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Magnetic Characteristics in Antarctica over Geological Contacts in Schirmacher Hill Region and the Ice Self near, Dakshin Gangotri (70°05'37"S, 12º00'00"E)

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ABSTRACT

Total intensity measurements of earth's magnetic field were carried out at Schirmacher Hill region and on the ice shelf in the vicinity of the Indian Permanent Station, *Dakshin Gangotri* using a couple of proton precession magnetometers. During the magnetic surveys strong diurnal fluctuations were often observed. Several sets of data were rejected when diurnal corrections could not be effectively made. Finally three magnetic traverses totalling about 3 line km with average station interval of 7 m and 6 short criss crossing magnetic profiles totalling over 2 line km in the Schirmacher Hill region were found suitable for further processing. The geological contacts between garnet biotite gneiss and sulphide bearing banded gneiss are found to be associated with sharp magnetic anomalies of the order of several hundred nT. The criss-cross magnetic profiles in the augen gneiss terrain permitted contouring magnetic anomalies at 100 nT interval. Quantitative interpretation of five anomalies which could be due to basic intrusives has been carried out using conjugate points and symmetrical curve procedure and geometric parameters of possible causative bodies are estimated. In the Princes Astrid Coast region a total of 60 line km of magnetic profile data were found suitabe for analys s 40 line km being at 260 m stat on interval and 20 km at 1 km interval. These profiles exhibit low amplitude short wave length magnetic anomalies superimposed over a broad anomaly. The two are treated separately. Analysis using Hilbert transform and graphical methods yielded comparable results. The broad anomaly could be interpreted as being caused by an about 12 km thick body with ts top at a depth of about 3.5 km and a polarization angle of about 60°.

INTRODUCTION

Geomagnetic measurements in Antarctica have been an integral part of geophysical investigations undertaken from the very beginning. During the first International Polar Year (1882-83) simultaneous studies of meteorology, geo- magnetism and aurorae were undertaken at twelve stations in Arctic and two stations in Antarctica. Later magnetic measurements in Antarctica got much impetus during the International Geophysical Year (1957-58) and subsequent International Years of Quiet Sun.

Geomagnetic investigations in Antarctica were initiated by the First Indian Scientific Expedition to Antarctica when the total magnetic intensity of earth as well as field components X, Y and Z were monitored for a few days in January 1982 at Princess Astrid Coast (lyengar and Rajaram, 1983). During the Second Expedition, eight magnetic profiles over the shelf ice extending to distance of upto 10 km southward from the shelf edge in the vicinity of the Indian summer camp (70°S, 12°E) were undertaken. The observed magnetic anomaly of 150 to 200 nT was interpreted in terms of a basic intrusion (Mittal and Mishra, 1985). Arora et al (1985) have contoured the total intensity magnetic observations along the above mentioned eight profiles. During the same expedition Rangarajan et al (1985) have reported two intense magnetic disturbances on January 10 and February 4,1983 and two magnetic substorms on February 12 and 13, 1983. These observations were made at 69°59 S, 11°55 E (Dipole latitude 65°30 S, longitude 54°30'E).

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During the expedition, detailed total intensity magnetic measurements were carried out using a couple of Geometries Model G 816/826 Proton Precession Magnetometers. These magnetometers are quite robust and easy to handle in difficult field conditions, and have a sensitivity of 1 nT. For the first time detailed measurements were made along a number of profiles over the exposed rocks in the Schirmacher Hill region crossing different geological litho units. Additionally, north-south running profiles were extended to distance of over 20 km south of the Indian Permanent Base Station, *Dakshin Gangotri.* Results of these investigations are presented here.

DIURNAL VARIATION MEASUREMENTS

The main purpose of diurnal variation measurements was to make necessary corrections to the field observations carried out at the Schirmacher Hill region and on the ice shelf. One magnetometer was continuously used for this purpose. Several sets of field observation data had to be rejected since magnetic storm like conditions prevailed during the time when field observations were made. Additionally, at Schirmacher Hill field camp (70°45'S, 11°37'E) and at the ice shelf (70°06'S,12°00'E) continuous magnetic observations were taken for several days. Fig 1 shows typical diurnal variations at Schirmacher Hill for four days (curves 1,2,3 and 4) and at the ice shelf base station for one day.

