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Magnetic Fabric and Rockmagnetic Properties of the Archaean Granites from part of the Hyderabad Granitic Region (HGR), Eastern Dharwar Craton, India

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ABSTRACT
Archaean granite samples, collected from unweathered basement from part of the Hyderabad Granitic Region (HGR) consisting of pink and grey varieties, are studied for their magnetic fabric and rock magnetic characters. Rock magnetic properties show wide range of characters for both the varieties and grey granite is found to be more magnetic than the pink variety. Average values of Natural Remanent Magnetization (NRM) intensity, Magnetic Susceptibility (K) and Koenigsberger's ratio (Qn) are found to be 488 and 637 Am^{-1}; 1689 and 1780; and 9 and 19.7 for pink and grey granites respectively. There are significant differences in the rock magnetic properties between the pink and grey granites such as NRM Intensity, magnetic susceptibility (K) and Qn. Probably this is an expression of grade of metamorphism that these rocks have undergone and thus may be attributed to the time difference in their formation. The magnetic mineralogy of the granites of the study area is dominated by multi domain magnetite as revealed by the Isothermal Remanent Magnetic (IRM) and thermo magnetic studies. Further, the fabric of the magnetic minerals shown by both pink and grey granites is similar. This indicates that the deformation recorded in these rocks is a wide spread, post-formational event in the Eastern Dharwar Craton (EDC) and is exactly preserved in the Hyderabad Granitic Region (HGR).

Key Words: Natural remanent Magnetisation, Anisotropy of Magnetic Susceptibility, Koenigsberger`s ratio, Isothermal Remanent magnetization, Thermo magnetism, Dharwar Craton, Hyderabad Granitic Region

INTRODUCTION

INTRODUCTION AND GEOLOGICAL SETUP

Several granitic plutons occur in the Andhra Pradesh part of the Eastern Dharwar Craton (EDC) and are known with their place of emplacement wherever they occur, such as Hyderabad, Karimnagar, Mahaboobnagar and Warangal etc,. Hyderabad pluton, possibly a composite batholith consisting of Karimnagar, Warangal and Mahaboobnagar plutons, shows compositional variation at different places (Rama Rao et al. 2001) and considered as a single largest pluton, broadly known as Hyderabad pluton or Hyderabad Granitic Region (HGR). Hyderabad granite is radiometrically dated to be 2500 Ma in age (Crawford, 1969) and is correlated with the Colsepet and Chitradurga granites of Dharwar Craton. This intra-cartonic granitic batholith of Hyderabad is one of the remarkable geotectonic sections in the northeastern part of the Eastern Dharwar Craton (EDC). Gravity and magnetic anomalies show that the HGR covers an area of about 100 square kilometers with a vertical thickness of 4 to 5 kilometers (Singh et al. 2004). As an independent pluton, HGR is bounded by Karimnagar granulitic terrane (Rajesham et al. 1993) and Godavari Graben in the northeast; Proterozoic Cuddapah Basin in the south and Deccan Traps in the northwest **(Figureure 1 inset)**. It is believed to be developed by lower crustal re-melting process of the earlier crystalline rocks (Radhakrishna, 1989; Divakara Rao, 1996). Many parts of the Indian shield have undergone extensive granitization-migmatization around 2.4 Ga and probably the HGR is formed during this stage (Divakara Rao et al. 1974). Yet, the granitization process that developed such large volume of pluton still remains debated. Hyderabad batholith has a layered structure with a thin highly radioactive surface of about one kilometer (Padma Kumari et al. 1977; Gupta et al. 1987).

Geologically, the HGR of southern India consists, in general, of unclassified granites and granite gneisses of Achaean age which are locally classified into three main varieties like pink, grey and leuco-granites besides the presence of pyroxene bearing granodiorites and charnockite assemblages at places (Sitaramayya, 1971). Plagioclase and potash feldspars, along with mafic minerals, are predominant in grey granite and pink granites respectively. Pink granites are relatively less magnetic compared to grey granites (Madhusudan Rao et al. 2002), indicating the presence of more ferromagnesian minerals in grey granite (Kanungo et al. 1975; Goutham et al. 2010). Metasomatic changes of potash feldspar from grey granite are presumed to have given rise to pink granite (Balakrishna, 1964).

