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VLF-EM AND *IN SITU* CONDUCTIVITY MEASUREMENTS IN SCHIRMACHER RANGE, EAST ANTARCTICA

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Abstract

As a part of three year research programme of the Centre of Exploration Geophysics (CEG), Osmania University, Hyderabad, Very Low Frequency-Electromagnetic (VLF-EM) measurements were carried out along four selected traverses to study the efficacy of VLF-EM method for geological mapping in Antarctic environment. The preliminary results revealed that the method can be successfully used to map geological boundaries and shear zones/faults. The VLF anomalies were seen to be due to shear zones/alterations near contacts of the rocks. It was found that the strength of the VLF signal, in general, decreased over the polar ice cap. It is suggested that the VLF instrument with better resolution and sensitivity should be used for effective geological mapping over ice covered areas. Conductivity measurements were also made along three traverses. The conductivity values for the rock types occurring in Schirmacher area varied in a limited range. However, variations have been noticed near contacts and sheared/altered rocks. A reconnaissance survey in Holtedahl mountain region revealed no anomalous radioactivity associated with the rock types occurring in the region.

Introduction

The CEG scientific programme as accepted by the D.O.D. had the following objectives:

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

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

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

As a part of the 15th Indian Scientific Expedition to Antarctica, the VLF-EM Conductivity and Radiometric methods were attempted to fulfil the remaining parts of objectives (i) and (ii). The third objective was not attempted due to the non-availability of boreholes during the expedition period.

Scientific Objectives of the 15th Expedition

1. To conduct test VLF-EM surveys for geological mapping in Antarctic environment.
2. To conduct in *situ* measurements of conductivity of rocks from the Schirmacher hills and radioactivity of rocks from the Orvin mountains.

Instruments Employed

1. VLF-EM 16 and 16 R unit (Make — M/s Geonics Ltd.)
2. EM-38 Conductivity Meter (Make — M/s Geonics Ltd.)
3. SRR2 Nucleonix (Indian) Recording unit with Russian Probe.

Location, General Geology and Geophysical Layout

The Schirmacher land mass is located approximately 80 km south of the Indian research station, Dakshin Gangotri and approximately 100 km north of Wohlthat massif. Actually it is a hill range of about 20 km length, trending east-west with a maximum width of 2.7 km in the centre. The land mass is dotted by a large number of fresh water lakes.

According to geological reports, the area consists of a variety of high grade metamorphic gneisses, amphibolites, migmatites, mylonites and blastomylonites. Keeping our objectives in view, three surface-exposed geological features were selected in the region, across which one traverse each was laid. Another traverse was laid on polar, ice where geology was not exposed. The layout of traverses are shown in **Fig.1.** The test VLF-EM and conductivity measurements were made along these four traverses.

VLF-EM Measurements

Geophysical methods like magnetic, gravity, seismic, E.M. and electrical methods have been successfully applied to study the basement structure near the shelf of eastern Antarctica (Mittal and Mishra, 1985; Arora *et al,* 1985, Gupta and Verma, 1986; Bormann *et al,* 1986; Verma *et al,* 1987) and also in

Geological map of Schirmacher area, East Antarctica showing Traverse location of 15th Expedition by C.E.G., Osmania University.

