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Paleomagnetic and Rock Magnetic Study of the Gulerghat Area Amravati, Maharashtra

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ABSTRACT

Magnetic Polarity and Stratigraphic studies of the Gulerghat section from Akot and Amravati districts area(Lat. $21^0$00'-$21^0$15'N; Long. 77^0–$77^0$15'E) are carried out. Total thousands of oriented samples from fresh basalts were collected at close intervals. Detailed palaeomagnetic investigation where carried on 250 samples collected from 20 lava flows belonging to 17 selected traverses were subjected to progressive thermal demagnetizer at 15 different steps of temperatures from 50˚C to 600˚C. Traverse attaining a total thickness of 800m in the study area. Some rocks may fail to retain the magnetic record due to the modification subsequence to their formations by a number of natural phenomena like geotectonic disturbance, metamorphism and alteration, which can produce various degrees of secondary magnetisation in the rock. The secondary magnetisation acquired by the rock is unstable as compared to naturally remain magnetism which can be removed by cleaning techniques like stepwise Alternating field demagnetisation (AFD) and Thermal demagnetisation (TD). The palaeomagnetic results indicate that the most of the flows showed irregular natural remnant directions while a few specimen even from other flows for which a meaningful NRM could be deciphered also showed inconsistent directions. Only 35% of the samples showing irregular directions initially improved on alternating field and stepwise thermal demagnetization. High degree of alteration of the flows appears to have affected the stability of the palaeomagnetic directions. The mean palaeomagnetic directions indicate the presence of lower transitional directions at the bottom part of the sequence and upper reversed polarity in remaining part of the sequence with a few samples showing scattered behavior. The polarity transition has take place in the study area. Ancient latitude calculated for the study area is 30º S and that of Nagpur is 31º S indicating that India has drifted by 51º due N which is more than 5000 Kms. since the formation of this lavas.

Keywords: Palaeomagnetism, Magnetic Polarity, Alternating field demagnetisation (AFD) and Thermal demagnetisation (TD).

INTRODUCTION

Paleomagnetism is the study of such remanent magnetization in rock samples to reconstruct the direction and strength of the past geomagnetic field as well as the ancient 2 pole positions (Condie, 2011). Ferromagnetic minerals record geomagnetic information such as the Earth's field intensity and orientation during their formation. The purpose is to explore their suitability for paleomagnetism and find the stable magnetic recorders with the aim to better understand the Caledonian orogeny. Another important magnetic property of the rock samples is magnetic susceptibility and thermomagnetic measurements can help determine the magnetic phases in the samples. In addition, it has been discovered that temperature cycling measurements of magnetic susceptibility offer information about the temperature that the samples experienced in the past (Spassov & Hus, 2006). As a result, the magnetic susceptibility as a function of temperature measurements were carried out to explore and test if the irreversibility of the heating and cooling segments can be used for showing which temperatures the samples were heated to during metamorphism.

Palaeomagnetic investigations of Deccan Traps were carried out by Subbarao et al., (1994) have given the stratigraphy and structure of Central Deccan Basalt Province and proposed various eruptive models which appear to have been originated due to isostatic adjustments. Khadri et al., (1996) have proposed stratigraphy, form and structure of east Pune basalt and reported the occurrence of a new picrite basalt horizon in the Wai subgroup. Khadri et al., (1996b) have made an attempt to correlate the Malwa Traps with the Western Ghat stratigraphy and established the chemical magnetostratigraphy of the region. Khadri and Nagar (1994) have identified the presence of some structural features in the Mandu region lying towards the northern side of Narmada River. Chandrasekharam et al., (2000) have reported petrogenetic significance of ferro-enstatite, orthopyroxene in basaltic dykes from the Tapti rift, Deccan flood basalts was provided Subbarao (2000) Mahoney (2000) has studied the geochemistry of the flood basalts of the Toranmal section, Northern Deccan Traps, India with implications for Regional Deccan stratigraphy.