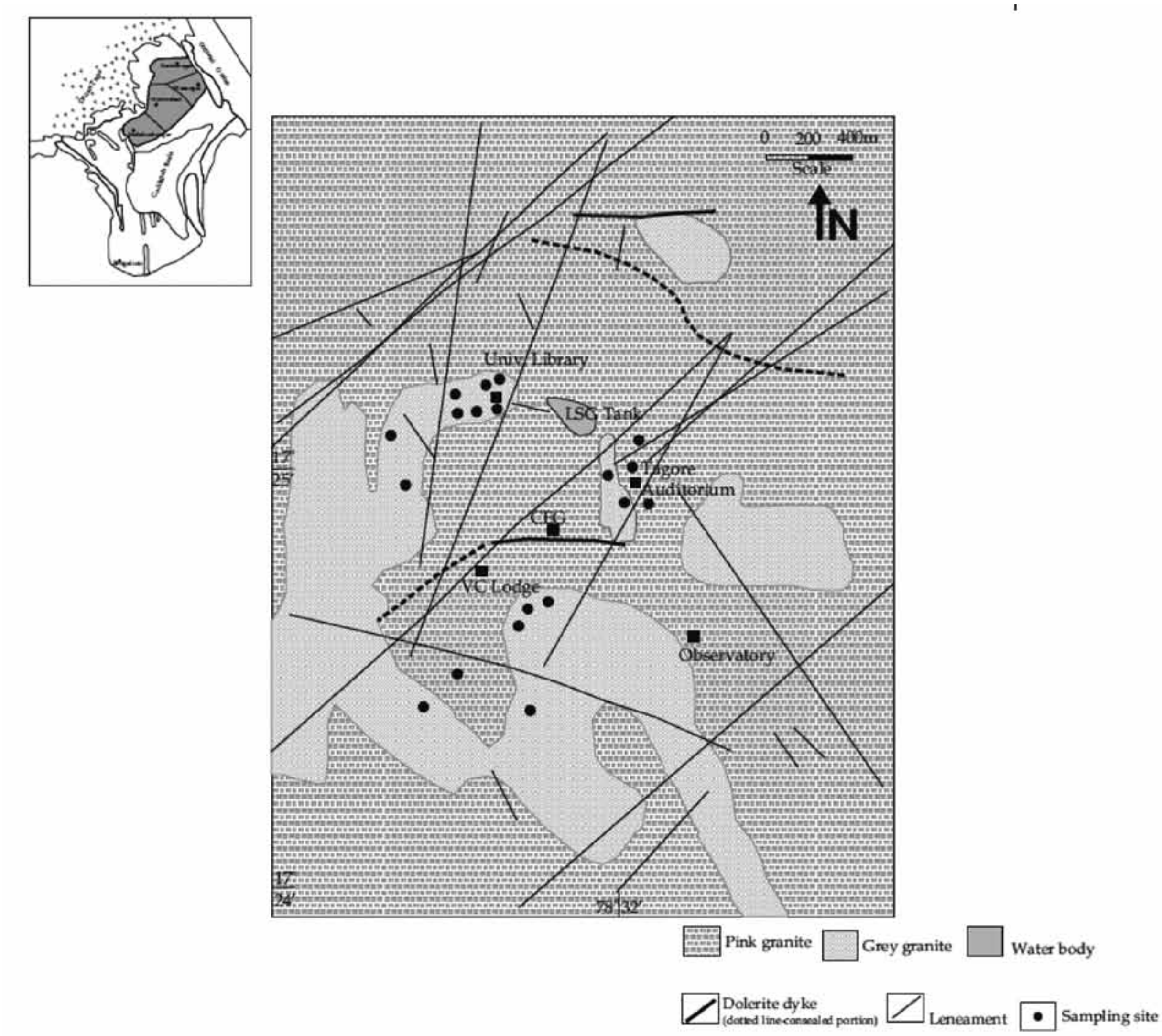

Figure 1. Geological map of the study area with sampling locations

Similar conclusion was drawn by another independent study stating that the pink granite has formed due to feldspathization of the grey granite (Kanungo et al. 1975). However, the possibility of evolution of these varieties from each other was debated (Satyanarayana, 1977). Texturally, these granites ranges from medium to coarse grained and at places fine grained nature observed in grey granite and display, in general, equigranular to porphyritic texture. Petrographically Plagioclase feldspar and potash feldspar (microline, antiperthite and myrmekite) along with ferromagnesian minerals as essential constituents for grey and pink granite respectively, which are distinguished with two sets of cleavage. Labrodorite is also identified by its lamellar twinning. Little amount of oligoclase is also present. Alteration is seen from plagioclase feldspar to perthite at places. Accessory minerals are represented by hornblende, biotite and epidote along with opaques (iron oxides). These iron oxides are responsible for carrying the magnetic properties and are distributed all over the sample (Figure. 2)

The boundary between grey and pink granite is transitory and gradational in both lateral and in vertical directions, the origin being the same for both the rock types (Madhusudan Rao et al. 2002). Alteration in rock colour may usually also be brought out by supergene processes such as reaction between groundwater and rocks (Tarling and Hrouda, 1993). Besides, late magmatic or hydrothermal fluids can also change the primary mineralogy of the rocks and result in formation of more oxidized iron oxides. Further, weathering and tectonic disturbances of these rocks may change the physical properties of the rocks and develop structural features like faults, fractures and joints. Most likely, this kind of structural features are responsible for the development of pseudo contacts between pink and grey granites at some places in HGR (Balakrishna et al. 1962).

