Thirteenth Indian Expedition to Antarctica, Scientific Report, 1997
Department of Ocean Development, Technical Publication No. 11, pp. 237-244

Delineation of Tectonic Features of Schumacher Oasis, East Antarctica Using Total Field Geomagnetic Profiling

MADHU SUDAN JOSHI

National Geophysical Research Institute
Uppal Road, Hyderabad 500 007

Abstract

Delineation of tectonic features of Schirmacher Oasis (S.O.) using total field geomagnetic profiling needs skill because:

a. The exposed rocks have little magnetic contrast and have undergone multiple episodes of metamorphism, migmatization and deformation.

b. The lithological contacts are sharp and generally steeply dipping, with the faults and shears trending east-west.

c. Topography is very rugged, dotted by numerous water bodies during summer and the north-south extent of S.O. on an average is 1.0 km and

d. Geomagnetic storms are sudden, large, frequent and long lasting, allowing few fortuitous windows for meaningful observations

A total of nine profiles were traversed crossing different geological units and suspected faults and shear zones identified by Bormann *et al.,* (1986) from photogeological map. Carefully selected, close-spaced observations brought out interesting magnetic anomalies. Two profiles east of Maitri, passing over the pyroxene-granulite hill, have well defined, sharp anomalies of the order of 200 nT, indicative of faults. A block faulting between the pyroxene-granulite hill and the leucocratic gneiss may probably be the reason for the present height of the hill.

Anomalies on other profiles are correlated with faults and geologic contacts. It is further observed that the gradation in the rock type changes from east to wet. The same banded and leucocratic rocks show totally different magnetic characteristics in Central Schirmacher compared to that in the eastern region. This may be due to absence of foliation in the banded gneiss in Central Schirmacher.

Geology and Tectonic Features

Schirmacher oasis of the Queen Maud Land, East Antarctic is oriented approximately east-west with maximum length of about 20 km, width 3.5 km (average 1.0 km) and an area of approximately 35 km^2. It is situated approximately half way between coastal ice shelf and the main mountain range of Queen Maud Land. The elevation varies from 0.0 m to 228 m asl (average 100 m). The undulating surface topography is dotted by many waterbodies in the austral summer, The northern edge has steep slope, frozen lakes and the iceshelf extending nearly 90 km in the summer, beyond Dakshin Gangotri. On the southern side is the continental ice-sheet (0.5 to 3.0 km thick) upto the major mountain range (Wohlthat, Gruber, Peterman) that runs for almost a thousand kilometers, roughly parallel to the coast line.

The Schirmacher belongs to the East Antarctic Charnockite province. The rocks have undergone multiple episodes of metamorphism, migmatization and deformation (Singh 1986,Sengupta, 1986). High grade gneisses, amphibolites, migmatites and mylonites are exposed. The gneisses comprise 90% of the exposed bedrocks and have four major sub-groups (i) banded gneiss, (ii) garnet-biotite gneiss (iii) augen gneiss and (iv) biotite gneiss. A single conspicuous exposure of pyroxene- granulite is located along the eastern boundary of Lake Priyadarshini on whose shore the Indian Station Maitri stands (Fig. 1). The intrusives, from few mm to 10.0 m thick, include amphibolites, pegmatites, quartz and quartz-calcite veins and dolerites. Four phases of tectonic deformation, folding, refolding and shearing, have been identified. In this region, the east-west morphological trend is intersected by northward flowing glaciers which are associated with fault-controlled valleys.

Geomagnetic Studies

The magnetic anomaly map of Dronning Maud Land, derived from Magsat, shows a large conspicuous regional negative anomaly reflective of the structure and composition of the crust (Bormann *et al.,* 1986). The magnetic anomaly field of S.O. correlates with the distribution of rocks, classified on the basis of photogeological interpretation and subsequent detailed geological mapping. They have also summarised the geophysical investigations (gravity, aero- and ground magnetics, deep seismic and reflection sounding) in and around S.O.