Chenet et al., (2008&2009) reported results from the upper third, and the lower two thirds of the 3500m thick composite section. The methods employed are the same, i.e., combined use of petrology, volcanology, chemostratigraphy, morphology, K-Ar absolute dating, study of sedimentary alteration horizons, and as the main correlation tool, analysis of detailed palaeomagnetic remanance directions. The thickness and volume of the flood basalt province studied in this way are therefore tripled. A total of 169 sites from eight new sections are reported. Together with the results of Chenet et al., (2008), these data represent in total 70% of the 3500m combined sectioned of the main Deccan traps province. This lava pile was erupted in some 30 major eruptive periods or single eruptive events (SEE), each with volumes ranging from 1000 to 20,000 kms and 41 individual lava units with a typical volume of 1300kms. Palaeomagnetic analysis shows that some SEEs with thicknesses attaining 200m were emplaced over distances in excess of 100km (both likely underestimates, due to outcrop conditions) and up to 800 km. The total time recorded in a very small number of intervening alteration levels marking periods of volcanic quiescence (so-called “big red boles”). The number of boles, thickness of the pulses, and morphology of the traps suggest that eruptive fluxes and volumes were larger in the older formations and slowed down with more and longer quiescence periods in the end. On the basis of geochronologic results published by Chenet et al., (2007) and palaeontological results from Keller et al., (2008), Chenet et al., (2009) proposed that volcanism occurred in three rather short, discrete phases or mega pulses, an early one at ~67.5 ± 1 Ma near the C30r/C30n transition and the two largest around 65 ± 1 Ma, one entirely within C29r just before the K-T boundary, the other shortly afterward spanning the C29r/C29n reversal. Chenet et al., (2009) next estimate sulphur dioxides (likely a major agent of environmental stress) amounts and fluxes released by SEEs: they would have ranged from 5 to 100Gt and 0.1 to Gt/a, respectively, over durations possibly as short as 100 years for each SEE. The chemical input of the Chiculub impact would have been on the same order as that of a very large single pulse. The impact, therefore, appears as important but incremental, neither the sole nor main cause of the Cretaceous-Tertiary mass extinctions.

DETAILS OF SAMPLING AND LABORATORY MEASUREMENTS

All the oriented block samples at different stratigraphic levels were collected by marking geographic coordinates (North and two Horizontal directions) on each sample by Brunton compass so as to facilitate its reorientation in the laboratory. Oriented block samples were properly numbered following the scheme of sampling given by Irving (1964).

The samples collected in the field were carefully brought to the laboratory without losing their orientation marks during transport. All the oriented block samples were reoriented in the laboratory on the cement base and drilled with the help of AIMIL-256 core drilling machine. The core were cut by core cutting machine to obtain two or more specimens of about 2.3 cm length on which the orientation marks were transferred. Each sample and core number was denoted by Arabic number also followed by specimen number in alphabets in such a way that the site, sample and specimen relationship is easily understood. About 1200 such cylinders were cored from 400 oriented samples.

The Natural Remanent Magnetic directions were (NRM), intensity (Jn), magnetic susceptibility (K), induced magnetic intensity (Ji) and Koenigsberger ratio (Jn/Ji) were measured at NGRI, Hyderabad for each specimen. The stability of NRM was checked by both alternating field demagnetization up to 100 mT and stepwise thermal demagnetization up to 600^0C. About thirty five specimens were demagnetized progressively in successive steps of 5mT, 7.5 mT, 10 mT, 12.5 mT, 15 mT, 17.5 mT, 20 mT, 25 mT, 30 mT, 40 mT, 60 mT, 80 mT, 100 mT and the results were tested for relative directions and intensity changes during demagnetization. Two hundred specimens were demagnetized by stepwise thermal demagnetization progressively in successive steps of 50^0C, 100^0C, 200^0C, 300^0C, 400^0C, 500^0C, 600^0C. About eleven specimens were treated for IRM progressively in successive steps of 0 mT, 15 mT, 20 mT, 30 mT, 40 mT, 50 mT, 60 mT, 80 mT, 100 mT, 120 mT, 140 mT, 160 mT, 180 mT, 200 mT, 250 mT, 300 mT, 350 mT, 400 mT, 500 mT.

Stepwise Thermal Demagnetization (TD)

Stepwise thermal demagnetization has been carried out to understand the stability of NRM direction of 35 specimens and to remove the secondary components. The samples were heated stepwise 100^0C to 600^0C and cooled in the field free space which was later measured for their stability. The results indicate mixed behaviour of the magnetic Grains. The behaviour of vector directions and change of intensity during stepwise thermal demagnetization have been plotted to understand the behaviour of magnetization with temperature. The results indicate three types of variations with increasing temperatures.

1. Majority of the samples show change in the intensity during demagnetization with a gradual fall throughout. This behaviour is exhibited by specimens with more or less reversed directions and maintains the same.
2. Some samples show an initial increase in the intensity followed by a gradual decrease resulting in the improvement of magnetic directions. The unstable component is removed by thermal demagnetisation and characteristic direction is obtained.
3. A few samples show a steep fall in the intensity in the initial stages indicating a strong isothermal

remnant magnetization. This specimen showed no improvement in the remnance direction evens after demagnetization due to the complete loss of primary directions.

