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GROUND GEOPHYSICAL SURVEYS, MARY RIVER AREA, NT, 1973

by

I.G. HONE & J.A. MAJOR

DEPARTMENT OF NATIONAL DEVELOPMENT

Minister: The Hon. K.E. Newman, M.P.
Secretary: A.J. Woods

BUREAU OF MINERAL RESOURCES, GEOLOGY AND GEOPHYSICS

Director: L.C. Noakes, O.B.E.
Assistant Director, Geophysical Branch: N.G. Chamberlain

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SUMMARY

From July to October 1973 a field party of the Bureau of Mineral Resources, Geology and Geophysics made a series of ground geophysical surveys to determine the geology and to search for mineralisation in a region of sparse outcrop west of the Mary River, Northern Territory. Lead-zinc mineralisation in a small quartz-filled fracture zone had previously been discovered nearby. Surveys were also made in areas of interest established by previous surveys.

At the Mary River West grid there appears to be good correlation between geophysical responses and rock type; zones defined by characteristc geophysical responses were differentiated. Electromagnetic anomalies can be attributed to carbonaceous shales; sharp magnetic anomalies occur in the zone of intense metamorphism around the Cullen Granite, which itself has flat geophysical responses.

The resistive zone of the Gubberah gossan, which overlies the mineralised fracture zone, was closely defined using the transient electromagnetic method (TEM). The efficacy of gravity surveying in this area was reduced by the effects of rugged topography. Areas north and south of the gossan were also investigated.

A conductive zone at Minglo 2, detected in 1972, was defined more precisely. Drilling revealed carbonaceous pyrrhotitic shales as the source of the anomaly.

Further work in some areas of the Mary River West grid is required before drilling targets can be selected to determine if any of the anomalies are related to mineralisation.

INTRODUCTION

During a helicopter reconnaissance survey for iron ore in 1966, geologists of the Northern Territory Resident Geological Section of the Bureau of Mineral Resources found a steep gossanous ridge ('Gubberah gossan') about 3 km north of the junction between the Mary River and Minglo Creek (Shields & Taube, 1967). Samples from the outcrop assayed anomalously high in lead, zinc, and copper; Government Mining Reserve No. 275 of about 65 km^2 was proclaimed in December 1966.

The locations of the present and previous surveys in the area are shown in Plates 1 and 2. From 1967 to 1971 a number of geological, geochemical, and geophysical investigations were made within the Reserve by BMR and the Northern Territory Geological Survey (Shields, 1969; Watts, 1970; Daly, 1971; Duckworth, 1969; Williams, 1971). These investigations did not locate any additional areas of potential economic interest but confirmed the potential interest of the Gubberah gossan, where diamond drilling by the Northern Territory Geological Survey (Daly, 1971) intersected lead-zinc mineralisation in a small quartz-filled fracture zone beneath the gossan. In June 1972 BMR flew a detailed low-level aeromagnetic survey to establish more clearly the magnetic features found in earlier airborne surveys; from July to October 1972 BMR (Michail, 1974) made a ground geophysical survey in areas where aeromagnetic data suggested that favourable structural control might be present to host sulphide mineralisation, and at the Gubberah gossan to determine the geophysical responses from the mineralisation beneath the gossan.

Present survey

From July to October 1973 a geophysical survey was made on a grid west of the Mary River ('Mary River West') in an attempt to determine the geology in a region of sparse outcrop. Other objectives were: to search for base-metal sulphide mineralisation, either conductive or resistive, i.e. similar to that encountered previously at the Gubberah gossan (resistive sulphide fissure filling in conductive shale); and to evaluate further the transient electromagnetic method (TEM). Surveys were also made in areas of interest (Gubberah gossan, Gubberah North, Gubberah South, and Minglo 2) established during the 1972 and earlier surveys: at Minglo 2 a TEM anomaly detected in 1972 was delineated more precisely and a drill site selected; the 1972 work at the Gubberah gossan was extended, and the area immediately north and a gossan to the south were investigated.

Geophysical methods used were magnetic, gravity, electromagnetic, self-potential, and radiometric. The electromagnetic methods used were Slingram, Turam, and TEM. During the later part of the survey two diamond drill holes (DDH 4 and DDH 5) were drilled at the Gubberah gossan to test further the mineralised lode, and one hole (DDH EM1) was drilled at Minglo 2 to investigate a TEM anomaly (Daly, 1975). Geophysical logs were made in DDH EM1, but not in the other holes because they had caved in.

Geophysicists who took part in the survey were J. Major (party leader), I. Hone (TEM survey party leader), and E. Wronski. They were assisted by J. Williams (Technical Officer), N. Ashmore and D. Hunter (Technical Assistants), and four field hands. Traverses were pegged and levelled by Department of Services and Property personnel W. Martyr (Surveyor), M. Hore (Technical Officer), and two chainmen.

GEOLOGY

The geology of Mining Reserve No. 275 and the surrounding area, based on the Ban Ban and Goodparla 1:63 360 geological maps, is shown in Plate 2. Hays (1960) describes the geology relevant to the western side of the area; the geology is similar in the east.

Outcrop is poor. Sedimentary rocks exposed belong to the Masson Formation, a unit of the Lower Proterozoic Goodparla Group. These sediments consist of interbedded quartzite, greywacke, sandstone, siltstone, and carbonaceous shale with a northwesterly strike and a steep westerly dip. In the south, coarse-grained massive granite (the Cullen Granite) intrudes these sediments. The boundary of the granite is thought to be extensively faulted; in the Reserve, alluvium and ferricrete generally conceal the granite-sediment contact. At Mary River West a narrow aureole of andalusite hornfels has developed in the sediments.

Within the Reserve, lead and zinc sulphides have been intersected by drill holes at the Gubberah gossan. Silver-lead has been recovered from minor workings at the Minglo mine about 2 km southeast of the Reserve. Eight kilometres west of the Reserve, at Mount Harris, cassiterite occurs together with accessory sulphides in quartz-hematite breccia within the Masson Formation, adjacent to the Cullen Granite. Similar lodes occur at Mount Masson and Jessop's Lode about 15 km west of the Reserve (Hays, 1960).

At the Gubberah gossan the country rock intersected by the drill holes consists of carbonaceous shale and siltstone which do not crop out; outcropping sediments are restricted to sandstone exposed on ridges. Faulting and shearing trend mainly northwest or northeast. The Gubberah gossan is about 280 m long and is associated with a fault trending northeast.

South of the Gubberah gossan at Gubberah South, gossanous quartz-hematite and sandstone rubble form a low ridge; diamond-drill hole DDH 1, drilled to test a geochemical anomaly, intersected sandstone, carbonaceous shale, and minor galena, sphalerite, and pyrite.

Outcrops of black shale were observed in creek cuttings at Mary River West. DDH EM1 at Minglo 2 intersected carbonaceous pyrrhotitic shale.

PREVIOUS SURVEYS

Reserve No. 275 is in the magnetically disturbed area of the metamorphic aureole around the Cullen Granite. The area was included in a reconnaissance aeromagnetic survey of the Darwin/Pine Creek region in 1963. Goodeve (1966) concluded from the results of this survey that granite underlies that part of the Masson Formation which is highly disturbed, but not the remainder of the magnetically disturbed area. From the results of the survey, an area of interest was defined around the Mount Harris tin field extending east to the Mary River. This area was covered by a detailed aeromagnetic survey in 1965 (Tipper & Finney, 1966). Tipper & Finney concluded that magnetic highs recorded over rocks of the Masson Formation adjacent to the Cullen Granite resulted from low-grade thermal metamorphism and metasomatism, and could represent favourable locations for tin mineralisation.

Following the discovery of the Gubberah gossan in 1966 (Shields & Taube, 1967), a geochemical survey was made in 1967 in areas of sparse outcrop south and southeast of the Gubberah gossan (Shields, 1969). Further geochemical surveys were made in 1969 (Watts, 1970) and 1970 (Daly, 1971). Significant lead and zinc and minor copper geochemical anomalies were found.

A reconnaissance geophysical survey over the geochemical survey area was made in 1967 (Duckworth, 1969) to attempt to trace possible extensions of the Gubberah gossan to the southwest beneath the black-soil plain. Slingram, self-potential, and magnetic anomalies were found but their significance was not determined. In 1970 Slingram, Turam, and magnetic surveys were made over gossanous outcrops within the 1967 survey area (Williams, 1971). Anomalies were found which were considered to be due to conductive carbonaceous rocks. In 1971 a self-potential survey was made in the area of the 1970 survey (Bullock, 1972). No correlation of the results with previous geochemical or geophysical results was apparent. An undisturbed area to the west and a disturbed area to the east were considered to reflect a contrast in lithology. Geochemical anomalies occur only in the disturbed area, but cannot be correlated with individual S-P anomalies.

A low-level detailed aeromagnetic survey was made in June 1972 over Reserve 275 and adjacent areas to up-grade the reconnaissance survey data.

In 1972 ground surveys were made to study the geophysical responses from the mineralisation at the Gubberah gossan and the Minglo mine and to investigate aeromagnetic anomalies in two areas, Minglo 1 and Minglo 2, to determine their source (Pl. 2). Magnetic, gravity, S-P, and EM methods were used. The results are described by Michail (1974) and Spies (1974a). Good correlation was established between geophysical anomalies and geology. The EM anomalies were attributed to carbonaceous rock units. Magnetic anomalies indicated areas of thermal metamorphism next to the Cullen Granite. The mineralisation at the Gubberah gossan was found to be associated with a discontinuity in EM anomalies attributed to a fissure and, possibly, resistive sulphide mineralisation. The gravity data at Gubberah gossan were severely affected by the steep terrain.

