DEPARTMENT OF NATIONAL RESOURCES

BUREAU OF MINERAL RESOURCES, GEOLOGY AND GEOPHYSICS

Record 1977/55

MAGNETIC INDUCED POLARISATION (MIP) SURVEY WOODLAWN, NEW SOUTH WALES, 1975

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SUMMARY

During March and April 1975 the Bureau of Mineral Resources conducted a magnetic induced polarisation survey over and around the Woodlawn orebody. Normalised magnetic field results clearly delineate the surface expression of the massive sulphides, but negative chargeabilities recorded over the orebody are similar to chargeability anomalies recorded over black shales and weakly mineralised dolerites and volcanics. Results of secondary magnetic field measurements are similar to the chargeability results, while chargeability decay ratios provide no information on the nature of the chargeable sources.

1. INTRODUCTION

During March and April 1975, the Bureau of Mineral Resources (BMR) conducted a magnetic induced polarisation (MIP) survey over the Woodlawn ore deposit, N.S.W., which is located in the Canberra 1:250 000 Sheet area, 40 km south of Goulburn (Plate 1). The survey was made to record the response of a volcanogenic sulphide deposit to the MIP method. For comparative purposes, a traverse was also made over a pyritic black slate about 2 km southwest of Woodlawn.

The survey was undertaken with the co-operation of Jododex Australia Pty Ltd and Scintrex Pty Ltd.

2. GEOLOGY

The Woodlawn orebody is a concordant lens of bedded copper-lead-zinc sulphides lying within a sequence of Silurian acid volcanics of the Lachlan Fold Belt. Mineralisation is essentially massive, and the main primary minerals are sphalerite, pyrite, galena, and chalcopyrite (Malone and others, 1975). The orebody has a north-south strike, and is about 200 m in length. The extent of the orebody in depth is greater than 300 m. In the north it is massive, sharply bounded, dips to the west at about 45^{o}, is up to 45 m thick and is capped by a 12 m thick clay gossan. In the south the orebody is smaller, and is surrounded by disseminated sulphides.

The black slate southwest of the orebody contains numerous stringers and veins of quartz-calcite containing up to 50 percent pyrite.

3. BACKGROUND GEOPHYSICS

The Woodlawn orebody is an excellent site for test surveys as its shape has been accurately defined by over one hundred drill holes, and numerous geophysical tests have provided a guide to the physical properties of the deposit. Table 1 shows the results of some laboratory physical property determinations by BMR (Young, 1976) which demonstrate the marked contrasts in specific gravity, resistivity and IP response between the massive sulphides and the host rocks.

TABLE 1 - Physical property measurements

Sample	Specific gravity	Resistivity (ohm-m) (1000 Hz)	IP response (F.E.%) (0.3 and 5 Hz)
Massive sulphides	4.6 - 3.8	3.3 - 0.4	50 - 10
Host rocks	2.9 - 2.6	26 000 - 1000	0

4. THE MAGNETIC INDUCED POLARISATION METHOD

Principles of operation

The MIP method uses a magnetic sensor to measure the magnetic fields associated with current flow in the ground.

Current flow is generated in a conventional manner using an IP transmitter and grounded electrodes. The electrodes are generally placed along strike, and measurements of horizontal magnetic field are made using a sensitive magnetometer at stations along traverses perpendicular to strike. When the primary current is being transmitted the equipment records the primary horizontal magnetic field. After the primary current ceases, the secondary field created by discharging sources is measured.

Seigel (1974) has developed a model to explain the MIP response. This model recognises that the current flow due to polarised sources is composed of an internal current flow in the source, and an oppositely directed external current flow around the source. Seigel's model predicts that for highly conductive bodies the internal current density will be greater than the current density around the source and negative chargeabilities may result. Howland-Rose (1976) has reported negative MIP chargeabilities over sulphide deposits in Australia.

Equipment

The survey was carried out using a Scintrex MFM-3 fluxgate magnetometer coupled to a Scintrex IPR-8 IP receiver. The transmitter used was a 2.5 kW time-domain unit employing a standard 8-second cycle.

The specifications of the MFM-3 magnetometer indicate a sensitivity of about 100 mV per nT and a noise level of about 10 pT. The IPR-8 receiver measures the decaying IP voltage as the average value over a single, 3, or 6 time-intervals in the period 130 ms to 1690 ms after current switch off. Chargeability values recorded by the IPR-8 are normalised with respect to a standard induced polarisation curve (Dolan & McLaughlin, 1967), and variations in the value of normalised chargeabilities at different time intervals indicate departure of the decay transient from the standard induced polarisation decay curve. The time interval over which the chargeabilities are measured are commonly called slices and, depending on the mode of measurement used, chargeability slices are sequentially labelled M_1, M_2 ..... to M_6. Under most survey conditions six chargeability slices are recorded.

Parameters recorded

Apparent chargeability (M). This dimensionless parameter provides an indication of the chargeability of subsurface sources, and is commonly expressed at mT per T.

Primary horizontal magnetic field (Hp). This parameter is the measured primary magnetic field and is expressed in units of nT.

Normalised horizontal magnetic field (Hn). This is a dimensionless, derived parameter which indicates conductivity changes in the ground. The parameter is derived by normalising Hp with respect to current and geometry as shown in equation 1. I is the current expressed in amps and K is a geometric factor with units of nT per amp.

$$Hn\% = \frac{Hp}{K x I} \times 100 \qquad \ldots (1)$$

High normalised fields indicate zones of high conductance, and low normalised fields indicate zones of low conductance. If the ground is homogeneous with respect to conductivity the value of Hn will be 100 percent at all locations.

Secondary magnetic field (Hs). This derived parameter has units of pT per amp, and is calculated from Hp, M and I, as shown in equation 2.

$$Hs = \frac{Hp \times M}{I} \qquad \ldots (2)$$

If Hm is the value of the magnetic field caused by polarisation currents, then $M = \frac{Hm}{Hp}$ and $Hs = \frac{Hm}{I}$. Hence Hm is proportional to Hp and accordingly varies with array geometry, as well as the chargeability of subsurface sources.

Chargeability decay ratio. If chargeability slices have the same sign, the shape of the IP decay curve is indicated by the ratio of early and late chargeability slices. When six chargeability slices are recorded it is normal to use the parameter M_6/M_1 as the chargeability decay ratio.

5. SURVEY DETAILS

Woodlawn survey

Grid co-ordinates. The survey was made on an imperial grid laid out by Jododex Australia Pty Ltd. The grid was oriented approximately NS-EW, and was pegged at 100 ft intervals. The relationship between traverses surveyed and the Jododex metric grid is shown in Plate 2.

Array locations. To investigate the MIP response of the Woodlawn deposit, various current-dipole arrays ranging from 240 m to 300 m were placed parallel to the orebody. The main body of mineralisation, and areas to the north and south, were investigated by seven traverses across the strike of the orebody. The location of current dipoles and traverses are indicated in Table 2. All IP measurements were made using 6 chargeability slices.