In general, the results of both the demagnetisation techniques utilized for cleaning the secondary components in the study area suggests that both the methods are equally effective or ineffective in removing the secondary components. Certain samples show both "Normal" and "Reversed" polarity directions even after demagnetization within a single flow shows "Normal" polarity whereas belonging to the same to the same flow showed "Reversed" polarity. This can be explained on the assumption that some zones of the flow got remagnetised after the polarity of the geomagnetic field has changed or by local action of self reversed mechanism in the magnetic minerals.

STATISTICAL ANALYSIS OF PALAEOMAGNETIC DATA

The mean directions of declination (D) and inclination (I) were computed by utilizing the total number of samples showing stable and consistent directions along with the precision parameter (K) using the Fisherian statistics for different sets of declination and inclination values obtained after demagnetization. Kono et al., (1972) has indicated that the secular variation of geomagnetic field at the time of Deccan Volcanism might have been much greater than the present trend. However, it is not clear that all such scatter could be linked to geomagnetic secular variations and not to some change in magnetic mineralogy. The mean directions of "Reversed" and "Normal" flows representing N-R-N sequence exposed in the study area have been computed using a personnel computer on Fisherian statistics. The mean declination (D) and inclination (I) of all the samples from a flow was calculated by taking the average directions of magnetization. The precision of the calculated mean directions are represented by the precession parameter (K = (N-I/N-R) where, N is the number of individual magnetization directions and R is the vector sum of individual magnetic vector circle of 95% confidence. Some flows show low values K which means that the data points are randomly scattered all over the stereo plot with higher K values indicating greater precision reflecting the clustering of data points about a mean direction.

PALAEO-LATITUDE AND POLE POSITION OF THE STUDY AREA AND THE REVERSAL PLATE MOVEMENT

The mean palaeomagnetic directions were computed along with the ancient latitudes and pole position for the study area together with those available for other region of the Deccan Traps. The pole position and palaeo-latitude for the study area are calculated from the mean inclination following the treatment of NRM data using the statistical methods. The ancient pole position computed for the lower transition and upper reversal the Chikhaldara region, the ancient pole position lies 34˚North and 81˚W of North America which falls more less near the estimated values from other part of the Deccan Traps (34.3˚N and 88.6˚W, Wensink, 1973). It is remarkable to note that excluding minor variations with other part of the Chikhaldara regions, the pole position obtained for the study area fall more or less near the same position in the polar wandering curve for the India.

The polarity transition has take place in the study area. Ancient latitude calculated for the study area is 30˚S and that of Nagpur is 31˚S indicating that India has drifted by 51˚ due N which is more than 5000 km. since the formation of this lavas. The result obtained in the study area indicate very good correlation with other part of the Deccan traps and the pole position fall more or less the polar wandering curve for India.

The Palaeomagnetic and rock magnetic data obtained for various flows exposed near Chikhaldara region and adjoining areas are not as good as those from other areas of the Deccan Traps Volcanic Province probably due the alteration and remagnetisation of many of the flows exposed in the study area. Hence, it is suggested that extreme caution have to be exercised in the interpretation of rock magnetic and palaeomagnetic data by deleting all the samples showing irregular directions in order to arrive at proper comparison of results.

CORRELATION OF PALAEOMAGNETIC DATA WITH THE SURROUNDING AREAS AND WESTERN GHATS

The Palaeomagnetic results obtained in the study area have been correlated and compared with the similar rocks belonging to adjoining areas and Western Ghats. Wensink (1971) and Klootwijk (1973) have compiled the Palaeomagnetic results from various parts of Deccan Traps indicating reversed polarity in 80% of the samples. The present investigation also confirms the above observation with the presence of the lower Chikhaldara mixed polarities and upper Chikhaldara reversed polarity.

Clegg et al., (1956), Deutsch et al (1955) and Sahastrabudhe (1963) have reported the rocks exposed towards the southern part of the Western Ghats lava pile occurring about 600 to +/ - 60m above MSL and normally magnetized and rocks occurring below are reversal magnetized.