The Mines Branch drilled three diamond-drill holes in 1970-71, DDH 1 at Gubberah South and DDH 2 and DDH 3 at the Gubberah gossan. Three diamond-drill holes were drilled in 1973, DDH 4 and DDH 5 at the Gubberah gossan and DDH EM1 at Minglo 2. The results are described by Daly (1971, 1975). Minor mineralisation was found at Gubberah South, massive sulphides were found at the Gubberah gossan, and carbonaceous pyrrhotitic shale was found at Minglo 2.

GEOPHYSICAL METHODS

The magnetic survey at Mary River West was made with a Sander proton precession magnetometer which has a reading accuracy of 1 nT. Base stations were re-occupied approximately every hour, and drift corrections were applied for diurnal variations.

A sharpe VP-6 instrument was used for the self-potential survey; three potential values were recorded at each station. Stacked profiles were drawn, smoothed, and contoured.

TEM was the principal electromagnetic method used, and is described in detail by Spies (1974a). The Russian-built MPPO-1 equipment was used, and was available for a limited period of three weeks. Other electromagnetic methods used were the Slingram moving-transmitter/moving-receiver system (horizontal coplanar coils) operated at frequencies of 440 Hz and 1760 Hz with a coil separation of 60 m, and the Turam fixed-transmitter/moving-receiver system operated at 220 Hz and 660 Hz used with either grounded cables or a loop as the primary energy source.

Gamma-ray intensity was measured with Austral SG-2B broad-band scintillometers.

Gravity measurements were taken using a Worden gravity meter (W 260) with a scale factor of 0.109 mGal per dial division. Latitude, free-air, and Bouguer corrections assuming a density of 2.3 g/cm^3 were applied.

A Widco Portalogger was used to obtain single-point resistance, self-potential, and gamma-ray logs of DDH EM1 at Minglo 2.

PROCEDURES AND RESULTS

Mary River West

Geology. The Mary River West grid is mainly on a soil-covered plain west of the Mary River (Pl. 2). The contact between Cullen Granite and sediments of the Masson Formation is in the southern part of the grid. Metamorphism decreases to the north away from the granite.

Outcrop is poor and is limited to the Cullen Granite in the south, metamorphosed sediments near to the granite at 2400S/150W and on Traverse 2250S at 90E, 150E and 240E, and carbonaceous shale at 2370S/330E, 2370S/450E, 1570N/30W and 1570N/180W.

Carbonaceous shale was observed in creek cuttings. Patches of quartz rubble occur in the northern part of the grid. Alluvium and ferricrete cover most of the grid, and in some of the creek cuttings were seen to be more than 6 m thick.

Magnetic. The aeromagnetic results (Pl. 2) show that the Mary River West grid lies within the magnetically disturbed zone of the metamorphic aureole around the Cullen Granite. Contour lines are parallel to the granite-sediment boundary close to the granite as a result of contact metamorphic effects. Further from the granite a general northwest trend in the contours reflects the strike of the sediments, some beds being more magnetic than others. However, as Tipper & Finney (1966) have noted, there is no obvious association between magnetic anomalies and particular lithologies in this region.

The general trends of the aeromagnetic contours (Pl. 2) and ground magnetic contours (Pl. 3) are similar, as expected, but the ground survey results resolve the anomalies better. The magnetic profile along Traverse 1500S is shown in Plate 7 and is discussed later.

A number of different magnetic responses can be distinguished. Although specific rock type cannot be inferred from these responses, the area has been divided into five zones based on magnetic and TEM data, as discussed below.

TEM. In the Mary River West grid the TEM method (Pl. 4) was used to define geological horizons of different conductivity and to search for mineralised targets.

Different loop sizes (the length of the side of a square loop) were tested to find the optimum for speed of coverage and resolution of anomalies. Three loop sizes were used: 150 m in the south, 60 m in the north, and 30 m in an area near the centre (see Pls. 4, 5). The larger the loop size the greater the coverage, and, in general, the deeper the penetration. Using a three-man team, an average daily work rate of thirty 150-m loops, or forty 60-m loops, or sixty 30-m loops was achieved; the TEM results at Mary River West were obtained in seventeen working days.

The Mary River West grid consists of traverses 150 m apart pegged at 30-m intervals. With 150-m loops, all the area surveyed was covered by the loops. With the 30-m loops each traverse was surveyed with half of the loop on each side of the traverse (a coverage of 20 percent.). With the 60-m loops every second traverse was surveyed east of 00 (20-percent coverage), and only every third traverse with some infilling was surveyed in the west (13-percent coverage). The 60-m loops were laid out to the south of the traverse with one side along the traverse.

It is apparent from Plate 4 that with the 150-m loops resolution of anomalies is poor and narrow individual conductors cannot be delineated; only gross trends can be seen. The 30-m loops (Pl. 5) give better resolution but the disadvantage is a slower rate of coverage. 60-m loops were a useful compromise, giving almost as much detail as the 30-m loops and, probably, better depth penetration. Nevertheless with both 30-m and 60-m loops, the comparatively wide traverse spacing hinders the tracing of conductors of short strike length from traverse to traverse.

Trends in the TEM data are similar to the trends in the magnetic data. Away from the granite they correlate in general with the strike direction of the sediments, indicating lithological control of the anomalies; near the Cullen Granite the trends tend to be parallel to the edge of the granite, indicating the dominant effect of the metamorphic aureole close to the granite.

TEM and magnetic zones. A number of zones of different TEM response can be distinguished. The area has been divided into five zones based on magnetic and TEM data (Pl. 3 , 4). Zone 1 overlies the Cullen Granite and is a zone of low magnetic susceptibilities and low conductivities. Zone 2 contains intense magnetic anomalies from the metamorphic aureole close to the granite (hornfelses were found in this zone); conductivities are low. Zone 3 is dominated by an elongate magnetic low broadly coincident with a conductivity high. Zone 4 is dominated by magnetic highs which decrease in amplitude north of 450N; north of 450N the zone is designated 4a. 450N may be the limit of significant contact metamorphism of the rocks in Zone 4. South of 450N the conductivities are low to moderate; north of it they are moderate to high. Zone 5 represents another elongate magnetic low and is subdivided into two at 1050N on the basis of conductivity. South of 1050N, conductivities are high; north of it (Zone 5a) they are moderate to low.

Magnetic contours in Zone 1 and magnetic and TEM contours in Zone 2 are parallel to the granite/sediment contact, indicating the dominant role of metamorphic effects associated with the intrusion of the granite. Away from the granite the magnetic and TEM contours in Zones 3, 4, and 5 trend northwest, which is the regional strike of the sediments. These three zones are interpreted to represent different lithologies in the sediments, Zones 3 and 5 probably representing the more carbonaceous sequences.

The mineralisation at the Gubberah gossan is associated with a fissure zone of low conductivity cutting across a zone of conductive carbonaceous shale, and the TEM data at Mary River West reveal two possible discordant resistive features which may be similar to that at the Gubberah gossan. These are at 2175S/675E and 1050S/600E. It is also possible that massive sulphide mineralisation could produce local TEM highs. It is appropriate to note that the major TEM highs are at 720N/150E, 570N/390W, 2025S/675E, 420N/510E and 300S/585E. However, it must be stressed that at Minglo 2 the local TEM anomaly was not due to massive sulphides but carbonaceous shale. Measurements on core samples (see Appendix) showed that the carbonaceous shale at Minglo 2 has a resistivity similar to that of many sulphide assemblages. It is concluded that in this environment, zones of high conductivity most likely represent carbonaceous shale.

Investigation of TEM anomalies using gravity and geochemical methods would help to determine their significance; follow-up gravity work was done over some of the TEM anomalies, and is discussed later.

The results from the 30-m loops (Pl. 5) show that a number of separate conductors were detected on the traverses across the broad conductors in Zone 5; agreement of results from 30-m and 150-m loops is reasonable. However, successful mapping of individual conductors with TEM requires a blanket cover using loops of size comparable with conductor widths. This was not attempted on the Mary River West grid because the TEM equipment was available for only three weeks.

Slingram and Turam. Slingram and Turam measurements were made over much of the area, using 60-m and 30-m staff separations respectively. The results are inconclusive and are not presented. Many small anomalies were observed which probably originate from the overburden. These are unrelated to the TEM response which, at later delay times, better indicates the bedrock conductivity.

Self-potential. The average rate of progress with SP was 75 stations/day, including site preparation; this is slightly faster than the rate of TEM coverage using 30-m loops.

The S-P results (Pl. 6) are broadly consistent with the other data. Potentials vary from high over the granite to low over the sediments, reflecting their carbon content. In the sediments the contours have a general northwest trend, indicating a stratigraphic control.

Within the sediments the contours describe two broad troughs. The first broadly coincides with the southern part of Zone 5, confirming a greater abundance of carbonaceous material here. The axis of the trough runs from 2850S/360E to 0/570E. The second, weaker, trough runs from about 300N/360W to 2850N/120W coinciding with Zone 3. The first broad trough encloses the largest anomaly, centred at 1800S/420E, the site of a shallow waterhole which is elongated along the strike of the sediments. The Turam results show a conductive zone coinciding partly with outcropping carbonaceous shale at 2250S/420E, passing 30 m west of the S-P centre. No anomaly was detected with Slingram, but the TEM shows generally high conductivity - the poor resolution of the TEM when using 150-m loops prevented sharp definition of such a small anomaly. It is likely that the S-P anomaly is caused by the carbonaceous shale which is maintained in a moist condition at or below the water table at the waterhole.

The only other sharp S-P low is at 2400S/180W, which is in the intensely metamorphosed zone adjacent to the granite. There is a coincident small Slingram anomaly. Accordingly, further work, e.g. gravity, should be considered to ascertain its importance.

North of the baseline the strongest S-P feature is the low coinciding with a TEM anomaly at 1350N/180E; the anomalies are probably generated by carbonaceous shales.

Gravity. To determine the response from the sediments, and the gravity signature produced by the granite/sediment boundary, Traverses 1800S and 1500S were surveyed. Traverse 1500S was extended to obtain information on a more regional scale (results discussed later).

