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COMBINED GROUND GEOPHYSICAL SURVEY, ALLIGATOR RIVERS AREA, NT, 1975

by

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DEPARTMENT OF NATIONAL DEVELOPMENT

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SUMMARY

A combined ground geophysical survey was carried out from June to October, 1975 in an area of poor outcrop west of the South Alligator River, Northern Territory, to assist geological mapping of the region. Methods used were transient electromagnetic (TEM), Slingram (EM gun), VLF, magnetic, and resistivity.

The ground magnetic method delineated small magnetic anomalies over the South Alligator River flood plain. Unfortunately these anomalies, although rising from bedrock sources, proved to be discontinuous and of no assistance to regional mapping. In areas away from the flood plain, ground magnetic data were dominated by high-amplitude short-wavelength anomalies produced by maghemite and laterite sources at or near surface, and as such the method again offered little scope for assisting mapping.

The TEM method successfully traced conductive carbonaceous units south of the Arnhem Highway. The carbonaceous units were commonly covered by up to 50 m of Cainozoic material which adversely affected the depth penetration of other electromagnetic methods. The resistivity method proved to be too slow for reconnaissance surveying; however, it was useful in controlling TEM data interpretation.

A regional TEM survey traced a zone of narrow conductive units from the Red Lily Prospect southwest for about 7 km, where the anomalies change in character and form a zone several kilometres wide extending farther to the southwest. The change in character of the anomalies southwest of Red Lily is thought to indicate an extension of the Jim Jim Fault Zone. Anomalies on both sides of the fault zone were tested by drilling and were found to be caused by graphitic shale. The results of the regional TEM survey indicate that carbonaceous rock units are wide and continuous within the Koolpin Formation in the Kapalga 1:100 000 Sheet area.

INTRODUCTION

In 1975 the Bureau of Mineral Resources, Geology and Geophysics carried out a ground geophysical survey in the Kapalga 1:100 000 Sheet area, Northern Territory, to assist in the 1:100 000-scale geological mapping of the Alligator Rivers region. The survey was mainly in the southeastern part of the Kapalga 1:100 000 Sheet area (Plate 1), where bedrock is obscured over large areas by Cainozoic sediments, and extended from 4 July to 29 September, 1975.

The objectives were to establish techniques for detecting certain Lower Proterozoic lithological units, and to aid geological mapping by tracing these units in areas covered by superficial Cainozoic sediments. Drilling had shown that the Koolpin Formation contains carbonaceous beds, and it was thought that it might be possible to map these beds by means of a combination of electrical techniques. Furthermore, aeromagnetic data include some magnetic trends near the South Alligator River, and it was thought that it might be possible to map, by ground magnetics, the rock types causing these trends.

The survey had two phases: the first involved test traverses to establish techniques for mapping, and the second comprised regional traverses to assist mapping in an area of poor outcrop. Methods employed during the survey were magnetic, electromagnetic, and resistivity. Electromagnetic methods used were EM Gun, VLF, and transient EM (TEM).

Test traverses were made in several areas using a variety of methods, and the sources of anomalies detected were investigated by drilling. The results of this and othe drilling are being presented in a forthcoming report by P.G. Stuart-Smith of the Geological Branch, BMR. Summary graphic logs of the relevant holes have been provided by Stuart-Smith for the present report. The regional survey investigated an area of 500 km^2 and principally employed the TEM method, supported by limited resistivity depth soundings.

The survey was carried out by B. Spies and D. Robson (Geophysicists); N. Ashmore (Technical Assistant); and E. Chudyk and K. Simpson (Field Hands).

GEOLOGY

The geology is outlined in Plate 1.

Cainozoic sand, sandy clay, and laterite up to 50 m thick overlie most of the area surveyed and largely conceal Lower Proterozoic rocks of the Mount Partridge, Masson, and Koolpin Formations.

One of the main exposures is near Kapalga Trig, where quartzite, arkose, and minor magnetitic siltstone and shale of the Mount Partridge Formation crop out. Other Lower Proterozoic rocks exposed are massive chert-banded haematitic siltstone of the Koolpin Formation which forms prominent arcuate ridges in a broad north-plunging syncline in the southwest of the area. Zamu Complex dolerite also crops out in this region. Drilling by Noranda (Australia) Ltd intersected carbonaceous shale between the ridges of hematitic siltstone. Carbonaceous shale has also been intersected by Australian Anglo American Ltd in the Red Lily Prospect, 10 km southeast of Kapalga Trig.

SURVEY CONTROL

Traverses were planned on aerial photographs and surveyed using a prismatic compass and a measuring tape or vehicle odometer. Results of the regional survey were plotted on an air-photo mosaic and reduced to 1:50 000 scale.

TECHNIQUES

The main techniques used were transient electromagnetic (TEM), magnetic, and resistivity. Minor use was made of the VLF and Slingram methods. Down-hole geophysical logging was carried out in support of BMR drilling.

Transient Electromagnetic (TEM)

Russian-built MPPO-1 equipment was used, and enabled measurements to be made at 12 sample decay times from 0.6 ms to 15 ms. The TEM method and equipment used is described by Spies (1974). For detailed survey work, loop size ranged from 100 m to 3 m square, and up to 50 percent loop overlap was employed. For the reconnaissance work, traverses were widely separated with stations read at intervals of 0.5 km or 1 km, using a 100-m loop; for such work about 20 stations were occupied per day.

Interpretation: The TEM results were interpreted using a procedure to be described in a forthcoming report by the author. This method converts TEM decay curves into apparent conductivity (or resistivity) curves. In general, apparent resistivities at early sample decay times are controlled by near-surface conductors; at late times they are controlled by deeper conductors.

Resistivity

Measurements were made using a variety of equipment. The most effective comprised a Norman petrol engine and 1-kW ABEM generator driving a BMR-designed rectifier unit. An Avometer was used for current measurement. The receiving unit was a Data Precision Model 245E digital multimeter or a Fluke high-impedance voltmeter. Transmitting electrodes were aluminium foil or brass stakes; receiving electrodes were Cu-$CuSO_4$ porous pots. Because much of the area surveyed had a high surface resistivity, the transmitted current was usually less than 100 mA.

The high surface resistivity precluded the use of instruments with a relatively lower input impedance, such as Geophysical Megger and Megger Null Meter.

Most of the resistivity work consisted of depth soundings using the Schlumberger array, with current electrode spacings from 2 m to 500 m.

Interpretation: Interpretation of soundings in the field was by partial curve matching; final interpretation was assisted by a computer inversion program based on a description by Zohdy (1975).

Magnetic

Measurements of total magnetic intensity were made with a Geometrics G816 magnetometer (accuracy 1 nT). Most measurements were made with the magnetometer head 2.6 m above ground. In areas of high geological noise head elevation was increased to 6.6 m. Several in-situ susceptibility measurements were made using a Bison model 3101A susceptibility meter.

Slingram

The ABEM EM Gun equipment was used with staffs vertical and separated by 30 m or 60 m. Measurements were made at frequencies of 1760 Hz and 440 Hz.

VLF

Measurements of the electromagnetic field from the VLF station NDT Japan (17.4 kHz) were made with a Geonics Ronka EM16 receiver.

ARNHEM HIGHWAY TEST TRAVERSE

The Arnhem Highway provides a convenient means of traversing across the regional strike of the Lower Proterozoic rocks. A 15-km magnetic and TEM traverse (Fig. 1) was made along the highway to determine whether magnetic or conductive marker horizons are present in the eastern part of the Kapalga Sheet area. TEM anomalies detected on this traverse were followed up by further TEM work, resistivity soundings, drilling, and down-hole geophysical logging.

