. The gabbroic dykes show intergranular to ophitic texture and consist predominantly of labradorite and light yellow to colourless augite. The clinopyroxene is mostly rimmed by hornblende, indicating possible crystal fractionation. Olivine with arcuate fracture is present. Opaques, including pyrite are invariably present[6].

The Malani Rhyolites around Jodhpur were originally dated by the Rb–Sr method at 745 ± 10 Ma (ref. 7). Rb–Sr ages of other volcanic rocks in the area range between 780 and 680 Ma, with post crystallization thermal disturbance between 500 and 550 Ma corresponding to the Pan-African thermotectonic event noted in different parts of the Indian shield[8]. Torsvik *et al.*[9] provide a more precise age on the Malani Rhyolite between 771 and 751 Ma by the U–Pb dating method. From the Seychelles, Torsvik *et al.*[10] report an U–Pb zircon age of 750.2 ± 2.5 Ma for a dolerite dyke coeval with the granitoid rocks of the Malani Rhyolite. However, no radiometric ages on any of the MIS dykes are available as yet.

Oriented samples were collected from one site each on a gabbro, dolerite, granite porphyry and aplite dykes near Sankra village. The gabbro dyke strikes at N 10°E and the dolerite dyke strikes at N 50°E, while the granite porphyry and aplite dykes strike in a direction of N 20°W. The geology of the sampling sites is shown in Figure 1 (ref. 6). Five to six oriented samples were collected from each site using both solar and magnetic compasses. Two to three vertical cores of 25.4 mm diameter were drilled from these samples and the cores were cut into cylindrical specimens of 22 mm length for laboratory studies on these samples.

Natural Remanent Magnetic (NRM) direction and intensity (Jn) of all the specimens were measured on Schonstedt Spinner Magnetometer (Model DSM2) and magnetic susceptibility was measured on a hysteresis and susceptibility apparatus[11]. The Koenigsberger Ratio (Qn) value was computed using a value of 0.05 mT for the earth's field intensity (H). The nature of remanent magnetic vector in the samples was investigated by subjecting the samples to laboratory demagnetizations using an AF demagnetizer similar to that described by Creer[12], and a Schonstedt thermal demagnetizer (Model TSD-1). NRM directions from the gabbro, dolerite and granite porphyry dykes show scatter with upward and downward inclinations. Those from the aplite dyke reveal good grouping with downward (+ve) inclinations. However, there is a good grouping of the specimen directions from all samples from all the sites. Since the rocks are of differing lithologies, their remanent intensities (Jn) and susceptibilities (K) show a wide variation of over 2–3 orders. Jn and K values of these samples are listed in Table 3.

To determine the Characteristic Remanent Magnetic (ChRM) vector in these rocks, one specimen from each sample from all sites was subjected to AF demagnetization on a pilot basis up to a peak field of 100 mT, in steps of 5–10 mT. The specimens exhibit good vector defini-

Table 3. Magnetic properties of phase III dykes, MIS

Dyke	NRM (Jn)	Susceptibility (K; SI)	Koenigsberger ratio (Qn)
Gabbro dyke	0.54–9.62 A/m	$38.70–64.0 \times 10^{-3}$	0.21–5.33
Dolerite dyke	3.61–50.0 A/m	$37.40–70.0 \times 10^{-3}$	1.54–20.39
Granite porphyry dyke	0.09–16.34 mA/m	$28.40–1420 \times 10^{-6}$	0.04–28.66
Aplite dyke	2.93–19.66 mA/m	$16.86–28.10 \times 10^{-6}$	0.38–2.06