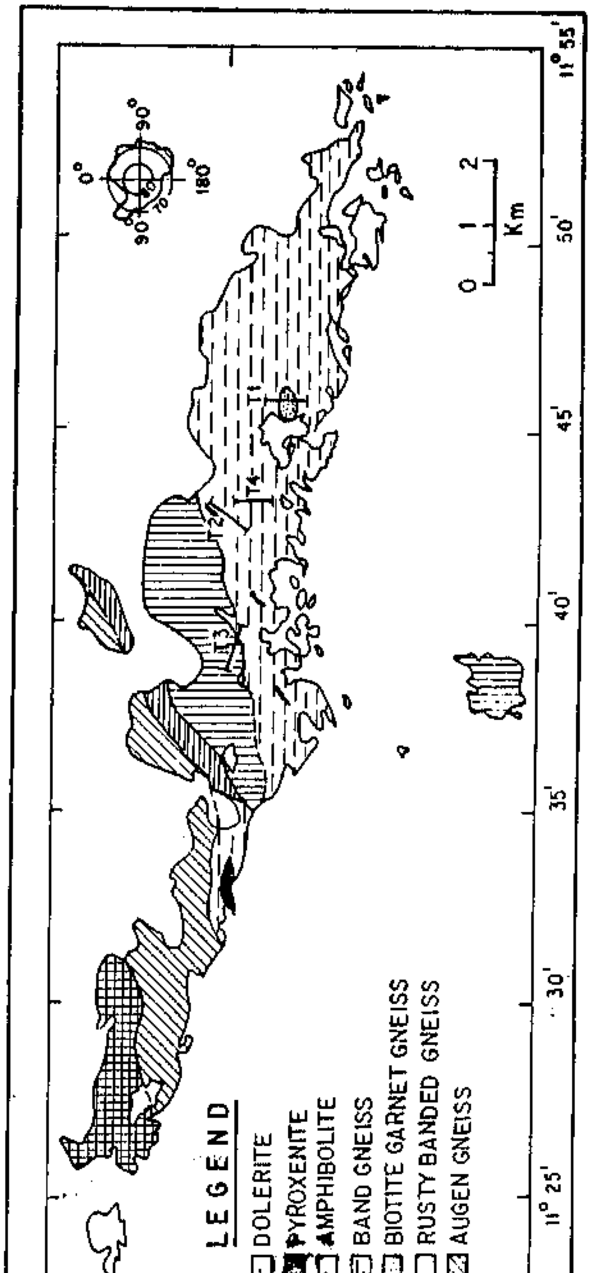


Fig. 1

the Schirmacher hills to locate mineralisation (Jain *et al,* 1988). However, no geophysical work has been reported using VLF-EM method from this region.

Primarily, the VLF-EM method is used to map conductive ore deposits. However, the method can be used to map geological bodies also (Aina and Emofurieta, 1991). The VLF-EM method is a frequency domain method which uses electromagnetic waves from powerful transmitters operating at low frequency band (10-25 kHz) of the EM spectrum. The VLF-EM 16 unit is a sensitive receiver covering the frequency band of the VLF transmitting stations and capable of measuring the vertical components of the secondary field generated by the lateral conductivity changes in the earth material.

The unit is first tested for the reception of clear signals to work in the Antarctica environment, as the Antarctica environment is known for frequent magnetic storms which may hinder transmission of VLF signals. It was observed with the VLF-EM unit that the Australian broadcasting signal (NWC, frequency 22.3 kHz) was clear enough to conduct VLF-EM survey in Schirmacher region. In all, four VLF profiles were obtained along the chosen traverses as mentioned above. During the survey, frequent repetitions were made to check the repeatability of the observations. Description and interpretation of the VLF anomalies along the four traverses are given below.

Traverse-I

Traverse-I runs across the Olivine Norite hill located adjacent to the Priyadarshini lake. The width of the body along the traverse is about 35 m. The total length of the traverse is 400 m and runs approximately 60 N. The profile begins at '0' point, 20 m south of the Survey of India station existing in the vicinity. The raw profiles of both inphase and quadrature components are shown in **Fig.2.**

The figure shows the inphase and quadrature profiles obtained with the features of a VLF response; the effect of width and background noise from small concealed fractures are reflected. Two main cross-overs in both inphase and quadrature profiles can be observed in the figure. The cross-over towards southern end with peak-peak amplitude of 40% in inphase component falls in the depression zone along the traverse. This may indicate a fault, as the faults are depression zones, partly to be recognised as shear bands (Bormann *et al,* 91).