The traverse extended along the Arnhem Highway from the edge of the South Alligator River flood plain (00 W) westwards to near Kapalga Trig. The westerly continuation of the traverse from Kapalga Trig. was to the south of the Arnhem Highway to avoid coinciding with a photo lineament which may indicate a fault in the bedrock between Flying Fox Creek and Kapalga Trig.

The main outcrop on the traverse is near Kapalga Trig, where sandstone and shale of the Mount Partridge Formation are exposed. The lithology and stratigraphic relationships of adjacent rock units are obscured by thick Cainozoic cover.

Results from this traverse are presented in Plate 2, together with a diagrammatic summary of drilling and down-hole logging results.

Magnetic Results

Readings were taken at 12-m intervals along the traverse; sensor height was 2.6 m. Most of the profile show- high-amplitude short-wavelength anomalies originating from near-surface sources. However, one broad anomaly having an amplitude of over 300 nT occurs near Kapalga Trig at 7100 W, and coincides with outcrop of Mount Partridge Formation.

The sources of the near-surface magnetic anomalies were investigated by in-situ measurements with a Bison susceptibility meter. The results show that the anomalies are produced by lateritic concretions on the surface and in the soil profile. A susceptibility of about 10^{-3} SI units was recorded from surface laterite; and a susceptibility of 20-30 x 10^{-3} SI units from small pisolitic concretions concentrated in the top few centimetres of soil.

In an attempt to reduce the noise level the magnetic survey was repeated from 8300 W to 6350 W and from 1950 W to 00 W, using a sensor height of 6.6 m, but this showed no significant reduction in noise.

The anomaly at 7100 W is attributed to magnetitic shales present in the Mount Partridge Formation cropping out near Kapalga Trig and coincides with an aeromagnetic anomaly striking about 350°. As shown by Horsfall & Wilkes (1975), this anomaly continues for a short distance south of the Arnhem Highway where it ends abruptly, due perhaps to faulting. The anomaly continues for many kilometres north of the highway.

Apart from the anomaly at 7100 W, no other magnetic anomalies suitable for mapping were detected on the Arnhem Highway traverse. The 7100 W anomaly ends south of the highway within the mapped outcrop area, and therefore does not assist geological mapping.

TEM and Resistivity Sounding Results

TEM was chosen as the main electrical method to locate conductors on the traverse, as previous experience (Spies, 1974) had indicated the method's ability to detect carbonaceous shale at moderate depths. Station spacing was 50 m, except between 2800 W and 7100 W where it was increased to 100 m. The traverse was surveyed using 100-m loops east of 7100 W and 50-m loops west of 7100 W. The change to smaller loops was necessary to overcome electrical interference which often affected readings made with the larger loop; however, the use of 50-m loops is disadvantageous in that larger loops have a greater depth penetration and are more suited to detecting conductive zones in the bedrock. The sources of the anomalies detected were investigated by resistivity soundings.

The TEM results shown in Plate 2 indicate two anomalies. The one at 13 100 W is an isolated simple anomaly (Anomaly A); the other, east of 2000 W, is a broad complex anomaly with several peaks (Anomaly B).

Anomaly A: Anomaly A was investigated by TEM with about 150 stations 50 m apart, using 50-m loops. The resultant contour map is shown in Plate 5, Inset B. The anomaly is elliptical and strikes northeast.

The TEM results at 13 100 W are expressed as resistivity values in Table 1 and show an increase of apparent resistivity with time (and, therefore, with depth).

TABLE 1. TEM APPARENT RESISTIVITY VALUES, ANOMALY A

LOOP SIZE	APPARENT RESISTIVITY (0.6 ms)	APPARENT RESISTIVITY (3 ms)
100 m	10 ohm-m	100 ohm-m
50 m	10 ohm-m	50 ohm-m

A resistivity depth sounding was made over the anomaly using a Schlumberger array. The results indicate a thin conductive layer with resistivity 1 to 5 ohm-m underlying some 15 m of resistive surface material with a resistivity of about 1000 ohm-m. Resistivity of strata beneath the conductive layer is estimated to be 50-200 ohm-m. The thickness of the conductive layer is difficult to determine but is probably greater than 5 m.

BMR drill hole Kapalga No. 5 was drilled to test TEM Anomaly A and the geophysical and geological logs of this hole are shown in Plate 2. The hole intersected phyllite and dolomite at a depth of 110 m after passing through 40 m of sandy clay and a further 70 m of quartzite, clay, and weathered phyllite. The conductive layer indicated by the resistivity depth sounding coincides with a zone of clay. However the layer is not reflected in the single-point resistance log.

It appears that the TEM response at 0.6 ms is influenced mainly by a conductive layer at 15 m and at later times the response is influenced by the underlying more resistive strata.

Anomaly B: Anomaly B, at 1500 W, is more complex. It was studied in more detail by two further TEM traverses (Plate 5, Inset C). To the east of Anomaly B a broad, large-amplitude anomaly was detected, coinciding with the flood plain of the South Alligator River.

BMR drill hole Kapalga 11 (Plate 2), at 1500 W, intersected carbonaceous material in the region 80-130 m after passing through sandy clay and quartz gravel.

A resistivity depth sounding was made over Anomaly B, and the results indicate that the surface layer is 15 m thick and very resistive (2500 ohm-m), and overlies a conductive zone (1 to 20 ohm-m).

The TEM decay curves over Anomaly B give apparent resistivities of 12 ohm-m at 0.8 ms and 7 ohm-m at 9 ms. It is unlikely that the near-surface clay layers are the cause of the anomaly, since the apparent resistivity decreases with time, and it is concluded that the anomaly is due to a bedrock conductor.

Flood Plain Anomaly: The anomaly extending east of 600 W is probably caused by conductive material in the flood plain sediments of the South Alligator River. Indeed, resistivity and TEM data show that the flood plain sediments are very conductive.

A resistivity depth sounding was carried out 600 m southeast of 00 W, for which two possible interpretations have been made (for three layers and four layers), as shown in Table 2. Both interpretations are consistent, in so far as resistive bedrock is seen to be overlain by conductive superficial deposits.

TABLE 2. RESISTIVITY DEPTH PROBE INTERPRETATIONS, SOUTH ALLIGATOR RIVER FLOOD PLAIN.

Interpretation	Layer	Thickness (m)	Resistivity (ohm-m)
A	1	6	1.1
	2	89	12
	3		1400
B	1	10	2
	2	50	8
	3	60	30
	4		500

The strong TEM response obtained over the flood plain exhibits a half-space response representing a resistivity of 2 to 4 ohm-m. At less than 1 ms, with a 100-m loop, the curves approach a low resistivity asymptote, implying that results at these times are being influenced by the top 10 m of the superficial material. These observations agree reasonably well with the resistivity depth sounding. It appears that the deep resistive layer was not detected by TEM.

It is interesting to note that the high conductivity extends up to 500 m to the southwest of the edge of the flood plain and then suddenly decreases. Thus, when using electrical and electromagnetic techniques within 500 m of the edge of the South Alligator River flood plain, one must be careful in interpreting results, as anomalies may only reflect superficial conductors beneath the flood plain, and furthermore their effects may still be detected several hundred metres beyond the edge of the flood plain. These conductors will mask the response of most electrical and electromagnetic techniques to bedrock conductors below and adjacent to the flood plain. The thickness of the superficial conductive material (about 100 m, Table 2) is equivalent to one skin depth at a frequency of 200 Hz, or half a skin depth at 40 Hz. Thus it is conceivable that an electromagnetic method operating at a frequency of less than 40 Hz could detect a bedrock conductor if its conductivity and thickness were large enough. However, lateral changes in the flood plain sediments would be difficult to distinguish from bedrock conductivity contrasts with both electromagnetic and electrical methods.