The dominant feature is the decreasing Bouguer gravity values towards the west, due to the granite's significantly lower density than that of the sediments (Pl. 7). Contours derived from the two profiles are roughly parallel to the granite/sediment contact and are consistent with the other geophysical data. The edge of the granite is in the region of the steepest gravity gradient. Quantitative interpretation of the profiles is precluded by their inclined orientation of 50° to the granite boundary and the paucity and inconsistency of density measurements. Measurements on drill-hole samples from the Masson Formation give densities from 2.73 to 3.04 g/cm^3 at Minglo 2 (Appendix), and 2.6 and 2.34 g/cm^3 at the Gubberah gossan locality (Michail, 1974).

Another gravity traverse (Traverse A) was read from 00/360W to 2850N/150W to ascertain whether there was an anomalous gravity response from the source of the TEM anomaly centred at 570N/390W. The results are shown in Plate 8. A possible mineralised target for gravity work would be one million tonnes of sphalerite mineralisation having a density of 3.86 g/cm^3 (density contrast with host rock of 1.0 g/cm^3) in a vertical tabular body 10 m thick and 300 m long, extending from 40 m to 130 m beneath the surface. This would produce an anomaly of 0.14 milligal with a half-width, at half-amplitude, of 65 m. The model thus envisaged is similar in length and thickness to the Gubberah gossan, and has the same density as the sphalerite in the mineralised zone of the gossan. The top profile in Plate 8 is the residual gravity after removal of a 1.3 mGal/km regional gradient caused by the low gravity values over the Cullen Granite. There is no gravity high associated with the main TEM conductor, which indicates that it is not a source of concentrated sulphide mineralisation.

With this model in mind, there are potentially interesting features at 1050N and 1700N. However, these features lack corresponding resistive TEM anomalies like that at the Gubberah gossan. The variations in each profile reflect local density variations caused by different lithologies, variations in intensity and depth of weathering, and variations in the density and thickness of the overburden.

The broad central high located between two troughs at 450N and 2600N could be caused by traversing, at a small angle to strike, across a zone of dense rock bounded by two narrow zones of less dense rock. This possibility is strengthened by the results along Traverse 150N, which was read to investigate the gravity signatures of the TEM conducting and non-conducting zones. There are three small gravity highs, the largest being 0.35 milligal from trough to peak, which is about the same amplitude as the broad central feature on traverse A. Although the anomalies are most likely due to variations in lithology and weathering, the remote possibility remains that they could be caused by mineralisation. For example the gravity high at 250E can be approximated by the anomaly generated by a horizontal cylinder of infinite length, with a radius of 17 m, a depth to centre of 50 m, and a density contrast of 1.0 g/cm^3. Such a body is geologically unlikely, but it has the same cross-sectional area and density contrast as the dyke model of the Gubberah gossan.

Comparison of Traverse 150N with the TEM results shows that there is some (although meagre) correlation between the conductivity highs and the gravity lows at 360E and 450E; a similar correlation was obtained on Traverse 1500S Extended.

The gravity work was curtailed by heavy rain and boggy conditions. Further traverses parallel to A would check the continuity of any features perpendicular to strike. Of particular interest would be further gravity work in the vicinity of cross-cutting resistive features in the TEM contours at 2175S/675E and 1050S/600E, seeking anomalies in excess of 0.15 milligals. More gravity readings over even a limited area of the grid could provide a valuable comparison with the zones defined by TEM and magnetics. Gravity work at Mary River West can be done rapidly because of the flat and fairly open country. Traverses A and 150N, comprising 134 stations, took two men four days to flag, level, and read. This is about half the rate of coverage by TEM with 30-m loops.

Radiometric. Total-count radiometrics were read every 30 m, along traverses 300 m apart from 2850 N to 2850 S between 750 E and 750W. Results are not presented, as no outstanding radiometric anomalies were found. In general, the radioactivity is least over the granite and greatest over laterite and alluvium near the river in the eastern part of the grid. Zone 5 has the highest average radioactivity.

Mary River West, Traverse 1500 S Extended

Traverse 1500 S at Mary River West was extended east to 2700 E to meet the Gubberah gossan grid and west to 3000 W (Pl. 2). TEM, total magnetic, and gravity readings were made to gain information on the alluvium-covered Masson Formation and the granite/sediment boundary.

Transient electromagnetic. The profiles for delay times 1.1, 5.2 and 10.1 ms for 60-m loops are shown in Plate 7.

The results indicate a block of conductive material between 300 E and 2280 E giving a large TEM response. This block probably consists of Masson Formation beds, with siltstone predominating and carrying varying amounts of graphite and minor disseminated sulphides, such as were found in DDH EM1 at Minglo 2 and at Gubberah South. The varying amounts of conductive material contained in the sub-surface rocks produce peaks and troughs in the profiles at late delay times. Near-surface conductors generate comparatively large responses at early delay times.

The poorly conducting zone west of 300 E is interpreted to contain metamorphosed sediments of the Masson Formation near the Cullen Granite; the similar zone east of 2280 E may contain quartz greywacke beds of the Masson Formation (these crop out south of Traverse 1500 S - Pl. 2).

One side of the TEM loop at stations 2160 E-2280 E and 1140 E - 1200 E , ran fairly close to a grounded fence, but the only spurious effects were at very early delay times.

Gravity and magnetic. The dominant features of the gravity and magnetic profiles (Pl. 7) are the gravity gradient produced by the density contrast between the Cullen Granite and the Masson Formation, and the magnetic anomaly over metamorphosed Masson Formation around the Cullen Granite. Superimposed on these features are smaller-scale features of uncertain origin. The gravity values are disturbed from 480 W to 1230 E; the disturbances are probably mainly the result of near-surface density variations related to the overburden and weathering. The small gravity low from 990 E to 1230 E is near a region of slightly increased TEM values at late delay times. These effects may reflect the presence of a softer, more easily weathered shale containing slightly more graphite than the surrounding rocks.

The coincident gravity and magnetic anomalies peaking near 1830 E in a region of high conductivity may represent a horizon with higher pyrrhotite and lower graphite disseminations than surrounding regions. The magnetic high is on the flank of a high about 0.5 km south of Traverse 1500 S.

Gubberah gossan

Gubberah gossan caps a resistive fissure filling of quartz, galena, and sphalerite in a conductive environment of carbonaceous shales. In 1972, TEM and gravity responses were recorded that may be due to mineralisation and/or structure (Spies, 1974a; Michail, 1974). In 1973, TEM coverage was upgraded, to test the interpretation; the previous gravity work was extended to try to resolve any distinctive response from the mineralisation.

Transient electromagnetic. Previous EM work indicated that TEM gave the best resolution of the resistive structure. The grid was re-read with 30-m loops, with sufficient loop overlap to enable a profile to be constructed across the break in the conductive beds, and to enable the whole grid to be contoured. Contours of response at a 1.1 ms delay time, and the constructed profile, are shown in Plate 9.

These results show a resistive feature cutting across the conductors. This feature follows the trend of the gossan fairly closely and indicates that the fissure filling consists of relatively poorly conducting minerals. Model studies of this gossan confirm this interpretation (Spies, 1974b).

Gravity. Gravity surveys were made which confirmed and complemented the 1972 results. Measurements on core suggest that the sulphide-bearing rock has a density contrast with the sediments of 1.0 g/cm^3 (Michail, 1974). The 1973 work confirms the 1972 conclusions that anomaly resolution is severely impaired by poorly controlled topographic and/or weathering effects, and that the extent of the mineralisation is insufficient to produce a gravity effect significantly larger than these effects. As the 1973 results are very similar to the 1972 results, they are not presented.

Gubberah North

Transient electromagnetic. 60-m loops were used in the area immediately north of the Gubberah gossan to determine whether breaks in electrical anomalies, due to geological structures, occur along the strike extension of the gossan. Steep slopes and cliffs along the traverses caused problems in laying out the loops. There was a high level of geophysical noise, which obliterated readings at late delay times, and, in some places, prevented any reading at all. Noise makes contouring impossible, except when using early delay times.

Plate 9 shows the contours for $t = 1.1$ ms. The readings vary less than at the Gubberah gossan, and were generally lower, suggesting less conductive country rocks; sandstone crops out in the immediate vicinity. Readings were highest in the northwest and southeast corners of the grid, with a trough running from the northeast corner, roughly centred on a steep sandstone cliff. The results are somewhat similar to those at the Gubberah gossan itself, but the contrast in readings is smaller.

Little is known of the effects of extreme topography on TEM readings. Lower readings would be expected from a loop affected by steep topography, i.e. one which does not describe a plane; this may explain the lower readings near the cliff.

Gubberah South

A quartz-hematite gossan crops out from the plain as a northwesterly-trending 200-m-long rise about 1 km south of the Gubberah gossan. Geochemical and geophysical surveys have been made (Shields, 1969; Duckworth, 1969; Watts, 1970; Williams, 1971; Daly, 1971; Bullock, 1972): geochemical anomalies have been detected over the gossan.

The geophysical responses were confused and appeared to be due to carbonaceous rock types. A diamond-drill hole (DDH 1) sited near the southern end of the gossan intersected sandstone and pyritic carbonaceous shale of the Masson Formation and minor galena, sphalerite, and pyrite associated with quartz and carbonate veining centred on 129-134 m down-hole depth (approximately 99-103 m vertical depth).

Transient electromagnetic. 60-m loops were used on the geochemical grid. The results (Pl. 10) showed no evidence of faults, but revealed a general northwesterly trend, parallel with the strike of the sediments. The contours describe a low-value trough, centred on the gossan, for delay times t = 1.1 and t = 3.2 ms, indicating a resistive feature. With later delay times this trough merges with low values to the west. The high readings in the northeast suggest the presence of shale, and the lower readings to the west sandstone.

The Turam and Slingram results of previous surveys (Williams, 1971) correlate poorly with each other and with the TEM results. Although, like the TEM data, the contours trend roughly parallel with the strike, the anomalies occur in different places.