Gupta and Varma (1986), Bormann *et al.* (1986) and Jain *et al.* (1988) carried out total field geomagnetic measurements in and around S.O. mainly to delineate geological contacts and infer the subsurface causative sources. The work of Gupta and Varma(1986) was confined to Western S.O. Bormann *et al.(* 1986), prepared a regional magnetic map using 105 stations spread over the 35 km^2 area. Jain *et al.,* could not observe significant anomalies in their 13 profiles over different parts of the Schirmacher. Most of the present work was,

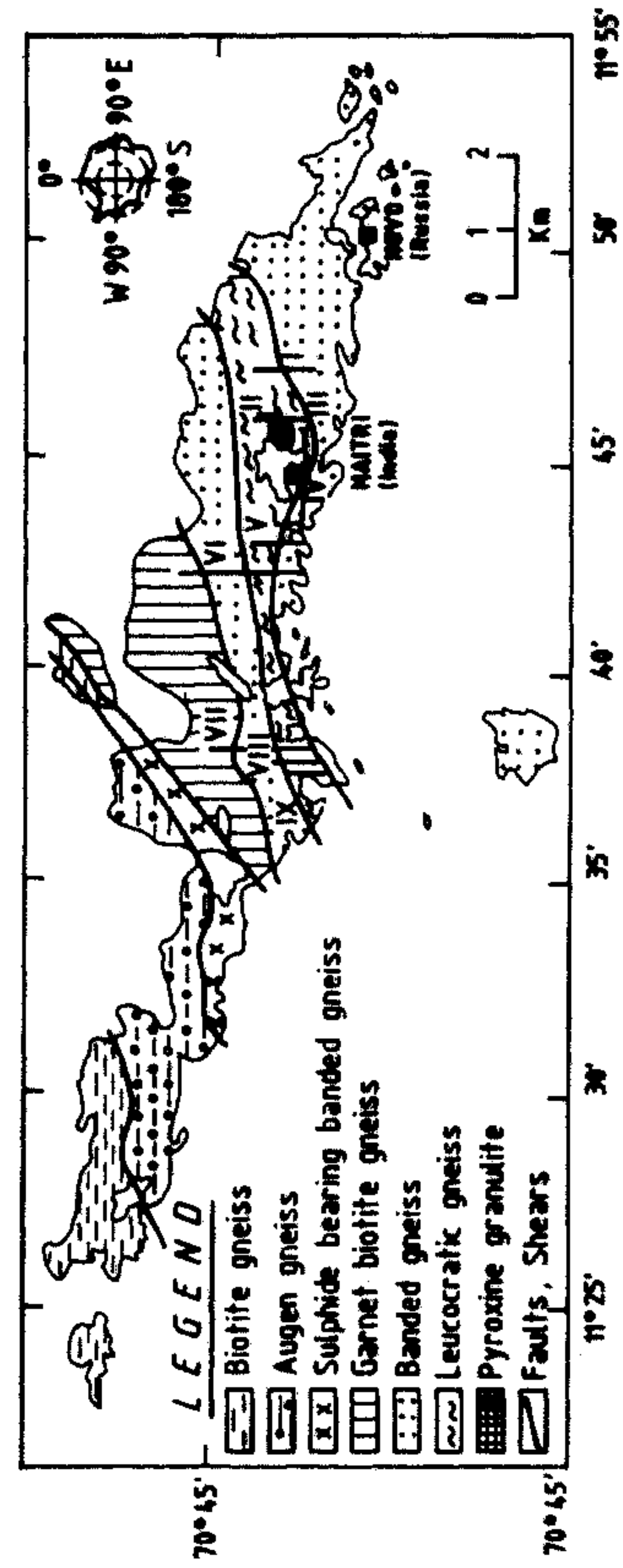

Fig. 1: General geology of Schirmacher Oasis, prominent faults and magnetic profile locations

therefore, planned for the eastern and central Schirmacher and across the tectonic faults inferred from photogeology by Bormann *et al.,* 1986.