In the present study an attempted has been made to compile the so far available palaeomagnetic data to understand the nature of polarity transition in Deccan traps. A critical observation of existing palaeomagnetic data on Deccan Traps indicated the presence of reversal with N-R sequence. It has been noticed that in most of the areas, one reversal is exposed. However, Sreenivasa Rao et al., (1984) and Sreenivasa Rao (1985) have reported the presence of N-R-N sequence towards the south of Narmada River. The present study area, which lies towards north of Narmada River are, characterized the lower N-R sequence with the absence of upper Normal polarity. This might be due to either removal of upper Normal flows because of erosion or might be due to non-eruption.

The remnant magnetic intensity (Jn), magnetic susceptibility (K), Koenigsberger ratio (Qn), Declination (D), Inclination (I) and relative and peak susceptibility for each flow are plotted as a function of its stratigraphic position. Most of the flows exposed in the study area exhibits Lower “Normal” and Upper “Reversed” polarity with a few samples showing scattered behaviour. Repeated random sampling for the scattered flows did not show any improvement in the NRM directions. Due to this reason, it can be concluded that more systematic studies of these individual lava flows showing polarity is yet to be undertaken. In the mean while there seems to be adequate justification for leaving out one specimen in a flow showing near “Normal” or “Normal” polarity when they occur in a thick pile of “Reversed” polarity.

In view of the above points, it is understood that the presence of one doubtful “Normal” flow within a pile of “Reversed” flow may not be represent a geomagnetic field reversal. Though a few specimens in Narnala traverse (NAR 1, 2, 6) are either showing scattered or unstable directions, they are treated as “Reversed” considering the polarity of the flows lying above and below. The high precision parameters obtained for the samples of both usual (expected of Deccan Traps) and odd directions suggests that there

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might be a total remagnetization in case of samples showing odd and stable directions or some zones of the flow got remagnetized after the geomagnetic field has changed.

The variation in the declination and inclination of certain flows compared to the average directions of the Narnala region can be describe to the secular variation of the ambient geomagnetic field and the strongly deviating directions in some are considered to be the result of polarity excursion of the ambient geomagnetic field. The above mentioned flows can be utilized as distinct marker horizons, Flow No. (BUN 30a2) D=141 and I= -13. This shallow negative inclination with “Reversed” azimuth gives a clue to be an excursion. Anomalous palaeomagnetic directions have been reported in different regions which are not due to excursion but rather formed as result of deformation of rocks (Verosub and Banerjee, 1977). This indicates that the odd and unusual directions can be attributed to the process of alteration.