Traverse	Metric grid locations*	Current Dipoles* North	South	MIP Stations* From	To
A	9500N	9620N/9490E	9370N/9490E	9320E	9700E
		9620N/9790E	9370N/9790E	9670E	9970E
G	9310N	9370N/9910E	9070N/9910E	9720E	10120E
H	9280N	9370N/9640E	9070N/9640E	9460E	9820E
		9370N/9910E	9070N/9910E	9820E	9990E
J	9220N	9370N/9640E	9070N/9640E	9450E	9760E
		9370N/9910E	9070N/9910E	9715E	10080E
L	9160N	9370N/9640E	9070N/9640E	9460E	9760E
		9370N/9910E	9070N/9910E	9760E	10120E
S	8950N	9070N/9640E	8830N/9640E	9640E	9820E
		9070N/9910E	8830N/9910E	9730E	10100E
U	8890N	9070N/9640E	8830N/9640E	9480E	9760E
		9070N/9910E	8830N/9910E	9730E	10080E
"Black Slate"	6600N	6720N/9670E	6480N/9670E	9590E	9850E

* locations are shown as approximate positions on Jododex metric grid

TABLE 2: Location of current dipoles and traverses

Station spacing was generally 100 ft (30 m), with a 50 ft (15 m) spacing over anomalous zones.

Black slate area survey

A traverse was made over a body of pyritic black slate located about 2 km southwest of the orebody. The traverse was 360 m long, and exployed a 240 m current array parallel to the strike. A station spacing of 30 m was used along the traverse.

6. RESULTS

Woodlawn

Profiles of the chargeability and normalised horizontal magnetic field results are shown with geological cross-sections in Plates 3, 4 and 5. Contour plans of the chargeability, normalised horizontal magnetic field, secondary horizontal magnetic field, and chargeability decay ratio are shown in Plates 6, 7, 8, and 9 respectively. Note that only the M_3 chargeability is shown, this being a measure of the average chargeability between 650 ms and 910 ms after current cut-off.

The MIP chargeability results (Pl. 6) show six distinct negative chargeability zones, of which the largest is zone A. Each of the zones has a characteristic chargeability and normalised magnetic field. The chargeability decay ratios do not correlate with the chargeable zones or with any geological units.

Zone A. This zone occurs over the massive ore immediately west of its subcrop. Chargeabilities of greater than -8mT/T are recorded in this zone. Updip of this chargeable zone, and directly over the conductive subcropping mineralisation, normalised magnetic fields (Plate 7) are in excess of 400 percent. Secondary magnetic fields (Plate 8) have a similar form to the chargeability results.

Zone B. A zone of strong negative chargeabilities occurs over mineralised volcanics at the southern end of the orebody. Coincident with the negative chargeabilities are secondary magnetic fields in excess of -40 pT/A. Unlike zone A, which is over the main body, zone B is not associated with an increase in the normalised magnetic field.

Zones C, D and E. Chargeability zones C, D and E have similar magnitudes of approximately -4mT/T, and show only minor variations in the normalised magnetic field.

Zone C occurs over dolerite; however the response could be caused by a buried rubbish pit at 9815E, traverse A. The secondary magnetic field results for zone C are similar to the chargeability results.

Zone D lies mainly over black shale and may be caused by disseminated pyrite in the shale. Small negative secondary magnetic fields are recorded over this zone.

Zone E lies over coarse-grained acid volcanics which include a prominent quartz vein; either of these units may be mineralised. Secondary magnetic fields greater than -10 pT/A occur over this zone.

Zone F. This zone is located directly over a small gossan west of the main orebody. Negative chargeabilities of -3mT/T occur with secondary fields of -2pT/A. There is no change in the normalised magnetic field.

Black slate area

Plate 10 shows the MIP results and geological cross-section across the pyritic black slate. A peak chargeable response of -12mT/T was observed within a broad chargeable zone of about -5mT/T. Broad normalised magnetic fields in excess of 170 percent are associated with the chargeable response.

7. DISCUSSION

Interpretation

The magnetic induced polarisation results show a strong response over the orebody. However only the normalised magnetic field results (Plate 7) clearly discriminate the orebody from other sources. The strong normalised magnetic field response is probably caused by the highly conductive subcropping mineralisation.

Although the chargeability and secondary magnetic field results do not uniquely identify the orebody, a large negative chargeability and negative secondary magnetic fields appear to be caused by black shales and mineralised volcanics and dolerites.

A comparison of the MIP results and the geological cross-sections shows that the chargeability anomalies over the orebody are down dip of the normalised magnetic field anomalies and suggests that the source of chargeable anomalies is deeper than the source of normalised-field anomalies.

Contours of chargeability decay ratio M_6/M_1 (Plate 9) provide no information on the orebody or the geology of the area.

Comparison with EIP results

Results of an EIP gradient array and a dipole-dipole array survey have been provided by Jododex Australia Pty Ltd, (Plates 11, 12 and 13) and allow a comparison of EIP and MIP results.

Gradient array. The results of an EIP gradient array survey centred on the Woodlawn orebody are shown in Plates 11 and 12. This array used an east-west current dipole of 1830 m, and a 30 m potential dipole.

EIP resistivity results (Plate 11) outline the subcropping mineralisation in a manner similar to the MIP Hn results. However EIP results indicate a second low resistivity zone centred at 9000N, 9770E.

EIP frequency effect results (Plate 12) show IP effects of greater than 10 percent over the mineralised volcanics in the southern part of the orebody. Surrounding this anomalous feature is a broader zone of greater than 5 percent, which clearly outlines the black shale east of the orebody. This result compares unfavourably with the strong MIP chargeability anomaly, which was directly over the massive ore in the north.

Dipole-dipole array. MIP and EIP dipole-dipole array results and the geological cross-section along traverse G are shown in Plate 13. The dipole-dipole array used a dipole spacing of 30 m, and a dipole separation of 60 m, 120 m and 180 m (n = 1, 3 and 5).

The dipole-dipole array results show a frequency effect centred at about 9900E, traverse G over black shale, whereas MIP negative chargeabilities lie over the region of mineralisation. EIP apparent resistivities highlight the conductive orezone directly below 9830E, whereas MIP normalised magnetic fields indicate a broad conductive high over the orezone.

Operational characteristics

Speed. At Woodlawn, an average of 50 MIP readings were recorded daily.

Noise. The primary magnetic field between stations at Woodlawn varied from 1 to 15 nT, and chargeability readings were usually repeatable to within 3 mT/T. MIP results are generally repeatable to within 0.5 mV/V.

Cost. With an average of 50 readings a day using a 30 m station spacing, the cost for an MIP survey in country such as at Woodlawn would be about $1000 per line kilometre.

8. CONCLUSIONS

The magnetic induced polarisation method successfully delineated the massive, pyritic, zinc-lead-copper orebody at Woodlawn. The high conductance of the subcropping mineralisation was particularly highlighted by the normalised magnetic field.

Although the orebody produced an MIP chargeability response, it is difficult to discriminate the chargeability anomaly over the orebody from anomalies over black shales, and mineralised dolerites and volcanics.

Secondary horizontal magnetic fields were similar to the chargeability responses, and did not provide any additional information.

The chargeability decay ratio parameter was not characteristic of any geological units.

Comparison of EIP and MIP results over Woodlawn indicates that MIP chargeabilities resolved the main massive sulphide mineralisation better than EIP chargeabilities.