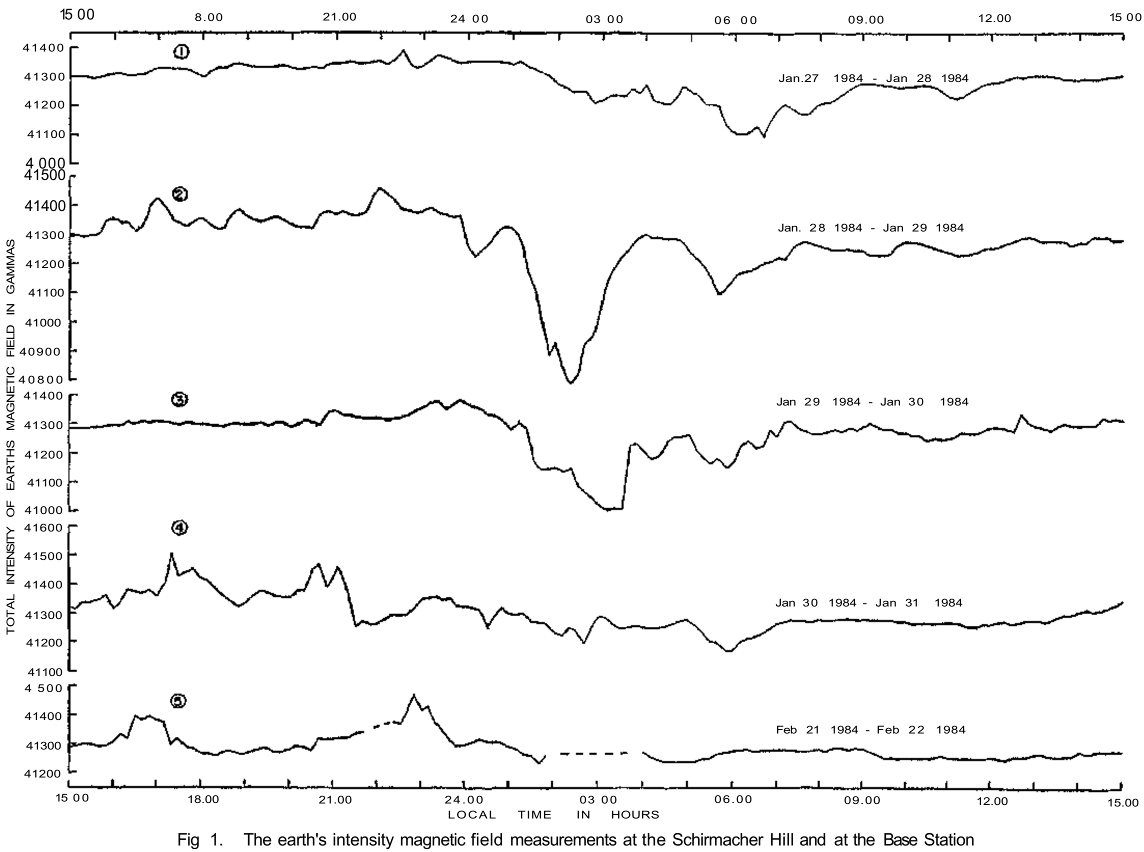

Fig 1. The earth's intensity magnetic field measurements at the Schirmacher Hill and at the Base Station

(curve 5). The total intensity is about 41300 nT. Polar storms, typically observed in Antarctica, lasting for 2-4 hours and having amplitudes of several hundred nT can be seen on January 28-29, 1984 betweeen 24 and 03 hrs.

SCHIRMACHER HILL REGION

During the Third Indian Scientific Expedition to Antarctica, a detailed geological mapping of the entire 35 sq km Schirmacher Hill range (latitude 70°44' 30"S to 70°46'30'S, longitude 11°22'40"E to 11°54'00'E) of the Queen Maud Land of East Antarctica at 1 25,000 scale was undertaken by the geologists (see Sengupta, 1986 Singh, 1986 - this report). High grade quartzo-feldspathic gneisses and its variants with intercalated metabasics are the dominant rock types in the area. A number of magnetic profiles crossing well recognized geological contacts were undertaken. Fig 2 depicts three of these profiles. Geological details are from Sengupta (1986, this volume). Spot measurements of total intensity were made every 7 m and the observations have been corrected for diurnal variations.

