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# Measurement of *Insitu* Petrophysical Properties, VLF-EM and Vertical Component Magnetic Surveys in Schirmacher Hills, East Antarctica

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## Abstract

**As a part of 3 year research program of the Centre of Exploration Geophysics, Osmania University, Hyderabad, *in situ* measurements of physical properties (density,magnectic susceptibility and gamma intensity) of major rock types from Schirmacher region were carried out during 13th Indian Antarctic Expedition. An experimental survey with Very Low Frequency Electromagnetic (VLF-EM) equipment was carried out to test its operational efficiency and to ascertain its efficacy in geological mapping for the Antarctic environment. Vertical component magnetic measurements were also carried out along selected traverses to infer the subsurface geology and structure.**

**A reconnaissance survey of the Orvin mountains revealed a highly concentrated zone of radioactivity which appears to be quite significant.**

## Introduction

The Centre of Exploration Geophysics, Osmania University, Hyderabad had submitted a 3-year research program to the Department of Ocean Development (DOD) for inclusion in the three successive Antarctic scientific expeditions. Accordingly the DOD has selected this program. The Scientific program had the following objectives.

(i) *Insitu* measurements of physical properties of rocks from Schirmacher and Humboldt regions of East Antarctica.

(ii) Assessing the role of VLF-EM method for geological mapping under Antarctic environmental conditions.

(iii) Geo-thermal logging (depending on the availability of a borehole) to assess intrusive activity.

As a part of the 13th Indian Scientific Expedition program to Antarctica, the objectives (i) and (ii) were attempted within the logistic and scientific constrains of the expedition. In addition vertical component magnetic surveys for structural investigations in the Schirmacher hills.

## Equipment used

For the purpose of this expedition, it was proposed to use the equipment available at the Centre of Exploration Geophysics, Osmania University, Hyderabad to conduct geophysical surveys over certain selected traverses in the Schirmacher region, Eastern Antarctica. The following equipment were used during the study.

1. VLF-EM 16 and 16R unit of m/s Geonics Ltd.
2. Fluxgate magnetometer (Vertical Component) of Scintrex make.
3. Differential Spectrometer GRS 500 of EDA make.
4. K-2 Susceptibility meter of EDA make.
5. Gamma absorption densitometer (modified version of a Russian make).
6. Sampsanov's density balance.
7. Basic surveying instruments.

## Insitu Measurement of Physical Properties of Rocks from Schirmacher Hills

Based on the megascopic study of the rocks and also on the published geological maps of the area (Sengupta, 1986 and Bormann, *et al.,* 1986) the rock sequences, intrusives and tectonites of the Schirmacher hills have been identified and classified as (i) Banded gneiss (thin bands), (ii) Banded gneiss (Thick bands), (iii) Augen gneiss, (iv) Biotite gneiss, (v) Garnet gneiss, (vi)Pyroxene granulites (or Olivine norites), (vii) Amphibolites, (viii) Calc-silicates, (ix) Dolerites, (x) Basalts, (xi) Vein Quartz, (xii) Pegmatites and (xiii) Mylonites. Wherever the measurements were made, representative rock samples were also collected for petrological and further laboratory studies.

## Susceptibility Measurements

Using a direct reading portable K-2 Kappameter, magnetic susceptibility values for all the above mentioned rocks were measured. Susceptibility values for the rocks are very low and varied in a limited range. However, a wide variation has been noticed for intrusive rocks. The values measured on hand samples are shown in Table 1 along with other properties measured.

**Table 1: Physical properties of rocks from Schirmacher, East Antarctica**

| S.No. | Rock Type | No. of measure-ments | Density gm/cc | Mag. Susc. K x $10^{-6}$ CGS units | Radioactivity $Tc_1$ cps | Radioactivity $Tc_2$ cps |
|---|---|---|---|---|---|---|
| 1. | Augen gneiss | 05 | 2.86(0.04) / 2.84-2.90 | <1 | 155(10) / 140-160 | 31(4) / 29-35 |
| 2. | Leucocratic gneiss | 12 | 2.65(0.02) / 2.64-2.67 | <1 | 250(30) / 210-280 | 50(6) / 42-56 |
| 3. | Thin Banded Biotite gneiss | 08 | 2.68(0.03) / 2.66-2.70 | <1 | 190(20) / 170-210 | 42(6) / 36-50 |
| 4. | Thick Banded Biotite gneiss | 10 | 2.86(0.06) / 2.80-2.92 | <1 | 160(15) / 140-180 | 30(5) / 24-36 |
| 5. | Garnetiferrous gneiss | 11 | 2.86(0.06) / 2.80-2.92 | 2(1) / 1-3 | 185(10) / 175-195 | 40(2) / 37-42 |
| 6. | Amphibolite | 14 | 3.10(0.05) / 3.04-3.18 | 2(2) / 1-4 | 120(15) / 100-135 | 20(4) / 16-25 |
| 7. | Dolerite | 07 | 3.02(0.05) / 2.98-3.10 | 4(2) / 1-6 | 110(15) / 100-135 | 20(4) / 16-24 |
| 8. | Olivine Norite (Pyroxene granulites) | 08 | 3.00(0.02) / 2.98-3.04 | <1 | 104(6) / 100-110 | 15(3) / 13-18 |
| 9. | Basalt | 06 | 2.96(0.04) / 2.90-3.01 | 3(1) / 1-5 | 230(30) / 180-260 | 40(6) / 35-48 |
| 10. | Lamprophyre | 04 | 2.91(0.02) / 2.90-2.93 | 3(1) / 2-4 | 176(4) / 170-180 | 36(2) / 34-38 |
| 11. | Mylonite | 04 | 2.80(0.02) / 2.78-2.82 | 2(1) / 1-3 | 160(10) / 150-170 | 30(2) / 28-32 |
| 12. | Calc Silicate | 07 | — | <1 | 155(10) / 150-165 | 26(4) / 23-30 |
| 13. | Vein Quartz | 05 | — | <1 | 92(4) / 90-96 | 18(2) / 16-20 |
| 14. | Pegmatite | 25 | — | — | 400(250) / 200-800 | 95(75) / 45-200 |

Note: Values in the numerator indicate average and in the brackets standard deviation; denominator shows the range.

Background count rate for $Tc_1$ is 40 cps and for $Tc_2$ 7 cps.

## Density Measurements

*Insitu* measurements were carried out using a gamma absorption unit which contains a Russian source and a compatible indigeneously developed receiver. The instrument is quite heavy and requires two persons to carry in the field. The instrument works on the principle of gamma absorption which is proportional to the density of the formation rock. Using this equipment density values were obtained for all the above mentioned rock units. To counter check, density measurements were also made on representative rock samples using a Sampsanov's density balance in the summer camp at Maitri. A marked density variation was noticed for all the above mentioned rock units.