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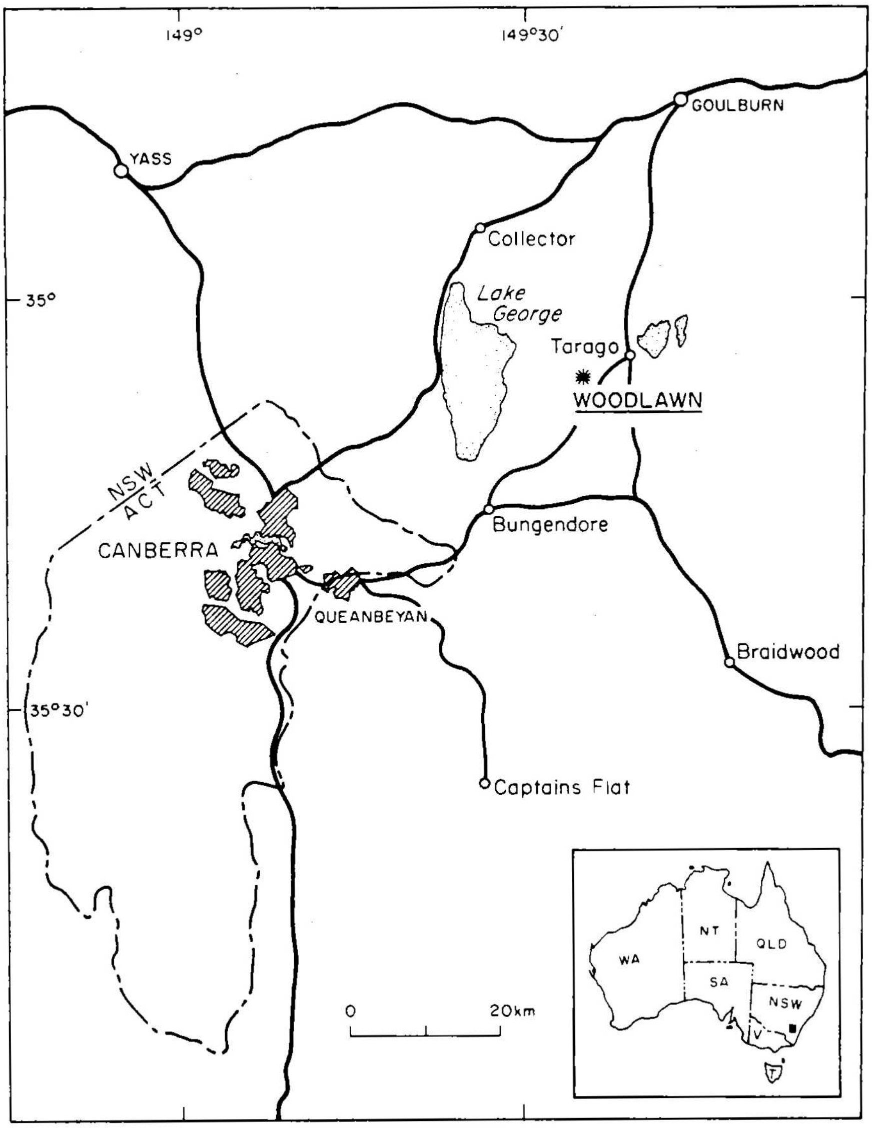
Plate I



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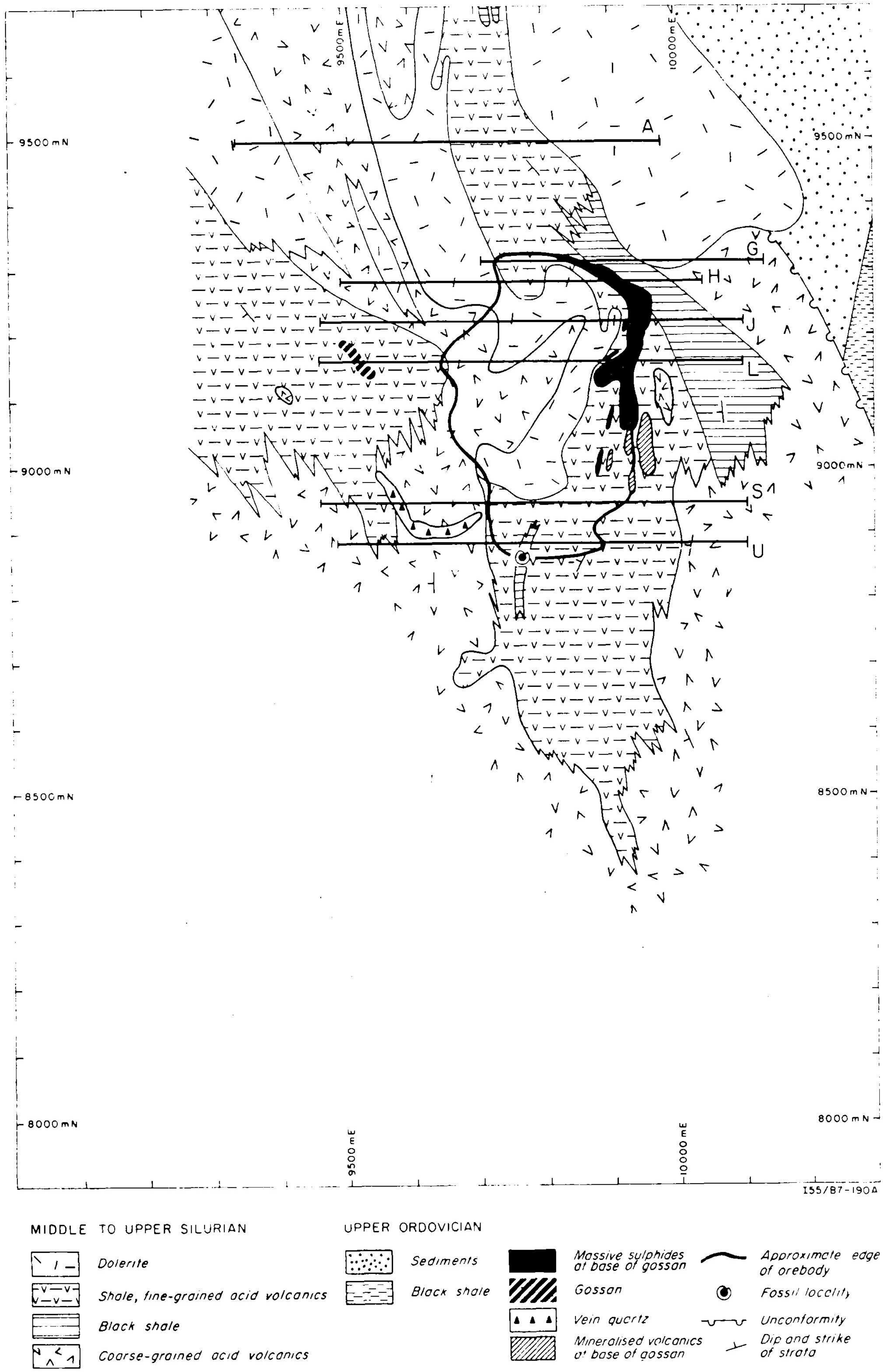
Locality map