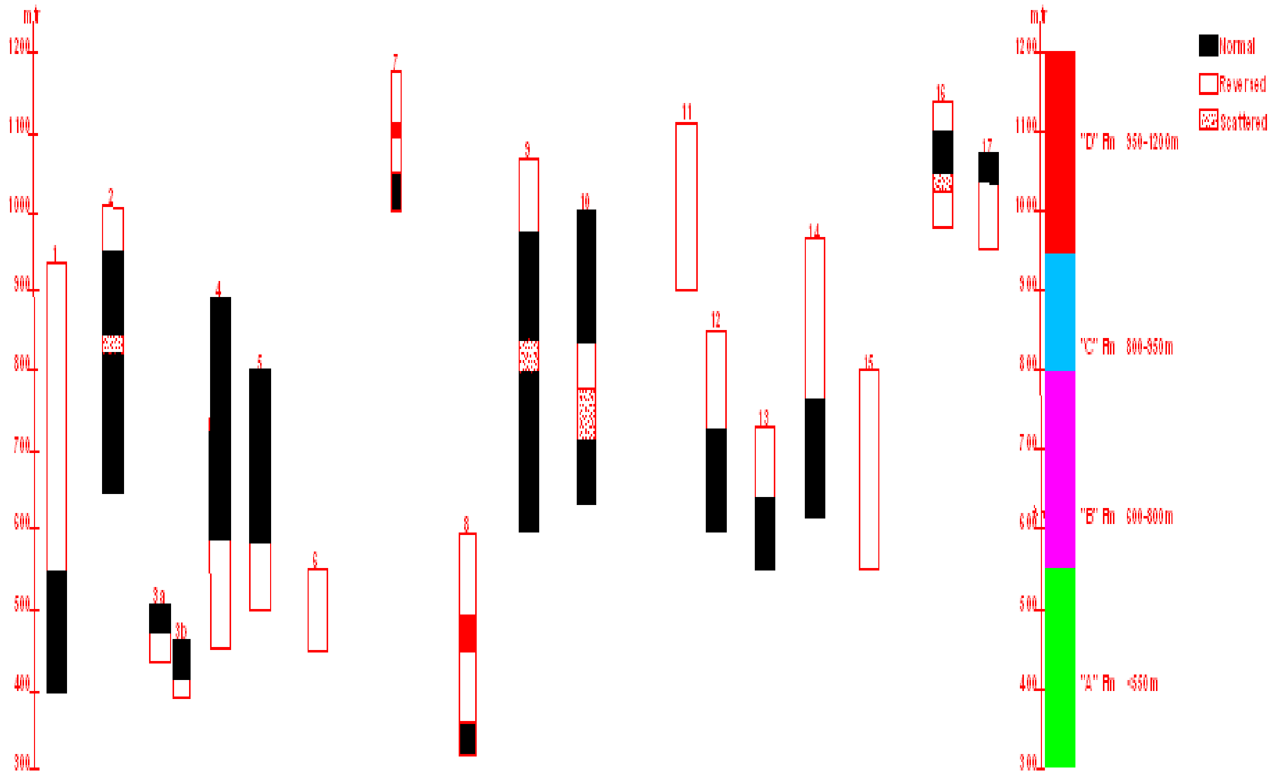

Fig. 1 Gist of palaeomagnetic polarity for various traverses exposed in the study area

1) Narnala
2)Gulerghat
3a)Khirkund and 3b)Mahagaon
4)Khatkali 1
5)Khatkali 2
6)Dhakana
7)Vairat
8)Shanur
9)Chikaldara/Motha
10)Sembadoh/Chikhaldara
11)Jamunala
12)Sembdoh
13)Raipur
14)Makla/Sembadoh
15)Kohana
16)Bundelkund
17)Dhoria/Bothia

