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Vertical Magnetic Surveys and Measurement of Petrophysical Properties in Schirmacher Oasis, East Antarctica

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Abstract

Vertical magnetic measurements were carried out along four-chosen profiles to have an insight and inference about the subsurface geology and structures of Schirmacher region In addition, insitu measurements of petrophysical properties like density, magnetic susceptibility and gamma ray intensity were also carried out along these profiles Further, on a reconnaisance visit to Orwin mountains, samples were collected and analysed tor their physical properties The results are presented here

Introduction

Geophysical methods continue to play a significant role in deciphering the bed rock topography and subsurface structures of the not so easily accessible and ice covered continent - Antarctica Though geophysical investigations were carried out in Antarctica during the early 1930s, the beginning of the systematic geo-investigations employing seismic reflection and refraction, ground and airborne magnetic and gravity surveys were realised only from 1950s (Bhattacharya and Majumdar, 1987)

In the very first Indian expedition to Antarctica, several geophysical measurements including magnetornetrics were initiated The results have cleaily demonstrated the utility of magnetic anomalies in delineating structural features of Antarctica margin *(Arora et al,* 1985) During the second expedition (1982-1983), magnetic measurements were carried out across Princess Astrid Coast and adequate information were obtained on magnetic characteristics and structures below the ice cover in this region (Mittal and Mishra, 1985) Results of the magnetic mapping over the Schirmacher region during the third expedition (1983 - 1984) is characterised by low amplitude fluctuations implying the low magnetisation (Gupta and Verma, 1985) Thus geophysical investigations


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have become an important and integral scientific component of Indian expeditions to Antarctica.

In this direction, as a part of three year research programme of Centre of Exploration Geophysics, Osmania University, Hyderabad - 500 007, various geophysical surveys during the 13th expedition (1993 -1994) were carried out to assess the physical properties of major rock types in Schirmacher region with an objective of establishing a correlative study with the petrophysical property data obtained from corresponding rock types of the Indian peninsula. The results clearly indicate the lithological variations and structural details of Schirmacher Oasis (Chandra Reddy, 1994). Further, it was reported that the gamma intensity recorded in Orwin mountains (71°.42'S, 9°.40'E) exceeded 15,000 counts per second which is nearly 20 times that of the maximum count recorded in the Schirmacher region.

In continuation of the investigations of 13th expedition, vertical magnetic measurements for structural investigations in the Schirmacher hills and insitu measurements of the petrophysical properties like gamma ray intensity, density and magnetic susceptibility of major rock types therein were some of the scientific objectives of the 14th expedition (Dec. 1994 - March 1995). Accordingly, these measurements were carried out and the results are presented in this report.

Geology of Schirmacher Range

The preCambrian basement of the east Antarctica shield is mostly covered with ice and restricted outcrops along the coastal line. The Schirmacher Range emerges as a rock oasis between the continental ice sheet and the coastal ice shelf occupying an approximate area of 35 sq. kms, between 70°.44'.30"S - 70°.46'.30"S south latitudes and 11°.24'.4"E - 11°.54' E east longitudes. The major mountain of Queen Maud Land runs for about a thousand kms approximately parallel to the coast. The Schirmacher range which runs roughly east-west belongs to the "East Antarctica Charnakites Province" the largest area of granulite facies rocks in the world and it is situated approximately half way between the main mountain range and the present coast line. Here, the rocks have undergone multiple episodes of metamorphism, migmatisation and deformation (Sudipta Sengupta, 1986).

Banded gneiss is the major lithological unit of the Schirmacher range; the compositional variation of gneisses is due to the non uniformity of the metamorphic rocks. The rock sequences,intrusives and tectonites of the Schirmacher hills have been classified as (a) Banded gneiss (thin and thick bands),(b) Augen gneiss, (c) Biotite gneiss, (d) Garnet gneiss, (e) Pyroxene granulites, (f) Amphibolites, (g) Calc-silicates, (h) Dolarites, (i) Basalts, (j) Vein quartz, (k) Pegmatites etc. The details are. marked up in the geological map of Schirmacher area (Fig. 1).