Plate 2



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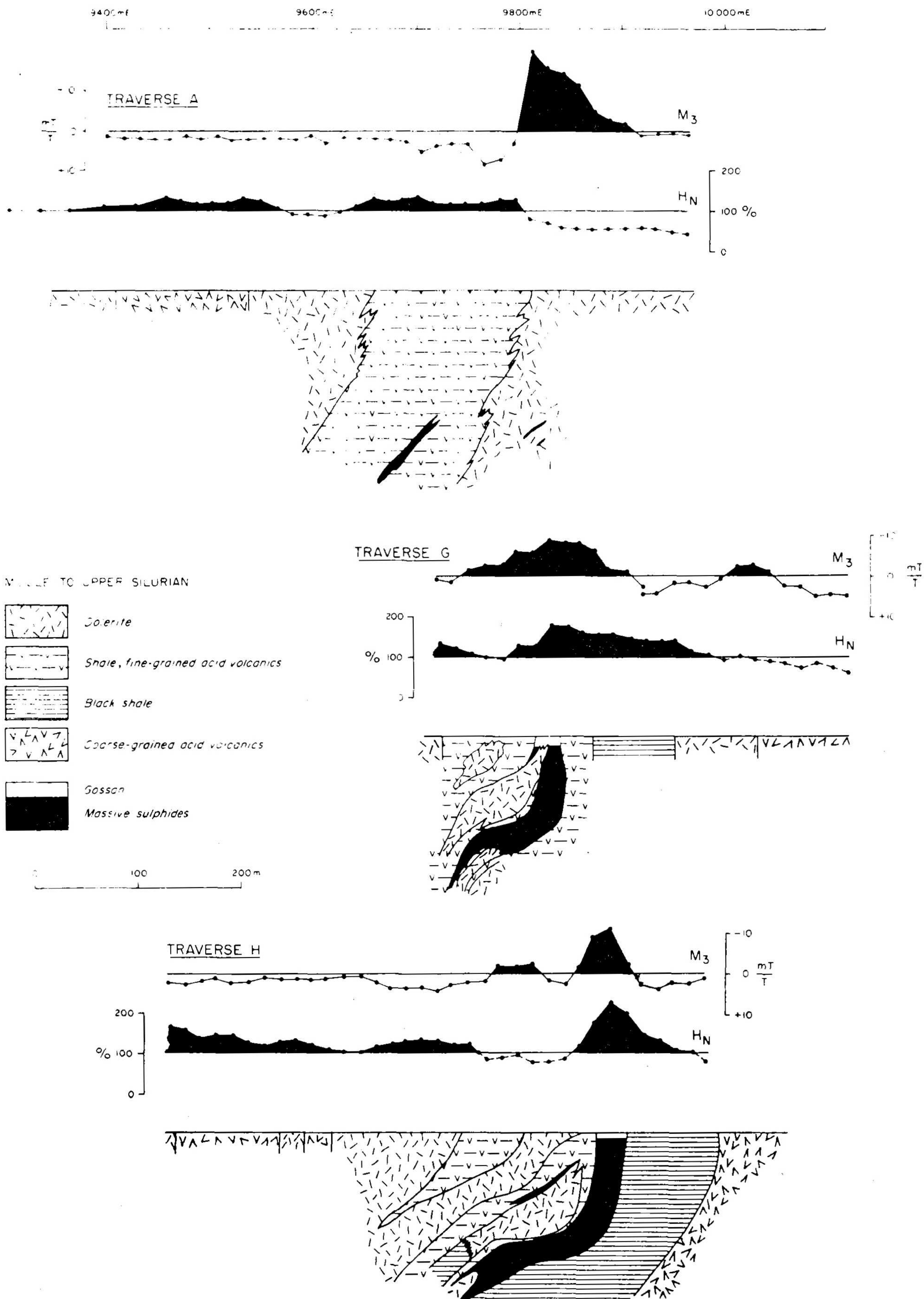
Geology and traverse locations

Plate 3



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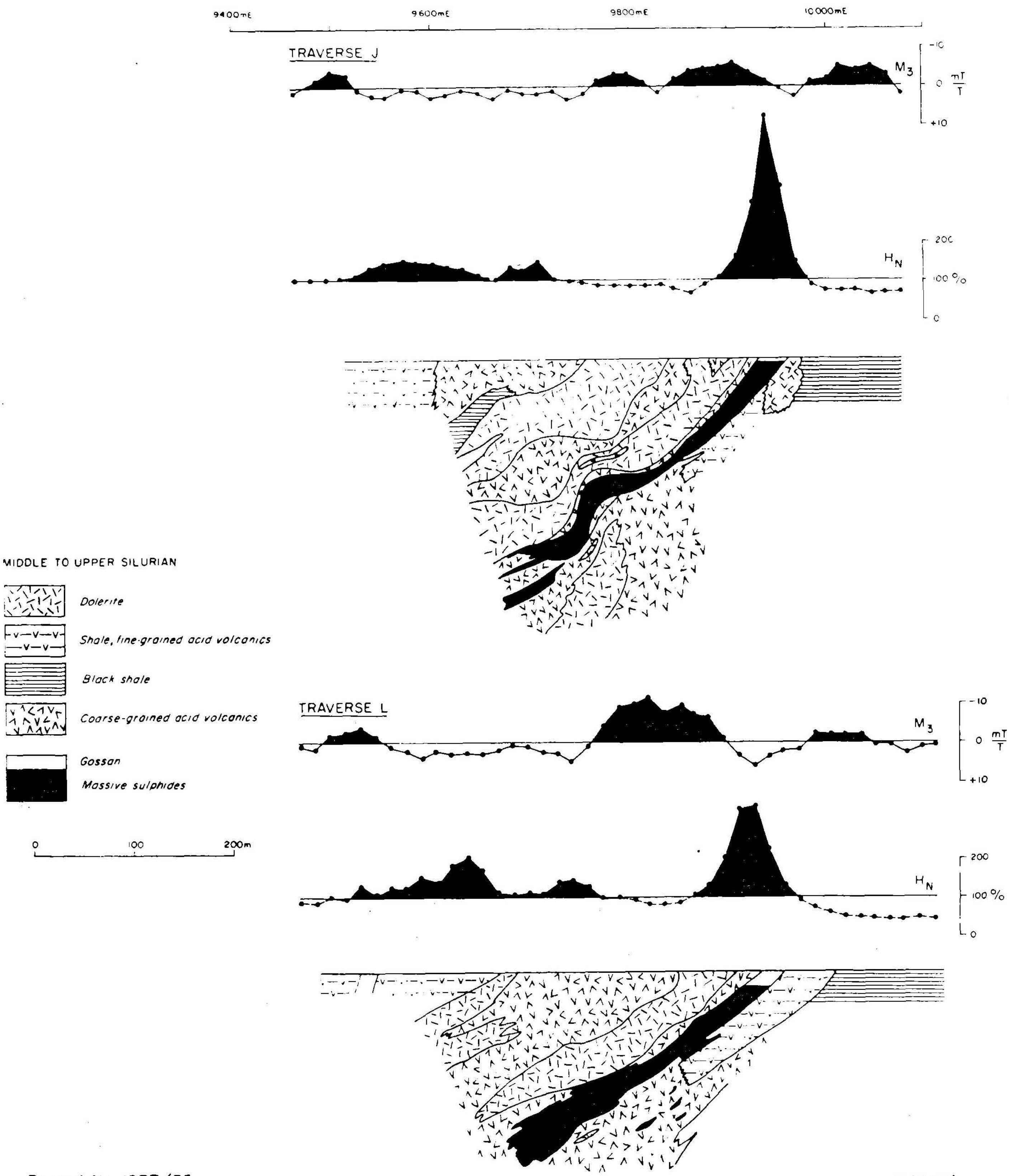
MIP results and geological cross-sections, traverses A, G and H