Drilling Results

In addition to holes BMR Kapalga 5 and 11, which were drilled to test TEM anomalies, a further eight holes were drilled on the Arnhem Highway traverse to aid geological mapping. Simplified geological and geophysical logs for those holes are shown in Plate 2 (geological information provided by P.G. Stuart-Smith). All holes passed through surface layers of sandy clay, and there is no evidence in the drilling results to indicate why a TEM anomaly was obtained at 13 000 W. The units logged as 'sandy clay' and 'clay' vary significantly in composition, and the logs suggest that high-conductivity clay minerals may be present for several hundred metres around station 13 000 W.

Carbonaceous phyllite and graphitic clay were intersected in Kapalga 6, but there is no associated TEM anomaly. Interpretation of a resistivity depth sounding at this location indicates that a zone of moderate resistivity

(100 ohm-m) lies beneath 12 m of 1000-ohm-m material and there is no indication that the carbonaceous material, intersected at 50 m, has a lower resistivity than the overlying sandy clay. This conclusion was supported by laboratory resistivity measurements on a core sample of the carbonaceous shale at 74 m, which indicated resistivities ranging from 100 to 200 ohm-m. Evidently, no TEM anomaly was obtained near Kapalga 6 because the carbonaceous shale is not sufficiently conductive.

The single-point resistance and self-potential logs run in most holes were of little help in interpreting the TEM results.

SOUTH ALLIGATOR AREA TEST SURVEY

This survey was carried out near the South Alligator River 10 km north of Kapalga Trig. The aeromagnetic data in this region show a weak north-striking anomaly which extends for about 15 m along the eastern side of the South Alligator River (Horsfall & Wilkes, 1975). To determine whether this feature could be traced south as a stratigraphic marker, small ground magnetic surveys were made in three areas.

Area 1 is north of the river (Pl. 3). Work consisted of a long magnetic line to pick up the aeromagnetic anomaly, and a grid of magnetic traverses 50 m apart. A short TEM traverse was also made.

Area 2 is south of the river, and the survey consisted of three magnetic traverses.

Area 3 is 2 km further south, work within the area comprising a single magnetic traverse.

The ground magnetic results from Areas 1, 2, and 3 are shown in Plate 3.

Results, Area 1

On Traverse 00 (the long line) a 90-nT anomaly relative to a low noise background (2nT) was recorded near the axis of the aeromagnetic anomaly. Traverses spaced at 50-m intervals on either side of Traverse 00 show that the anomaly broadened and decreased in amplitude to the north and south, finally disappearing at 150 S. On Traverse 150 N the anomaly develops a twin peak.

A TEM traverse was surveyed over the magnetic anomaly on Traverse 00. Although headings indicative of flood plain sediments with a resistivity of 0.5 to 5 ohm-m were obtained, there was no evidence that the source of the magnetic anomaly was conductive.

Results, Area 2

The magnetic traverses surveyed south of the river do not show an anomaly of the form observed in Area 1. However a negative anomaly which weakens to the south occurs close to the position of the aeromagnetic anomaly.

Possible explanations for the negative anomaly in Area 2 are:

(i) A strong magnetic source exists just north of the traverse, under the South Alligator River, and produces a negative anomaly on the southern flank.

(ii) A profile of this shape could be obtained over a thin tabular body having a very shallow dip and striking at 040^{o} to 050^{o}. However, on geological grounds this is unlikely.

(iii) The most likely possibility is that the source is remanently magnetised in a direction opposite to the Earth's present field. Such a situation suggests the presence of small basic intrusions in the underlying strata; perhaps the line of anomalies corresponds to a fracture or shear zone.

Results, Area 3

The magnetic traverse in this area is west of the flood plain, and near-surface responses similar to those recorded on the Arnhem Highway traverse were observed. There is no evidence of a deeper magnetic source.

Discussion

It appears that the lineament present in the aeromagnetic contours is discontinuous and variable in form, and a possible source for the line of anomalies is small basic intrusions along a fracture or shear. Some phases of the intrusions are possibly remanently magnetised.

WEST ALLIGATOR AREA TEST SURVEY

This area is located immediately west of the West Alligator River, about 10 km north of the Arnhem Highway. Exploratory drilling by The Broken Hill Proprietary Company Ltd had intersected carbonaceous shales in the area, and it was hoped that these rocks might be conductive marker horizons.

Several east-west traverses were surveyed with TEM and magnetic methods. The TEM profiles are shown in Plate 5, Inset A. The TEM response over the entire area is less than 50 V/A at 1.1 ms, which corresponds to apparent resistivities greater than 10 ohm-m. There is an apparent contrast between the more resistive eastern half of the area (sandy alluvium adjacent to the river) and the western half of the area. However, there are no distinct anomalies which can be attributed to carbonaceous shale.

The magnetic results show only the affects of magnetic laterites, and are not presented.

RED LILY AREA TEST SURVEY

This survey was made in an area where a line of Australian Anglo American Company Limited exploration drill holes had intersected carbonaceous shales.

Work at Red Lily consisted of test traverses using a variety of methods along the line of drill holes. Later a semi-regional TEM survey was conducted. Interpretation of the test traverses and the semi-regional survey was supported by resistivity depth soundings.

Drill Line Surveys

The line of drill holes was designated Line 9 (Plate 5); TEM, VLF, EM Gun, resistivity, and magnetic surveys were made along or near the drill line. The results of the test surveys are shown in Plate 4.

Drilling Results: Drilling intersected pyritic-graphitic shales at the southeastern end of the traverse at a depth of 40-50 m, beneath weathered or partly weathered siltstone and phyllite. Pyrite content of the graphitic shales is up to 5 percent in places.

TEM and Resistivity Results: A moderate TEM anomaly, centred at about 250 SE, was detected. The anomaly decreases rapidly to the southeast and more gradually to the northwest, and could be caused by pyritic-graphitic shale intersected in Drill Holes 3, 4, and 5. The TEM results over the peak of the anomaly give values of apparent resistivity of 11 ohm-m at 0.8 ms and 7 ohm-m at 5 ms, implying increasing conductivity with depth. The interpretation of resistivity depth sounding L9/200 SE, displayed at the bottom right of Plate 4, indicates that the pyritic-graphitic shale has a low resistivity compared with the overlying weathered phyllite and siltstone. It appears that later parts of the transient decay curve are being influenced by the pyritic-graphitic shale at some depth below the weathered zone. The TEM anomaly extends past Drill Holes 3a and 1a and may be caused by graphitic shale either adjacent to or deeper than the drill holes.

EM Gun Results: The EM Gun results show small real-component anomalies of up to 10 percent, but these anomalies do not correlate with the TEM anomalies and appear to be due to shallow conductors.

VLF Results: The VLF results are shown in normal and filtered form (Fraser, 1969). Three conductor axes are evident in the southeastern half of the traverse; they appear to be due to shallow conductors which possibly represent variations in the surface clay layers rather than sources in the bedrock.

Magnetic Results: Magnetic results along Line 8.5, which is parallel to and 220 m northeast of Line 9, are also shown in Plate 4. The results show the usual shallow-seated anomalies caused by laterite. No distinct deeper-seated anomalies are apparent.