Vertical Magnetic Survey

Though the total magnetic measurements were carried out in the continental shelf around Dhakshin Gangotri (DG) to assess the basement features and the geology of Schirmacher hills (Mittal and Mishra, 1985, Arora *et al.,* 1985, Gupta and Verma, 1986, Verma *et al*., 1987 and Jain *et al.,* 1988), the vertical component measurements were made only from 13th expedition (1993-1994).

The preference of vertical magnetic measurements over the total component measurements are partly attributed to the simplicity of interpretation of such anomalies with better accuracy. Chandra Reddy(1994), had reported based on the vertical magnetic surveys in Schirmacher region that the contacts/shears/faults deciphered from magnetic surveys may be of some help in locating economic mineral zones besides bringing the lithological variations and structural details. However, the country rocks here are characterised by low magnetisation.

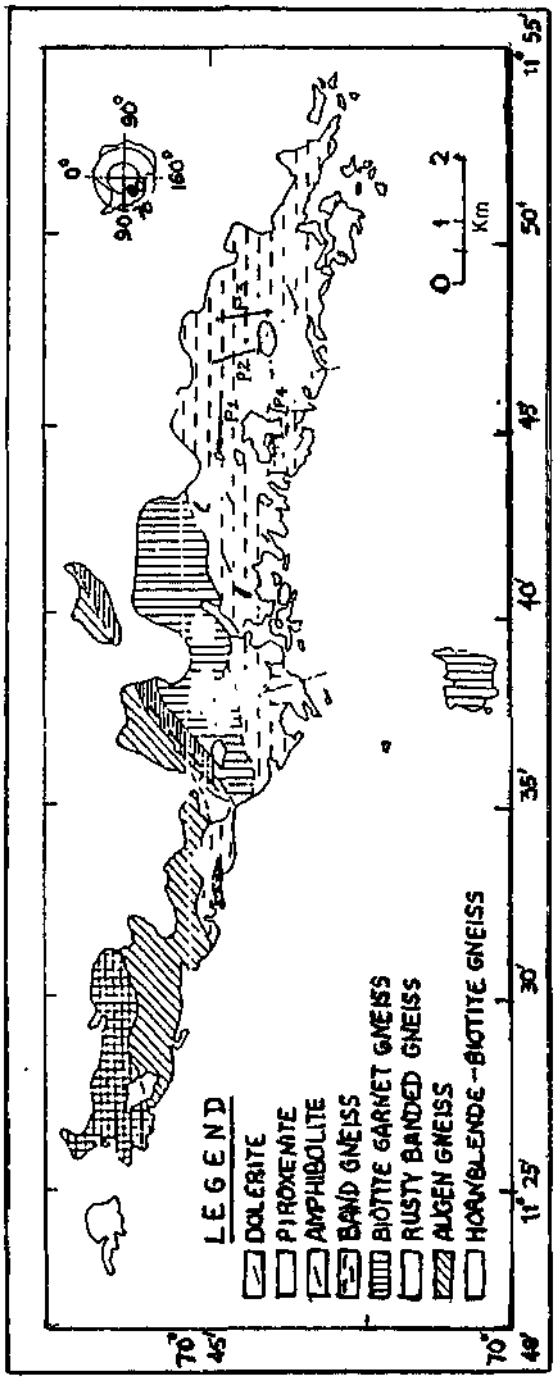

Fig.1: Geological map of Schirmacher area, East Antarctica, showing location of magnetic traverses