The self-potential results (Bullock, 1972) show the same trend, but contain an anomalous zone in the east and an undisturbed zone in the west; the position of the boundary between these zones coincides reasonably well with the 20 μV/A contour southwest of the gossanous outcrop for t = 1.1 ms shown in Plate 10.

The TEM results broadly resemble those at Gubberah gossan, a similar resistive feature in a more conducting environment; however, the trough is less marked than at Gubberah gossan, and the resistive feature does not cut across the conducting trends but is parallel to them. It is not clear whether the resistive response is due to the minor sphalerite mineralisation, or to the leached upper parts of the mineralised zone where sulphides have been removed, leaving quartz and hematite behind.

Magnetic. The total magnetic field contours are shown in Plate 10. No magnetic feature was associated with either the gossanous outcrop or the faults. The magnetic gradient in the southwest corner is associated with magnetic highs about 0.6 km west of the grid. These magnetic highs could be caused by metamorphosed sediments around a granite cupola west of the grid or by a greater than normal concentration of magnetic minerals in the sediments. No changes in lithology or structure within the area covered by the grid can be deduced from the magnetic results.

It is interesting to compare the smoothness of these contours with the profiles presented by Williams (1971) for the same area. The smoother results from the 1973 survey derive from the filtering effect due to a greater sensor height (2.5 m, as against 1 m).

Gravity. No significant gravity responses were obtained in the vicinity of the gossan, suggesting that mineralisation intersected in DDH 1 is minor. Plate 10 shows the gravity profiles along Traverses 33S, 35S and 8E. Traverse 8E shows a regional gradient of about 0.7 mGal/km, indicating a gravity low to the south caused by the Cullen Granite. Traverse 33 S shows a slight high of about 0.06 mGal over the gossanous outcrop.

Minglo 2

The area is flat with almost no outcrop. Cullen Granite crops out south of the grid.

Transient electromagnetic. In 1972 a strong TEM anomaly and a nearby magnetic anomaly were found. In 1973 this TEM anomaly was re-surveyed with 60-m and 30-m loops, each with 50 percent loop overlap, to define a drilling target to determine the source of the anomaly. TEM contours are shown in Plate 11. At early delay times all values are generally high, with a west-northwest-trending zone of higher values which has a central, closed high. At later delay times, the zone of higher values and its enclosed peak are more prominent, whereas the rest of the area has a low response, indicating the presence of a weaker conductor.

A short traverse using 10-m loops was surveyed along 84.5W over the peak of the anomaly. The anomaly was not defined, indicating that the penetration using the 10-m loops was not sufficient to reach the source of the anomaly.

The decay curves in Plate 12 show the responses of the conductive overburden at location A and of the conducting horizon at B and C. The response at station A is approximately that of a homogeneous half-space with conductivity of 0.19 S/m (resistivity of 5.3 ohm-m).. Most of the surrounding area with a similar TEM response must have a similar conductivity. The conducting horizon has higher conductivities than this, but none of the stations over the conducting horizon had decay curves which could be quantitatively interpreted. However, assuming the response at late delay times is close to that of a half-space, the conductivity around location C is estimated to be about 2 S/m (resistivity of about 0.5 ohm-m). The decay curves for all stations in the vicinity of the conducting horizon (region defined by the 750 μV/A contour in Plate 11) have time constants at the latest delay time which indicate conductivities similar to that at C. The higher response recorded at C for all delay times is considered to be due to thinner overburden over the conducting rock.

Gravity. Traverse 85 W was surveyed. The results (Pl. 13) show a gradient of about 0.8 mGal/km decrease towards the Cullen Granite to the south. A broad high of about 0.12 mGal centred near 27 S is superimposed on this regional gradient. Two gravity lows occur, at 18 S and 39 S, of 0.07 mGal. Approximate calculations show that a horizontal cylindrical body, at right angles to the traverse, of radius 5 m with a density contrast of 0.3 g/cm^3 would produce the observed lows. The highs and lows could be due to rock density variations or variations in overburden thickness.

Drilling. DDH EM1 was drilled by the Northern Territory Geological Survey to test coincident TEM and magnetic anomalies (Pls. 11 and 13). Results are described by Daly (1975). The hole was drilled vertically to a depth of 89 m at grid co-ordinates 86.3W/25.5 S. The core consisted entirely of carbonaceous shale and siltstone. Much of the core has a spotted texture due to thermal metamorphism from the nearby granite. The main sulphide mineral (10% in some zones) is pyrrhotite, which is the probable cause of the distinctive magnetic zone next to the granite throughout the survey area.

Gamma-ray, self-potential, and single-point resistance logs (Pl. 14) were obtained. Physical property measurements were made on selected core; the results are listed in the Appendix.

The water table was at 12.8 m. The low S-P values between 12.8 m and 14.3 m could be caused in part by an electrochemical effect between the saturated carbonaceous shale below the water table and the drier rock above. The S-P log shows no great variations for the remainder of the hole. The single-point resistance log has flat regions separated by regions containing resistive peaks of short wavelength (0.3 to 0.6 m). The radioactive measurements were fairly featureless.

Measurements on the core (Appendix) gave low resistivities, compatible with those estimated from the TEM results, and large IP effects. Wet resistivities, measured with the core saturated with a saline solution, were higher than the dry resistivities; this is due to the IP effect opposing the flow of electric current and so reducing the voltage measured, and increasing the resistivity calculated using this voltage. This effect occurs only in highly conductive rocks with large IP effects (M. Idnurm, pers. comm.).

The specific gravity measurements gave values about 0.4 greater than those of Michail (1974) on carbonaceous shale from near the Gubberah gossan. The magnetic survey data and drilling results at Minglo 2 indicate the hole is in an area of metamorphosed sediments, and the larger specific gravities measured at Minglo 2 may be due to the metamorphic effects. The absence of a distinct gravity anomaly suggests that, in the area of the gravity traverse, specific gravities of the country rock vary little from those measured.

The magnitude of the magnetic susceptibilities measured are not sufficient to explain the 1500-nT vertical magnetic field anomaly detected in 1972 at 90W/22.5S (Pl. 13). However, the effect of remanent magnetism has not been considered; furthermore, the pyrrhotite probably has a variable distribution.

CONCLUSIONS AND RECOMMENDATIONS

Surveying at Mary River West revealed a lithological control on geophysical results, allowing zones of different responses to be defined; the TEM and magnetic results were used to define these zones. Magnetic anomalies originate in metamorphosed sediments around the intrusive Cullen Granite; carbonaceous shales are considered to be responsible for the electromagnetic and self-potential anomalies. The limited gravity work did not locate any anomalies that could be due to mineralised bodies. Investigation of TEM anomalies using gravity and geochemical methods would help to determine their significance, and is required before drilling targets can be selected.

The resistive zone of the Gubberah gossan was defined more closely and traced north. The rugged topography in this area hinders geophysical surveying, particularly gravity; a prohibitive amount of topographic surveying would be required for computation of the necessary terrain corrections. Variations in lithology and depth of weathering would probably mask an anomaly of about 0.5 mGal, which is the maximum amplitude expected from a model of the mineralised body, based on drilling results.

TEM results at Gubberah South show the presence, under soil cover, of carbonaceous shale to the east, and less conductive rock, probably sandstone, to the west. The absence of a significant gravity response over the gossan suggests that sulphide mineralisation is minor. No further geophysical work is recommended.

Diamond drilling revealed the source of the TEM anomaly at Minglo 2 to be carbonaceous pyrrhotitic shale, and the nearby magnetic anomaly is considered to be due to a local concentration of pyrrhotite.

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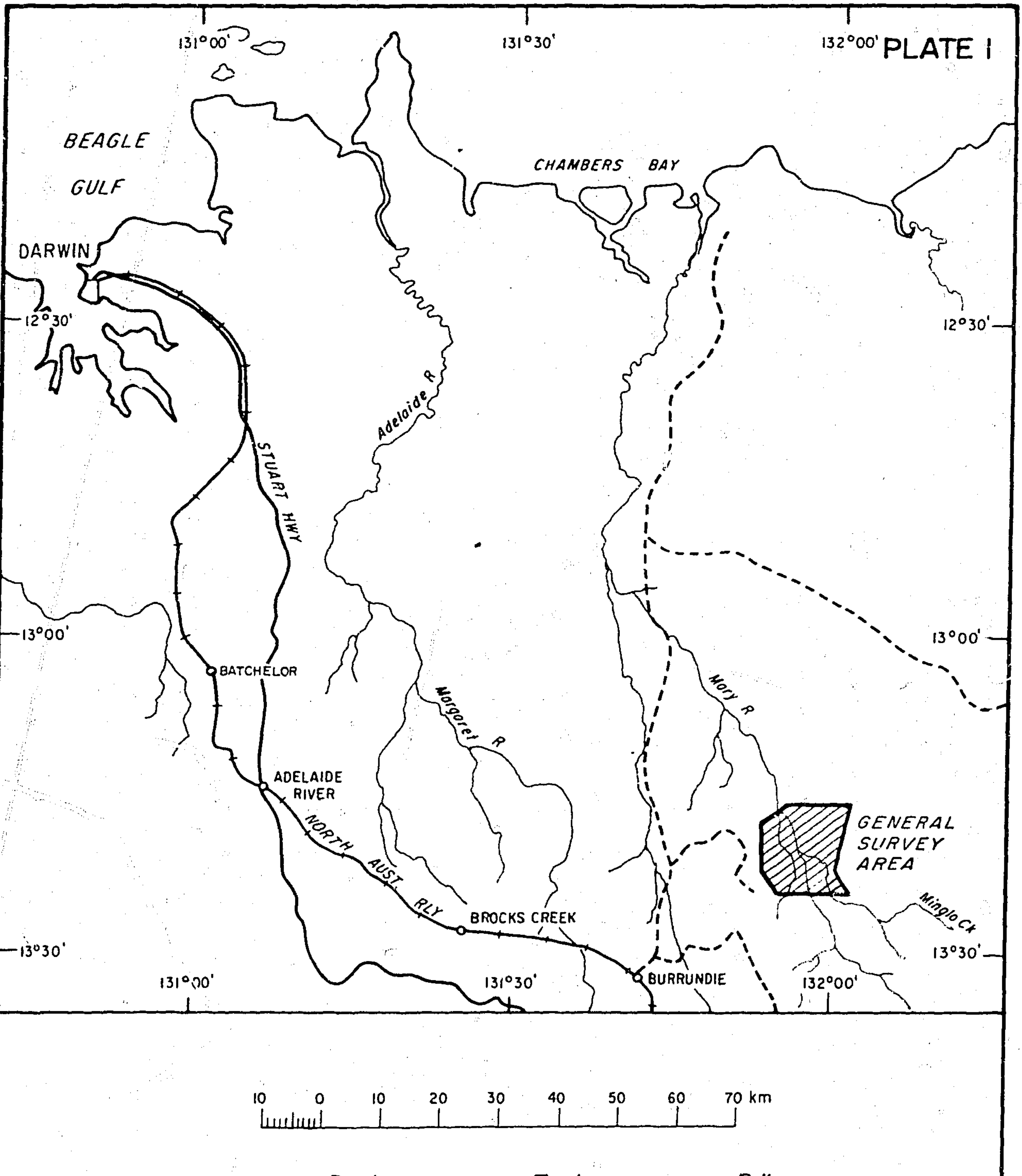
APPENDIX