Semi-Regional Survey

TEM Results: To investigate the continuity of the TEM anomaly detected on Line 9 and its applicability in geological mapping, long TEM traverses were made at 250-m or 500-m intervals on either side of the line. Stations commonly were read at intervals of 100 m using 50-m loops. The results of this survey are contoured in Plate 5, Inset D. Two anomalous zones were detected, the short, intense zone to the northwest correlating with the anomaly detected on Line 9.

The zone associated with the TEM anomaly on Line 9 increases in strength to the east (Line 8.5, apparent resistivities decreasing from 15 ohm-m to 5 ohm-m with time). However, no lines were surveyed northeast of Line 8.5 because of the presence of the flood plain. This zone decreases in amplitude to the west, and is not present west of Line 11.

The conductive zone located southeast of Line 9 was traced 3 km to the southwest. The broad, large-amplitude anomalies detected on Lines 9A and 9.5A are probably due to the influence of the flood plain which lies a few hundred metres to the northeast. As this zone is separate from the first zone it was tested by a BMR drill hole (Kapalga 10) on Line 14. This hole intersected carbonaceous chloritic schist, weathered to a depth of 55 m, below 7 m of Cainozoic sand and gravel.

Resistivity Results: To aid interpretation of the TEM results several resistivity depth soundings were made in the area of the semi-regional survey. The sites and results of these soundings are shown in Plate 5.

The geo-electric sections shown in Plate 5 were derived by methods of interpretation which assume horizontal layering. As the rocks in this area are known to be steeply dipping, the interpretations can only be used as a guide to rock resistivity and depth. In particular it is important to note that the results reflect the effects of lateral changes in surface resistivity, and that the influence of narrow dyke-like conductors is not great.

The depth sounding results at sites where TEM anomalies were recorded (Lines 9 and 13) are dissimilar, but they indicate that the sources of the anomalies are fairly shallow. Away from the TEM anomalies the geo-electric sections do not indicate the presence of shallow conductors.

The depth sounding on Line 9 has been discussed in considering the TEM results along the drill line. The results indicate that the TEM anomaly is due to a pyritic-graphitic shale from about 50 m to about 100 m below the surface, below a conductive surface layer and a more resistive zone of weathering.

The sounding on Line 13 was made near the peak response of the second TEM zone. Results indicate that the thickness of the conductive surface layer and the resistivity of the weathered zone are greater than on Line 9. The sounding indicates a conductive zone at a depth of some 300 m, but it is unlikely that this zone is the source of the TEM anomaly. The geological log from BMR Hole Kapalga 10 indicates that clay was intersected to 6 m, graphitic clay and phyllite from 6 to 22 m, and graphitic phyllite to the bottom of the hole (55 m). The graphitic clay and phyllite are probably moderately conductive and are the likely source of the TEM anomaly.

The depth sounding on Line 11 is away from the TEM anomalies. Apparent resistivities are much higher, and there is evidence of a conductive zone at a depth of about 80 m. Since there is no TEM anomaly at this location the conductive zone must be below the depth of TEM penetration. Alternatively the resistivity results may be affected by the adjacent conductor 500 m to the east.

REGIONAL SURVEY

A regional TEM survey was carried out in an area of approximately 500 km^2 south of the Arnhem Highway (Pl. 5) to aid mapping in the area. The survey was based on the results of the test surveys which indicated that conductive zones at Red Lily and on the Arnhem Highway might be useful stratigraphic markers. The survey employed 100-m loops at station spacings of 500 m to several km along widely spaced traverses.

Presentation of Results

The results and interpretation of the regional survey are given in Plate 5. Locations of TEM readings are indicated by circles, and interpretation of the decay curves (using a method to be described in another report) is shown by the shading and small figures. Open circles indicate apparent resistivities greater than 100 ohm-m over the time range measured; full circles imply a response similar to a homogeneous ground with apparent resistivity less than 100 ohm-m, and where the apparent resistivities at early and late times differ by less than a factor of two. Where the response differs significantly from that of a homogeneous ground, a horizontal line has been drawn through the circle and either the top or bottom segment shaded depending on whether apparent resistivities increase or decrease with time. The number on the top of the circle is the early-time (0.8 ms) apparent resistivity, and the lower number is the late-time (3 or 6 ms) apparent resistivity.

This method of presentation assists correlation of results and allows surface conductors to be identified and culled while studying the results. A bedrock conductor is readily identified as an anomaly with the lower half of the circle shaded. Half-space responses usually indicate a carbonaceous shale but the same type of response can be obtained over a thick sequence of flood plain sediments.

Results

In the Red Lily area the character of the anomalies changes near Line 15. To the northeast of Line 15 the anomalies are narrow (Pl. 5, Inset D) but to the southwest they are broad, which is typical of a homogeneous ground. A drill hole in the broad zone (Kapalga 13) intersected carbonaceous schist at a depth of 60 m, underlying sandy clay and weathered chloritic schist. The change in anomaly character possibly coincides with an extension of the Jim Jim Fault Zone, an hypothesis supported by photo-interpretation (R.S. Needham, pers. comm.).

The resistivity depth sounding results on Lines 22 and 24 (Plate 5) show that surface resistivity in the zone of broad anomalies is about 1000 ohm-m, but conductive zones occur at depth. On Line 24 there appears to be a gradual transition to lower resistivities.

The broad anomalous zone extends to the south and west and in the south the results are consistent with the outcropping geology - arcuate ridges of Koolpin Formation chert-banded siltstone outlining a major synclinal structure (Plate 1). Drilling by Noranda (Australia) Limited has intersected carbonaceous shales between these ridges. Two traverses were run over the syncline, one along the axis to the south (Line 30), the other along the Arnhem Highway from the West Alligator River east for about 11 km. The broad anomalous zones recorded are similar to those southwest of the Red Lily area, and suggest that carbonaceous units may form thick continuous segments within the Koolpin Formation in this area. This hypothesis is supported by the results of BMR drilling in 1976 which intersected carbonaceous rocks at a site 2 km east of the West Alligator River on the Arnhem Highway, i.e. on the western limb of the syncline. The hole intersected carbonaceous, pyritic phyllite at a depth of 110 m after passing through a sequence of phyllite and siltstone (Stuart-Smith, pers. comm.).

The continuity of carbonaceous beds north from the Red Lily Prospect cannot be definitely established because of the masking effect of the South Alligator River flood plain sediments. However, it is possible that the anomalies recorded on Lines R2, R3 and the Arnhem Highway traverse (Anomaly B, Inset C) reflect extensions of the Red Lily carbonaceous shale zone.

CONCLUSIONS

Effectiveness of Methods in Assisting Geological Mapping

Magnetic: Magnetic rock units occur in the Alligator Rivers area and Horsfall & Wilkes (1975) have illustrated the usefulness of aeromagnetic surveys for regional mapping.

The ground magnetic method is commonly hampered by the presence of widespread lateritic material of high susceptibility which produces anomalies of equal or greater magnitude than broader anomalies generated by short-wavelength bedrock sources. By reducing the station spacing to 5 or 10 m, resolution of the anomalies will be enhanced. Although the magnetic anomalies resolved over the flood plain had too short a strike length to help in regional mapping, the ground magnetic method is a potentially effective mapping tool in such areas, where recent sediments are non-magnetic. Smooth profiles obtained in these areas make resolution of bedrock anomalies possible.

Electromagnetic: The only EM Method which proved successful for mapping was TEM. VLF and EM Gun methods were ineffective owing to the low surface resistivities in the area.