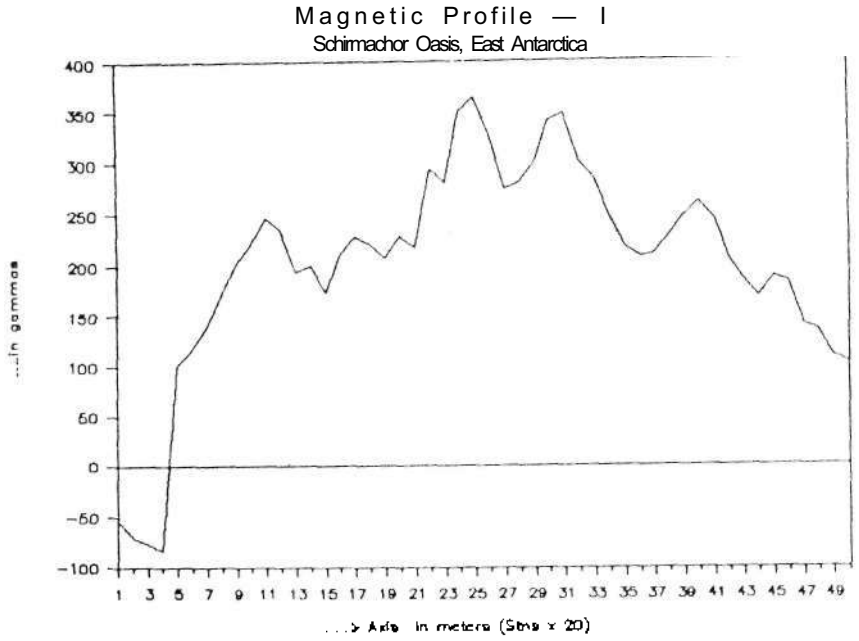
Magnetic Profile — I
Schirmachor Oasis, East Antarctica
....In gammas
400
350
300
250
200
150
100
50
0
-50
-100
1 3 5 7 9 11 13 15 17 19 21 23 25 27 29 31 33 35 37 39 41 43 45 47 49
....> Axis in meters (Step x 20)

Fig.2

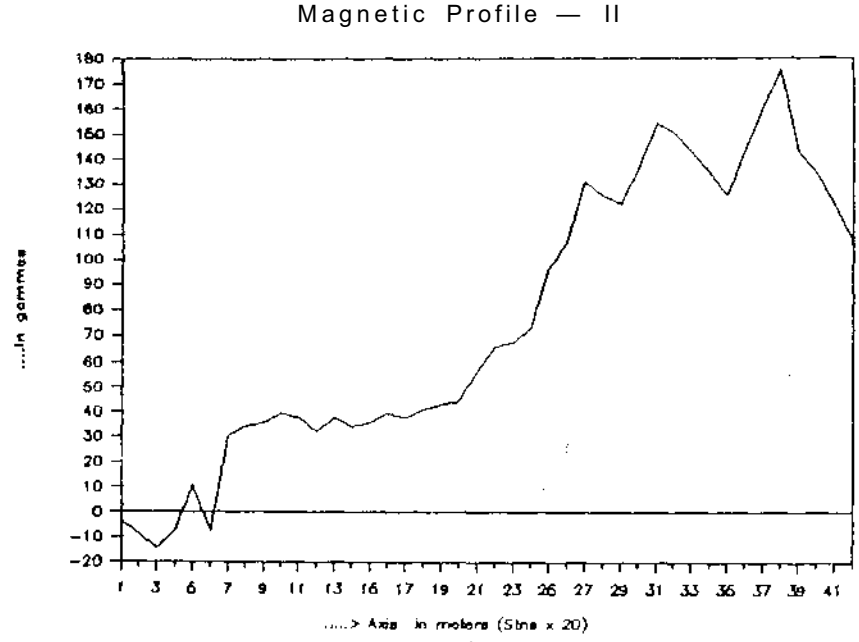
Magnetic Profile — II
....In gammas
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
-10
-20
1 3 5 7 9 11 13 15 17 19 21 23 25 27 29 31 33 35 37 39 41
.....> Axis in meters (Step x 20)