The other cross-over with a 40% peak-peak amplitude in the middle of profile corresponds well with the southern margin of the olivine norite body. At the northern margin of the body, the inphase signature displays a large

VLF-EMI6 Profile across a Norite Body (Traverse - I)

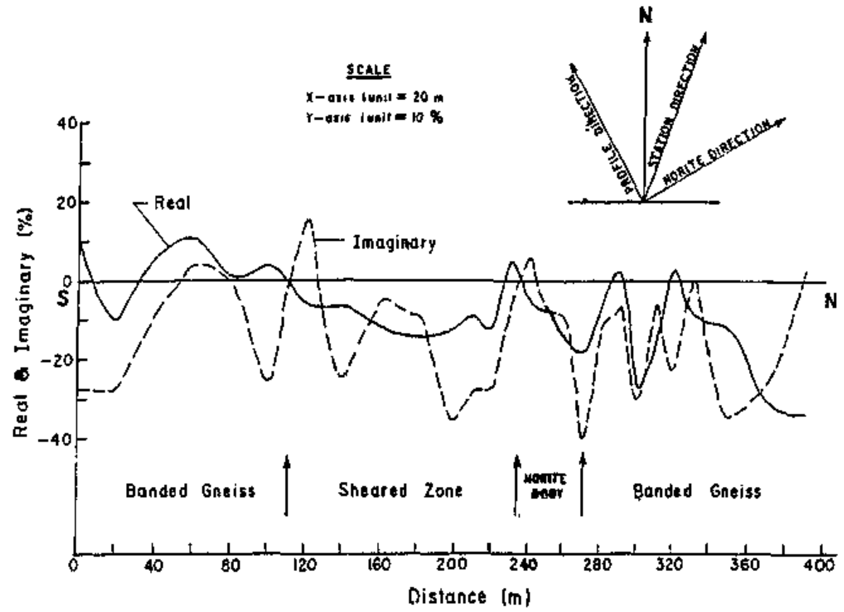


Fig. 2

negative / amplitude (~ 45%). The quadrature profile also shows similar signature but of smaller in amplitude.

Traverse-II

This traverse runs 70N direction, across a narrow shear zone (adjacent to a lake), located 1 km west of Maitri. This shear zone of 1.5 m width, is demarcated by the presence of mylonite. VLF-EM profile taken along this traverse is shown in Fig.3. The inphase signature displays a cross-over near 129 m, which marks the location of the narrow shear zone. The imaginary signature, on the other hand, shows an inverse relationship with topography, and this is probably the result of terrain effect.

Traverse-Ill

This traverse was laid across a fault located near Trishul hill (4 km west of Maitri). The strike of the fault is 100 N. This fault had displaced 2 m wide pegmatite phase, within the Banded Gneissic rock. This pegmatite abruptly ends against the fault plane and the displaced pegmatite on the other wall is not traceable due to ice cover. VLF readings at 10 m interval were taken along the

VLF-EM16 Profile on Shear Zone
(Traverse —II)

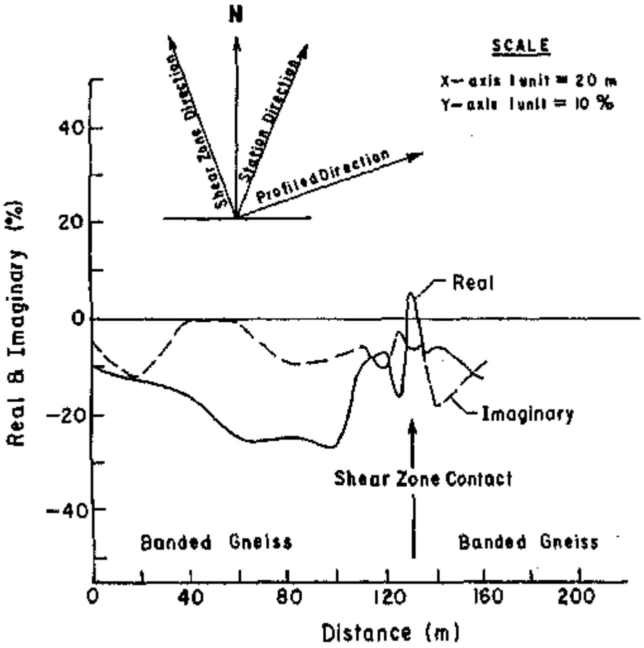


Fig. 3

traverse across the fault. The inphase and quadrature responses are given in **Fig.4.** Although the shapes of the inphase and quadrature anomalies are not untypical, they don't indicate the presence of the fault. This may be due to the fact that the direction of propagation of VLF signal is almost perpendicular to the strike of fault, that leads to 'poor geometric coupling' between the primary field and the geological body. (Hayles and Sinha, 86). This emphasises the need to conduct orthogonal VLF survey.