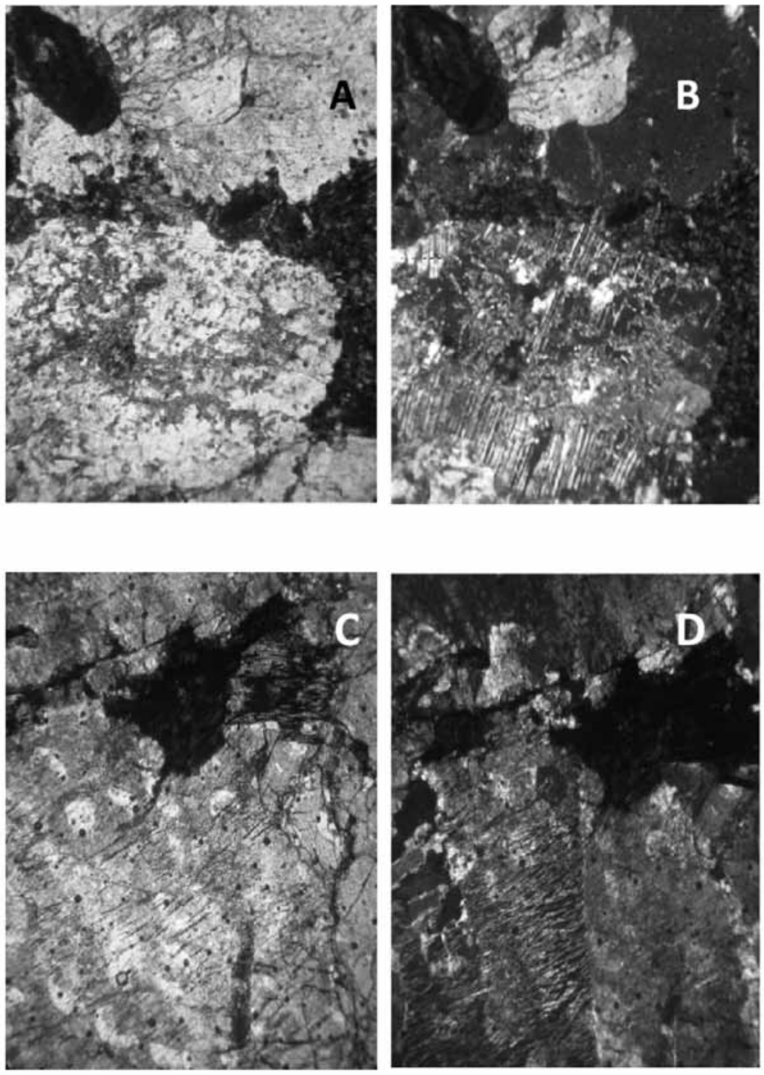

Figure 2. Photomicrographs of Grey and Pink granites. A: Grey granite (Plane polarized light); B: Grey granite (crossed nicols); C: Pink granite (Plane polarized light); D: Pink granite (crossed nicols).

However, later the grey granite is reported to be older than the pink variety (Crawford, 1969) and is considered to be equivalent of Closepet granite (2500 Ma). Structurally, the general trend of the HGR seems to corroborate with the Dharwarian trend and the trend of foliation and lineation is N-S to NNW-SSE in the study area. Foliation and lineations are better developed in grey granites than in pink granite (Kanungo et al. 1975). However, the foliation is not always clear but can be seen with careful observation while the lineation is due to elongated minerals of hornblende and biotite and is parallel to the foliation direction (Balakrishna and Raghava Rao, 1961).

Rock magnetic properties such as Susceptibility (K) and intensity of magnetization, were measured by using Bartington Susceptibility apparatus (MS2) and spinner