Fig. 3

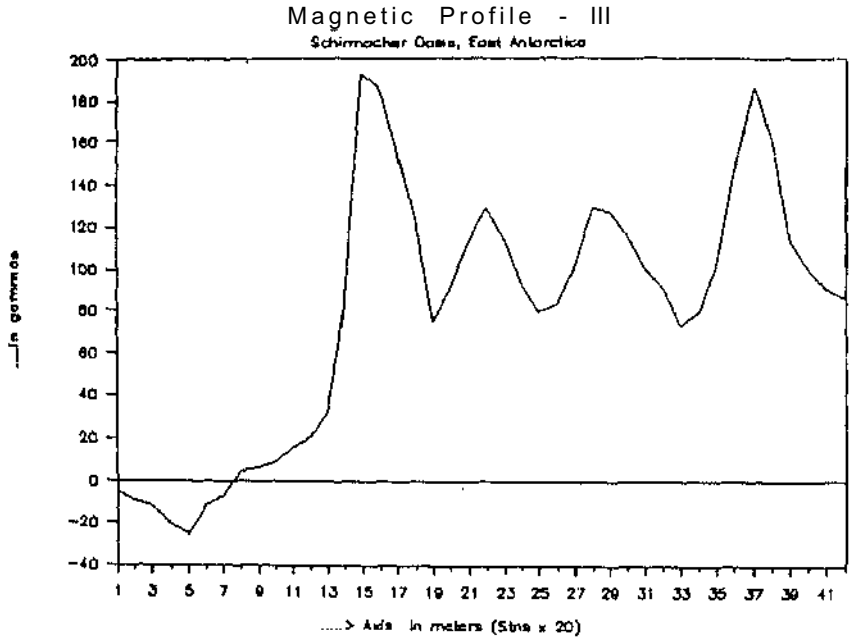
Magnetic Profile - III
Schirmacher Oasis, East Antarctica
...in gammas
200
180
160
140
120
100
80
60
40
20
0
-20
-40
1 3 5 7 9 11 13 15 17 19 21 23 25 27 29 31 33 35 37 39 41
.....> Axis in meters (Stns x 20)

Fig.4

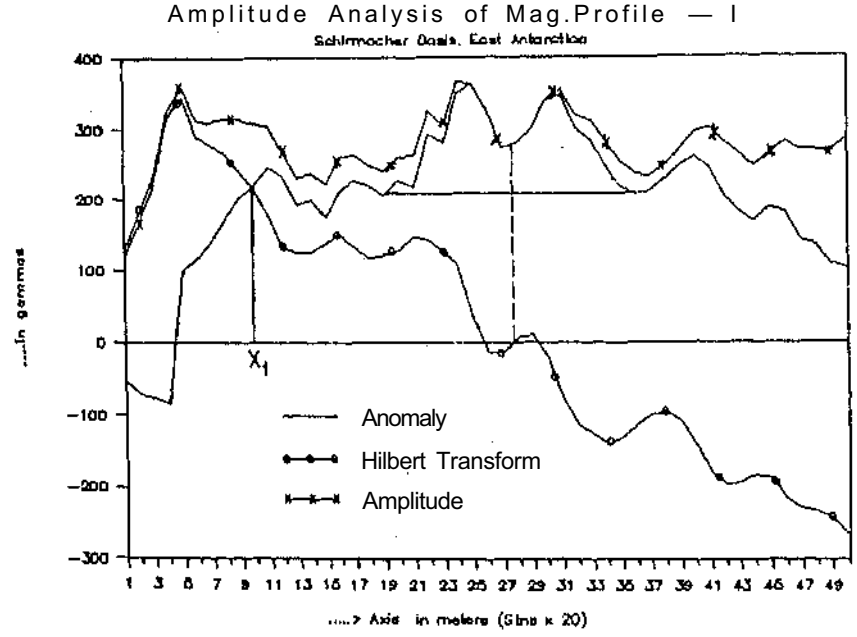
Amplitude Analysis of Mag.Profile — I
Schirmacher Oasis, East Antarctica
...in gammas
400
300
200
100
0
-100
-200
-300
X1
Anomaly
Hilbert Transform
Amplitude
1 3 5 7 9 11 13 15 17 19 21 23 25 27 29 31 33 35 37 39 41 43 45 47 49
.....> Axis in meters (Stns x 20)