The TEM method was successful in detecting carbonaceous shale units beneath moderately conductive surface clay layers. Anomalies from different sources could be distinguished by converting the transient decay curves into apparent conductivity curves.

The success of the TEM method in regional surveying would suggest that airborne electromagnetic methods may be useful in defining the broad conductive carbonaceous zones present in the area.

Resistivity: This method was an effective detector of bedrock conductors but the slow progress of reconnaissance resistivity depth soundings suggests they are unsuitable for routine mapping. The effectiveness of the resistivity method in this situation lies in its ability to assist in the interpretation of EM results. The effects of lateral resistivity changes permit only the qualitative interpretation of electrical depth soundings in this area.

Geological Interpretation

The regional TEM survey south of the Arnhem Highway traced a zone of narrow conductive units from the Red Lily prospect to the southwest for about 7 km, to a region where the TEM anomalies change in character, forming a zone several kilometres wide, extending farther to the southwest. This change is thought to reflect an extension of the Jim Jim Fault Zone. Anomalies on both sides of the suspected fault zone were tested by drilling, the results indicating that the sources of the anomalies are graphitic shale. The results of the regional TEM survey indicate that carbonaceous units form wide continuous sequences within the Koolpin Formation in the south of the Kapalga Sheet area; this conclusion is consistent with the geology of adjacent areas of outcrop.

The sources of small aeromagnetic anomalies near the abandoned Kapalga Homestead, in the area of the South Alligator test survey, appear to be discontinuous pod-like bodies which are possibly small basic intrusions along a fracture or shear.

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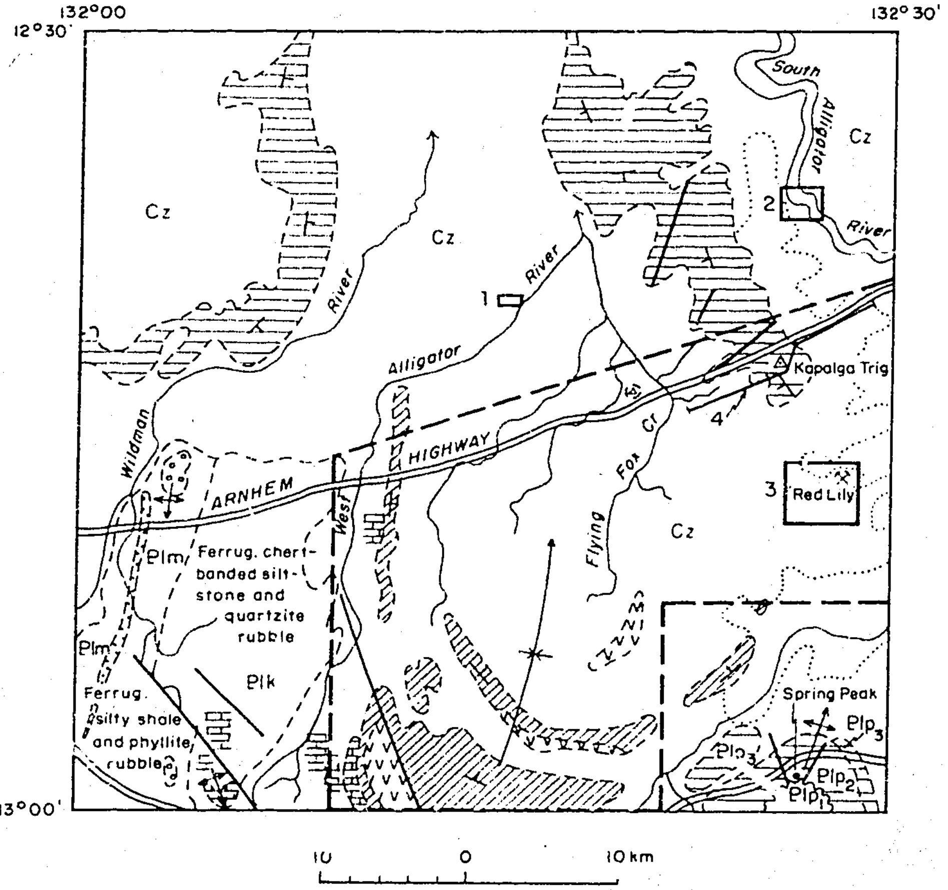


Cz Cainozoic

Breccia conglomerate

Plk Koolpin Formation

Chert-banded siltstone

Silicified dolomite

Plm Masson Formation

Quartzite

Chert conglomerate

Plp Mount Partridge Formation

Feldspathic sandstone, siltstone, arkose, conglomerate

Zamu Complex

Dolerite

Unconformity

Dip and strike of strata

Edge of South Alligator River flood plain

Road

Geological boundary

Fault

Anticline, showing plunge

Syncline, showing plunge

Test areas:

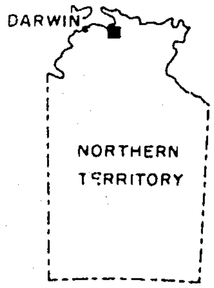
1 West Alligator

2 South Alligator

3 Red Lily

4 Arnhem Highway traverse

Boundary, regional survey area



GEOLOGY AND LOCATION OF SURVEY AREAS, KAPALGA 1:100 000 SHEET AREA

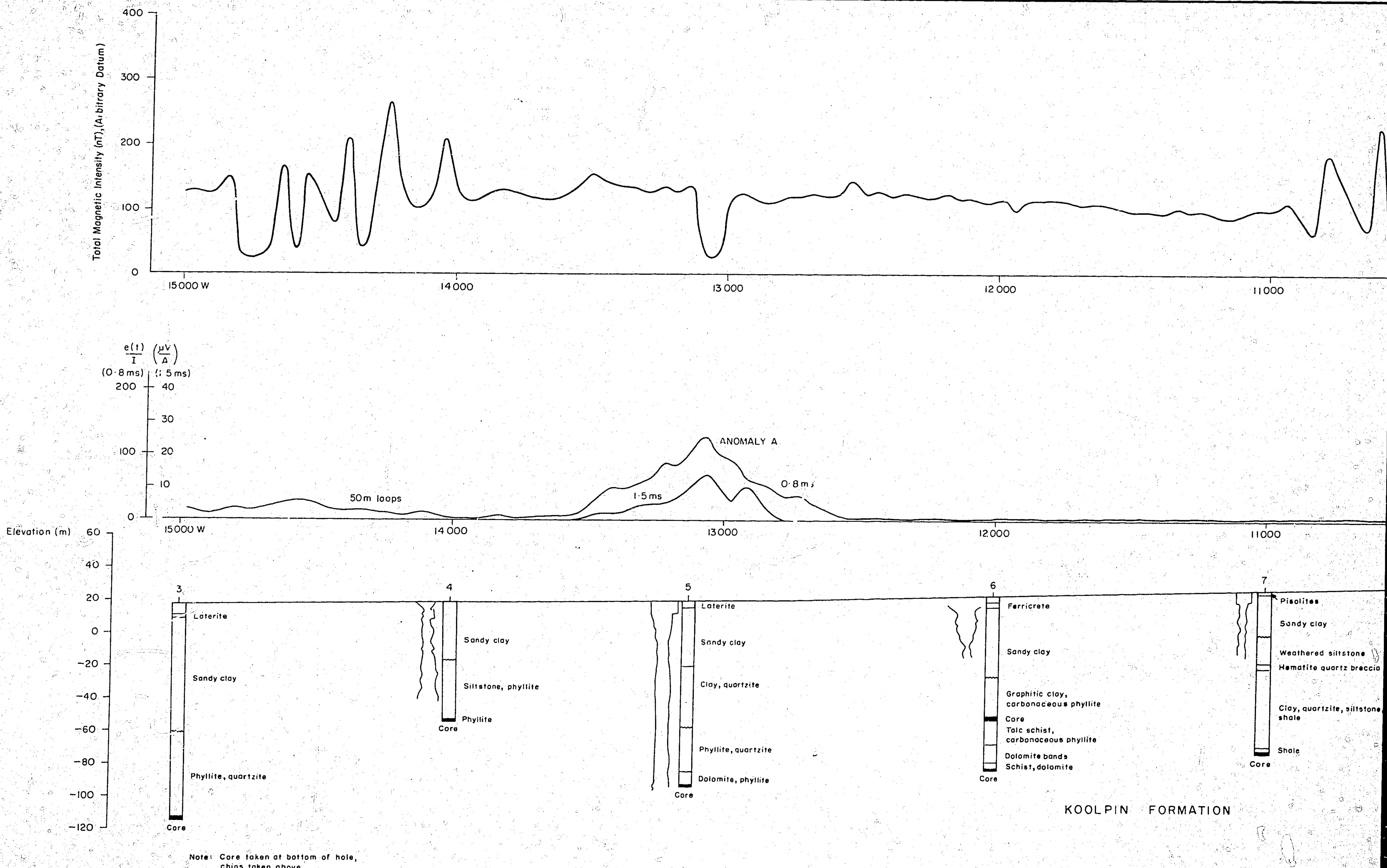


PLATE 2. Magnetic, TEM, and drilling results, Arnhem Highway traverse