Traverse-IV

In order to test the workability of VLF-EM methods on ice covered area, where geology is not exposed, one traverse was laid on polar ice cap near 'dozer point' of Maitri. The VLF-EM profile taken along this traverse is shown in Fig.5. It was found that the VLF signal level on the polar ice cap was drastically

VLF Profile across a Fault (Traverse-III)

(1 Km East of Shivling, SCHIRMACHER OASIS)

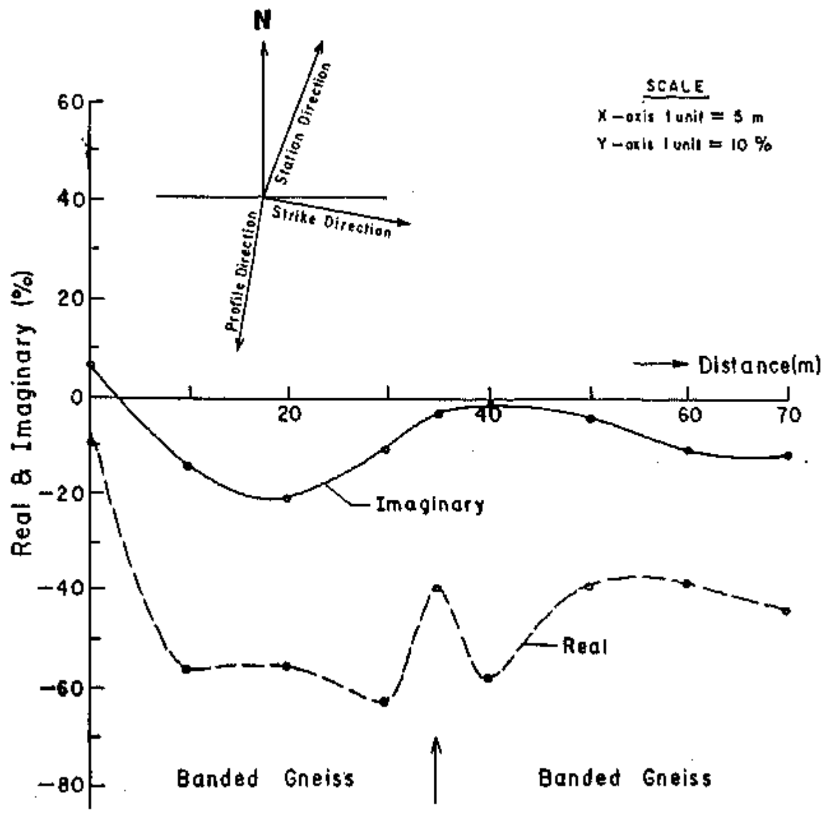


Fig. 4

reduced. The inphase signature shows a cross-over between station distances 40 and 110 m, indicating boundary of the depression zone.

In situ Conductivity Measurements

In situ conductivity measurements were made using a conductivity meter (EM-38, Geonics make) along the three chosen traverses. The instrument measures apparent conductivity (in mS/m) of surface rocks by inducing very small electrical 'eddy' currents in the sub-surface and measuring the magnetic field that these currents generate. A small transmitter coil located at the rear of the EM-38 unit is used to generate the time-varying magnetic field which induces the eddy currents in the ground, and a small receiver coil located at the front end measures both this strong primary magnetic field and the much smaller secondary magnetic field arising from the eddy currents in the ground. The instrument is portable and one man can operate it in the field. So far no *in situ* conductivity measurements have been reported from the Schirmacher region.

Results of in situ measurements of rock conductivities

The measurements were made both in horizontal and vertical modes along Traverses I, II and IV whose results are shown in **Figs 6,7&8,** respectively. Frequent repetitions were made to confirm the repeatability of observations.