magnetometer of Molspin make (UK) respectively. Thermomagnetic measurements (Temperature susceptibility) were made by using KLY2 instrument. Low field Anisotropy of Magnetic Susceptibility (AMS) of the specimens was measured by using Kappa Bridge AMS instrument (AGICO).

RESULTS AND DISCUSSION

The remanant magnetic intensity of the specimens shows a large variation which ranges between 103 and 4613 Am^{-1} with a mean value of 637 Am^{-1} for grey granites; and from 56 to 2014 Am^{-1} with a mean value of 488 Am^{-1} for pink granites. Magnetic susceptibility of specimens also varies over a wide range between $630x10^{-5}$ and 6790.5 $x10^{-5}$ with an average value of 1780 $x10^{-5}$; and from 54 $x10^{-5}$ to 3480 $x10^{-5}$ with an average of 1689 $x10^{-5}$ for grey and pink granites respectively. This distribution shows that grey variety is more magnetic than pink

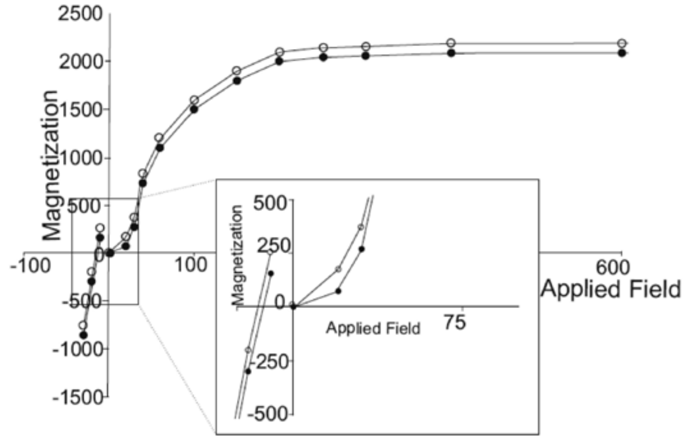

Figure 3. Results of IRM acquisition for representative specimens. Inset: Blown up portion of the curve to show the Coercive force. (Units for both the axes are mT).