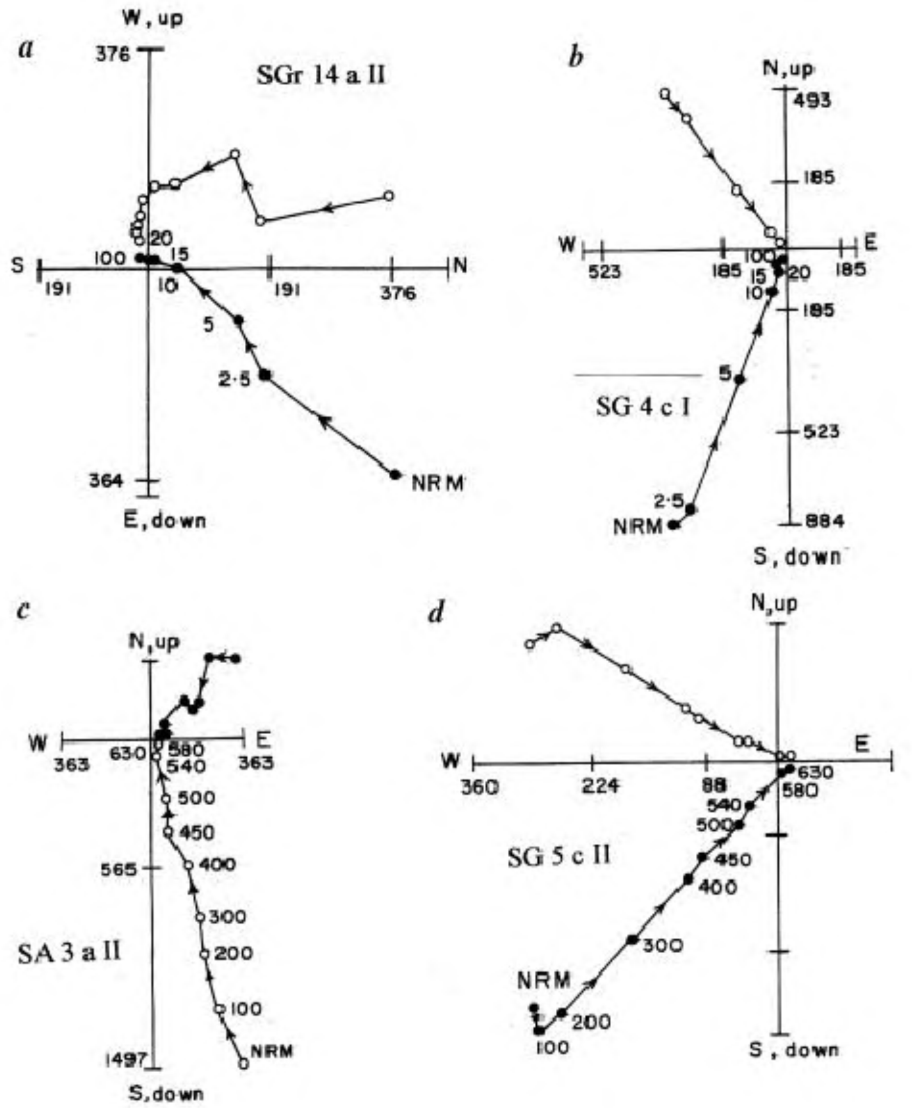

Figure 2. Zijderveld diagrams depicting typical examples of response of Sankra dykes to AF (***a***) SGr 14 a II and (***b***) SG 4 c I and thermal (***c***) SA 3 a II and (***d***) SG 5 c II pilot studies. Solid (open) circles denote projection of the end point of the remanent magnetic vector on E–W horizontal (N–S vertical) plane. Numbers denote peak AF fields in mT and temperatures in °C. Intensities are in 10^{-2} mA/m for aplite and granite porphyry dykes and 10^{-2} A/m for dolerite and gabbro dykes.

tion with AF demagnetization revealing ChRM direction to these tests, with mean destructive field values varying between 5 and 20 mT. Typical demagnetization characteristics are shown in Figure 2*a* and *b* as Zijderveld diagrams, revealing the vector behaviour. Peak fields of 15–20 mT at which the observed viscous effects nullified for each dyke were selected for demagnetization to isolate the ChRM in these rocks. At least one specimen from each core of all the samples was demagnetized at these fields to recover the ChRM vector from these samples and the other specimen was retained for thermal demagnetization.

The ChRM in these samples has been also investigated by thermal demagnetization. Three specimens from each site of these dyke samples have been subjected to thermal demagnetization on a pilot basis to investigate the thermal history of these rocks. The specimens were heated in steps of 50–100°C up to a peak temperature of 680°C, and the remanent vector was measured after cooling to room temperature in the absence of any external magnetic fields. The specimens reveal ChRM vector in all the samples. These studies reveal unblocking temperatures of around 580°C after which the remanent vectors exhibit large migration, thus inferring magnetite as the remanent carrier in these rocks. Peak temperatures between 400 and 580°C were selected for demagnetization to obtain the ChRM in these samples and the remaining specimens from all the sites were demagnetized at these temperatures. Typical demagnetization behaviour of the pilot specimens during thermal demagnetization is shown in Figure 2 *c* and *d* as Zijderveld diagrams revealing the nature of the vector to heating.