## Radioactivity Measurements

The measurements were made using a differential gamma ray spectrometer. The instrument is a compact portable one with five channels for measuring all terrestrial gamma radiation. The first two channels are the lower energy levels at 80 Key and 400 Kev. The remaining three channels are (i) k, all gamma energies between 1350 Kev and 1590 Kev, (ii) u, all gamma energies between 1650 and 1870 Kev, and (iii) t, all gamma energies between 2450 and 2790 Kev.

Using the above instrument, gamma intensity count rates were measured in all the five channels for the rock sequences mentioned earlier. It is significant to note that the rock units differ greatly with regard to the gamma intensity. Pegmatite veins showed the highest count rates.

## VLF - EM Measurements

The VLF-EM transmitters which are used for communications with submarines are utilised as an EM source for making dip angle measurements. For this purpose the VLF-EM 16 unit of Geonics, Canada was employed. It is a sensitive receiver covering the frequency band of the VLF transmitters and is capable of measuring the vertical components of the secondary magnetic field generated by the conducting earth materials. The VLF-EM 16 R unit with a mounting console accessory measures apparent resistivity.

The unit was primarily used to test the reception in Antarctica of the various VLF-EM transmitters situated around the globe. It is well known that the Antarctic environment is known for frequent magnetic storms which may hinder transmission of VLF signals. It was observed from Maitri that Australian VLF-EM signal (NWC, frequency 22.3 KHz) is quite good compared to the nearby Argentina transmitter. A few observations of the real and imaginary components were also noted along a traverse. However, no resistivity measure-

**ments could be possible as the operation requires the assistance of another scientist trained in the line of activity.**

## Vertical Component Magnetic Surveys

**Total field magnetic measurements were made by earlier workers in the continental shelf region around Dakshin Gangotri station to study the basement structure and also in the Schirmacher hills to map the geology (Mittal and Mishra, 1985, Arora, *et al.,* 1985, Gupta, and Verma, A.K., 1986, Verma, *et al.,* 1987, Shikar Jain, *et al.,* 1988). Bormann, *et al.,* 1986 prepared a total component magnetic contour map from 105 magnetic observations collected at a spacing of 250 meters. However, no work report of vertical component magnetic field data from this region, was known to the author.**

**Therefore vertical component magnetic field measurements were made along five traverses at an interval of 10 m and over anomalous zones at an interval of 5 m. The main object of the field investigations was to check the magnetic response of the structural features depicted in the photo-geological map published by Bormann, *et al,* 1986. Accordingly the traverses were planned and laid. Location of these traverses are shown in Fig. 1. The latitude position of Schirmacher area being at about 70S, nearly vertical magnetisation can be expected for geological features and therefore vertical component measurements were preferred. Fluxgate magnetometer of Scintex make with a sensitivity of one gamma was used for this purpose. On the whole more than 400 magnetic observations were made covering a distance of 4 line kilometers.**

**Magnetic observations were made only on magnetically quiet days. Frequent repetitions were made to check the diurnal variations. Nearly, twenty percent of the observations were repeated for estimating the diurnal correction and accuracy of the survey. The magnetic anomalies were referred to different local base points instead of one due to logistic constraints. The overall accuracy of the magnetic anomalies is estimated to be +5 gammas.**

**Description and analysis of magnetic anomalies along the five traverses are given as follows:**

### Traverse I

**Traverse I runs along the route mapped by the Survey of India around Maitri station and Priyadarshini lake. The total length of this traverse is 1350 meters and it runs approximately East-West. The profile begins at 'O' point from East and runs towards west parallel to the Priyadarshini lake for some distance and then to Maitri station. The entire profile falls in the biotite gneissic terrain. As shown in Fig. 2 the anomaly on this traverse ranges from 20 to -400**

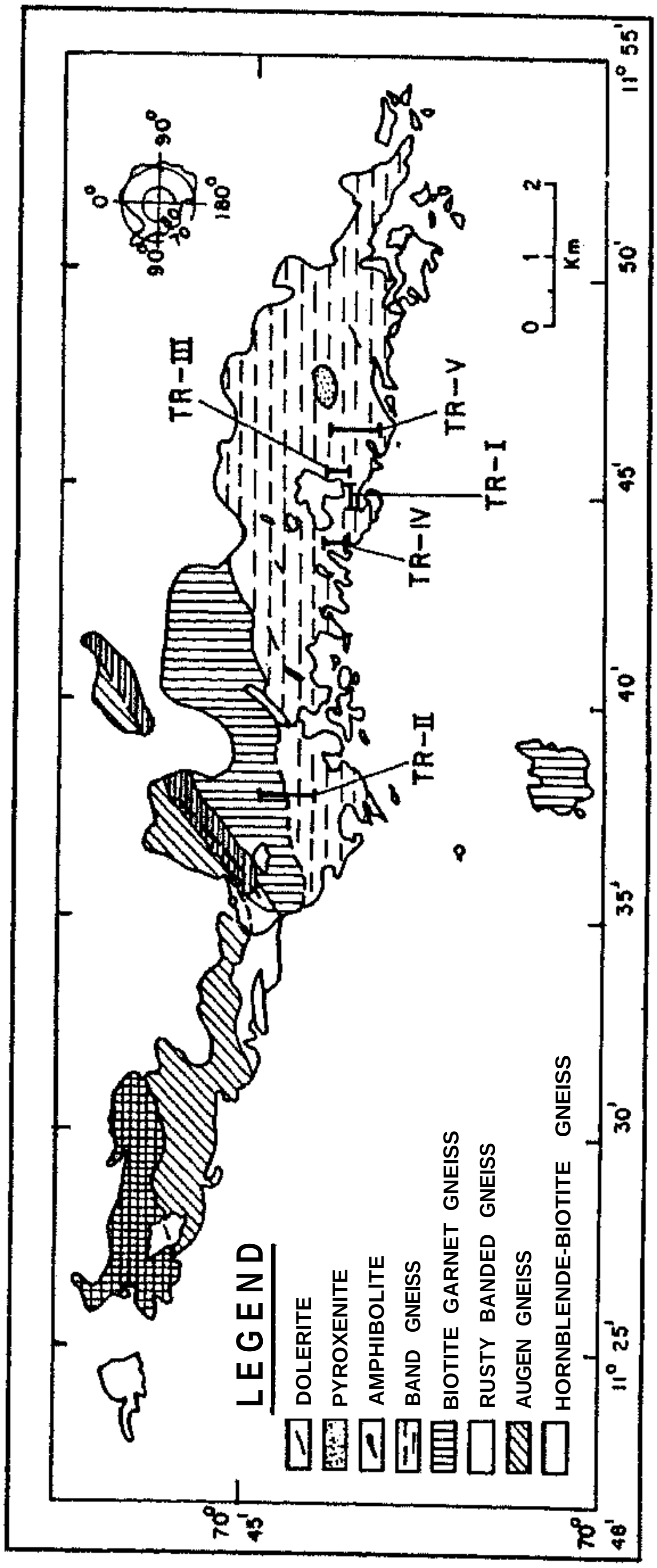


*Fig. 1: Geological map of Scirmacher area, East Antarctica, showing location of Magnetic Traverses*