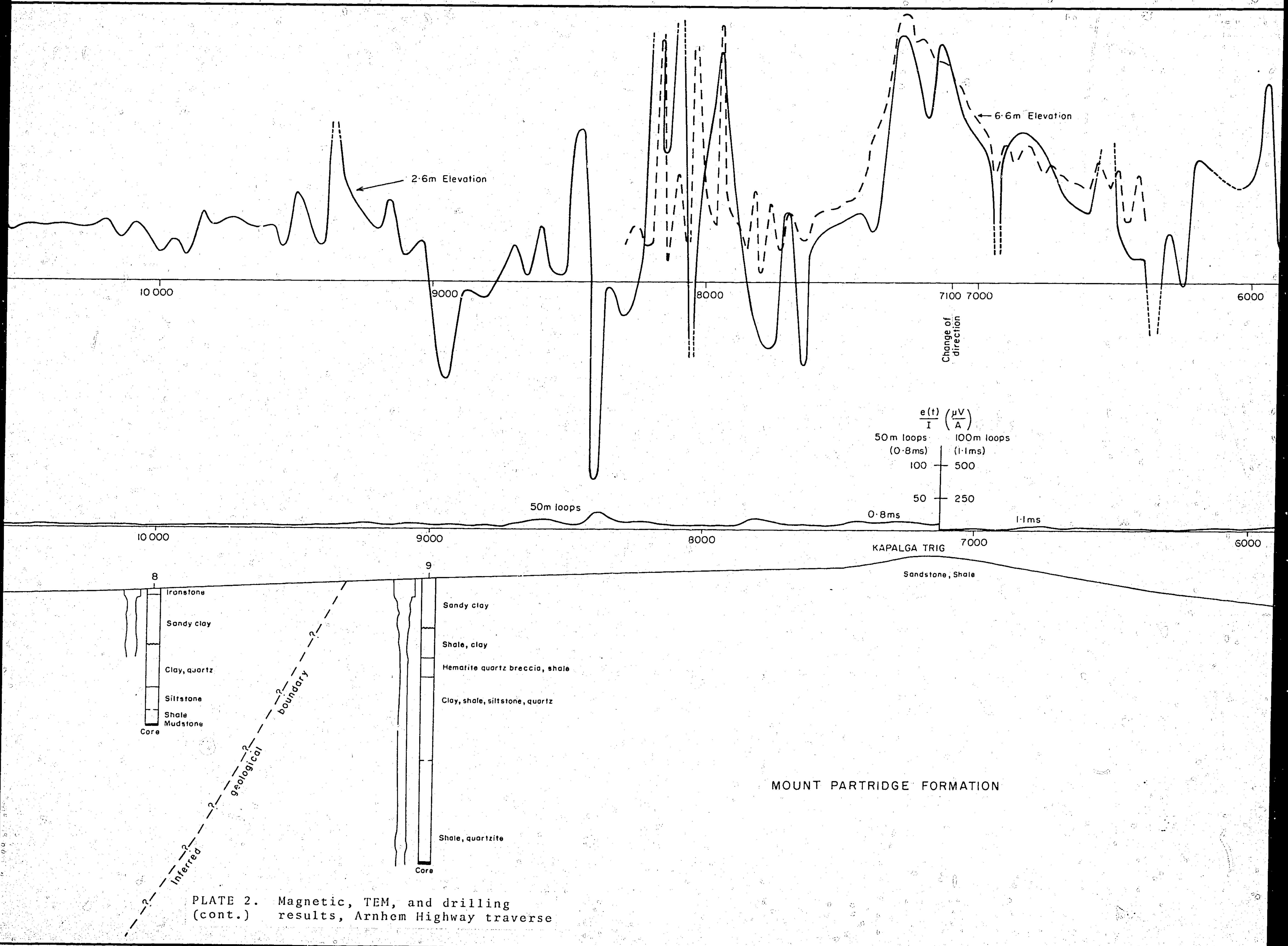


PLATE 2. (cont.) Magnetic, TEM, and drilling results, Arnhem Highway traverse

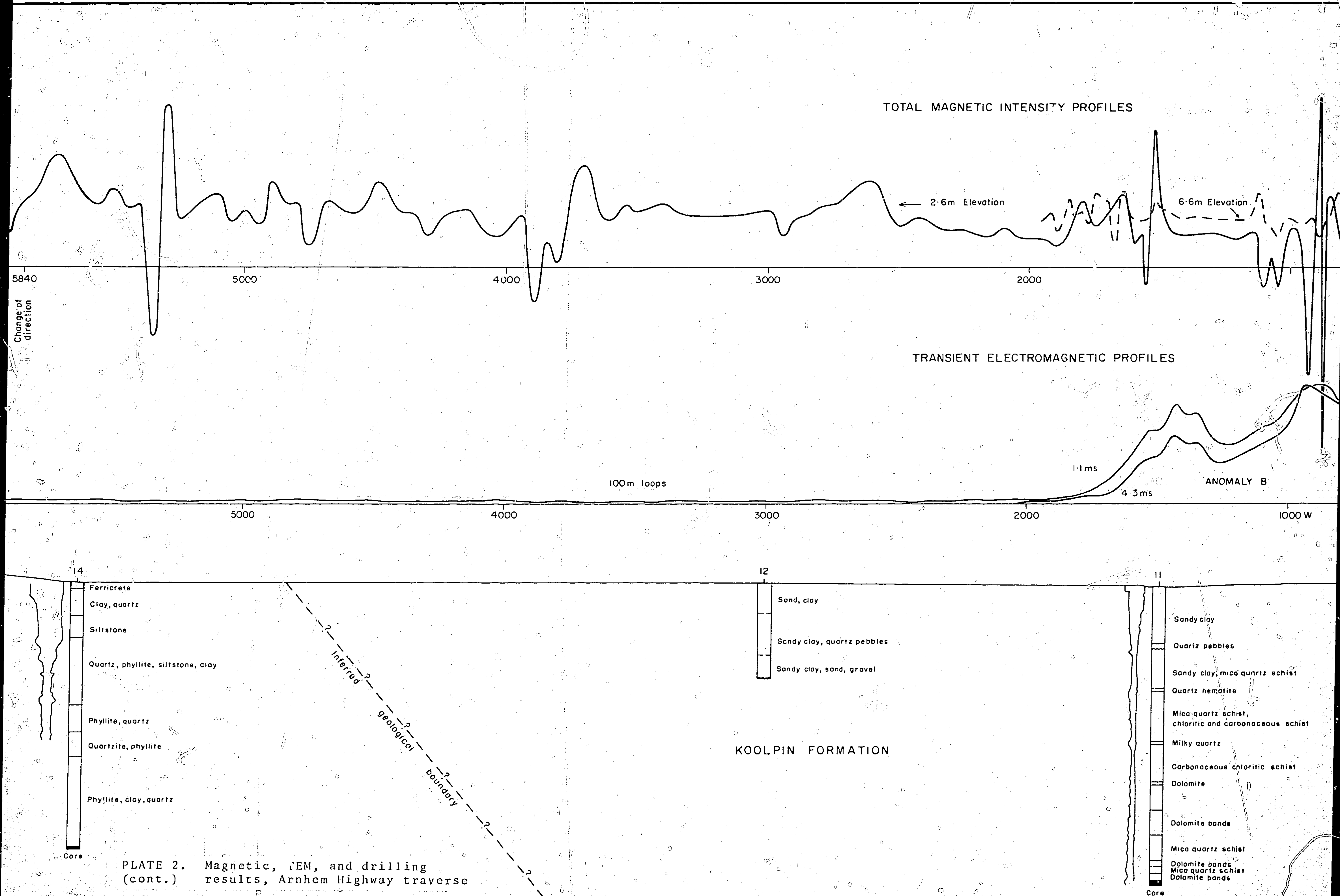


PLATE 2. (cont.) Magnetic, TEM, and drilling results, Arnhem Highway traverse

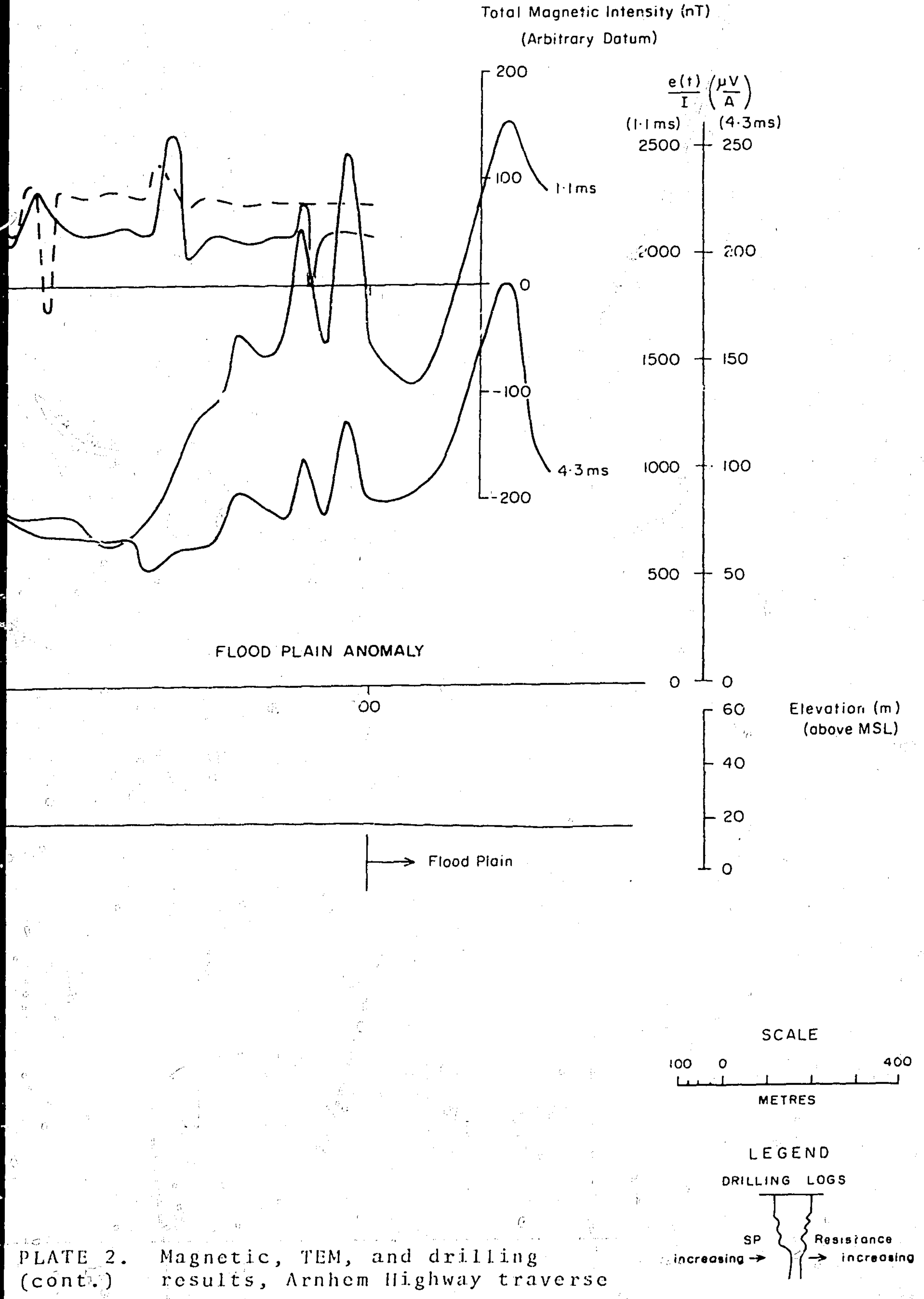
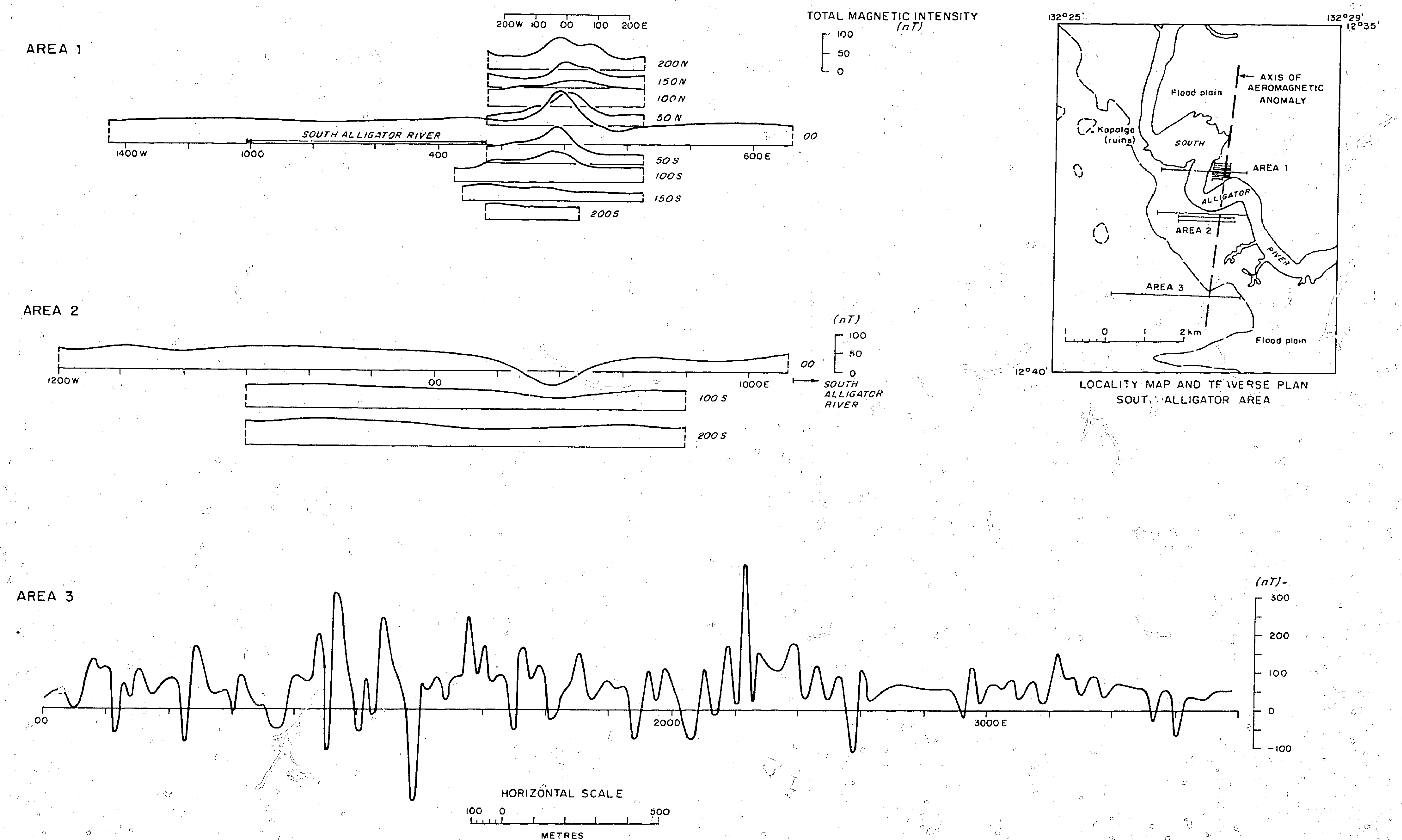