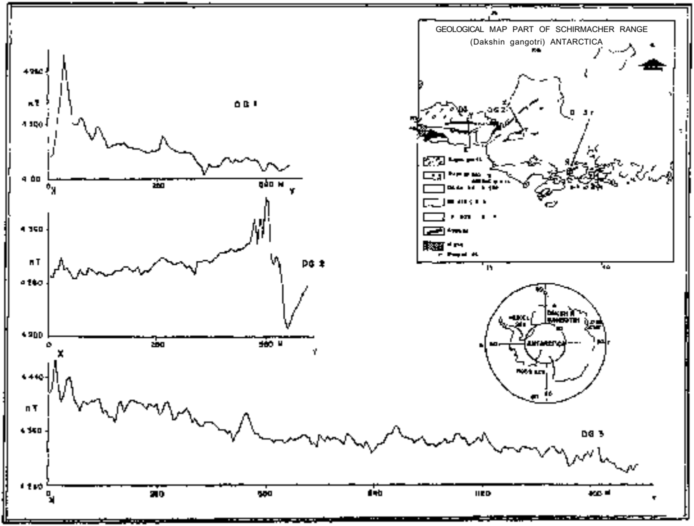

Fig 2 Magnetic traverses across geological units — Schirmacher Hill region. The geological details are from Sengupta, 1986 (this volume)

Profile DG 1 and DG 2 are both about 600 m long. The DG 1 profile begins from very near the snout of a glacier at X, traverses over the sulphide bearing banded gneiss terrain and ends in augen gneiss terrain. Profile DG 2 begins from augen gneiss terrain traverses over sulphide bearing banded gneiss and terminates in garnet-biotite gneiss terrain. On both these profiles, the contact of garnet biotite gneiss and sulphide bearing banded gneiss is characterised by magnetic anomalies of several hundred nT. The shape of the anomaly indicate that while the DG 1 anomaly could be due to a sharp contact, the DG 2 anomaly may be due to an intrusive along the contact plane. It if is so the intrusive must have been considerably metamorphosed to account for the low order of magnetization in comparison to the anomaly across the contact plane along the profile DG 1. The low amplitude anomalies of identical shape, noticed along the middle of the profiles DG 1 and DG 2 may correspond with the amphibolite veins in the sulphide bearing banded gneiss.

Certain assumptions are made for quantitative interpretation of these magnetic anomalies. It is assumed that the magnetization of the anomalous body is caused by induction in the earth's field, that the direction of magnetization is uniform throughout the body, and that the remnant magnetization, if present, is also in the direction of earths field or is negligible. Further more it is assumed that the depth extent of the body is infinite. Under these assumptions, the amplitude and shape of a magnetic anomaly depends only upon the depth of burial of the body producing the anomaly, its geometry and its magnetic suceptibility contrast. Under these assumptions the following quantitative estimates (Table 1) are made for the anomalies associated with DG 1 and DG 2 profiles using Hilbert transform analysis. This technique yields good results for small profiles regarding correct location of the origin and information regarding the field under consideration. The technique being a kind of filter, the amplitude of spectral components are not altered, ensuring signal enhancement (Mohan et al 1982).

TABLE 1

Quantitative Interpretation of Magnetic Profiles Across Geological Contacts at Schirmacher Hill (Refer Fig 2)

Profile	*Location of the body*	*Depth (m)*	*Width (m)*	*Polarization angle*
DG 1	42 m from X	6 6	Contact	66°
DG 2	588 m from X	5 0	59 0	73°

The profile DG 3, about 1500 m in length does not show any significant anomaly except minor anomalies associated with the contact of sheared leucocratic gneiss and banded gneiss. The magnetic intensity values along all the three profiles exhibit a northward decreasing trend.