Laboratory measurements on drill core from Minglo 2 area (DDH EM1)

Lab No.	Depth (m)	Geological description	Susceptibility (c.g.s. x 10^{-6})	Specific gravity	Porosity (%)	Resistivity (ohm-m) dry	Resistivity (ohm-m) wet at 1000 Hz	wet at 3 Hz	wet at 0.1 Hz	Frequency effect (%)
74/1	15.9	Carbonaceous shale	170	2.95	< .1	0.18	1.0	7.2	12.4	47
74/2	30.5	Carbonaceous shale	440	2.86	< .1	0.19	11.8	19.6	35.8	42
74/3	36.6	Carbonaceous shale	480	3.04	< .1	0.17	1.5	6.2	13	61
74/4	43.9	Carbonaceous shale	540	2.73	< .1	0.03	0.7	4.7	14	110

Notes: For wet-resistivity and frequency-effect measurements, specimens were saturated under vacuum with saline solution of conductivity approximately 5 x 10^{-2} S/m.
Frequency effect is $100\ (\rho_{0.3} - \rho_{3.0})\ /\ \rho_{3.0}$



LOCALITY MAP, 1973 GROUND SURVEY

BMR Report 206 (Microfiche 30)

D52/B7-674A

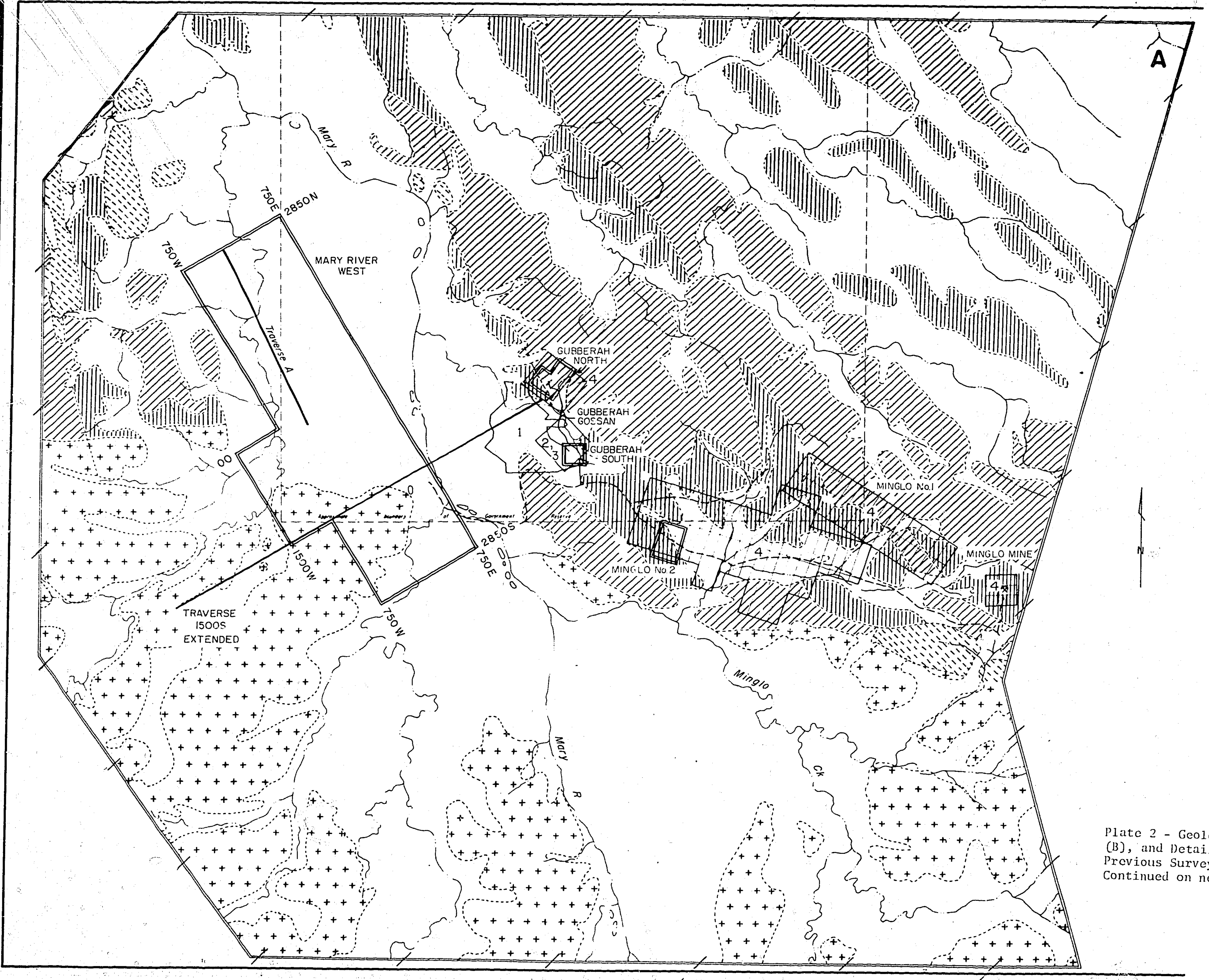


Plate 2 - Geology (A), Aeromagnetic Contours (B), and Detailed Locations of Present and Previous Surveys.
Continued on next frame.

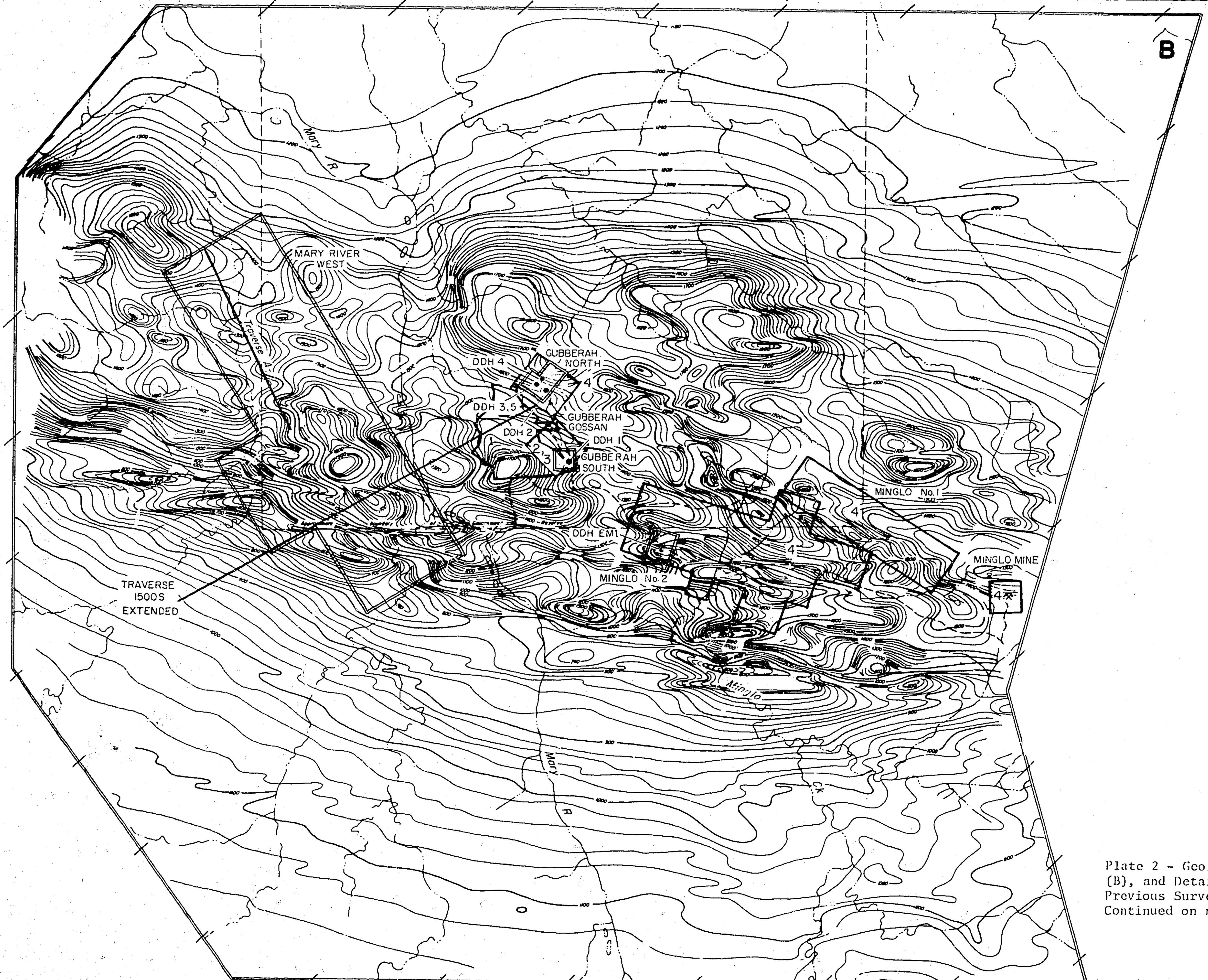


Plate 2 - Geology (A), Aeromagnetic Contours (B), and Detailed Locations of Present and Previous Surveys.
Continued on next frame.