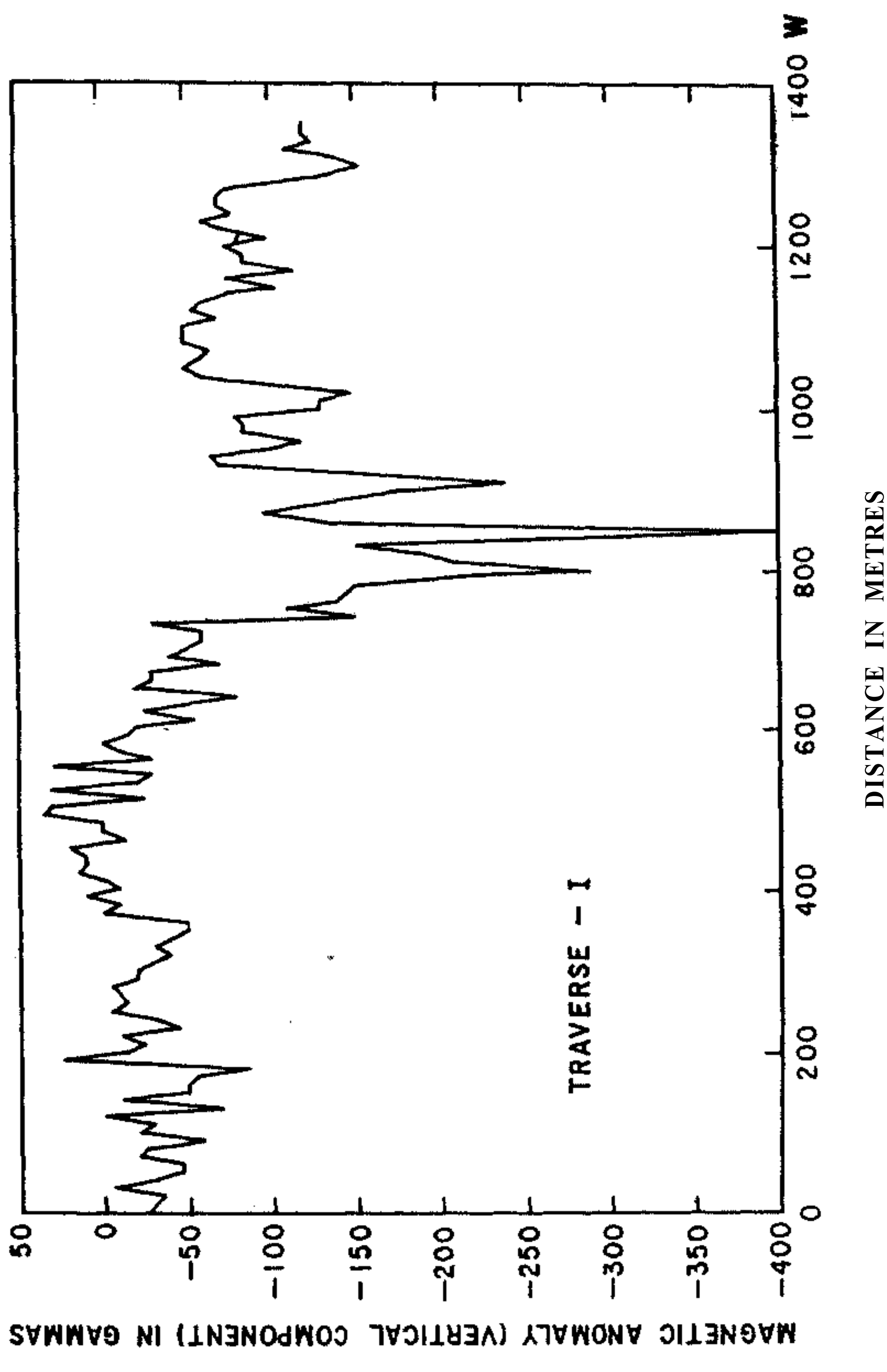


*Fig. 2: Magnetic anomaly (Vertical Component) - Traverse I*

gammas. However, the anomalies region between 700 to 1000 meters appears mainly due to the presence of iron material and power lines around Maitri station. Barring this, three prominent variations in the anomaly may be noted at 200 m, 400 m, and at 1300 m. The variations in the anomaly indicates presence of fractures/shears/faults. As all the anomaly is of low amplitude and spread over short distances subsurface structure could be shallow and localised. It is interesting to note that these zones are more or less matching with the three fault lineations marked in the photogeological map of Bormann *et al.*, 1986. The locations of these zones are more clearly depicted in the magnetic anomaly reduced map to pole as shown in Fig. 3. It is interesting to note that the anomaly zone at 400 m coincides with the feeder water channel from the glacier to the Priyadarshini lake.

## Traverse II

Traverse II is located N35W of German hut which is located close to the Dakshin Gangotri (DG) glacier. The '0' point starts 10 m west of German hut and the total length of the traverse is 920 meters. Unlike traverse I, this traverse covers biotite gneiss and garnet gneiss terrain. The anomaly in this traverse ranges from 200 to -400 gammas (Fig. 4). The region between 50 and 200 m