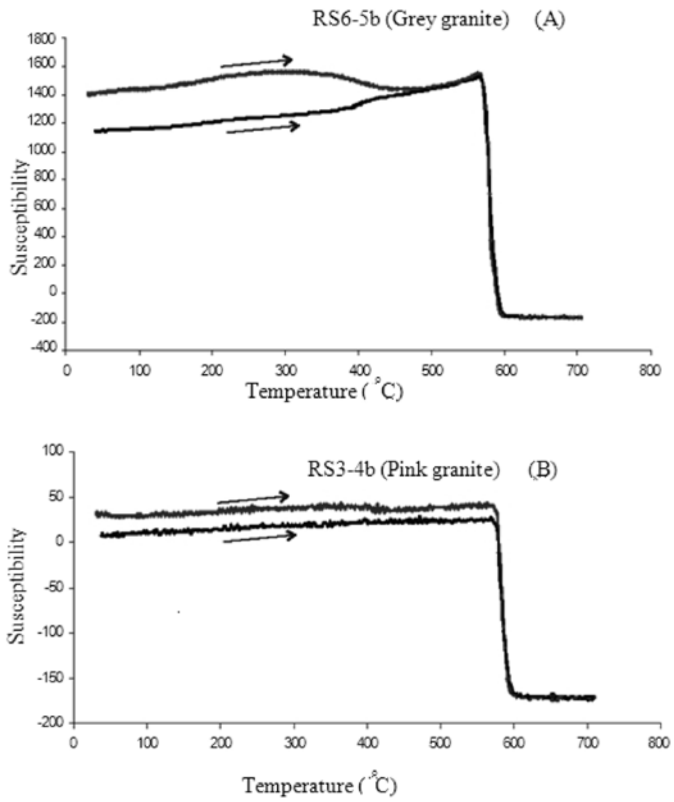

Figure 4. K-T curves of A: Grey granite, B: Pink granite

variety. Megascopically it is evident that the rocks under investigation consist of diamagnetic minerals, such as quartz and feldspars, paramagnetic minerals, such as hornblende and biotite, and ferrimagnetic mineral magnetite. The contribution of diamagnetic minerals to the magnetic susceptibility is negligible because their inherent magnetic susceptibility is low compared to that of other minerals (Rochette, 1987). Conversely, magnetic susceptibility may change with the grade of metamorphism with depth (Hrouda, 1982; Shive et al. 1988). Perhaps the wide range of susceptibilities mentioned above may be the expression of grade of metamorphism that these granites undergone. Globally, granites show bimodal distribution of susceptibility with two distinct values around 10^{-3}-10^{-2} and 10^{-5}-10^{-4} SI units which lead to the classification of granites into ilmenite-series and magnetite-series granites (Ishihara, 1977; Ishihara et al. 2000; Gregorová et al. 2003)