The ChRM vector in these dykes was determined by PCA analysis[13]. Mean ChRM vectors for all the sites were evaluated using Fisher[14] statistical methods by averaging specimen and sample mean vectors. Corresponding Virtual Geomagnetic Pole (VGP) positions were computed along with other palaeomagnetic parametres and palaeolatitudes in case of each dyke. Mean ChRM vectors of the dykes are shown in Figure 3 along with 95% circles of confidence. The VGP positions of the four investigated dykes are plotted on the Apparent Polar Wander Path (APWP) of the Indian subcontinent[15] as shown in Figure 4, to assign probable periods of the magmatic activity in the region.

The aplite dyke of sub-phase I of phase III of MIS occurs towards the west of Sankra village, striking about N 20°W. Six oriented samples were collected, and their NRM and ChRM vectors reveal good grouping. Peak AF fields of 20 mT and temperatures of 450°C have been applied to recover the ChRM directions from these samples. The ChRM direction recorded for this dyke is $Dm = 352.5$, $Im = +60.0$ ($k = 18.6$, $\alpha_{95} = 16.2$, $N = 4$, Figure 3) with the corresponding VGP at $\lambda p = 74.6°N$, $Lp = 49.8°E$ (Table 4).

The granite porphyry dyke striking N 20°W has been collected from north of Sankra village. Five oriented block samples were collected from this dyke, the NRM directions of which are scattered with upward (negative) inclinations. One sample exhibited shallow downward (positive) inclination. Demagnetization at peak AF field of 15 mT and temperatures of 400–500°C revealed ChRM directions in these samples. One sample with upward inclination did not change from its NRM level, whereas the ChRM directions of the remaining four samples grouped well (Figure 3) as a result of laboratory demagnetizations. The ChRM vector is $Dm = 281.0$, $Im = -64.9$ ($k = 27.91$, $\alpha_{95} = 13.2$, $N = 4$) (Figure 3), with the corresponding VGP at $\lambda p = 12.3°$ S, $Lp = 65.0°W$ (Table 4).

Five oriented, block samples were collected from the dolerite dyke striking N 50°E and located towards north

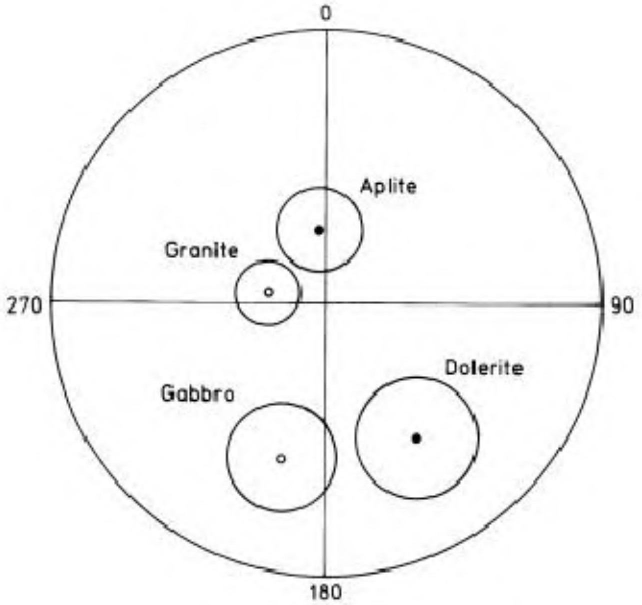

Figure 3. Stereographic plot of mean ChRM directions of dykes derived by demagnetization in Sankra pluton, northwestern Rajasthan. Lithology of the dykes investigated is as indicated. Closed (open) circles denote downward (upward) pointing inclinations. Circles denote mean ChRM directions of dykes with their 95% confidence limits.