Chandra Reddy (1993) measured *in situ* magnetic susceptibility of rocks in Schirmacher and placed them in four groups of increasing susceptibility but with little difference (i) augen gneiss, leucocratic gneiss, banded biotite gneiss and pyroxene-granulite, (ii) garnetiferous gneiss, amphibolite and mylonite, (iii) basalts and lamprophyres, and (iv) dolerite. Thus the magnetic contrast between the exposed rock types is very small and the geological contacts, faults and shears quite sharp which render their delineation by magnetic method.

Present Investigations

The main objective of the present magnetic survey was to obtain magnetic response of the geological units and structural features inferred from the photo-geological map of Bormann *et al.* (1986). Accordingly several traverses were planned and laid (Fig. 1). A close station spacing (5-6m) was found necessary in view of the peculiar geology and the magnetic properties of rocks described above. Observations were made only on relatively magnetic quiet days, which are rare in these parts. Longer profiles were not possible because of (i) very rugged, uneven topography and (ii) numerous water bodies with meltwater accumulating in the troughs. A Portable Proton Precession magnetometer (Geometries G 816/826 A) with an accuracy of 1.0 nT was used for the field measurements. Another Proton Precession magnetometer (NGRI 600 R), also with 1.0 nT accuracy, was continuously run at Maitri coupled to a poly-chart recorder (T0A ETR 200 A) for monitoring the diurnal variation of the earth's total magnetic field.

Due to high electrostatic charge in this cold and dry region sensitive electrical and electronic equipments are liable to behave very erratically unless a proper earthing is provided. The diurnal monitoring setup intrigued and frustrated for several days by its violent behaviour till a good electrical earthing was rigged up.

Results and Discussion

Some of the observed anomaly profiles are shown in Figs 2(a,b) and are discussed in the following. The base total magnetic field for most of the profiles is 41,300 nT.