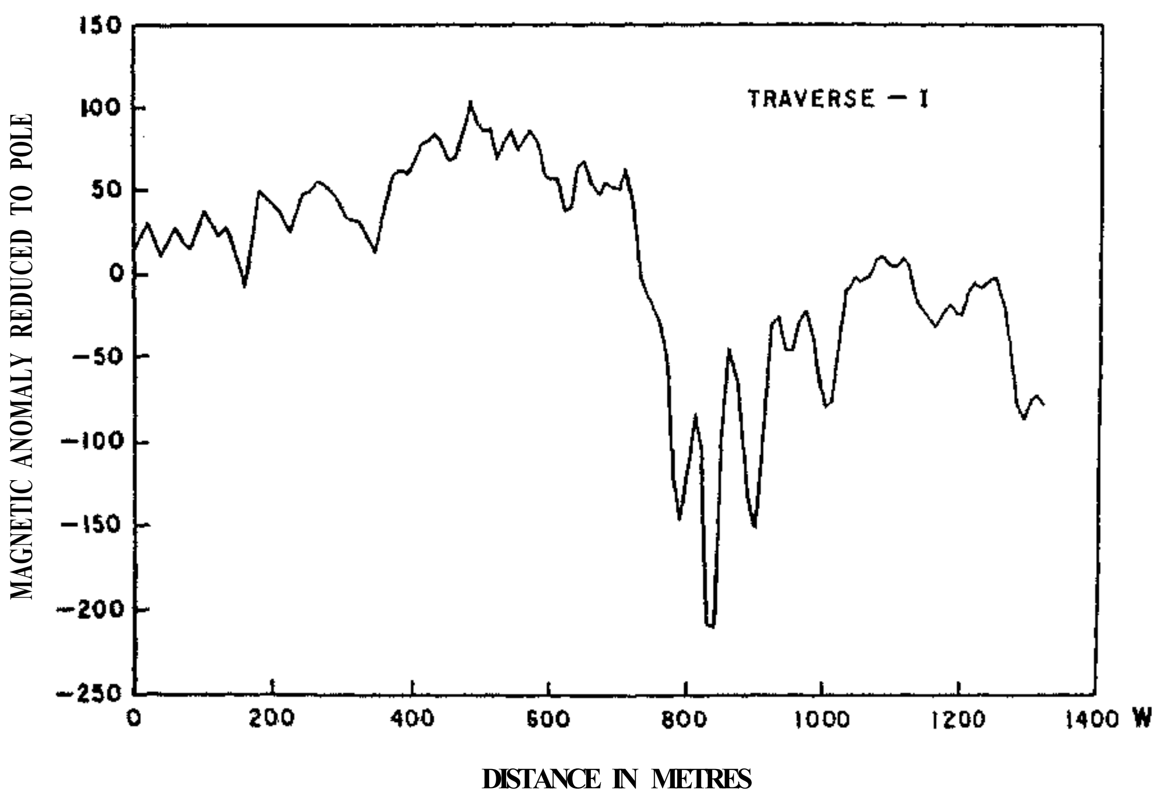


*Fig. 3: Magnetic anomaly reduced to pole - Traverse I*

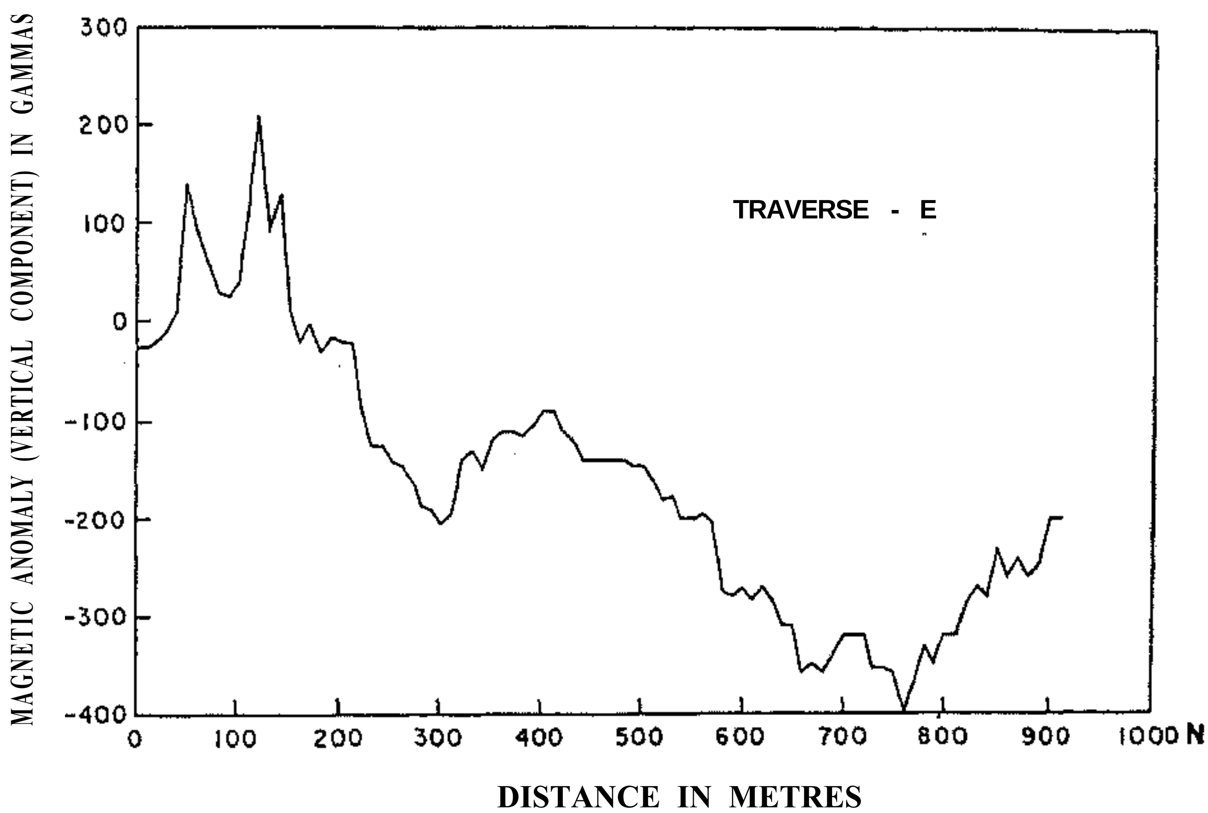


*Fig. 4: Magnetic anomaly (Vertical Component) - Traverse 11*

is marked by sharp rise in the magnetic anomaly. This zone-corresponds well with the overthrust zone marked by Bormann *et al,* 1986. The sharp rise in the anomaly may be due to the accumulation of ferromagnetic substances along this zone. The magnetic anomaly reduced map to pole clearly brought out this feature as a broad magnetic high as shown in Figs 5 & 6. Rest of the anomaly picture shows a marked broad high and low with inflection point around 550 m which depicts the contact between the biotite gneiss and garnet gneiss. The anomaly spread between the litho units is quite long which indicates a deeper source.