Boundary of area surveyed by ground geophysics prior to 1973

1. *Duckworth (1969/90)*
2. *Williams (1971/34)*
3. *Bullock (1972/52)*
4. *Michail (1974/166)*

Road or track

River or stream

Boundary of airborne survey, 1972

1200

1300

Total magnetic intensity contours

Areas covered by 1973 ground surveys

GEOLOGY

Geological boundary

QUATERNARY

Soil and alluvium, ferruginous cemented detritus

LOWER PROTEROZOIC

Cullen Granite

Biotite-hornblende granite

Masson Formation

Quartz greywacke, quartz conglomerate, sandstone, siltstone, carbonaceous siltstone, banded siltstone

Quartz greywacke

Siltstone predominant

1 0 1 2 3 4 5 km

GEOLOGY (A), AEROMAGNETIC CONTOURS (B), AND DETAILED LOCATIONS OF PRESENT AND PREVIOUS SURVEYS

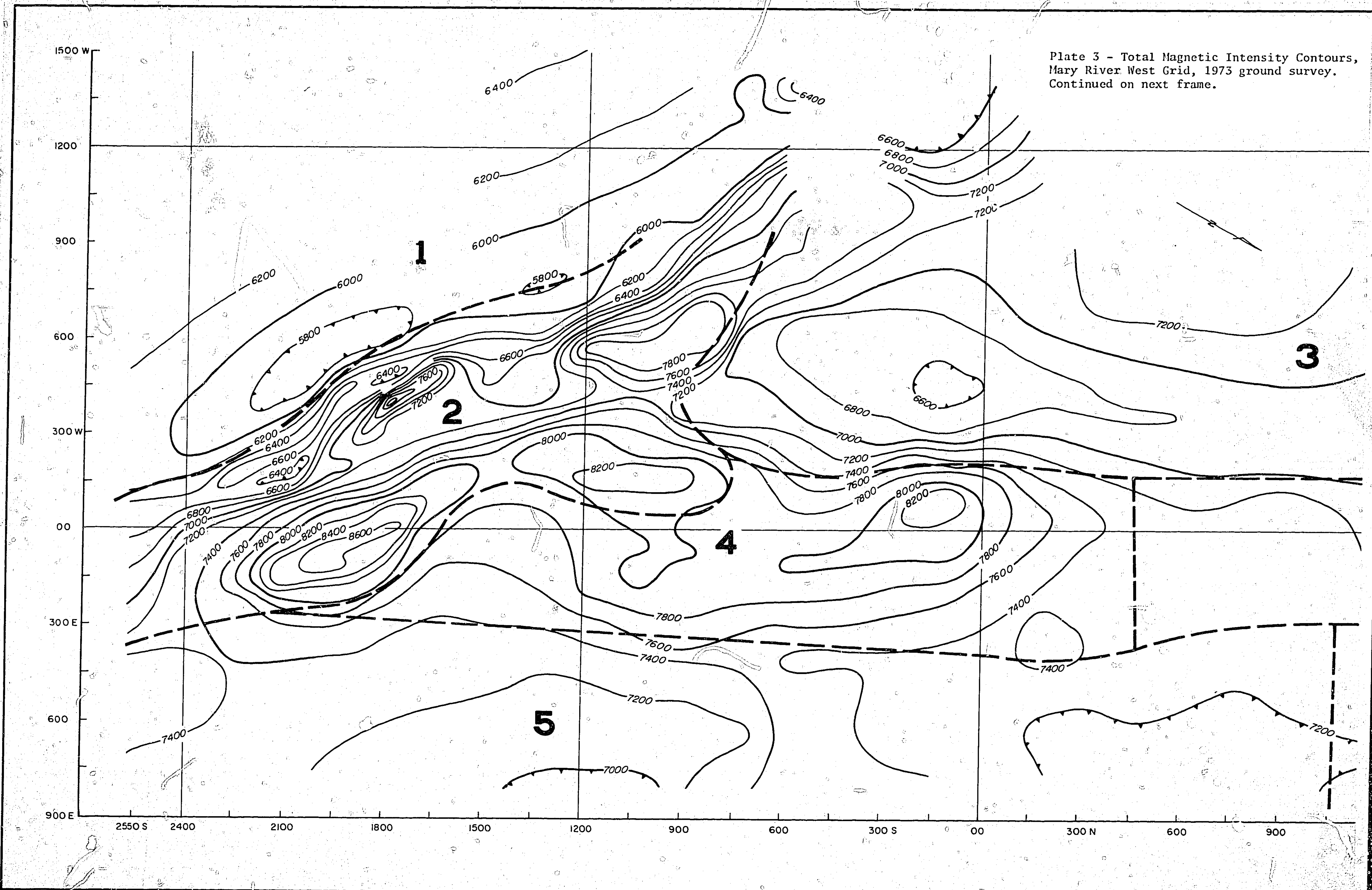


Plate 3 - Total Magnetic Intensity Contours, Mary River West Grid, 1973 ground survey. Continued on next frame.