Plate 4



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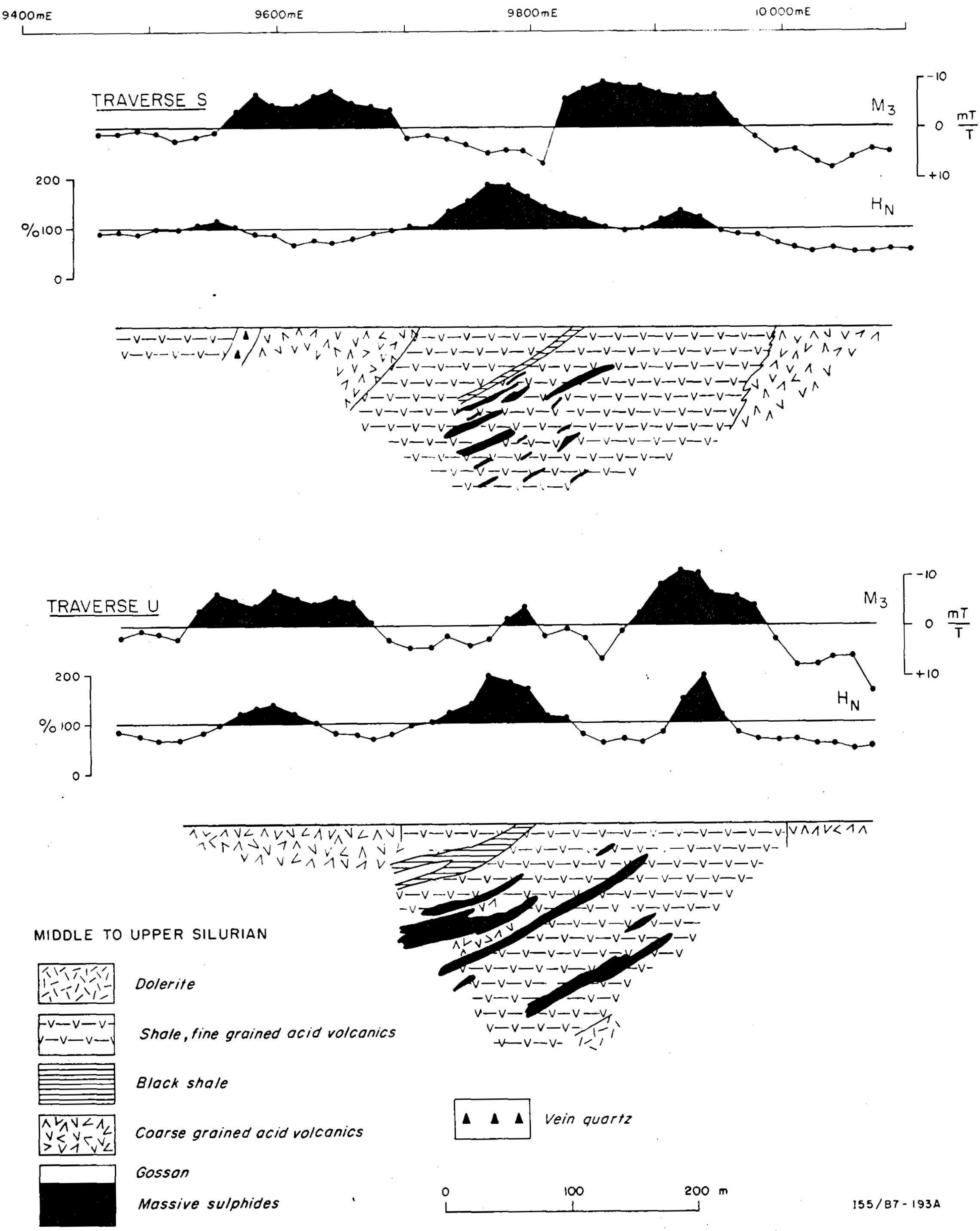
MIP results and geological cross-sections, traverses J and L

Plate 5



MIP results and geological cross-sections, traverses S and U

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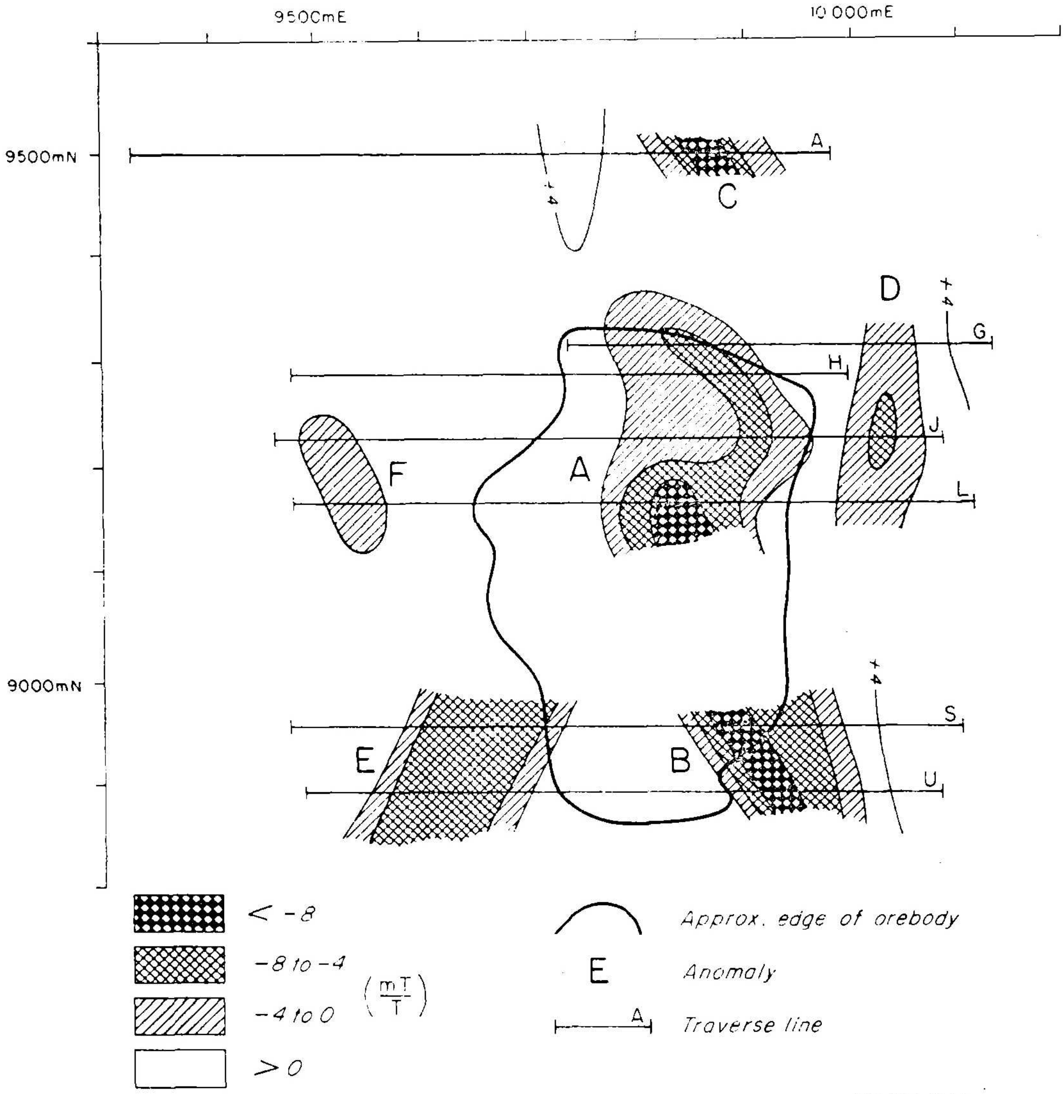
Plate 6