The analysis of conductivity data reveals that the exposed rock surface has an average value of 15 mS/m while the ice cap has an average value of 2 mS/m. However, within the shear zone the conductivity values show adecreasing trend **(Fig.7).** It may also be observed that high conductivity values are recorded near the contacts of the intrusive body. In general, the conductivity measurements revealed that the ice cap is more resistive than the exposed rock surface.

Reconnaissance Radiometric Survey in Holtedahl Mountain

On a reconnaissance visit to Holtedahl mountain on 26th and 27th January 1996, along with the GSI team, radioactivity measurements were carried out on different types of rock surfaces. In this region, various types of granitic rocks are found as intrusives in the older gneissic rocks. Both aplite (pink) and pegmatite phases have shown relatively higher radioactivity when compared to other granitic and gneissic rocks. No anomalous radioactivity associated with these rocks has been observed.

Conclusions

The VLF-EM surveys in the Schirmacher region proved useful in geological mapping in Antarctica environment. The *in situ* measurement of ground conductivity has shown that the polar ice is less conductive compared to the exposed rock surface.

Recommendations

1. The VLF-EM surveys should be taken up with more sensitive (preferably automatic and microprocessor based) instrument to work in the areas covered by polar ice.

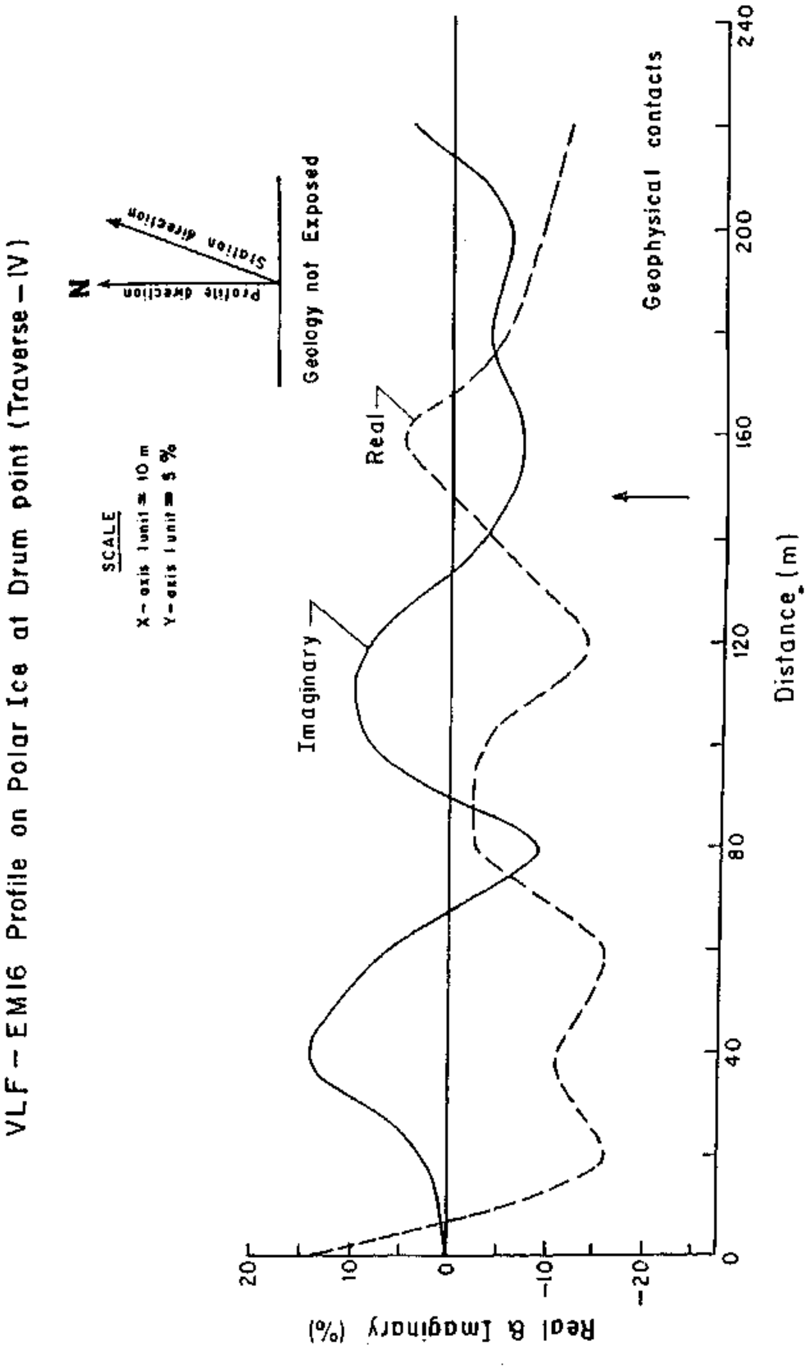

VLF – EM16 Profile on Polar Ice at Drum point (Traverse – IV)
SCALE
X – axis 1 unit = 10 m
Y – axis 1 unit = 5 %
N
Profile direction
Station direction
Geology not Exposed
Imaginary
Real
Geophysical contacts
Real & Imaginary (%)
20
10
0
−10
−20
0
40
80
120
160
200
240
Distance (m)