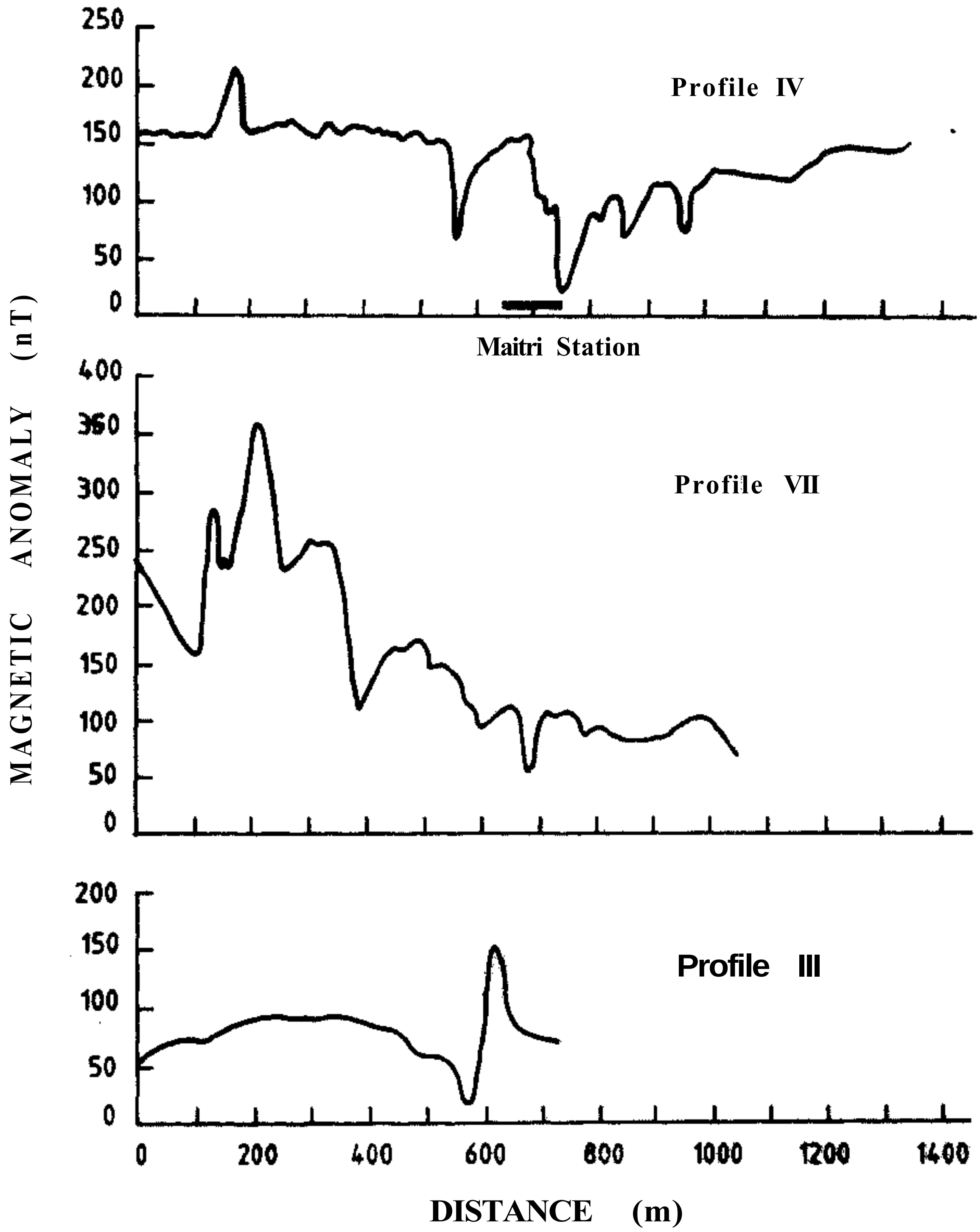

Fig. 2a: Total field magnetic anomaly profiles

Profile I

The 650 m long N-S profile about 1.5 km east of Maitri traverses over leucocratic and banded gneiss terrains, both having same magnetic susceptibility. It has two well defined magnetic anomalies at about 200 m and 600 m with