Chargeability contours

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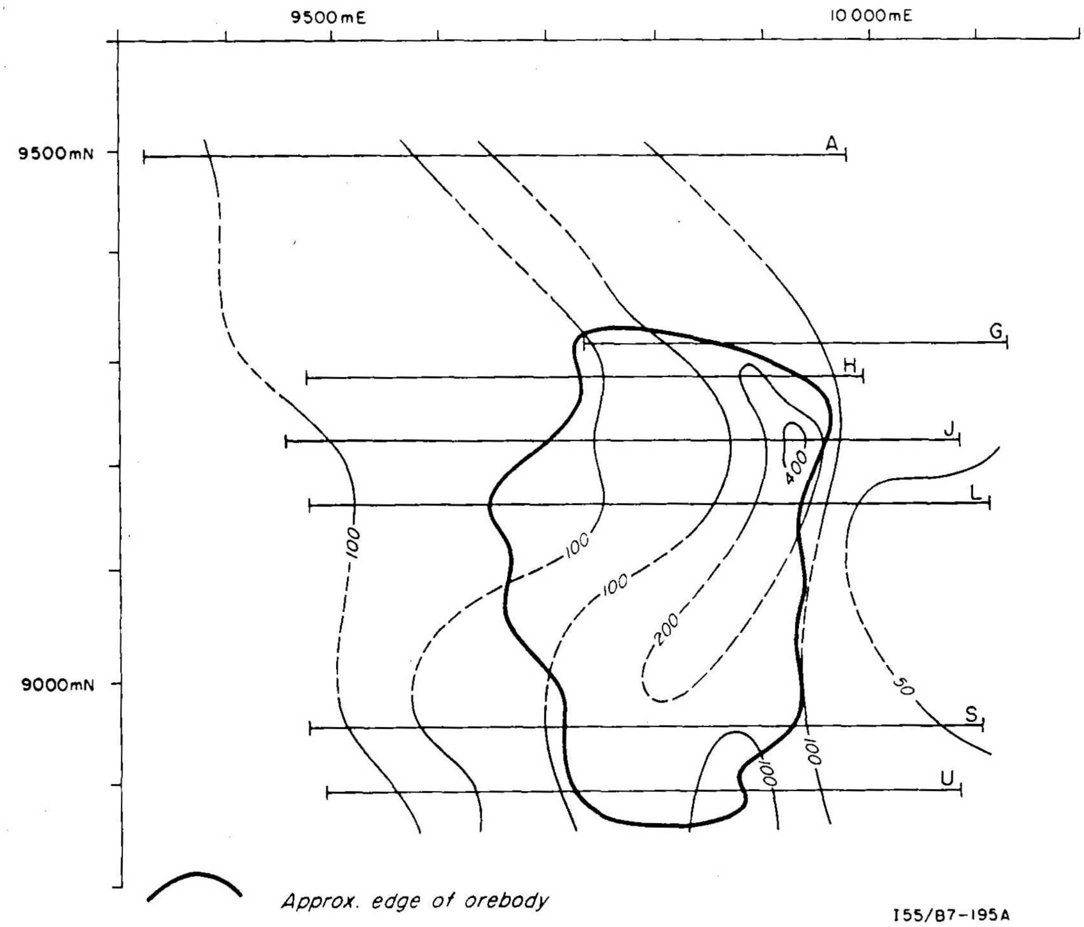
Plate 7



Normalised horizontal magnetic field contours

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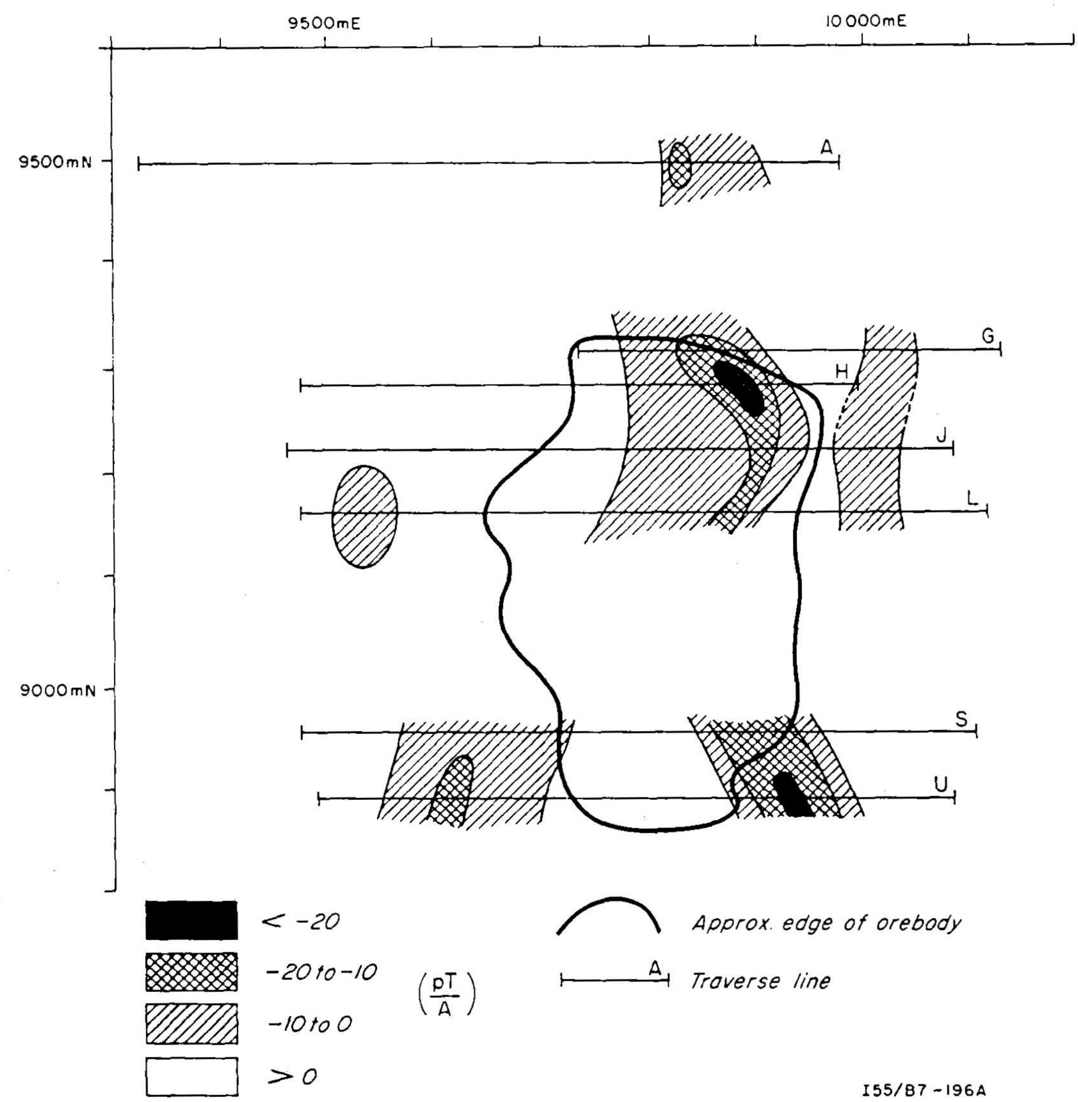
Plate 8



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Secondary horizontal magnetic field contours