Fig.5

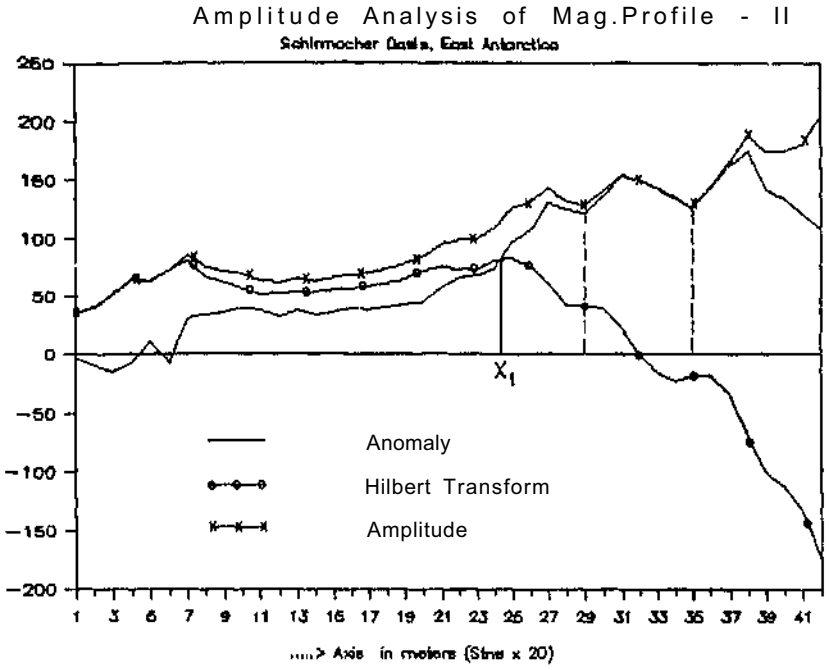

Fig.6

Vertical magnetic surveys were carried out along four chosen traverses at an interval of 20 meters with an objective to check the magnetic response of the structural features. Fluxgate magnetometer of Scintrex make with a sensitivity of 1 gamma was made use for the investigations. The measurements were made only on quite magnetic days and adequate repeatations were made to monitor the diurnal variations. For obvious reasons, magnetic anomalies are referred to different local base stations instead of one as in usual practice.

Measurements were made along four traverses of length approximately one km. each; the profiles are shown in the geological map of Schirmacher region (Fig. 1). Profile -1 (Fig. 2) is located approximately 300 meters behind Maitri station and runs approximately E-W. The entire profile lies in the biotite gneissic terrain with sharp increase from south to north varying from -15 to 170 gammas. Profile - II (Fig.3) runs approximately N-S adjusant to Priyadarshini Lake. This anomaly ranges from -80 to 350 gammas with some sharp variations which could be due to faulted contact. Profile - III (Fig.4) is located 400 meters away east of Maitri station and also runs N-S featuring four sharp peaks of

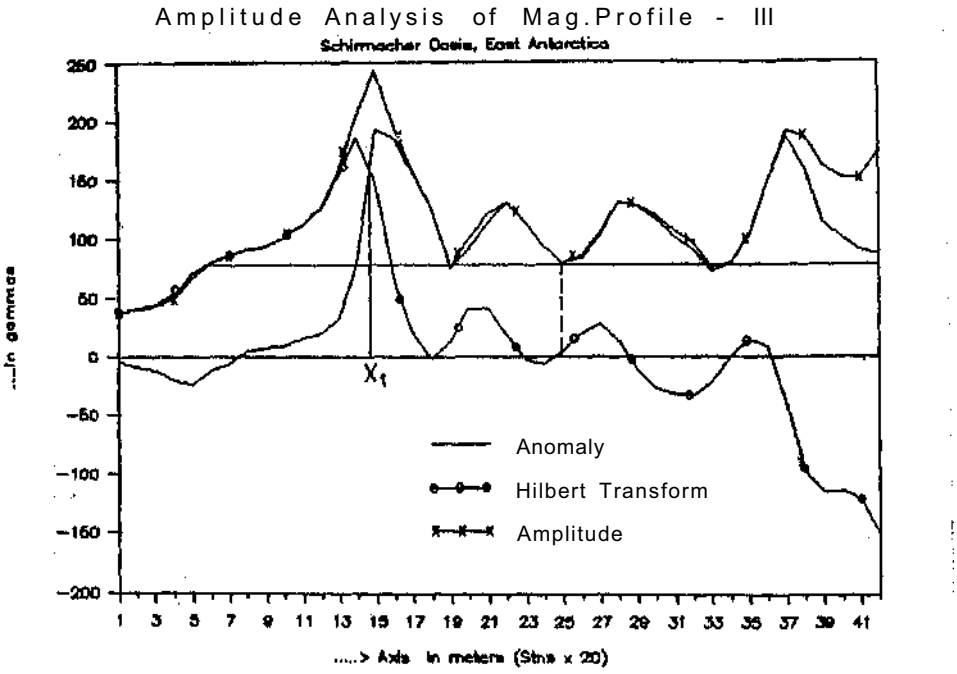

Fig.7

which two high peaks with 180 gammas are flanked by two low peaks with 120 gammas on either side. The profile ranges from -30 to 190 gammas.