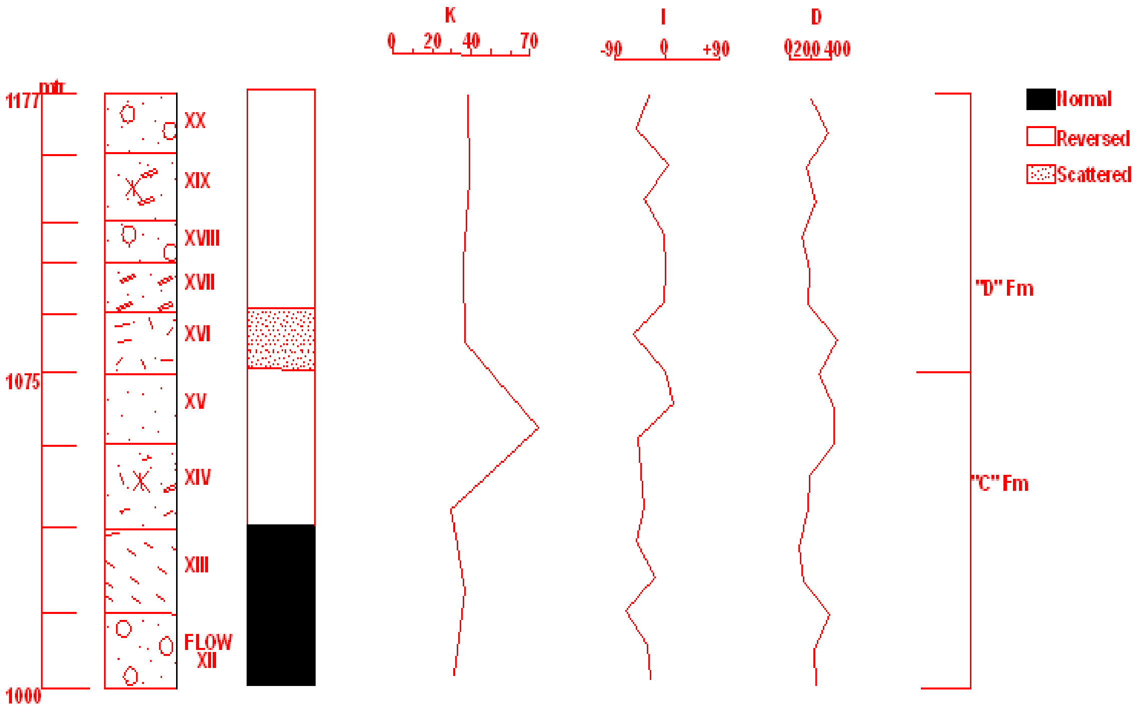

Fig. 2 Magnetostratigraphy of the Vairat traverse

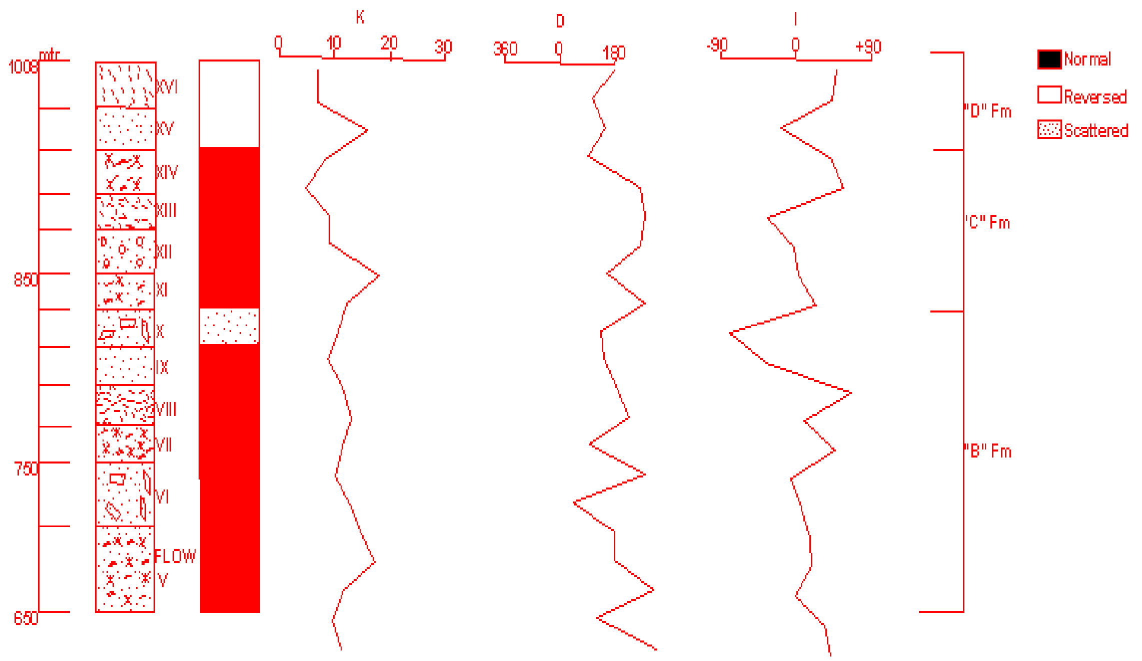

Fig. 3 Magnetostratigraphy of the Gulerghat traverse

Rock magnetic investigations indicate the presence of mixed behaviour of the domain states showing their stability conditions along with the presence of mixed behaviours multi domain magnetic contamination in certain flows. The palaeomagnetic results indicate that the most of the flows showed irregular natural remnant directions while a few specimen even from other flows for which a meaningful NRM could be deciphered also showed inconsistent directions. Only 30% of the samples showing

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irregular directions initially improved on alternating field and stepwise thermal demagnetization. High degree of alteration of the flows appears to have affected the stability of the palaeomagnetic direction. The mean palaeomagnetic directions indicate the presence of Lower transitional directions at the bottom part of the sequence (flow I) and upper reversed polarity in remaining part of the sequence with a few samples showing scattered behaviour. The polarity transition has take place in the study area is 30^0 S and that of Nagpur is 31^0 S indicating that India has drifted by 51^0 due N which is more than 5000 km. since the formation of this lavas.Bhore study area is characterized by 803m thick lava pile, which can be grouped into four formations namely A, B, C and D consisting of twenty four lava flows grouped into five chemical type.