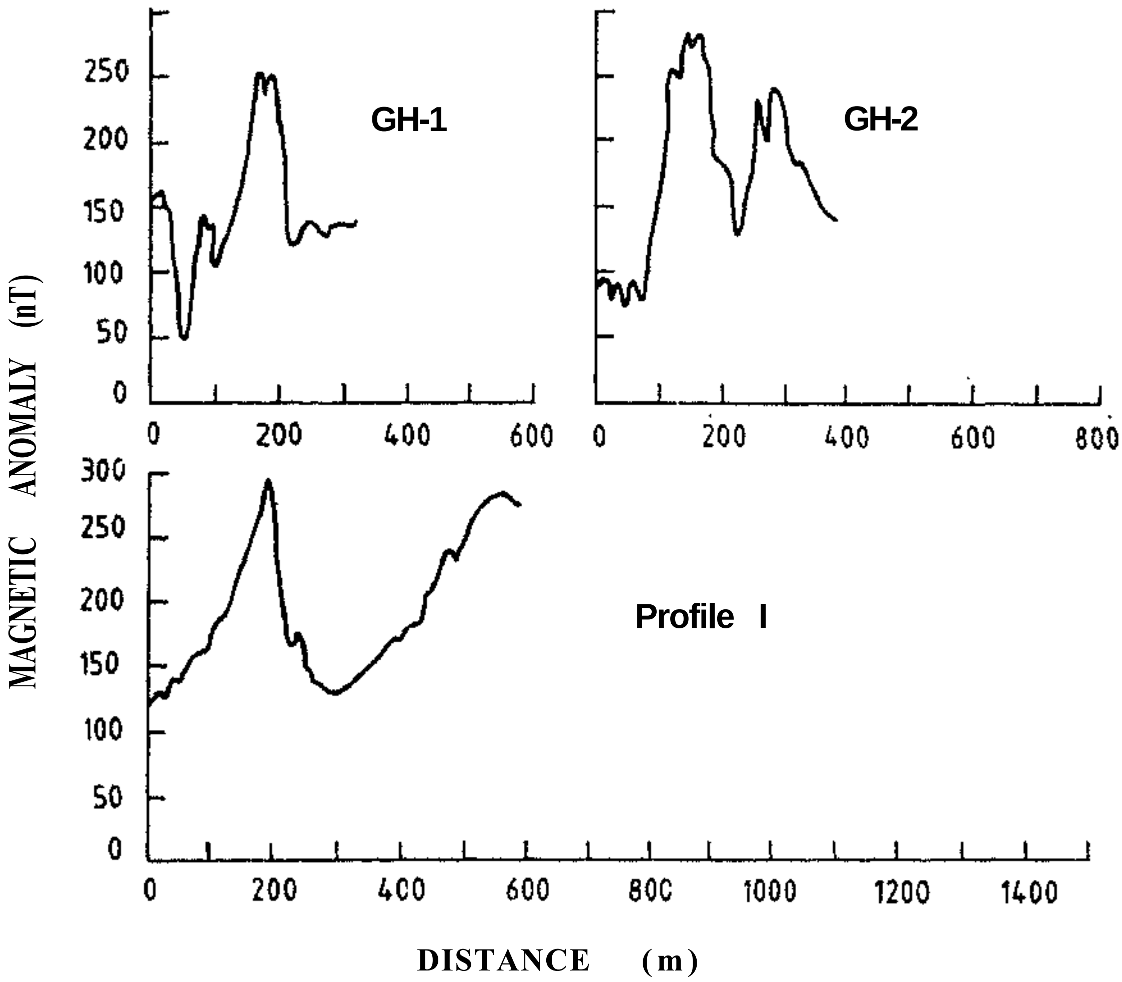

Fig. 2b: Total field magnetic anomaly profiles

amplitudes of nearly 200 nT. These can be correlated with two east-west trending faults identified from photogeology by Bormann *et al.* (1986).

Profiles II and III

The pyroxene-granulite hill on the eastern shore of Priyadarshini Lake is a conspicuous feature within the leucocratic gneiss terrain. Both rock types have about the same magnetic susceptibility. However, the photogeological map of Bormann *et al* (1986) shows complicated fault lineations trending E-W and NNE-SSW. One 750 m long S-N profile (No. III) trending N 15°E and a short parallel S-N profile (No. II, not shown in the diagram) were recorded cutting across the hill. Both profiles show a single sharp anomaly at the contact between the pyroxene- granulite and leucocratic gneiss. The 150 nT anomaly on profile III is representative of a steep fault. Other faults could not be traced due to inaccessible terrain but they may have contributed to block faulting and subsequently uplifting the pyroxene-granulite hill to its present prominence.

Profile IV

Entire 1,300 m long east-west profile runs from east of Maitri Station, parallel to it and towards west lying over leucocratic gneiss. The anomalies at 550 m and 750 m are due to metallic structures of the Maitri Station and the fuel dump, respectively. The other small (~ 50 nT) anomalies seen at 200 m, 850 m, 975 m may be associated with the fracture, shears and fault zones marked on the photogeological map.

Profiles V and VI

Profile V, west of Maitri, is S-N and 500 m long traversing banded gneiss and leucocratic gneiss and is totally featureless. The fault/lithological contact also could not be picked up. Similarly, Profile VI, 1350 m long and further west lies over banded gneiss, leucocratic gneiss and garnet-biotite gneiss. 0- 750 m southern portion of the profile, mostly covering the first two rock types, is featureless. Further north there are several short period, low amplitude (~ 50 nT) anomalies with one bigger (100 nT) anomaly at 1100 m. This corresponds to the magnetic contrast between the leucocratic gneiss and garnet biotite gneiss as well as the fault running NE-SW.