Amplitude Analysis

The amplitude analysis for the interpretation of magnetic anomalies under discussion involves computation of the Hilbert transform and amplitude of the analytic signal as discussed by Nabhigian, (1972), Mohan *et al,* (1982) and Sundararajan (1982). The magnetic anomaly, the Hilbert transform and amplitude of these profiles are shown in Figs (5),(6) & (7). Taking into account certain characteristic points on the individual peaks of the amplitude and the abscissa of the point of intersection of the anomaly and the Hilbert transform, all the three profiles are analysed and the depth to top of the structural features such as geological contacts/faults are obtained. From profile-I, the depth is estimated to be between 200-280 meters, from profile - II, it is estimated that the depth varies from 120 - 280 meters whereas profile - III yields the depth as varying from 80 - 260 meters.

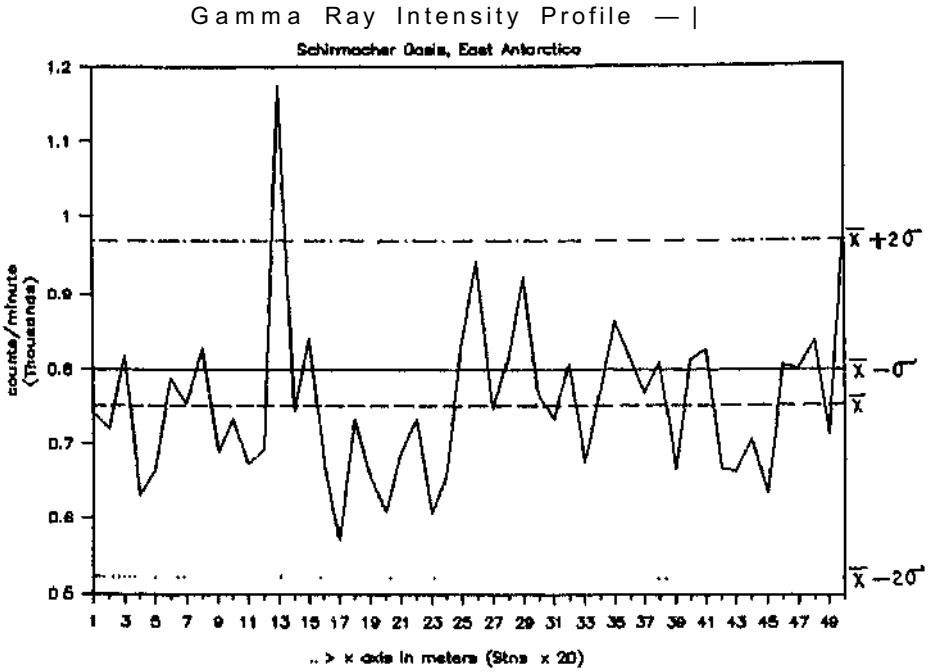

Fig.8

Petrophysical Properties

Gamma Ray Intensity

The radiometric measurements were carried out along the profiles as in the case of magnetic measurements using the portable scintillometer with digital read out that has been mdigeneously assembled and developed for the purpose of Antarctica expedition. The fluctuations of measured radiation count along the traverses are mostly within the standard deviation (σ) of the mean for the profiles. Profile -I has recorded a mean count corresponding to 17 μR/h. While profiles- II & III recorded a lower radiation intensity level (mean of 14.5 μR/h). Small positive anomalies beyond 2σ level (95.5% confidence interval) are observable only at a few observation points [as indicated in Figures (9) & (10)]. Variations beyond x + σ level (65.3% confidence interval) have also been noted. While no significance in radiometric anomalies are perceived along the traverses, the few positive anomalies can be interpreted due to localised features such as minor fractures in the area. However, significant variations of the mean radiation intensity level for profile -I vis-a-vis profiles-II & III may be viewed

as consequences of local variations of geology in the area which therefore needs further investigations in detail.