In addition to the above mentioned profiles six short magnetic traverses, three in E-W and three in almost N-S directions, criss-crossing one-another, with a total length of 2060 m were laid over augen gneiss with station spacing of 6 m (Fig 3 geology from Sengupta, 1986, this volume). Certain interesting anomalies, 600 nT to 900 nT in amplitude, are found to be associated with these profiles. Proximity of these traverses permitted contouring of the observed anomalies at 100 nT intervals (Fig 4). From this controuring, five anomalies have been picked for quantitative interpretation using graphical method (Koulomzina et al. 1970). Using this method, the field profile is decomposed into its symmetrical and antisymmetrical components using arbitrarily chosen conjugate points. The symmetrical and antisymmetrical components of the field profile are analyzed separately. This procedure

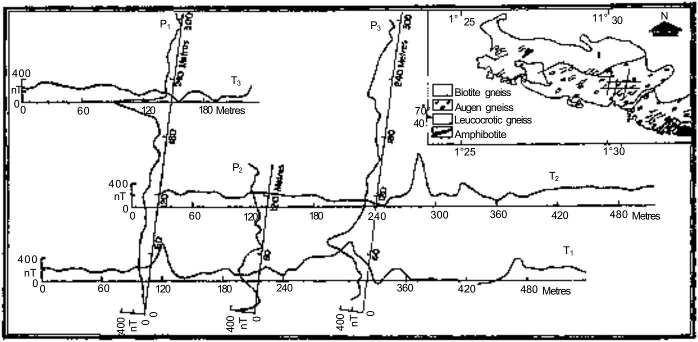

Fig 3 Profiles showing magnetic response over augen gneiss - Schirmacher Hill region. The geological details are from Sengupta 1986 (this volume).

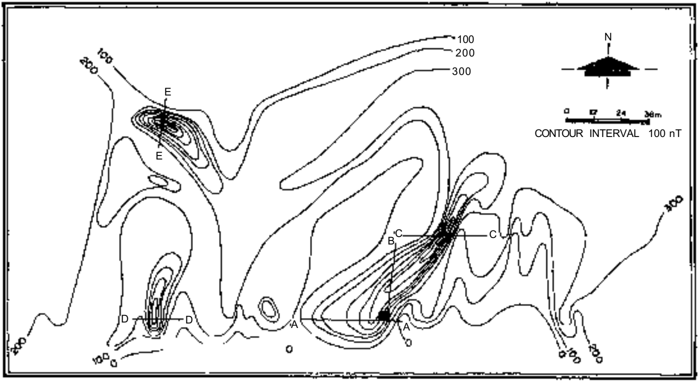

Fig 4 Magnetic intensity contour map to demonstrate the influence of shallow intrusives on magnetic measurements over augen gneiss Schirmachar Hill. Profiles AA BB CC DD and EE are considered for quantitative interpretation.

does not require any previous knowledge or assumption of the zero datum level or of the centre of the body. It is assumed that these anomalies are caused by intrusive bodies. The results of the analysis are presented in table 2.

TABLE 2

Quantitative interpretation of magnetic anomalies in the Augen Gneiss Terrain Schirmacher Hill (Refer Figs 3 & 4)

Anomaly	*Depth (m)*	*Width (m)*
AA	4.0	6.0
BB	10.0	2.0
CC	5.0	2.0
DD	3.0	2.0
EE	6.0	Contact

MEASUREMENTS OVER SHELF ICE

The work of magnetic measurements, initiated during the second expedition, was extended considerably towards south. Four profiles, running approximately in north south direction were taken between the Runway Hut (70°02 S, 12°00'E) and the Base Station (70°05' 37 S, 12°00 '00 E). These profiles were separated by about 400 m and station spacing was 400 m (Figs 5 and 6). These four profiles, after reduction, showed similar magnetic field pattern (Fig 6). The profiles had to be discontinued for about a kilometre in the vicinity of *Dakshin Gangotri* Base Station as there was lot of magnetic material associated with the construction of the Base Station as well as vehicular traffi. Two of these profiles were continued further south of the base station for a distance of 10 km (Fig 5) and were found to have similar magnetic field pattern (Fig 6). Keeping in view of the shortage of time, logistic problems and the fact that magnetic field pattern for these two profiles was similar, only one profile was extended further south to a total distance of 28 km from the starting point (Figs 5 and 6).

The above described magnetic profiles over the shelf exhibit low amplitudes and localized fluctuations superimposed in broad variations. The localized fluctuations could be due to the presence of intrusives or due to contact of litho- units with different magnetic susceptibility. The short wave length is suggestive of shallow and thin causative bodies. The first such anomaly encountered within the first few kilometres of the Runway Hut (Fig 6) is quantitatively interpreted as to have been caused by a dyke of infinite extent of depth. For the above assumption the body is found to be located at a distance of 1.75 km from the Runway Hut with a width of about 800 m and depth of 250 m from the surface.