Fig. 5

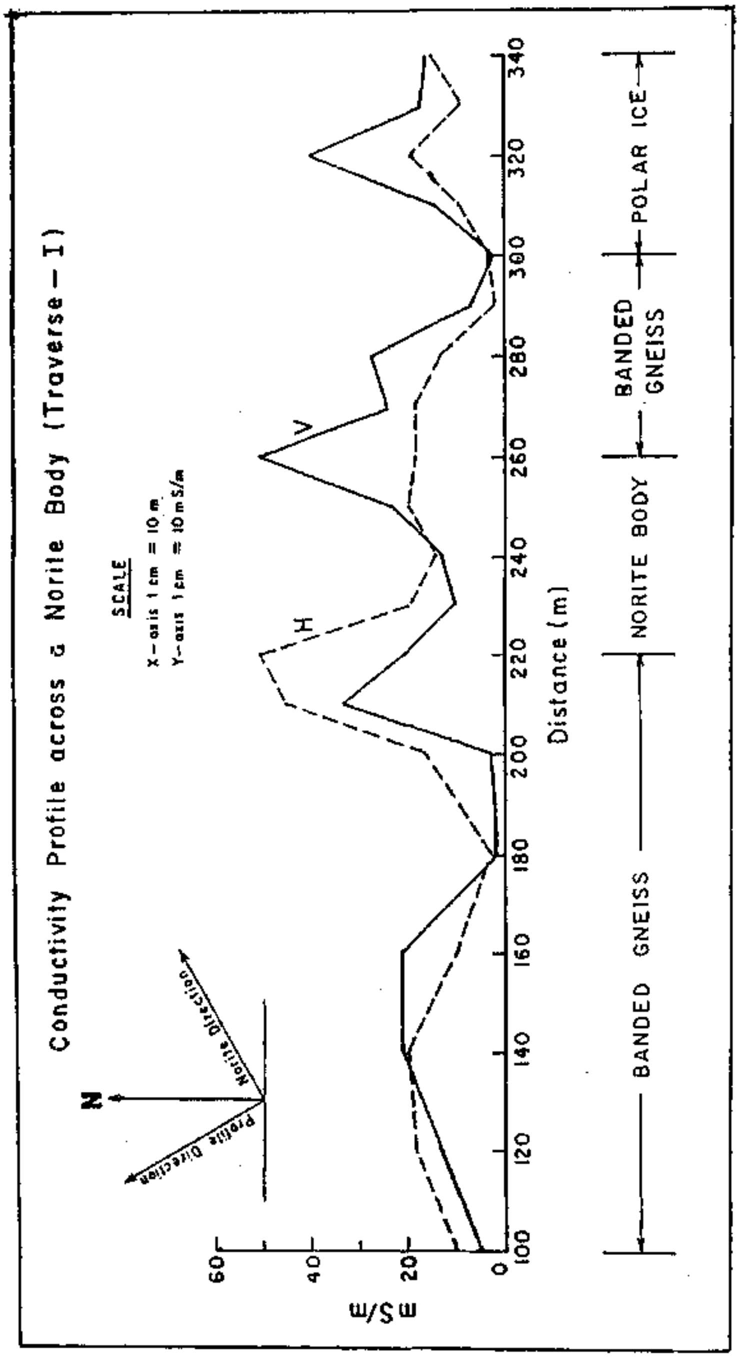

Conductivity Profile across a Norite Body (Traverse – I)
SCALE
X – axis 1 cm = 10 m
Y – axis 1 cm = 10 mS/m
N
Profile Direction
Norite Direction
V
H
mS/m
Distance (m)
BANDED GNEISS
NORITE BODY
BANDED GNEISS
POLAR ICE

Fig. 6

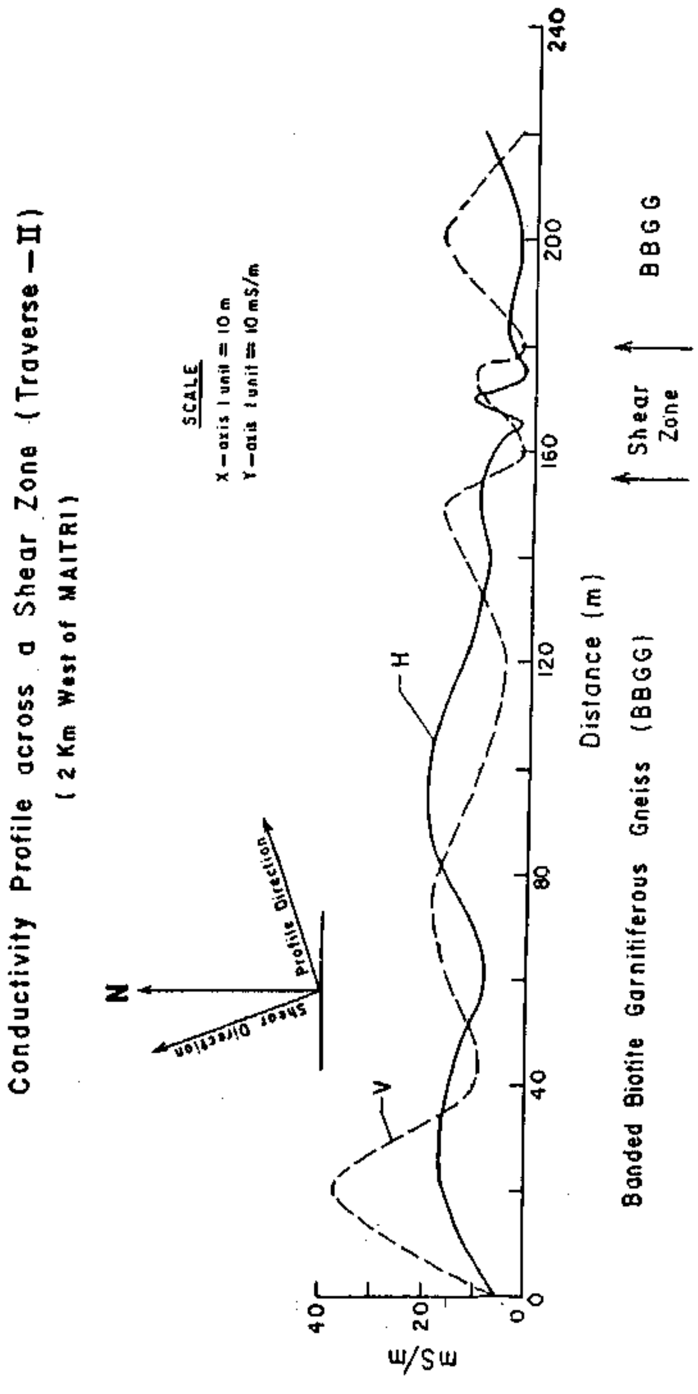
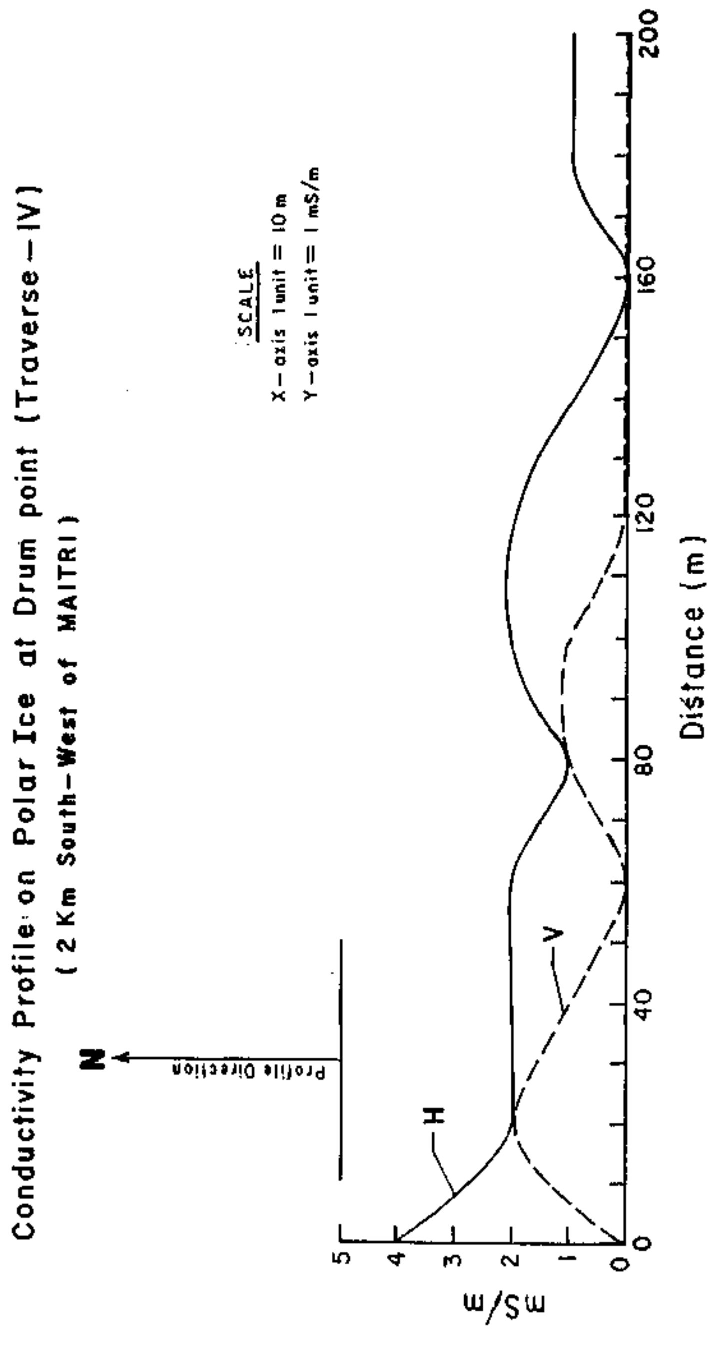

Conductivity Profile across a Shear Zone (Traverse — II)
(2 Km West of MAITRI)
N
Shear Direction
Profile Direction
SCALE
X — axis 1 unit = 10 m
Y — axis 1 unit = 10 mS/m
mS/m
40
20
0
0
40
80
120
160
200
240
V
H
Distance (m)
Banded Biotite Garnitiferous Gneiss (BBGG)
Shear Zone
BBGG

Fig. 7



Conductivity Profile on Polar Ice at Drum point (Traverse — IV)
(2 Km South-West of MAITRI)
N
Profile Direction
SCALE
X — axis 1 unit = 10 m
Y — axis 1 unit = 1 mS/m
H
V
mS/m
0
1
2
3
4
5
0
40
80
120
160
200
Distance (m)

Fig. 8

2 Otthogonal VLF-EM surveys should be taken up for effective geological mapping. For this,, the VLF-EM unit should be capable ot receiving signals from at least two nearby transmitters, namely, NWC ot Australia and LPZ of Argentina.

3 The reconnaissance radiometric survey should be continued for locating 'anomalous zones', if any, in the granitic intrusions of the mountain chain further south.

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