TOTAL MAGNETIC INTENSITY CONTOURS, MARY RIVER WEST GRID, 1973 ground survey

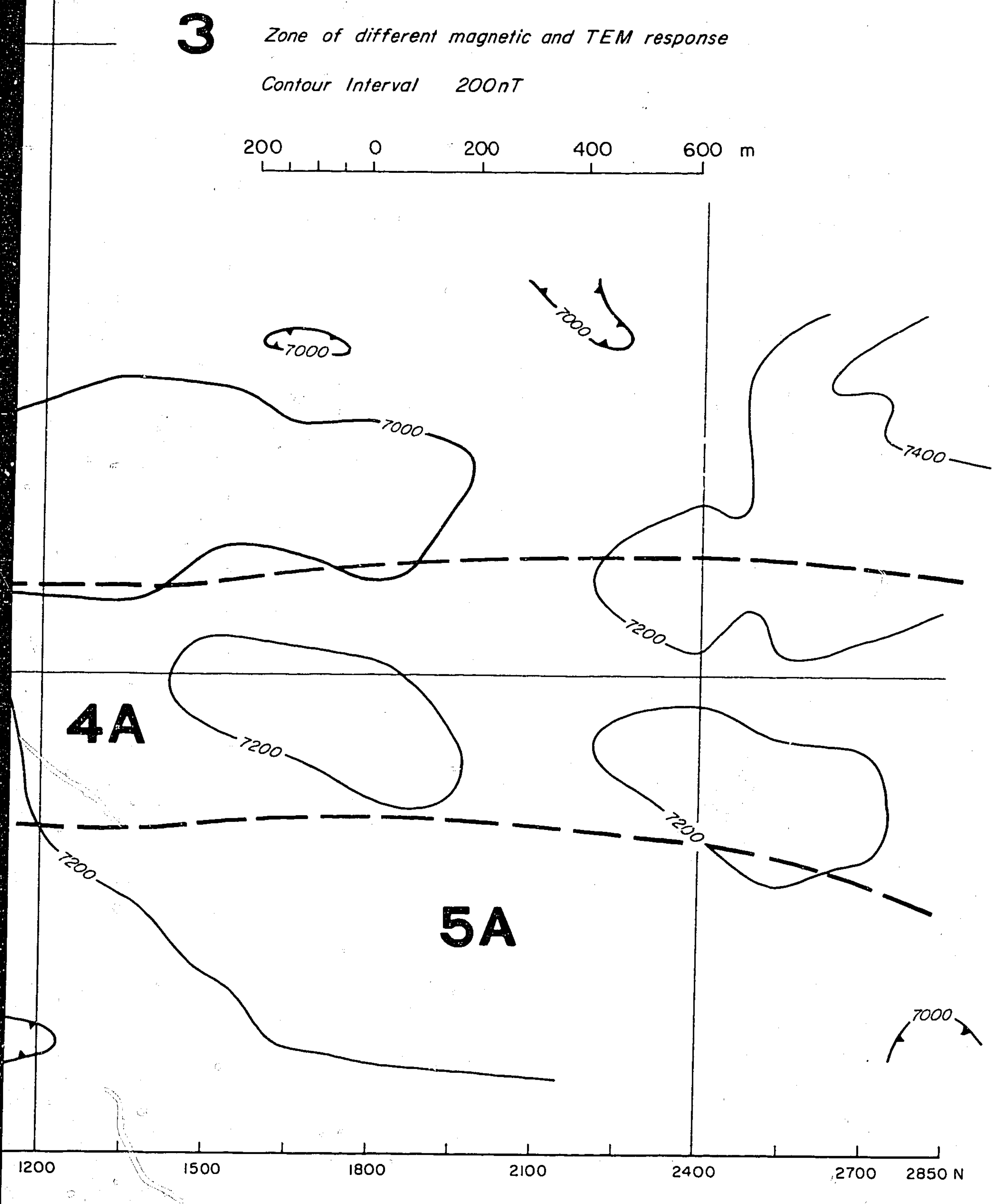


Plate 4 - TEM Contours, Mary River West Grid, 1973 ground survey.
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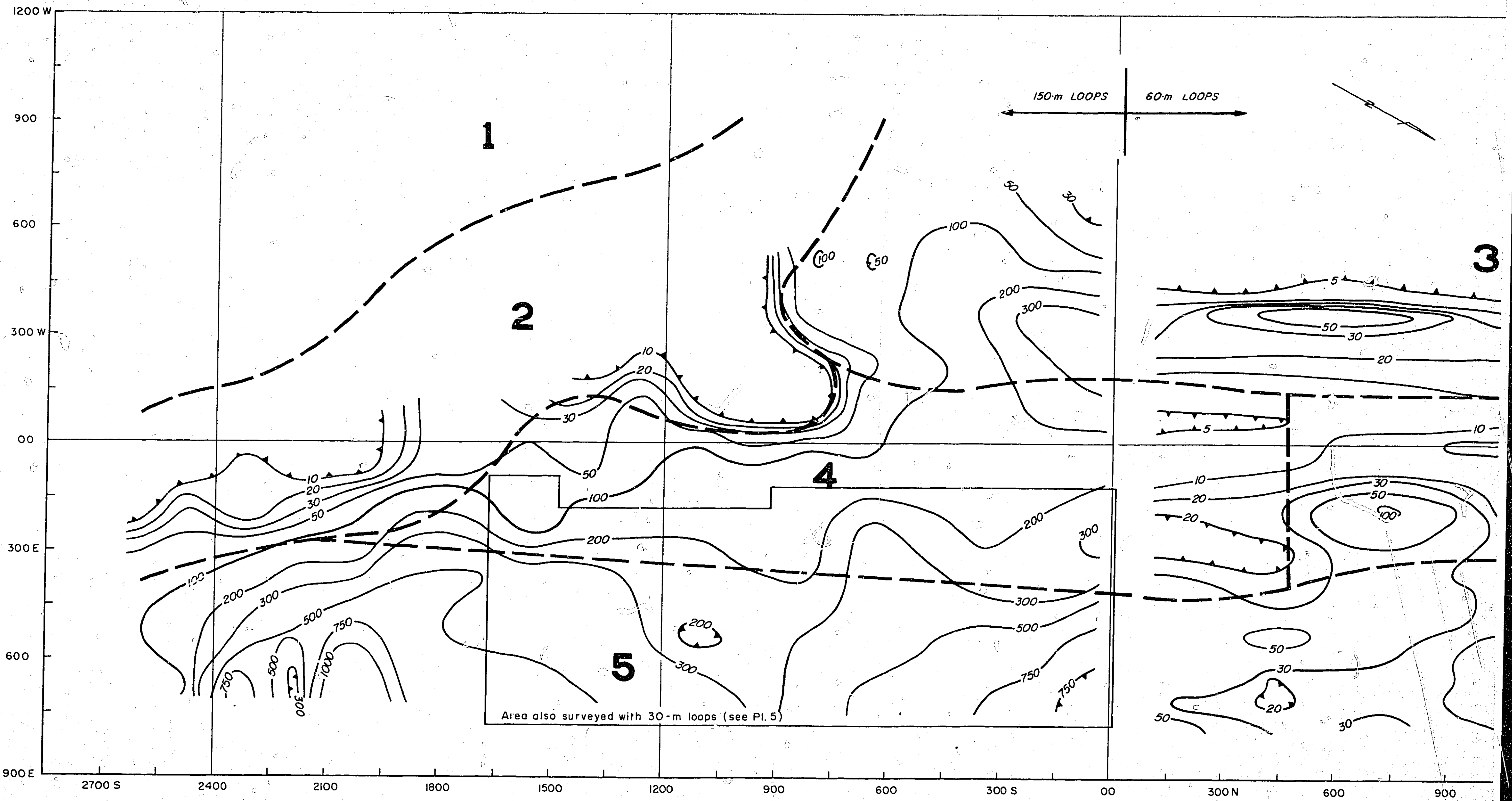
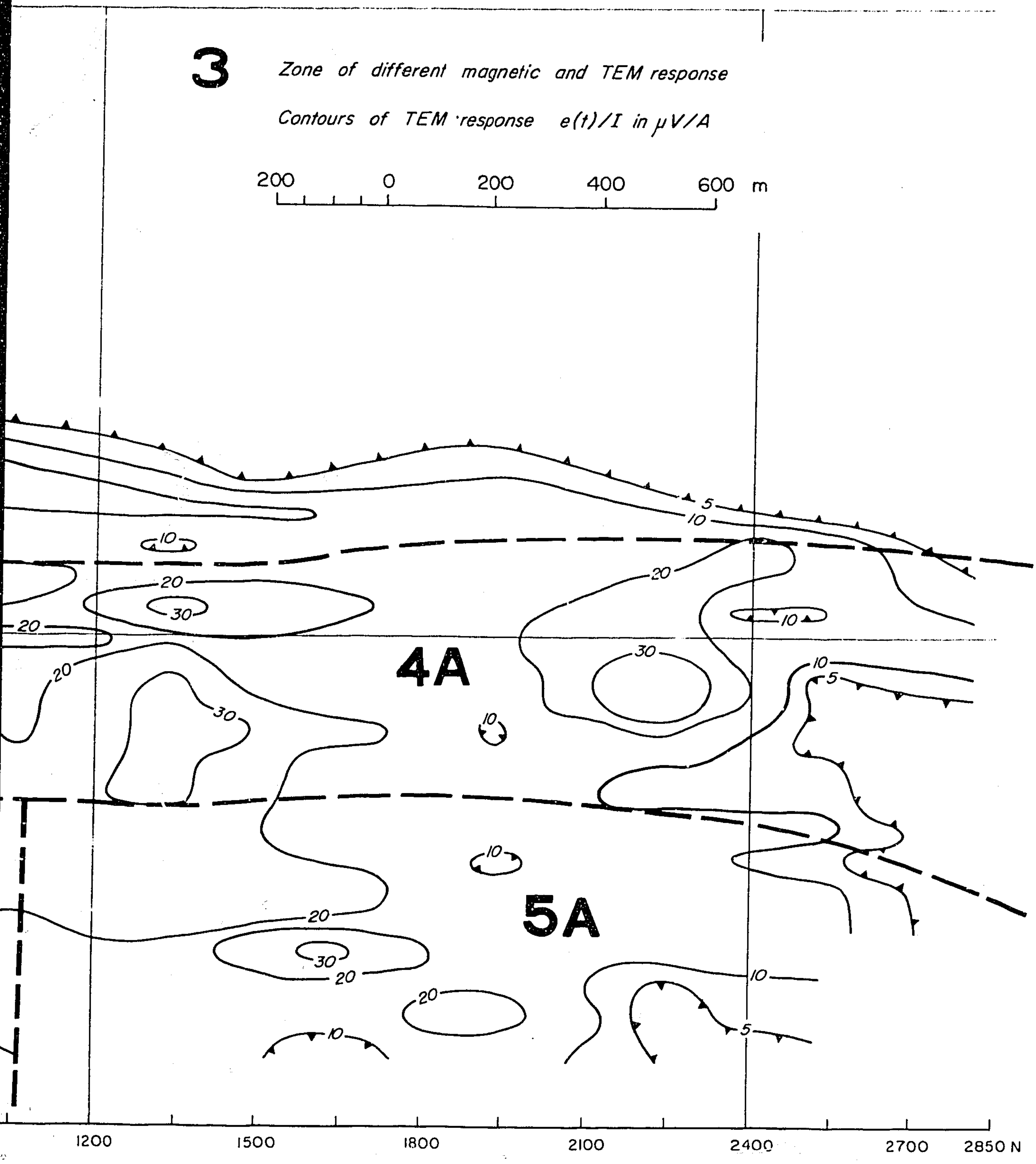
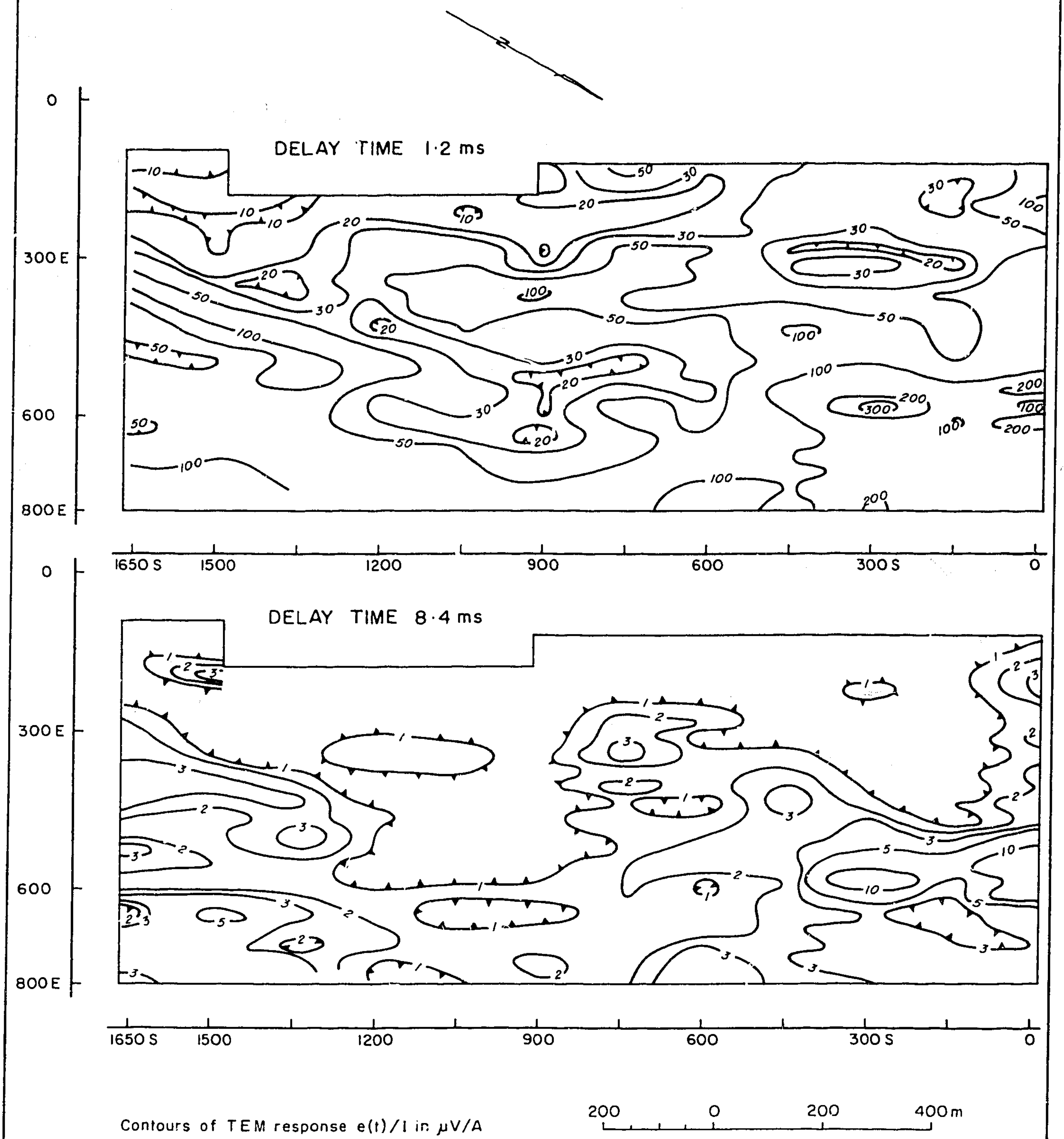