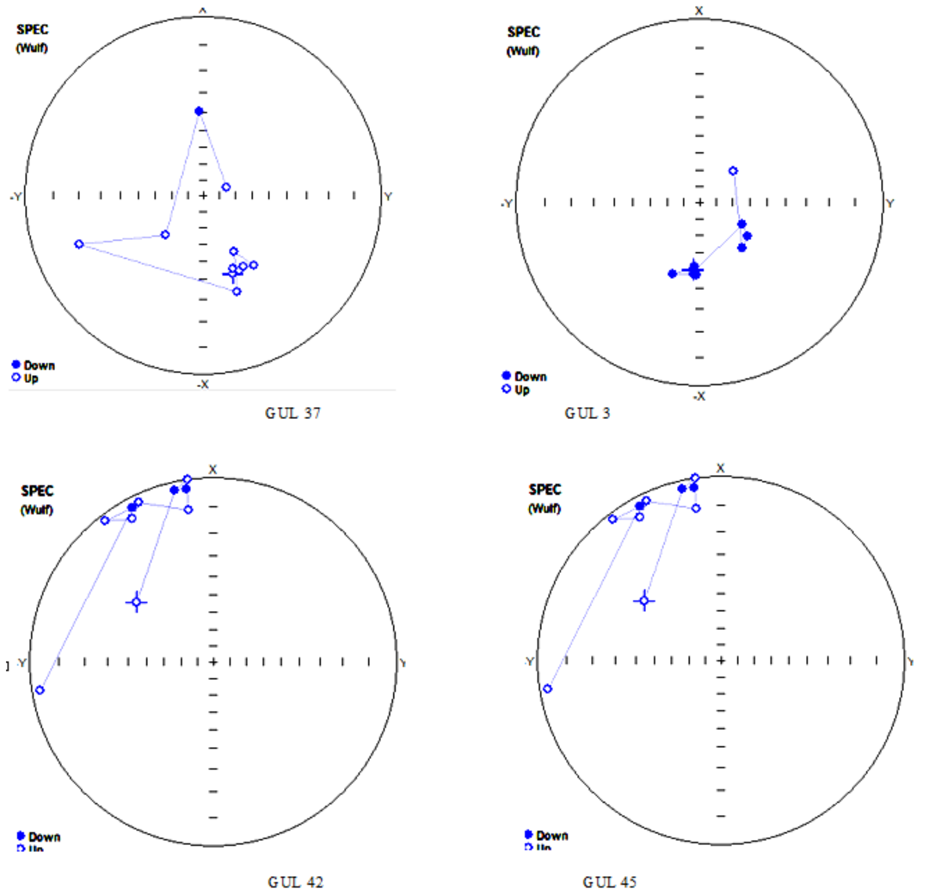
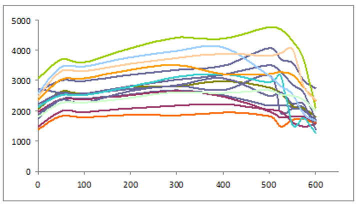


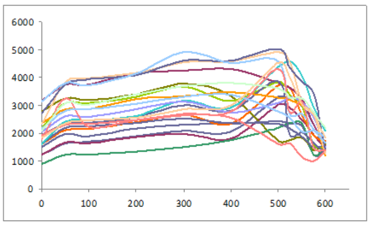
Fig. 4 Behaviour of vector directions in representative specimens during thermal demagnetisation, Inclinations positive (+ve) downward, negative (-ve) upward, arrow indicates increased demagnetisation

Table 1 Results of Magnetic susceptibility with progressive step wise Thermal Demagnetization