## Traverse III

Traverse III trends N15E direction and cuts across the olivine-norite hill located adjacent to Priyadarshini lake. Along this traverse the anomaly ranges from -40 to 350 gammas with sharp variations at different points. Between 50 m to 150 m the anomaly rises from -10 to 170 gammas depicting a faulted contact between biotite gneiss and olivine norite massif. The pseudo gravity anomaly map prepared from the magnetic anomaly reveals that the fault plane dipping towards south (Fig. 7). The faulted contact is located around 100 m point. Apart from this the other two prominent anomalies identified are between

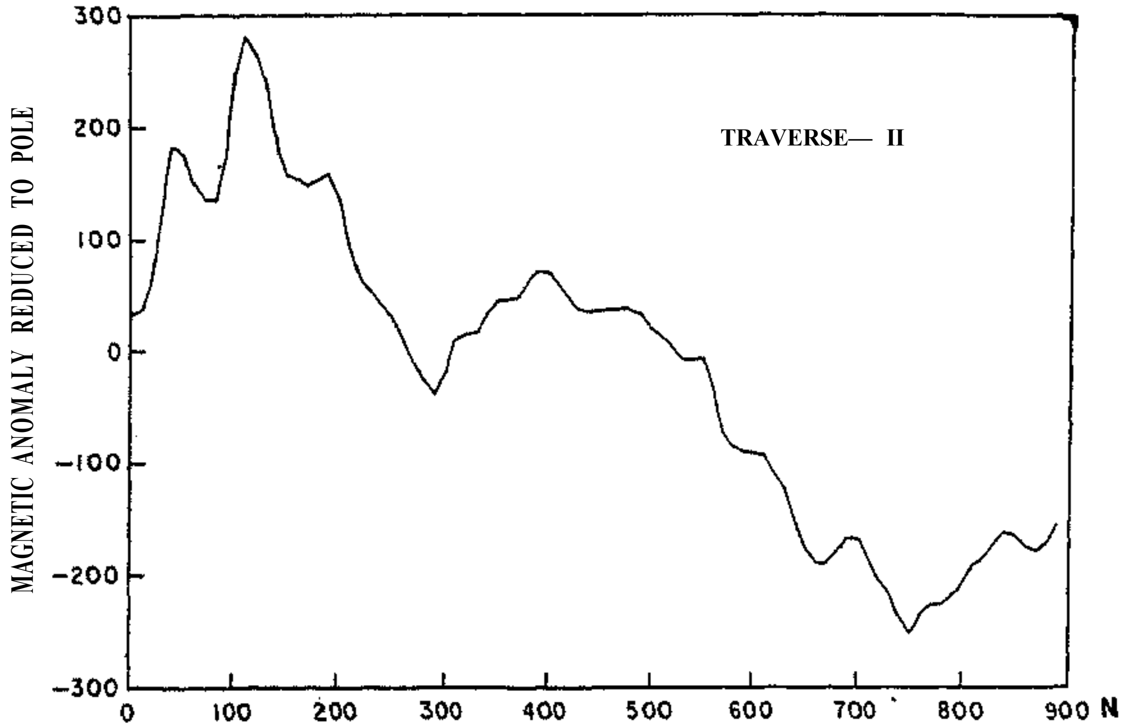


*Fig. 5: Magnetic anomaly reduced to pole - Traverse 11*

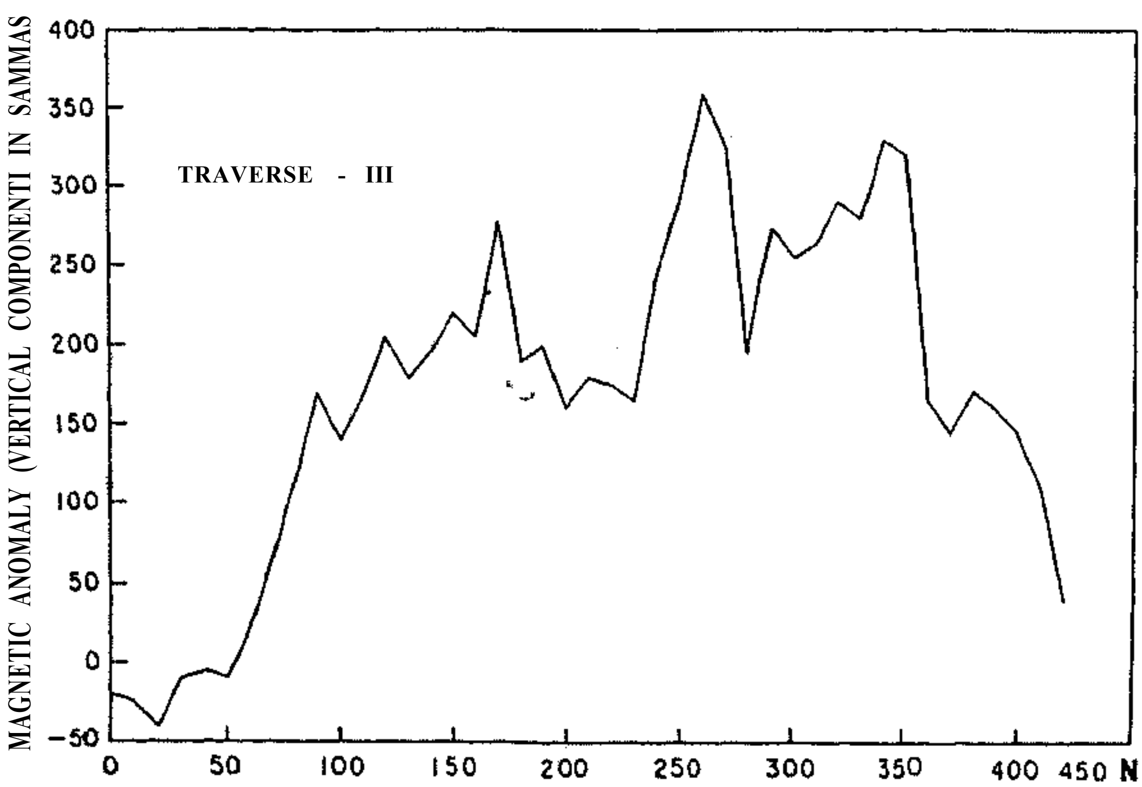


*Fig. 6: Magnetic anomaly (Vertical Component) - Traverse III*

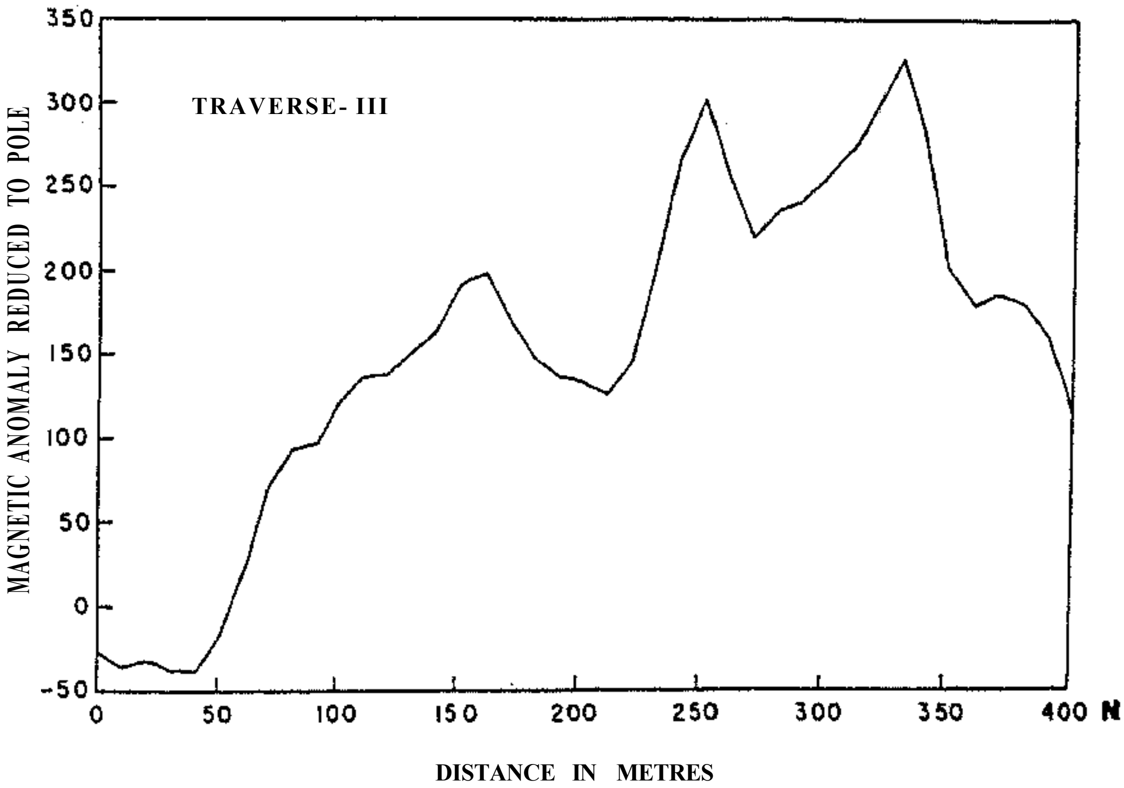


*Fig. 7: Magnetic anomaly reduced to pole - Traverse III*

200 and 270 meters and 300 and 400 meters. The anomaly between 200 and 270 meters may be again a faulted contact between biotite gneiss and olivine norite massif. Thus it may be postulated that a block faulting between olivine norite massif and the biotite gneisses can be visualised which probably may be a reason for the present height of the olivine norite massif. The third anomalous zone between 300 and 400 meters is not fully traced due to inaccessibility of the area which again appears to be a major faulted boundary.

## Traverse IV

Traverse IV is located 500 m west of Maitri station. It runs in a N-S direction for a length of 430 m. The entire traverse falls in the biotite gneissic terrain. The anomaly in this traverse ranges from -10 to 250 gammas (Fig. 8). The anomaly shows a sharp rise between 550 and 300 meters area depicting a faulted plane. The anomaly reduced to pole and the horizontal gradient profile (Figs 9 & 10) reveal that the fault phase is located around 2/5 m point. In this traverse the anomaly rise in general is from south to north indicating a sequence of more basic rock along this direction.