Profile VII

The nearly 1075 m long N 35^{O} E trending S-N Profile (Fig. 2a) cuts across leucocratic, banded and garnet biotite gneisses. The magnetic susceptibility of the first two is about the same and that of the third, relatively more. This contrast is reflected in the anomaly at 700 m. The broad and larger amplitude (250 nT) anomaly in the 100-400 m zone may be correlated with the overthrust zone marked by Bormann *et al,* (1986).

Profiles VIII and IX

The two short profiles (marked GH-1 and GH2 in Fig. 2b) are near the German Hut of George Foster Station. They overlie leucocratic gneiss. The nature of the anomalies is similar to that exhibited by Profile VII over the thrust zone.

It is further observed that the gradation in the rock type changes from east to west. The same banded and leucocratic rocks show totally different magnetic characteristics in central Schirmacher compared to that in the eastern region. This may be due to absence of foliation in the banded gneiss in central. Schirmacher.

Conclusion

Magnetic mapping of this complex geological province for delineation/correlation of lithological and tectonic features needs special care. Close-spaced observations are required because of the poor magnetic contrast and the resulting low amplitude magnetic anomalies. Changing magnetic character of a particular rock type may affect observations considerably. If necessary, proper electrical earthing of the diurnal monitoring equipment be done. With such constraints overcome, prominent geological contacts, faults, shear-zones and overthrusts in the Schirmacher region have been correlated well.

Acknowledgements

Grateful thanks are due to Dr. Harsh K. Gupta, Director, NGRI for motivating and enthusing me in Antarctic studies. I collectively thank all connected with the XIII Indian Antarctic Expedition for the unique opportunity. Drs. SH Jafri (NGRI) and P.C. Reddy (Osmania University) especially made the expedition and the field work a memorable event. At NGRI I have considerably benefited from discussions with Drs. S.B. Gupta and B.S.P. Sarma.

References

Bormann, P., Bankwitz, P., Bankwitz, E., Damm, V., Hurtig, E, Kampf, H., Menning, M., Paech, H.J. Schaffer, U. and Stackebrandt, W. (1986). Structure and development of the passive continental margin across the Princess Astrid Coast, East Antarctica, J. Geodynamics, 6, 347- 373.

Chandra Reddy, P. (1993). Measurement of insitu Petrophysical properties, VLF - EM and vertical component magnetic surveys in Schirmacher Hills, East Antarctica, Preliminary report, XIII Indian Scientific Antarctic Expedition, DOD, New Delhi.

Gupta, H.K. and Varma, A.K. (1986). Magnetic characteristics in Antarctic over geological contacts in Schirmacher Hill region and the ice-shelf near Dakshin Gangotri, Scientific Report III Indian Scientific Expedition to Antarctica, DOD, New Delhi, 231-239.

Jain, Shikhar Ch., Dhar, R.L., Reddy, K.N.S. (1988). Geophysical investigations in Schirmacher land-mass, Scientific Report V Indian Scientific Expedition to Antarctica, DOD, New Delhi, 145-150.

Singh, R.K. (1986). Geology of Dakshin Gangotri Hill range, Antarctica, Scientific Report III Indian Scientific Expedition to Antarctica, DOD, New Delhi, 181-185.

Sengupta, S. (1986). Geology of Schirmacher range (Dakshin Gangotri) East Antarctica, Scientific Report III Indian Scientific Expedition to Antarctica, DOD, New Delhi 187-217.

Sengupta, S. (1988). History .... Events in the Schirmacher Hills.....East Antarctica, Journ Geol. Soc. Ind., Vol-32.