A large and extensive graben extending southward from the coast for almost 700 km is reported (Bentley, 1983). Magnetic data show a non-magnetic presumably sedimentary section about 5 km thick. This rift is the best defined in terms of geophysical evidence of several rift zones that may exist around Antarctica (Kadmina et al, 1983). The broad magnetic anomaly, observed south of the base station, extending over 20 km is suggestive of an approximately E—W trend of the causative structure. Work carried out during the second expedition (Mittal and Mishra 1985, Arora et al, 1985) indicated existence of a rift of about 2 5 km width, a depth of 500 m to 1000 m and its possible continuation to

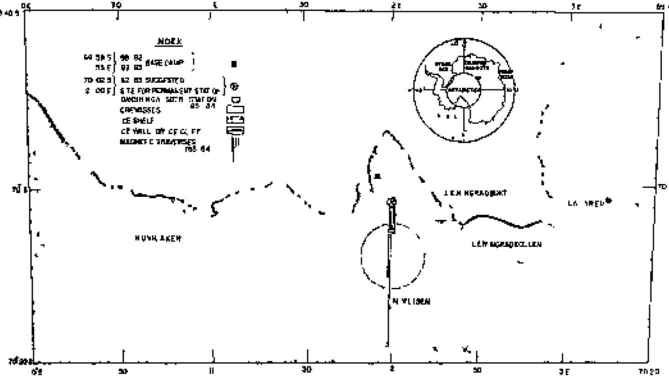

Fig. 5 Map showing the location of Permanent Station Dakshin Gangotri and lay- out of north south running regional magnetic traverses.

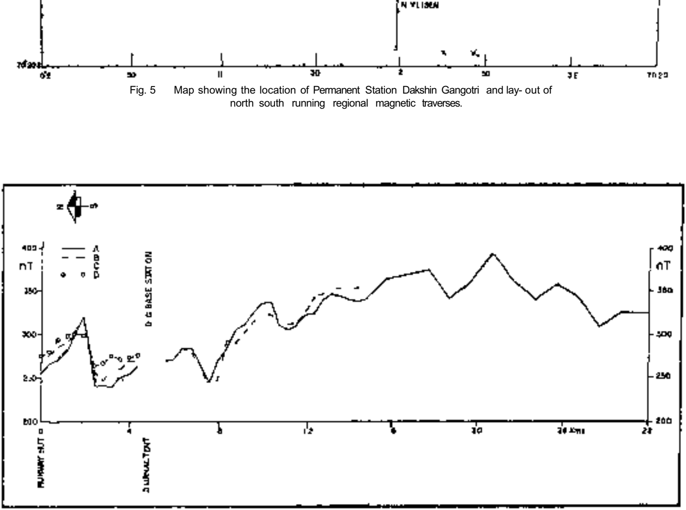

Fig. 6 Magnetic anomaly map along the profiles over Princess Astrid Ice Shelf.

further south. This may be responsible for the presently reported broad anomaly with low order of magnetization. This anomaly is interpreted quantitatively using graphical methods (Koulomzine et al 1970) and Hilbert Transform Technique (Mohan et al, 1982). The results obtained are presented in table 3.

TABLE 3

Quantitative Interpretation of Magnetic Traverse over the Shelf Region Princess Astrid Coast (Refer Figs. 5 & 6)

Location of the body	*By Hilbert Transform technique*	*By Method of Koulomzine et al (1970)*
At 18 km from RUN WAY HUT	Depth = 3 5 km Width = 1 1 6 km Polarization angle = 62°	Depth = 3 7 km Width = 12 2 km

CONCLUSION

The results of the magnetic studies over Princess Astrid Shelf and adjoining Schirmacher Hill reflects the applicability of magnetic method in understanding the regional and detailed geology of a part of polar region. The magnetic response over the Schirmacher Hill is characterised by low amplitude fluctuations suggestive of low order of magnetization. However significant anomalies can be noticed over the contacts of garnet-biotite gneiss and sulphide bearing banded gneiss whereas the contact of augen gneiss is left unnoticed. These magnetic profiles also exhibit considerable anomalies over a number of intrusives for which the parameters are determined quantitatively. The broad anomaly observed over the Princess Astrid Shelf and its quantitative analysis supports the reported south-ward extension of the basement depression.

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