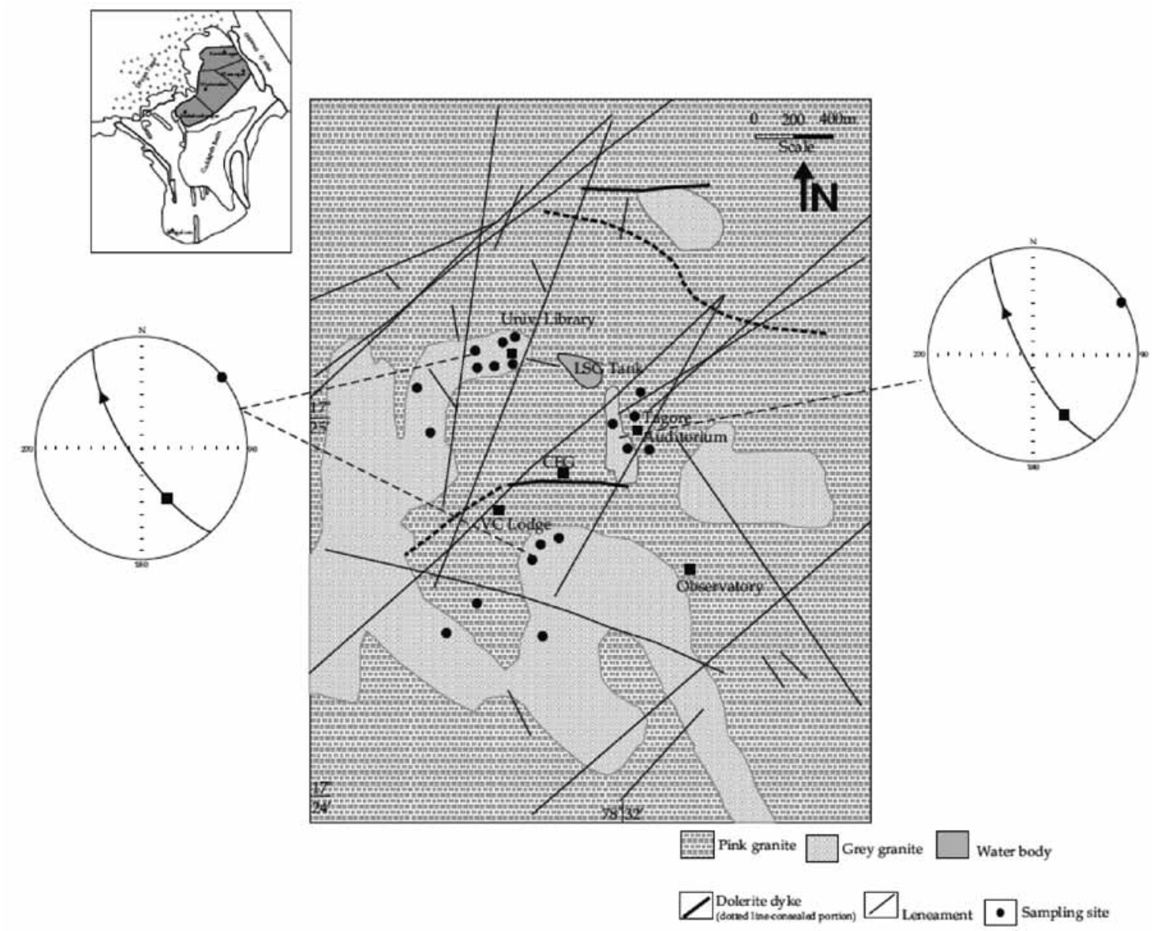

Figure 5. Magnetic fabric (lineation and foliation) of part of the HGR

Isothermal Remanent Magnetization (IRM) Results

Representative specimens are subjected to Isothermal Remanent Magnetization (IRM) to evaluate the minerals carrying the magnetic remanence in the rocks under study by applying the increasing forward magnetic fields from 20mT to 1000 mT in different steps. The magnetization induced in the specimens is measured after each step of induction. Specimens are then subjected to reverse field to get the coercivity of remanence (Jr). All the specimens saturated around 150 mT suggesting magnetite is the carrier of remanence. The remanent coercive force (Hc) is very low (<20) (**Figure. 3**) suggesting the dominance of multidomain grains in the samples.

Temperature Susceptibility

Thermomagnetic experiments in high temperature were carried out on representative specimens from gray and pink granites and are shown in Figure. 4. It is apparent from this study that magnetite is the major magnetic carrier in the samples.