Density Measurements

A large number of samples were collected along the traverses and identified and then the density were determined using Sampsanov's density balance. In each type of rock, there were quite a few measures and then the average was found out. It is observed that the density range for a given rock type varies marginally and the results are presented in Table 1.

Susceptibility Measurements

Using a direct reading portable K-2 Kappameter, magnetic susceptibility values for all the above samples were determined in the laboratory. The results

Table 1 : Petrophysical properties (Schirmacher Oasis)

S.No	Rock type	No. of samples/ measurements	Density (σ) gm/cc	Susceptibility (K) 10^{-6} CGS units
1	Augen gneiss	15	2.25 - 2.90 2.67*	0- 10.00 2.00
2	Banded gneiss	20	2.00 - 2.95 2.53*	10- 820 58.00*
3	Garnet banded gneiss	02	—	10-50.00 30.00*
4	Biotite gneiss	10	2.50 - 2.95 2.73*	0-13.00 1.30*
5	Pyroxene granulites	9	2.68 - 2.90 2.28*	5-40.00 19.00*
6	Leucocratic gneiss	3	2.45 - 2.85 2.68*	< 1
7	Migmatite	3		10-21 .00 17.00*
8	Quartz	4	2.70 - 2.75	0-10.00 5.00*
9	Garnetbiotite gneiss	18	2.50 - 2.97 2.65*	0-21.00 2.00*
10	Pegmatite	2	2.45*	0-10.00 5.00*
1]	Graphic granite	2	2.55 - 2.70 2.60*	<1.00

* average

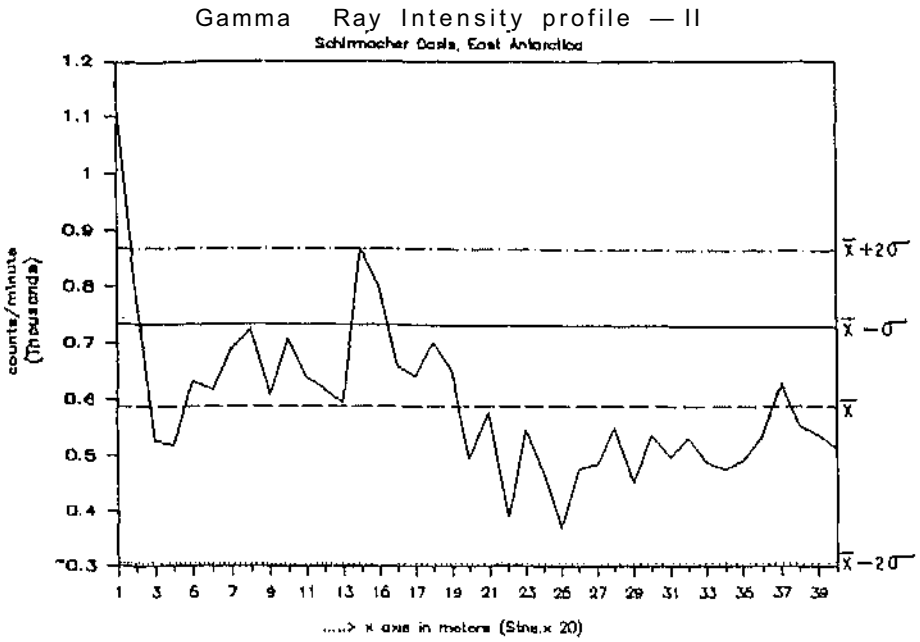
Gamma Ray Intensity profile — II
Schirmacher Oasis, East Antarctica
counts/minute (Thousands)
1.2
1.1
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
$\bar{X}+2\sigma$
$\bar{X}-\sigma$
$\bar{X}$
$\bar{X}-2\sigma$
1 3 6 7 9 11 13 16 17 19 21 23 25 27 29 31 33 35 37 39
.....> x axis in meters (Stns.x 20)