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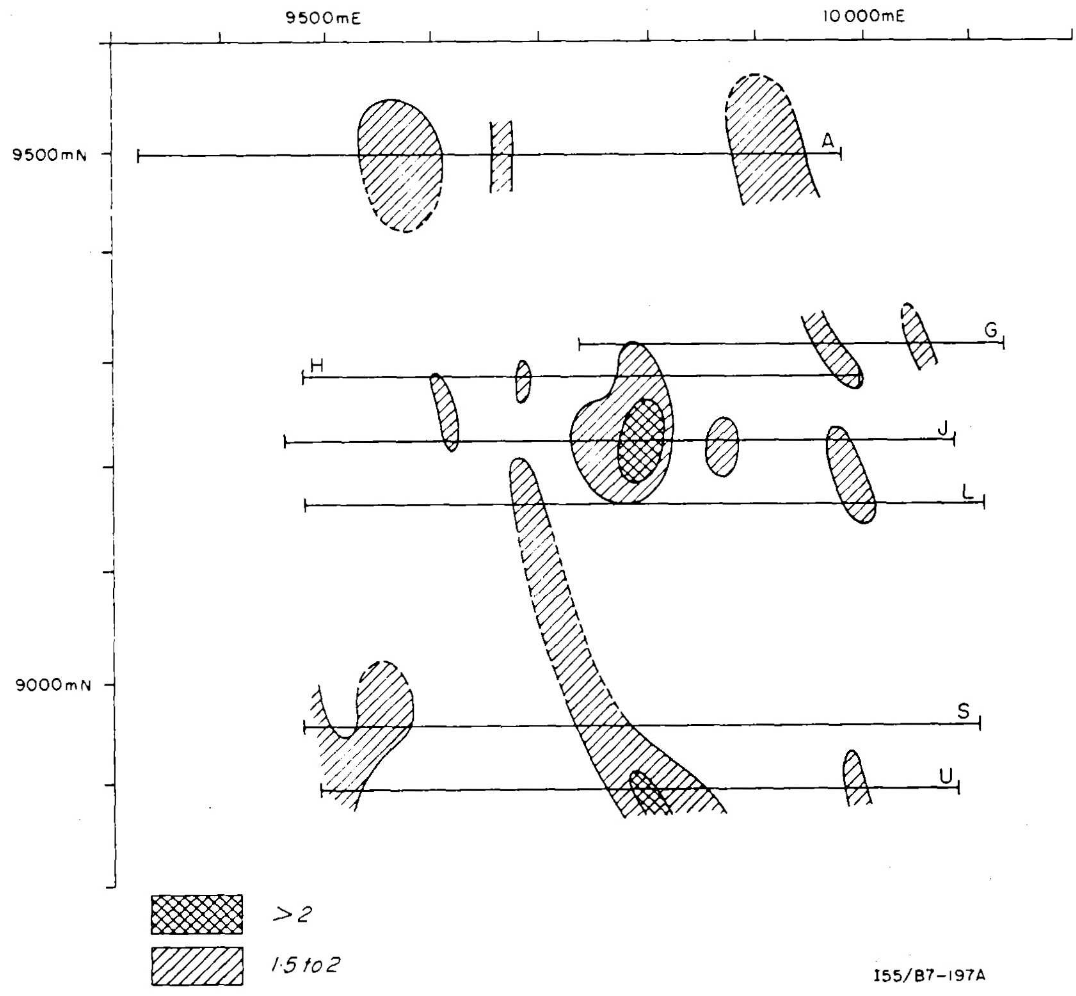

Chargeability decay ratio contours

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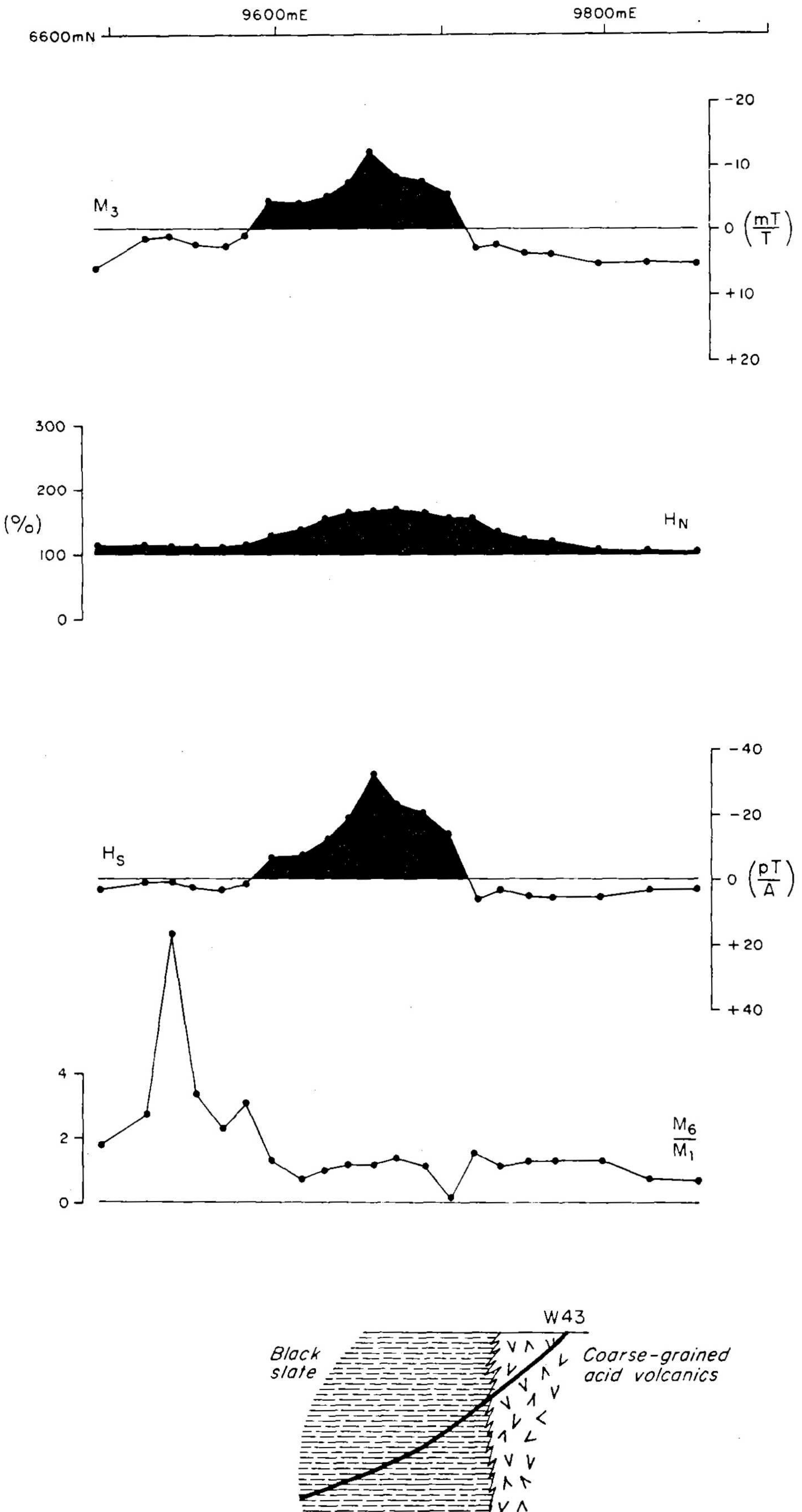