PLATE 2. (cont.) Magnetic, TEM, and drilling results, Arnhem Highway traverse

PLATE 3



MAGNETIC RESULTS, SOUTH ALLIGATOR AREA

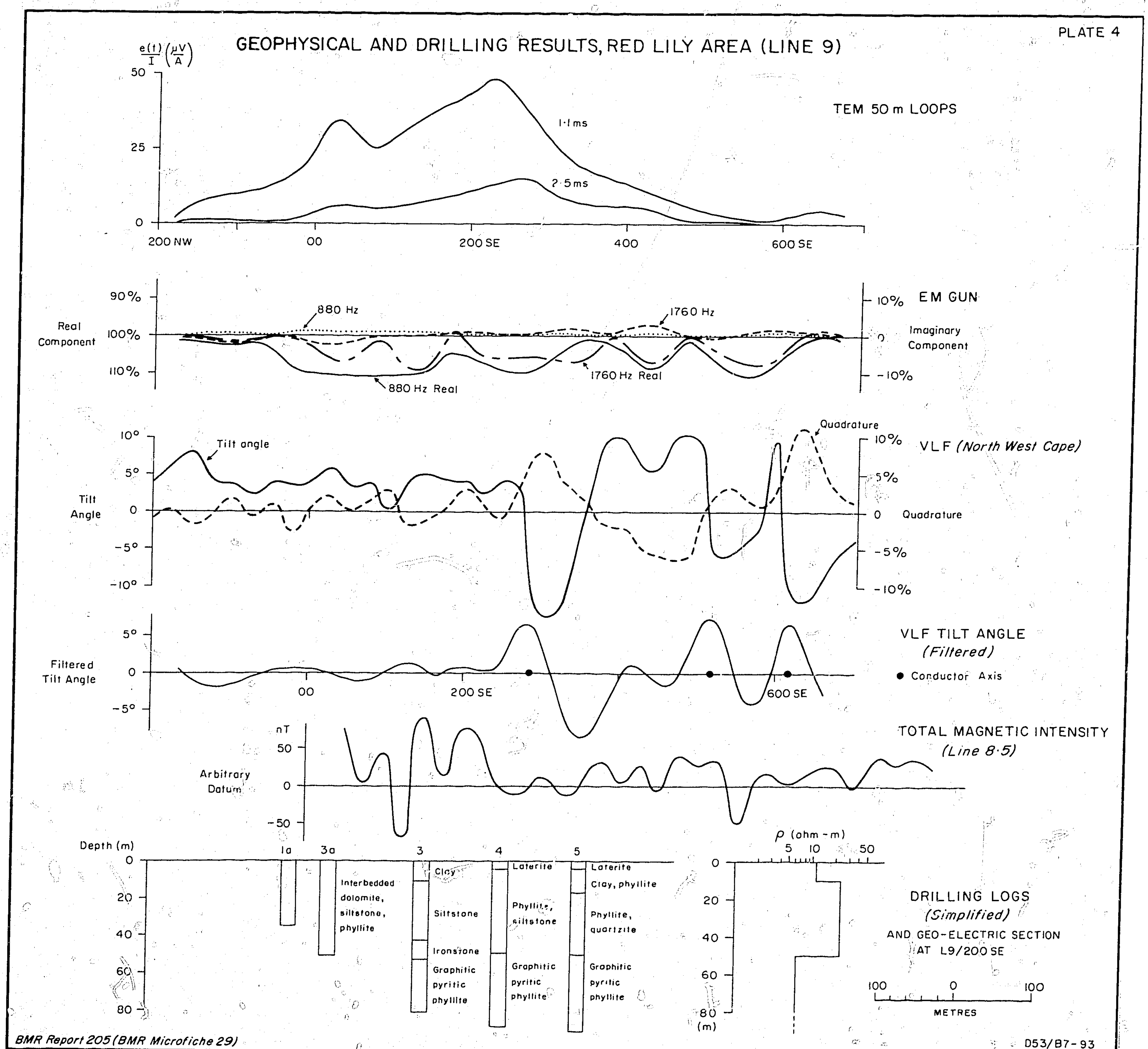


PLATE 4
GEOPHYSICAL AND DRILLING RESULTS, RED LILY AREA (LINE 9)
TEM 50 m LOOPS
1·1 ms
2·5 ms
200 NW
00
200 SE
400
600 SE
EM GUN
Real Component
Imaginary Component
880 Hz
1760 Hz
880 Hz Real
1760 Hz Real
VLF (North West Cape)
Tilt angle
Quadrature
Tilt Angle
VLF TILT ANGLE (Filtered)
Filtered Tilt Angle
Conductor Axis
TOTAL MAGNETIC INTENSITY (Line 8·5)
Arbitrary Datum
Depth (m)
Interbedded dolomite, siltstone, phyllite
Clay
Siltstone
Ironstone
Graphitic pyritic phyllite
Laterite
Phyllite, siltstone
Clay, phyllite
Phyllite, quartzite
ρ (ohm - m)
DRILLING LOGS (Simplified)
AND GEO-ELECTRIC SECTION AT L9/200 SE
METRES
BMR Report 205 (BMR Microfiche 29)
D53/B7-93

GEOPHYSICAL RESULTS AND INTERPRETATION