Fig. 9

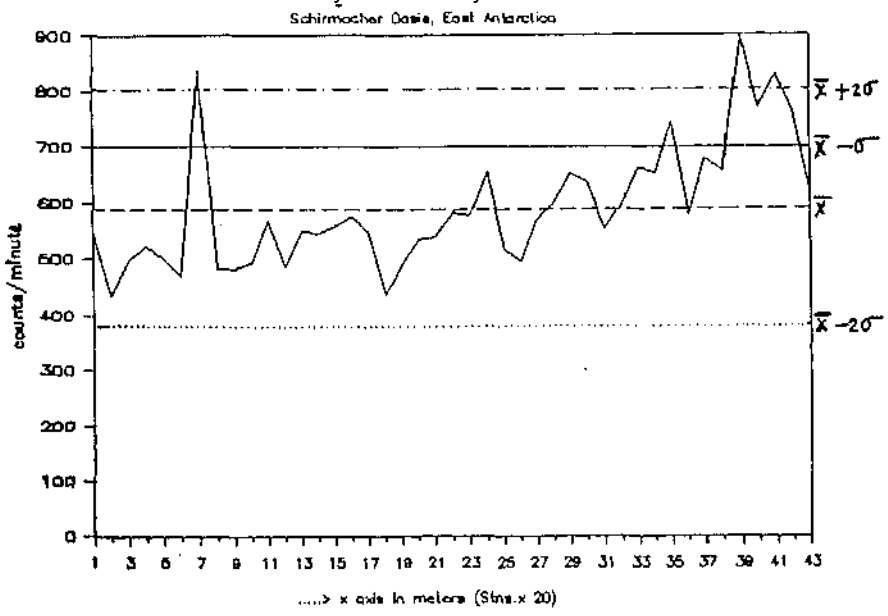
Gamma Ray Intensity Profile — III
Schirmacher Oasis, East Antarctica
counts/minute
900
800
700
600
500
400
300
200
100
0
$\bar{X}+2\sigma$
$\bar{X}-\sigma$
$\bar{X}$
$\bar{X}-2\sigma$
1 3 5 7 9 11 13 15 17 19 21 23 25 27 29 31 33 35 37 39 41 43
.....> x axis in meters (Stns.x 20)

Fig. 10

Table 2 : Petrophysical properties (Orwin mountains)

S.No	Rock type	No. of measures	Density (σ) gm/cc	Susceptibility (K) 10^{-6} CGS units
1.	AUgen gneiss	3	—	10.00 - 10.00 27.00*
2.	Banded gneiss	5	2.50	0-15.00 6.00*
3.	Biotite gneiss	4	2.50 - 2.62 2.57*	10.00 - 22.00 12.00*
4.	Garnet biotite gneiss	2	2.50	0 -10.00 5.00*
5.	Graphic granite	1		<1.00
6.	Garnet gneiss	4	2.60 - 2.62 2.61*	0 - 22.00 13.00*

* average

are presented in Table 1. It is observed that for some type of rocks the range in susceptibility varies significantly whereas for other types the variations are within the normal range.

Density and Susceptibility in Orwin Mountains

On a reconnaissance visit to Orwin mountains on 30th January, 1995, rock samples were collected at quite a few places within a radius of 100 meters and their density and magnetic susceptibility were determined in the laboratory. The results are presented in Table 2. The density of various rock types here are similar to those of the Schirmacher region whereas the susceptibility differs substantially for some rock types.

Conclusions

Despite the low magnetic character of the country rocks, the vertical magnetic surveys in Schirmacher Oasis found to be useful in geological and structural mapping. The deciphered structural features such as faults/contacts/shears/ from the magnetic anomalies found to be of shallow features.

No significant radiometric anomalies - gamma ray activity are perceived. However, a few positive anomalies along the traverses are attributed due to the localised features.

For some rock types the range in density and magnetic susceptibility are found to be marginally high.

In the case of rock samples from Orwin Mountains, the values of density are found to be similar to those of Schirmacher region whereas the magnetic susceptibility varies substantially.

Acknowledgements

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