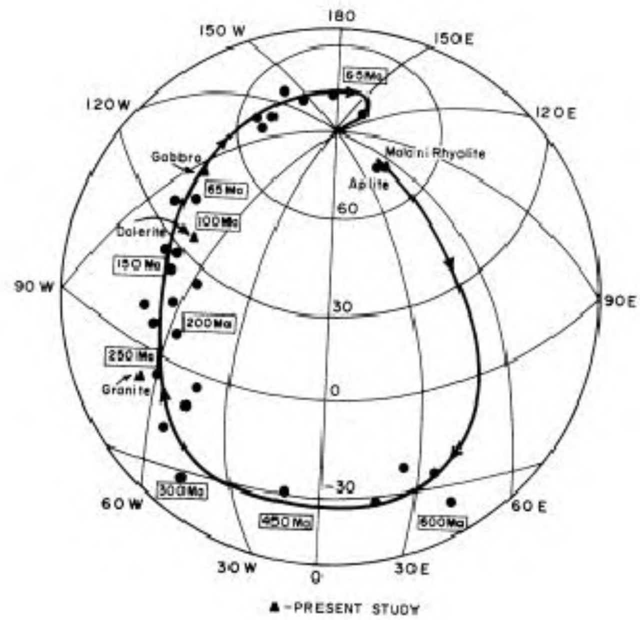

Figure 4. Apparent polar wander path of the Indian subcontinent for the period late Neoproterozoic to Recent[15]. The virtual geomagnetic pole positions of the dykes from the Sankra pluton, MIS, are plotted as triangles and their lithology is also indicated.

of the Sankra village. NRM vectors reveal high scatter, three samples with downward (positive) inclinations and two samples with upward (negative) inclinations. Demagnetization at peak AF field of 15 mT and temperatures of 400–500°C reveal stable palaeomagnetic signature in this dyke. One sample that did not group with others from this dyke is not considered for evaluating the mean ChRM vector. The isolated ChRM is $Dm = 149.1$, $Im = +26.8$ ($k = 27.94$, $\alpha_{95} = 8.37$, $N = 4$, Figure 3) with the corresponding VGP at $\lambda p = 39.4°N$, $Lp = 68.3°W$ (Table 4).

The gabbro dyke striking N 10°E north of Sankra village has been sampled for palaeomagnetic study. NRM directions of the five samples exhibit good grouping with reverse magnetization with upward inclinations. However, two samples reveal downward inclinations, one with normal magnetization and the other with reverse magnetization. Blanket demagnetization at peak fields of 15 mT and temperatures of 400–500°C reveal ChRM directions in these samples. The isolated ChRM is $Dm = 194.9$, $Im = -26.7$ ($k = 8.16$, $\alpha_{95} = 24.51$, $N = 4$) (Figure 3) with the corresponding VGP at $\lambda p = 45.69°N$, $Lp = 87.03°W$ (Table 4).

Heron[2] and Gupta *et al.*[3] have described the regional geology of the Aravalli mountain range in Rajasthan, which suggests an intermittent record of basic and acid magmatism from 3500 to 750 Ma, with magmatic events continuing in the Trans-Aravalli region up to the Palaeocene. These are grouped into four major lithounits as (i) the Banded Gneissic Complex, (ii) the Aravalli Supergroup, (iii) the Delhi Supergroup and (iv) the Late Neoproterozoic Erinpura granite and Malani rhyolite. The magmatic history of the region is divided into three distinct periods defined as (i) the Archaean magmatic events (> 2500 Ma), (ii) the Palaeo–Meso Proterozoic events within the Aravalli Supergroup (2500–2000 Ma) and the Delhi Supergroup (> 1450 Ma) and (iii) the Late Proterozoic magmatic events manifested by the Erinpura granite and Malani Rhyolite[16]. Major phases of acid magmatism ranging between 3500 and 750 Ma have been dated by Choudhury *et al.*[17]. The oldest dated mafic magmatic event is 3500 Ma[18] and the youngest is 50 Ma[1]. The Erinpura granite and Malani Rhyolite are dated to be 850–750 Ma[7,17]. Crawford and Compston[7] dated the Malani Rhyolite to be 745 ± 10 Ma and Rathore *et al.*[8] reported Rb–Sr ages on Malani volcanics and associated granitoids in the region to range between 780 and 680 Ma. The revised age estimate using U–Pb dating on the Malani Rhyolites by Torsvik *et al.*[10] is between 771 and 751 Ma. Basu *et al.*[19] and Rathore *et al.*[20] also obtained younger ages from the Mundwara complex acid magmatic events between 70–60 Ma.