Anisotropy Of Magnetic Susceptibility (AMS) Studies

The AMS technique provides a precise and quick measurement of the alignment of magnetic grains present in the rock. The technique has been successfully applied to document the magma flow direction in igneous rocks and for provenance studies in sedimentary rocks (Tarling, 1993; Borradaile and Henry, 1997; Tauxe et al. 1998; Bouchez, 2000; Herrero-Bervera et al. 2001; Femenias et al. 2004; Patel, 2006). The anisotropy of magnetic susceptibility (AMS) can be defined by a triaxial ellipsoid with orthogonal maximum (K1), intermediate (K2) and minimum (K3) axes, where K1>K2>K3. Different parameters are being used to define the properties of the ellipsoid (Tarling, 1983). The most commonly used are lineation (L) = K1/K2, foliation (F) = K2/K3 and degree of anisotropy (P) = K1/K3. The technique involves the measuring of magnetic susceptibility (k) of a rock in 15 different directions and defining the magnitude (intensity and orientation) of the three principal axes K1, K2, K3. The anisotropy of magnetic susceptibility (AMS)

Table 1. AMS data of the study area

Site	Rock Type	Location	N	n	Km	K1		K2		K3		L	F	Pj	T
						D	I	D	I	D	I				
1	Pink Granite	N 17° 24.8' E 78° 31.7'	5	17	1.02E-02	152.8	5.1	261.3	74.3	61.5	14.8	1.096	1.104	1.212	0.033
2	Grey granite	N 17° 24.9' E 78° 31.8'	7	26	3.69E-02	152.3	37.2	326.6	52.7	60.2	2.8	1.127	1.117	1.263	-0.055
3	Pink Granite	N 17° 24.6' E 78° 31.5'	8	23	2.57E-02	161.7	34.2	333.5	55.5	69.1	3.8	1.12	1.149	1.29	0.082
4	Grey granite	N 17° 25.0' E 78° 31.6'	12	27	1.31E-02	141.7	47.9	319.1	42	50.3	1.3	1.079	1.113	1.206	0.142
5	Grey granite	N 17° 25.0' E 78° 31.5'	7	7	2.30E-02	100	70.7	325.9	13.7	232.6	13.3	1.037	1.081	1.128	0.375

N= Numbers of samples; n= Number of specimens; Km=Magnitude of susceptibility; K1, K2, K3= Maximum, intermediate and minimum axes; L= Lineation; F= Foliation; Pj= Corrected degree of anisotropy; T=Shape parameter

is a powerful tool to understand the internal structures of the plutons where the preferred orientation of the minerals is not clearly seen or absent (Bouchez, 1997). Generally granites do not develop observable planar or linear fabrics unless they are significantly deformed. AMS studies facilitate accurate measurement of the foliation and lineation and thereby to understand the pluton emplacement mechanism.

As the Anisotropy of Magnetic Susceptibility (AMS) of rocks is controlled by preferred orientation of magnetic mineral grains, it provides information on both magnetic susceptibilities and the orientations of the mineral grains as well as the regional deformations that acted on the magma during crystallization and after consolidation of the rocks. The bulk magnetic susceptibility of a rock depends on the magnetic susceptibilities and proportions of the rock-forming minerals present in the rock. For the AMS study, 100 cylindrical specimens were drilled out from 39 oriented block samples collected from 5 sites.

AMS results of the study area are grouped into two datasets, one represents the grey granite and the other represents pink variety. Surprisingly, foliation planes of both the groups reveal NNW-SSE trend (Figure. 5). The AMS results are shown in Table 1. As mentioned earlier, grey granite is reported to be older than the pink granite (Crawford, 1969). However, the fabric of the magnetic minerals shown by both the granites is similar. This indicates that the deformation recorded in these rocks is a wide spread, post-formational one in the EDC and is exactly preserved in the Hyderabad Granitic Region.

CONCLUSIONS

Grey and pink granite samples of HGR show wide range of rock magnetic properties which may be the outcome of grade of metamorphism to which they are exposed. Out of the two varieties (grey and pink), grey granite is more magnetic than pink granite. The AMS investigations on the part of the HGR shows a NNW-SSE foliation indicating that the general structural trend of the Dharwarian rocks preserved in the granites of Hyderabad region. This indicates that the deformational event recorded in the Hyderabad granites is a primary and a wide spread one that is acted on the Eastern Dharwar Craton. The magnetic properties in both grey and pink granites are carried mainly by multi-domain-magnetite.

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