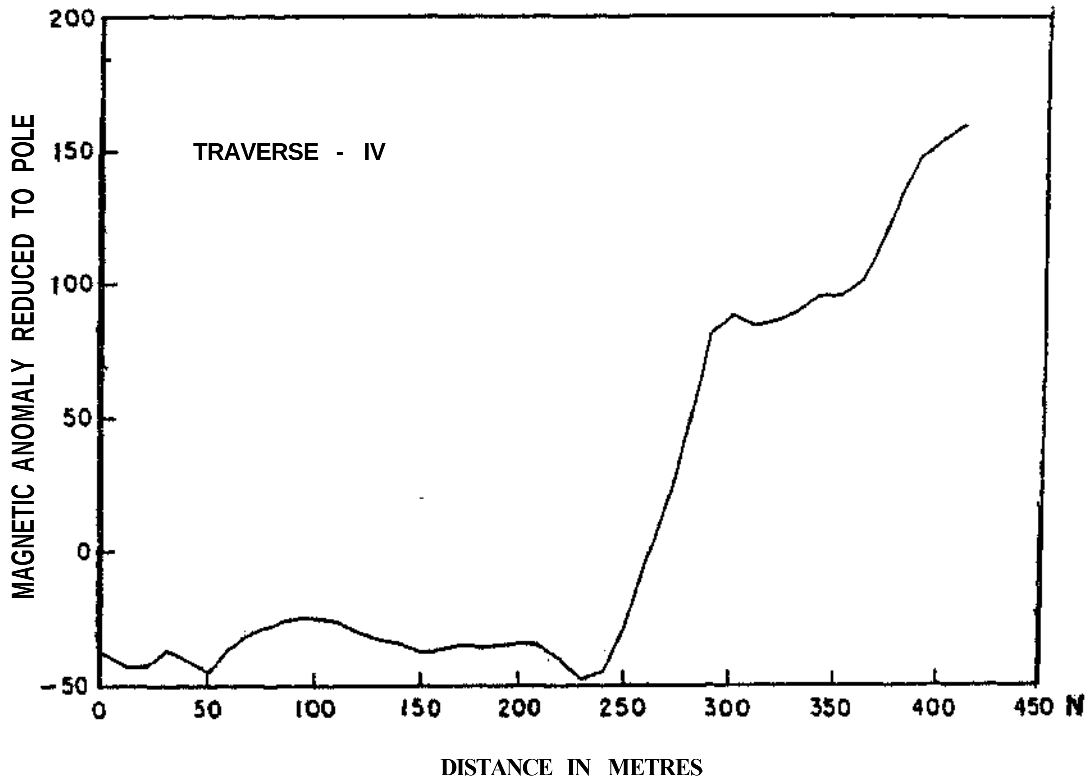


*Fig. 8: Magnetic anomaly reduced to pole - Traverse IV*

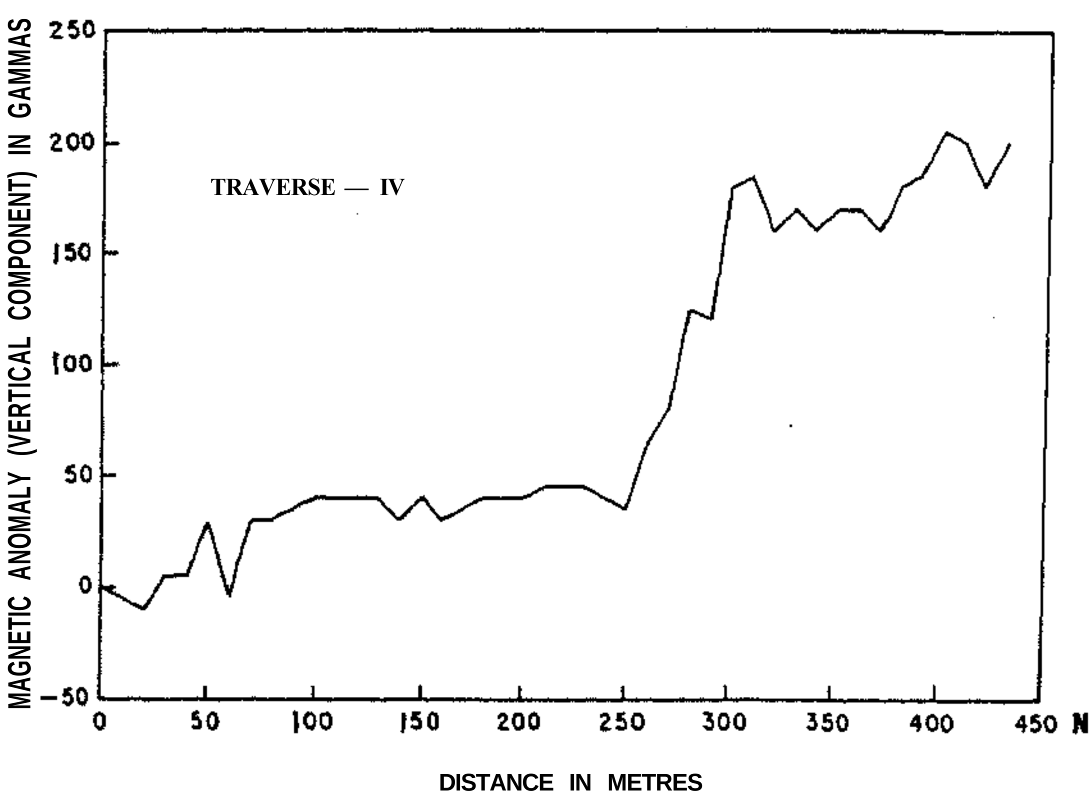


*Fig. 9: Magnetic anomaly (Vertical Component) - Traverse IV*

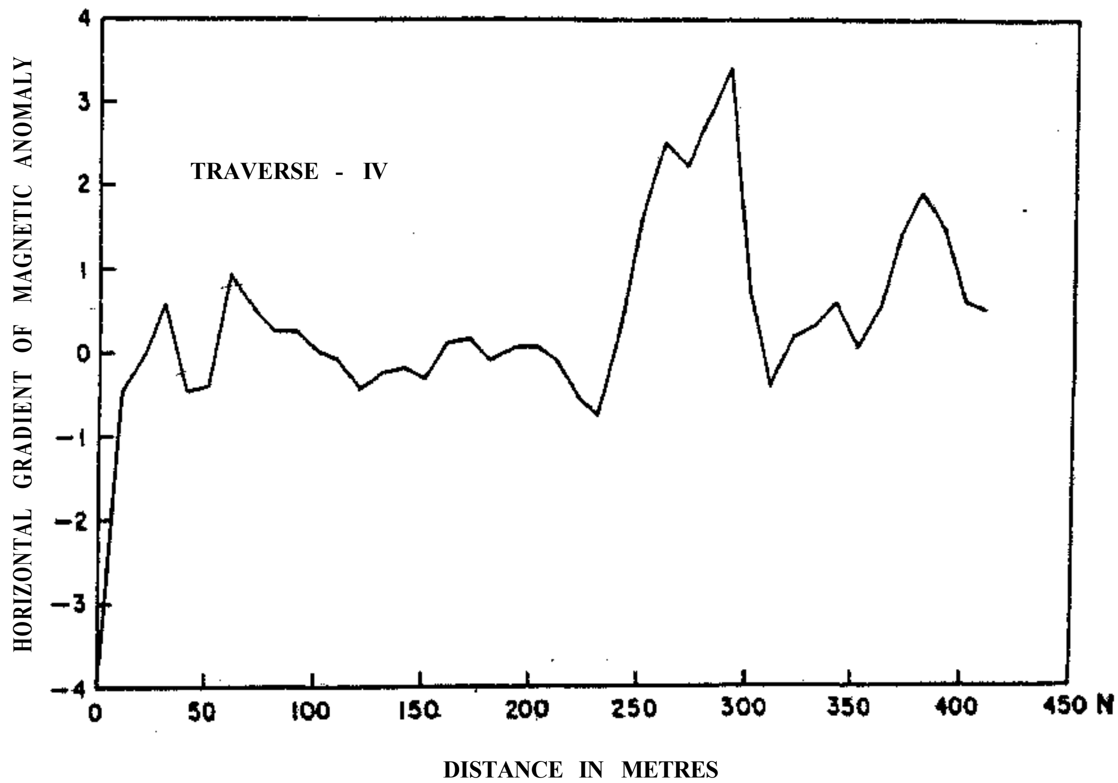


**Fig.** ***10: Horizontal gradient of magnetic anomaly - Traverse IV***

## Traverse V

**Traverse V is located 1.5 km east of Maitri station. This traverse aiso runs in a N-S direction for about 750 meters. The magnetic anomaly and the anomaly reduced to pole along this traverse are shown in Figs 11 & 12. The magnetic anomaly on this traverse revealed a couple of rock sequences depicted by a faulted boundary. The faulted boundary is located around 300 m point and is characterised by a steep rise in the anomaly. The anomaly region between 700 and 750 meters appears to reflect a more basic rock sequence.**

## Reconnaissance Survey in Orvin Mountains

**On a reconnaissance visit to Orvin mountains on 24th January, 94, along with GSI team, radioactivity measurements were undertaken at three drop points. At the second drop point around Sandneshatten area (71°42'S, 9°40'E) the total counts of gamma intensity recorded exceeded 15,000 counts per second, which is nearly twenty times that of the maximum count rate recorded in the Schirmacher ranges. The high count rate may be due to concentration of radioactive elements in that region. This region deserves to be a target for future geological/geophysical exploration.**