Bhushan and Khullar[6] have mapped the dyke swarms around Sankra in the MIS in Jaisalmer district, Rajasthan. All these dyke swarms have been grouped as phase III of the MIS, whereas phase II and phase I were identified as manifested by basic and acid lava flows and subjacent discordant plutons, bosses and ring dykes of granite (Table 1), respectively. On the basis of field mapping, cross-cutting relationships and aerial photo evidence, the dyke swarms around Sankra–Sanawra in the Jaisalmer district have been further divided into five sub-phases, as listed in Table 2. Dykes of acidic, intermediate and basic composition following a differentiation trend represent the heterogeneous swarm. None of the dykes of the Sankra pluton is radiometrically dated and therefore, it is difficult to assume that all the dykes in the region belong to the igneous activity related to the late Neoproterozoic Malani activity. This is true in view of the recent report of some ages reported from the Mundwara Complex and elsewhere[10,19,20]. Furthermore, the younger dykes of the region follow the lineaments, which evolved during the Mesozoic–Cenozoic. Late Cretaceous magmatic underplating in the form of komatiite was reported by Kataria and Roy[21] and confirmed by the palaeomagnetic study of Poornachandra Rao *et al.*[22]. More detailed field studies and radiometric dating of these dyke swarms have been advocated for precise determination of the sequence of magmatic events to constrain the MIS.

Palaeomagnetic study is considered as one of the powerful tools in addressing several geological and geophysical problems. Therefore, this technique has been employed in the present case in constraining and confirming the sequence of magmatic activity associated with Sankra dyke swarm. ChRM directions have been isolated through detailed laboratory studies using AF and thermal demagnetization methods on four of the dykes from the Sankra pluton. From each of the dyke samples collected from the aplite, granite porphyry, dolerite and gabbro, several specimens were subjected to pilot studies using AF and thermal fields to investigate their magnetic behaviour in progressively increasing fields and temperatures up to 100 mT and 680°C, respectively. After selecting the effective fields and temperatures, they were demagnetized in these fields at selected levels to recover the magnetic signature from them. The mean remanent magnetic signatures of these dykes have been isolated and are shown in Figure 3, along with their 95% circles of confidence. VGP position for each dyke was evaluated using the ChRM signatures isolated from these dykes. The ChRM directions and VGP positions are listed and compared with other available results (Table 4). The VGP positions of the four investigated dykes are shown in Figure 4 along the late Neoproterozoic and Phanerozoic APWP for the Indian subcontinent, to constrain the sequence of magmatic events in the region on the basis of location of VGPs of the dykes investigated.

The APWP of the Indian subcontinent constructed by well-constrained palaeomagnetic data[15] shown in Figure 4, ranges between late Neoproterozoic and Cenozoic periods. The late Neoproterozoic period is constrained by radiometric dating and palaeomagnetic data[7,9,10,23,24]. The

Table 4. Palaeomagnetic data of MIS dykes, northwest Rajasthan

Dyke	*N*	*Dm*	*Im*	*k*	α_{95}	λp	*Lp*	λm	Reference
Gabbro dyke	5	194.9	–26.6	8.16	24.5	45.7 N	87.0 W	21.1 S	Present study
Dolerite dyke	5	149.1	+26.8	8.37	27.9	39.3 N	68.3 W	22.5 S	Present study
Granite porphyry	5	281.0	–64.9	27.91	13.2	12.3 S	65.0 W	54.5 S	Present study
Aplite dyke	6	352.5	+60.0	18.60	16.2	74.6 N	49.8 E	32.3 N	Present study
Malani rhyolite	60	353.0	+56.0	–	10.0	78.0 N	45.0 E	31.0 N	23
Malani rhyolite	45	354.5	+53.5	35.5	8.0	80.5 N	43.5 E	29.0 N	24
Malani rhyolite	85	008.7	+65.4	29.4	9.7	67.7 N	88.3 E	34.3 N	10

N, Number of samples; *Dm*, Mean declination; *Im*, Mean inclination; *k*, Precision parameter, α_{95}, Radius of circle of confidence at 95% probability; λp, Latitude of VGP; *Lp*, Longitude of VGP; λm, Latitude of the reference town (Nagpur).

APWP is well-constrained from several good-quality data during lower Palaeozoic, upper Palaeozoic and several other Mesozoic and Cenozoic data[15]. The VGP position of the aplite dyke with $\lambda p = 74.6°N$, $Lp = 49.8°E$ is in good agreement with that of the Malani Rhyolite (mean value $\lambda p = 74.5°N$, $Lp = 71.2°E$ (refs 10, 23 and 24), thus assigning an age of approximately 750 Ma to the aplite dyke investigated. This is also in conformity with that inferred from the field relations as sub-phase I in phase III of the MIS[5,6]. The large polar movement between Malani Rhyolite and other lower Cambrian period poles denotes the rapid migration of the Indian subcontinent from the northern to the southern hemispheric latitudes during that period in the subsequent formation of the Pangaea supercontinent.