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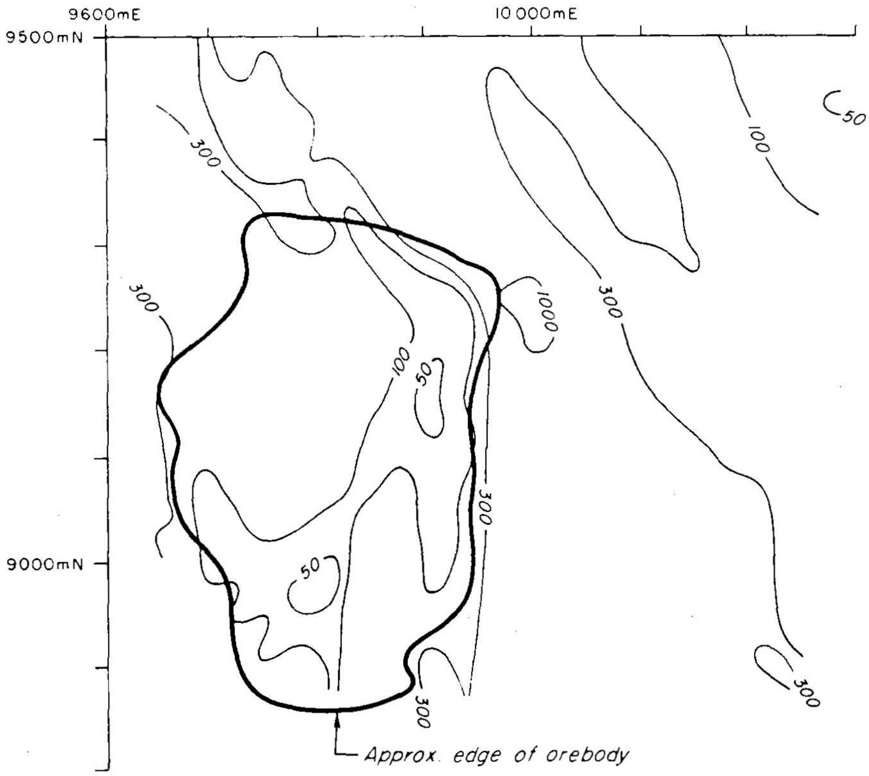
MIP results, black slate area

Plate 11



(E I P results courtesy of Jododex Aust. Pty Ltd.)

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EIP gradient-array apparent resistivity contours (ohm-ft/2π)

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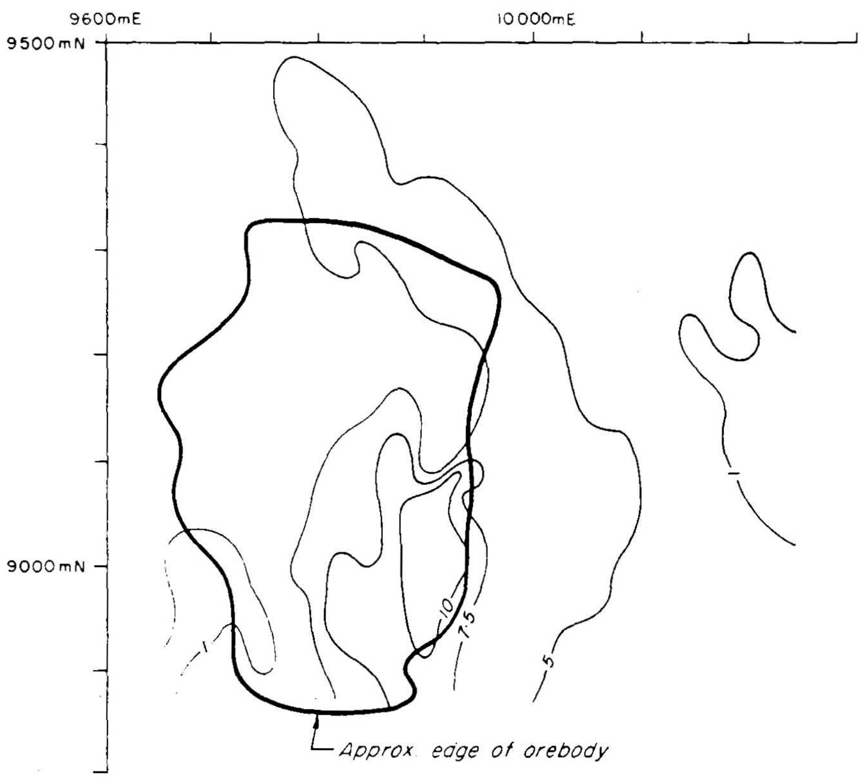
Plate 12



(EIP results courtesy of Jododex Aust. Pty Ltd.)

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E I P gradient-array percent frequency effect contours

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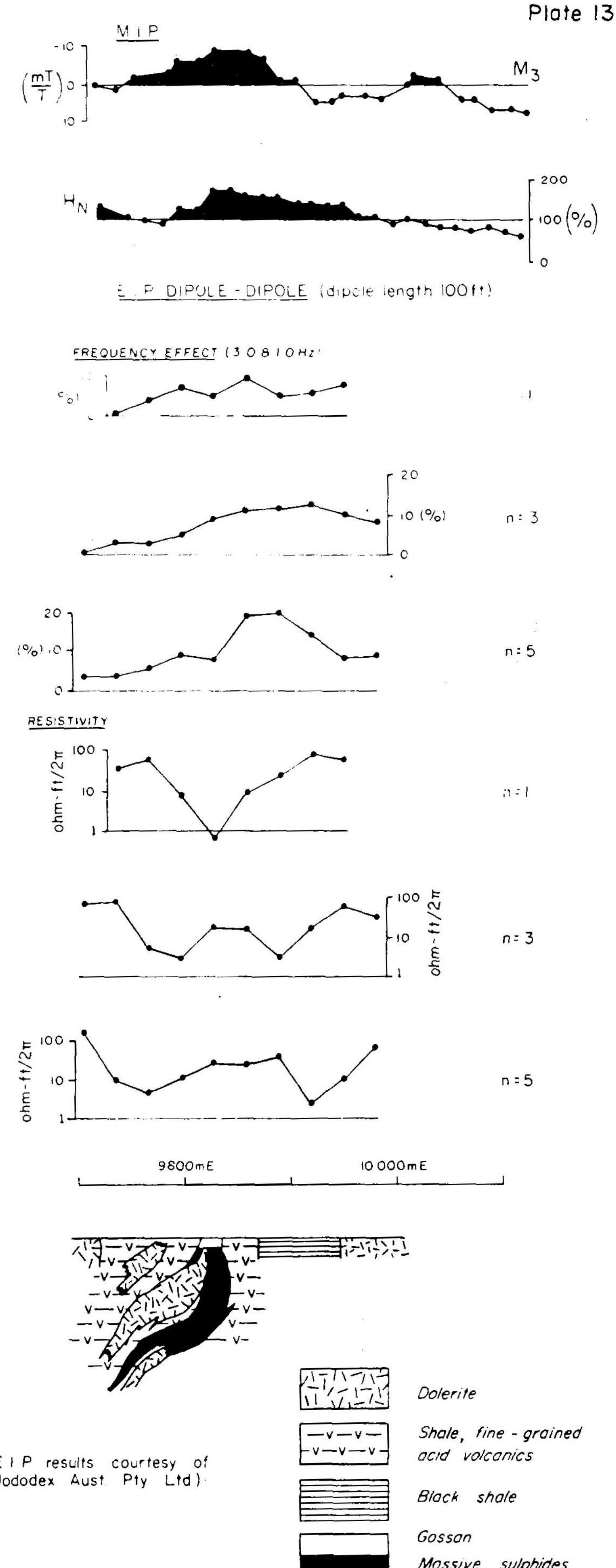
Plate 13



(E I P results courtesy of Jododex Aust Pty Ltd)

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E I P dipole-dipole array and M I P profiles, traverse G