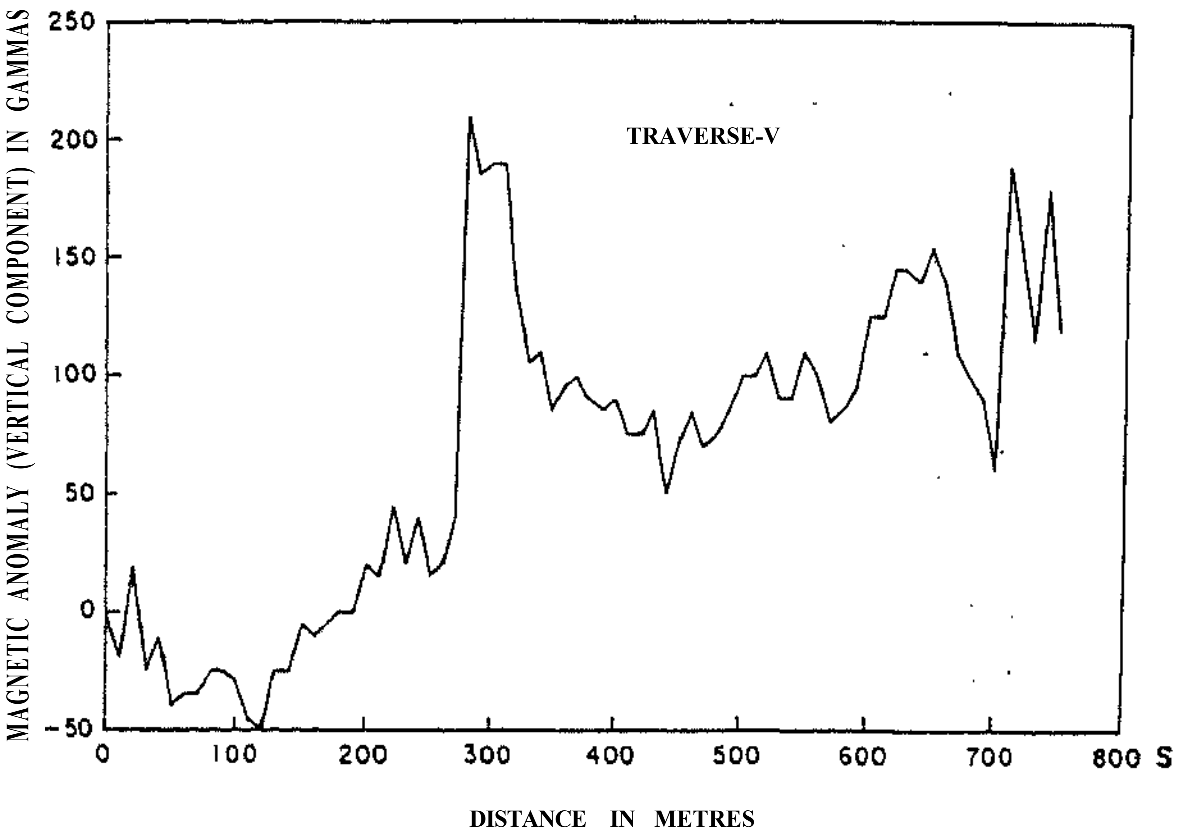


*Fig. 11: Magnetic anomaly (Vertical Component) - Traverse V*

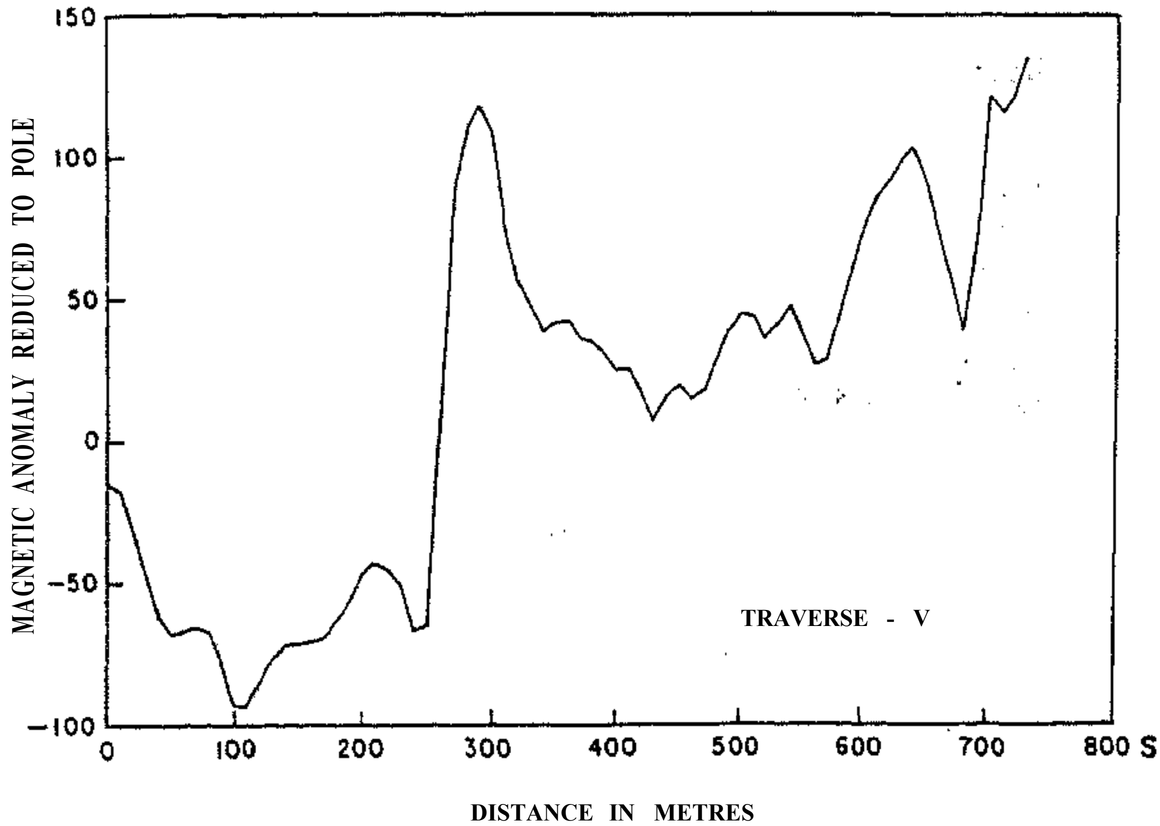


*Fig: 12: Magnetic anomaly reduced to pole - Traverse V*

## Conclusions

1. The vertical component magnetic surveys in the Schirmaeher Oasis reflects the usefulness of magnetic method in geological and structural mapping.
2. Detailed vertical component magnetic surveys have clearly brought put the lithological variations and the structural details of the Schirmaeher Oasis inspite of the low magnetic character of the country rocks.
3. The contacts/shears/faults deciphered from magnetic surveys may be of great help in locating economic mineral zones.
4. Physical property measurements should be continued in the Schirmaeher region (electrical properties and elastic properties need to be measured) and should be extended to the mountain chains further south (in particular Orvin mountains for detailed radioactive surveys).
5. Detailed magnetic mapping should be undertaken to decipher the structural fabric of the Schirmaeher and other mountain ranges.
6. Micro magnetic surveys are necessary for understanding the nature of geological contacts/structures.
7. VLF-EM measurements should be continued to establish its efficacy in the Antarctic environment for geological and structural investigations.
8. Any field oriented activity should consist of a team of minimum two scientists fully identified for the task.

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