The granite porphyry dyke represents sub-phase III in the Phase III of the MIS. This resulted in a VGP of $\lambda p = 12.3°S$, $Lp = 65.0°W$, that plots well with the VGPs of Permo-Carboniferous rock formations[23] assigning an age of 250 Ma for this dyke. The sub-phase V of phase III of the MIS is represented by dolerite and gabbro dyke activity. Both these dykes studied from north of Sankra village, resulted in ChRM directions with VGPs of $\lambda p = 39.4°N$, $Lp = 68.3°W$ and $\lambda p = 45.69°N$, $Lp = 87.03°W$ respectively. The VGP of the dolerite dyke plots at mid-late Cretaceous period on the APWP whereas the VGP of the gabbro dyke groups well with the those of the Deccan Traps of late Cretaceous – early Tertiary period on the APWP. Therefore, from the position of the VGPs of the dolerite and gabbro dykes on this polar wander curve these dykes may be assigned 100 and 60 Ma, respectively for sub-phase V dykes in Phase III of the MIS. The VGPs of the investigated dykes belonging to various sub-phases of Phase III of the MIS suggest their ages to be between 750 and 60 Ma and are in agreement with magmatic events inferred from field observations, mapping, cross-cutting relationships and aerial photos in the region[6]. The age assigned to the aplite dyke with similar magnetic signature as that of the Malani Rhyolite also confirms this inference.

The Malani Rhyolite magnetic direction and its pole position have been found to produce a good fit of Seychelles Islands with the Indian subcontinent at 750 Ma, from the palaeomagnetic data on granitoids from the Seychelles Islands[10] having the same age data. During this period, the Seychelles Islands and the Indian subcontinent have been found to be located at 30° and 32°N, respectively forming the tectonic-trio towards the western margin of the Rodinia supercontinent at 750 Ma[9,25]. Rb–Sr ages of 730–700 Ma on granitoid rocks from Malani Group, western Rajasthan by Rathore *et al.*[8] and the U–Pb ages on granitoids from Seychelles Islands by Torsvik *et al.*[9] further support these inferences. Thus, the palaeomagnetic ages assigned through these studies to Phase III dyke activity of the MIS in all probability may be considered as their emplacement ages indicating the sequence of magmatic activity pending their confirmation by radiometric dating.

1. Roy, A. B. and Jakhar, S. R., *Geology of Rajasthan (Northwest India) Precambrian to Recent*, Scientific Publishers (India), Jodhpur, 2002, p. 421.
2. Heron, A. M., The geology of central Rajputana. *Mem. Geol. Surv. India*, 1953, 79, 339.
3. Gupta, S. N., Mathur, R. K. and Arora, Y. K., Lithostratigraphy of Proterozoic of Rajasthan and Gujarat – A review. *Rec. Geol. Surv. India*, 1992, **115**, Parts A & B.
4. Bhushan, S. K., Classification of Malani Igneous Suite. *Spec. Publ., Geol. Surv. India*, 1984, **12**, 199–205.
5. Bhushan, S. K., Malani Rhyolites – A review. *Gondwana. Res.*, 2000, **3**, 65–77.
6. Bhushan, S. K. and Khullar, V. K., Geochemistry and tectonic significance of dyke swarm in Malani Igneous Complex around Sankra, District Jaisalmer, Rajasthan. *The Indian Precambrian* (ed. Paliwal, B. S.), Scientific Publishers (India), Jodhpur, 1998, pp. 482–491.
7. Crawford, A. R. and Compston, W., The age of the Vindhyan System of the peninsular India. *J. Geol. Soc. London*, 1970, **125**, 351–372.
8. Rathore, S. S., Venkatesan, T. R. and Srivastava, R. K., Rb–Sr isotope dating of Neoproterozoic (Malani Group) magmatism from southwest Rajasthan, India: Evidence of younger Pan-African thermal event by $^{40}Ar–^{39}Ar$ studies. *Gondwana Res.*, 1999, **2**, 271–281.
9. Torsvik, T. H., Carter, L. M., Ashwal, L. D., Bhushan, S. K., Pandit, M. K. and Jamtveit, B., Rodinia redefined or obscured: Palaeomagnetism of the Malani Igneous Suite (NW India). *Precambrian. Res.*, 2001, **108**, 319–333.
10. Torsvik, T. H., Ashwal, L. D., Tucker, R. D. and Eide, E. A., Neoproterozoic geochronology and palaeogeography of the Sey-