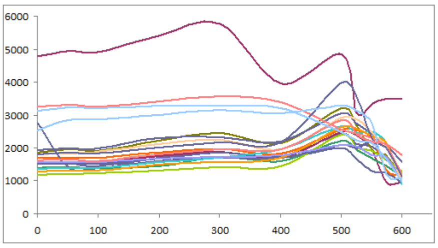
Narnala(II) Traverse											
NAR(II) 1	1765	2377	2407	2541	2694	2527	2184	2207	2132	2098	1631
NAR(II) 2	1977	2393	2391	2532	2651	2479	1992	1775	1828	1801	1652
NAR(II) 6	2066	2630	2559	2802	2790	2981	2787	2588	2155	2076	1810
NAR(II) 10	1875	2360	2274	2658	2823	2691	3161	1948	2086	2007	1683
NAR(II) 16	2731	2598	2581	2816	3034	3187	3511	3280	2878	2590	1722
NAR(II) 20	1385	1822	1778	1868	1856	1938	1831	1475	1708	1736	1591
NAR(II) 22	2611	3004	2994	3196	3354	3501	4079	3696	3589	3018	2757
NAR(II) 24	1480	1997	1965	2089	2186	2232	2028	1991	1616	1479	1575
NAR(II) 28	3070	3707	3620	4074	4414	4394	4769	4710	4312	3714	2106
NAR(II) 32	2219	2601	2550	2723	2841	3074	2510	2617	2226	1383	1383
NAR(II) 39	2139	2516	2532	2801	3116	3224	2930	3156	1526	1770	1273
NAR(II) 48	2371	3041	3084	3355	3517	3221	3224	3282	3206	2781	2331
NAR(II) 52	2387	3444	3482	3776	3986	4098	3170	2834	2557	1891	1660
NAR(II) 55	2474	3320	3310	3573	3745	3878	3826	3906	4024	2834	2364
NAR(II) 58	2426	2865	2673	3208	3346	3327	Broken				
NAR(II) 60	1797	2268	2271	2440	2619	2386	2686	2549	2511	2372	2007
Gulerghat Traverse											
GUL 3	1214	1631	1686	1887	2073	2064	3294	3207	2983	2309	1331
GUL 7	1209	1633	1647	1832	1963	1807	3026	2918	2482	1946	1480
GUL 9	2780	3244	3184	3401	3772	3329	1735	1753	1832	1393	1612
GUL 12	1487	1967	1880	2159	2302	2346	2427	2321	2251	1221	1373
GUL 15	895	1234	1229	1322	1500	1739	2199	2352	2346	1230	1506
GUL 20	1613	2119	2143	2394	2679	2326	3719	3640	2635	1908	1716
GUL 25	1625	2197	2254	2367	2535	2367	2343	2163	1864	1513	1549
GUL 29	3165	3744	3757	4157	4246	4294	3797	3628	3213	2293	1550
GUL 31	2187	3095	3087	3293	3663	3137	3825	3362	2966	1592	1503
GUL 34	1950	2347	2357	2594	3013	2819	3851	1935	2040	1638	1285
GUL 37	1601	2406	2484	2622	3168	2930	4397	4578	4056	2912	2078
GUL 39	2128	2827	2936	3101	3339	3409	BROKEN				
GUL 42	2372	2873	2850	3221	3340	3486	3282	3188	2988	2635	1199
GUL 45	2063	2600	2575	2868	3138	2740	3071	3281	3118	2549	1487
GUL 48	1920	2307	2328	2472	2630	2544	1598	1630	1149	995	1349
GUL 49	2340	3830	3981	4164	4547	4575	4904	4597	3076	2657	1294
GUL 51	2726	3733	3934	4091	4604	4611	5034	4365	3856	3406	1409
GUL 54	3129	3815	3717	4147	4922	4536	4593	2688	2688	2147	1675
GUL 56	1775	3241	2234	2463	2701	2775	4306	2760	3113	1485	1398
GUL 58	2169	2810	2858	3047	3308	3382	2784	2566	2044	2075	1869
GUL 59	1945	2363	2465	2555	2859	2990	4540	3987	3018	2661	1839
GUL 62	2089	3083	3022	3381	3698	3799	3603	3288	3254	2737	2207
Vairat Traverse											
VAI 1a1	1546	1559	1458	1700	1857	1757	2433	2124	2040	1692	1185
VAI 1a2	1553	1565	1589	1751	1899	1708	2488	2382	1927	964	952
VAI 3	1860	1965	1916	2214	2453	2143	3203	2651	1942	1756	1129
VAI 6	1515	1518	1533	1672	1853	1694	1998	1658	1286	1248	942
VAI 9	1401	1425	1398	1443	1737	1599	2221	1939	1675	1452	1133
VAI 11	1714	1712	1698	1866	1966	1824	2555	2544	2294	1308	1180
VAI 13	1943	1985	2002	2305	2327	2210	3048	2750	2441	2065	1565
VAI 15	4774	4939	4910	5410	5772	3956	4837	3051	3348	3482	3498
VAI 17	1181	1203	1234	1329	1428	1448	2406	2021	1925	1617	1303
VAI 23	2766	1416	1399	1606	1694	1706	2100	1999	2177	1631	1146
VAI 27	1365	1393	1386	1565	1699	1966	2659	2451	2478	2139	912
VAI 30	1298	1329	1307	1491	1565	1702	2637	2574	2362	2155	985
VAI 32	1566	1567	1569	1669	1731	1795	2099	2054	1779	1712	981
VAI 35	3262	3322	3270	3415	3560	3380	2564	2419	2302	2049	1213
VAI 39	1810	1839	1883	2113	2242	1978	2925	2866	2468	2006	1028
VAI 45	1813	1870	1825	2024	2184	2175	3974	3542	2285	1999	1150
VAI 49	2327	2845	2879	2998	3165	3045	3291	3129	2741	1192	1076
VAI 52	1619	1645	1615	1819	1954	1953	2856	2417	2188	2131	1790
VAI 54	3132	3220	3216	3272	3297	3196	2491	2229	2149	1643	983



Narnala



Gulerghat



Vairat

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