chelles microcontinent: The India link. *Precambrian Res*., 2001, **110**, 47–59.
11. Likhite, S. D. and Radhakrishnamurty, C., An apparatus for the determination of susceptibility of rocks in low fields at different frequencies. *Bull. Natl. Geophys. Res. Inst*., 1965, **3**, 1–8.
12. Creer, K. M., AC demagnetization of unstable Triassic Keuper Marls from southwest England. *Geophys. J. R. Astron. Soc*., 1959, **2**, 262–275.
13. Kirschvink, J. L., The least-squares line and plane and the analysis of palaeomagnetic data. *Geophys. J. R. Astron. Soc*., 1980, **62**, 699–718.
14. Fisher, R. A., Dispersion on a sphere. *Proc. R. Soc. London Ser. A*, 1953, **207**, 295–395.
15. Athavale, R. N., Rao, G. V. S. P. and Rao, M. S., Palaeomagnetic results from two basic volcanic formations in the western Himalayas and a Phanerozoic polar wander curve for India. *Geophys. J. R. Astron. Soc*., 1980, **60**, 419–433.
16. Srivastava, R. K., Magmatism in the Aravalli mountain range and its environs. *Mem. Geol. Soc. India*, 1988, 7, 77–93.
17. Choudhary, A. K., Gopalan, K. and Sastry, C. A., Present status of the geochronology of the Precambrian rocks of Rajasthan. *Tectonophysics*, 1984, **105**, 131–140.
18. Macdougall, J. D., Gopalan, K., Lugmair, G. W. and Roy, A. B., The banded gneissic complex of India: Early crust from depleted mantle at 3.5 Ga. *Trans. Am. Geophys. Union*, 1983, **64**, 381.
19. Basu, A. R., Renne, P. R., Das Gupta, D. K., Teikmann, F. and Poreda, R. J., Early and late alkali igneous pulses and a high ^{3}He plume origin for the Deccan flood basalts. *Science*, 1993, **261**, 902–906.
20. Rathore, S. S., Venkatesan, T. R. and Srivastava, R. K., Mundwara alkali igneous complex, Rajasthan, India: Chronology and Sr isotope systematic. *J. Geol. Soc. India*, 1996, **48**, 517–528.
21. Kataria, P. and Roy, A. B., Occurrence of undeformed komatiite from the Precambrian terrain of southern Rajasthan – a possible Neo-Aravalli signature. *Indian Mineral.*, 1997, **31**, 1–11.
22. Poornachandra Rao, G. V. S., Kataria, P., Roy, A. B. and Jaya Prasanna Lakshmi, K., Reconstitution of the Precambrian Aravalli crust at *K–T* boundary: Evidence from southcentral Rajasthan. *J. Appl. Geochem*., 2002, **4**, 115–125.
23. Athavale, R. N., Radhakrishnamurty, C. and Sahasrabudhe, P. W., Palaeomagnetism of some Indian rocks. *Geophys. J*., 1963, **7**, 304–313.
24. Klootwijk, C. T., A note on the palaeomagnetism of the late Precambrian Malani Rhyolites near Jodhpur, India. *J. Geophys*., 1975, **41**, 189–200.
25. Weil, A. B., Van der Voo, R., Niocaill, C. M. and Meert, J, G., The Proterozoic supercontinent Rodinia: Palaeomagnetically derived reconstructions for 1100 to 800 Ma. *Earth Planet. Sci. Lett*., 1998, **154**, 13–24.

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Erratum

Food plants and feeding habits of Himalayan ungulates

Anjali Awasthi, Sanjay Kr. Uniyal,
Gopal S. Rawat and S. Sathyakumar
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Some errors have inadvertently occurred in the paper. These are:

1. On page no. 721, line no. 7: *Oxytropis cachemiriana* should have been in the family Fabaceae instead of Ranunculaceae.
2. On page no. 722, line no. 9: *Galium aparine* and *Galium* sp. should have been in the family Rubiaceae instead of Rosaceae.
3. In Table 1, **Gral** (Goral) should have been under the head **Wild** instead of **Domestic**.

The errors are regretted.

— Authors