TEM CONTOURS, MARY RIVER WEST GRID, 1973 ground survey

Delay time 8·4 ms, 150-m and 60-m loops





Contours of TEM response e(t)/I in µV/A

TEM CONTOURS, MARY RIVER WEST GRID, 1973 ground survey
Area covered by 30-m loops. Delay times 1·2 ms, 8·4 ms

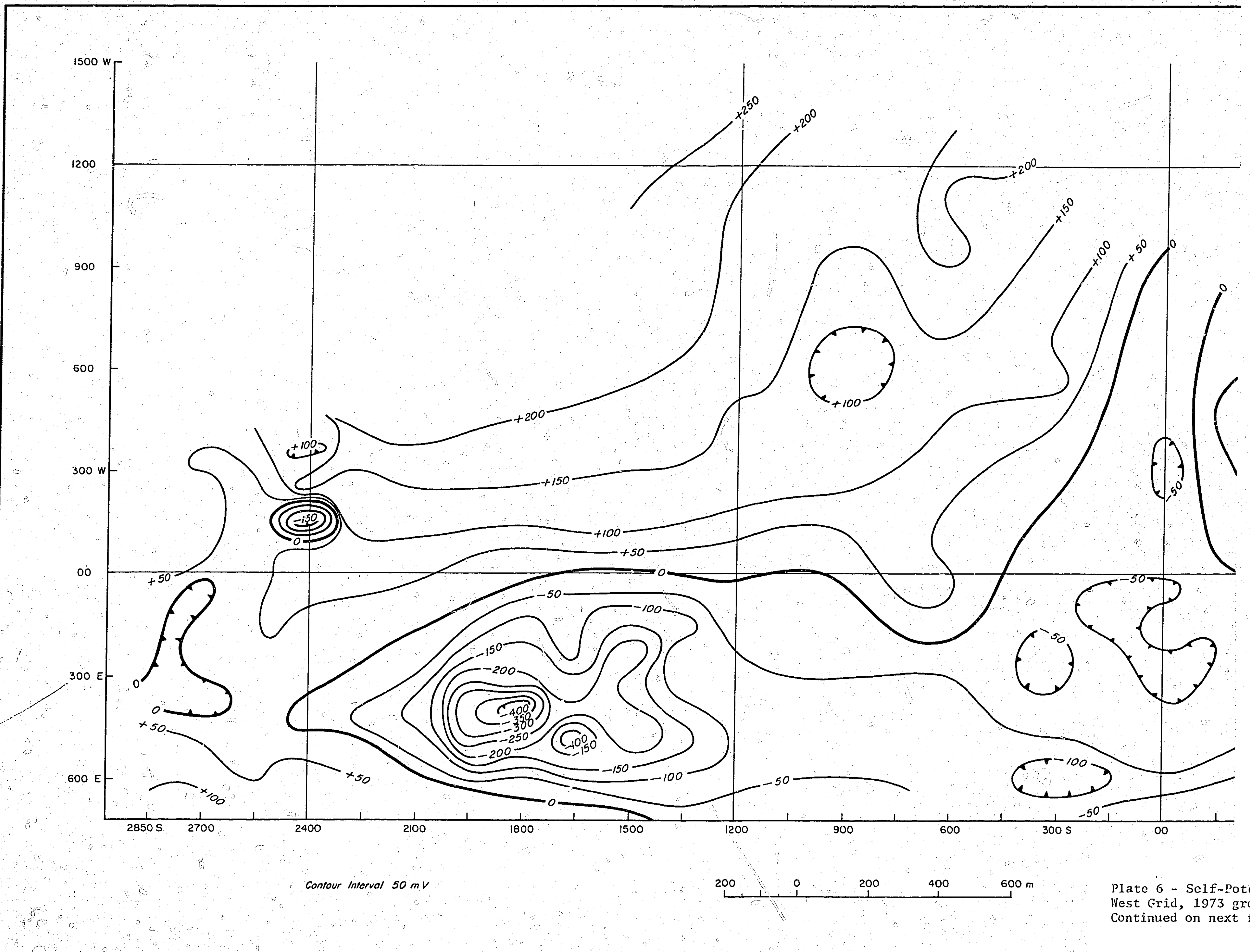
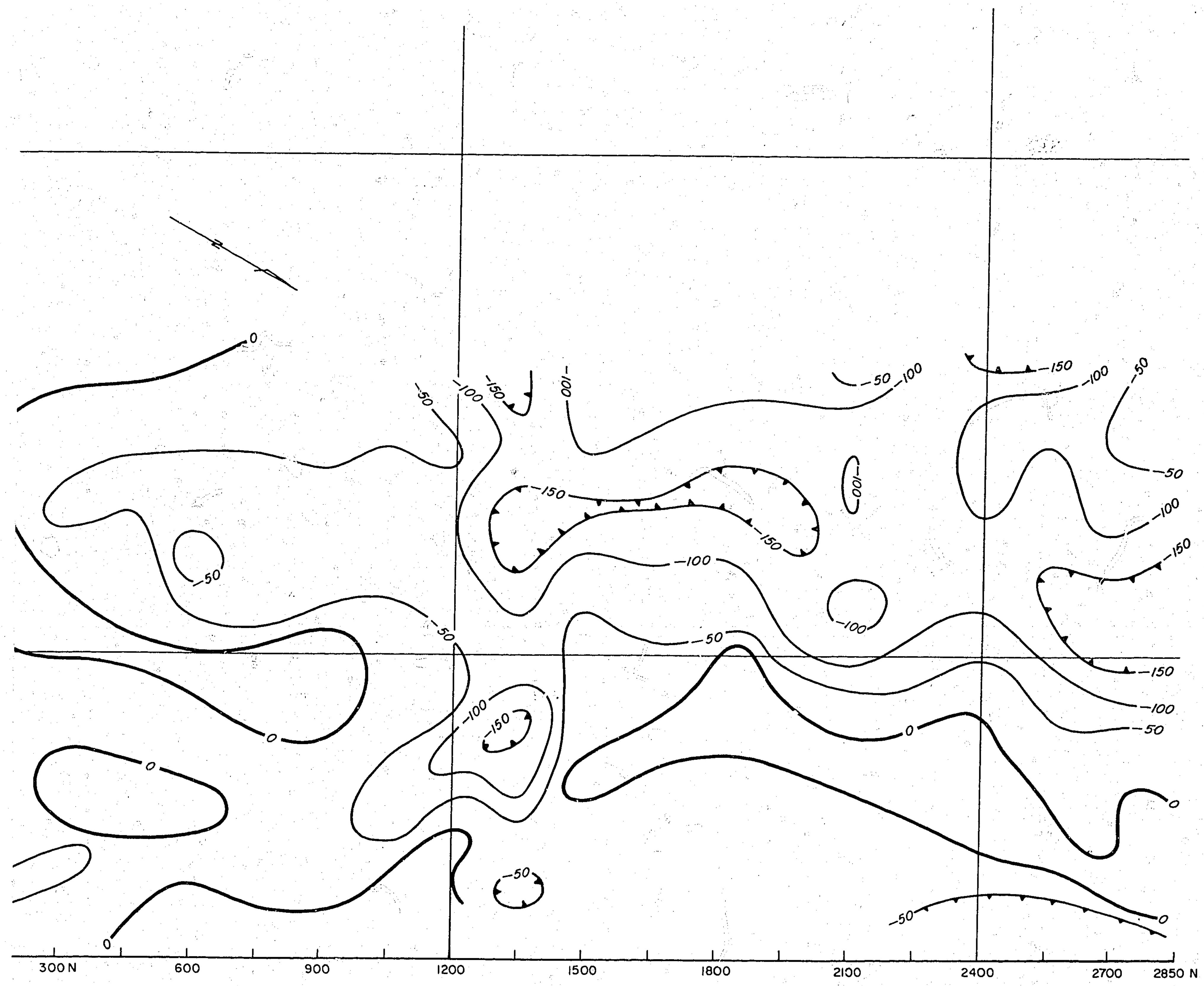


Plate 6 - Self-Potential Contours, Mary River West Grid, 1973 ground survey.
Continued on next frame.

PLATE 6



SELF-POTENTIAL CONTOURS,
MARY RIVER WEST GRID, 1973 ground survey

D 52/B7-682

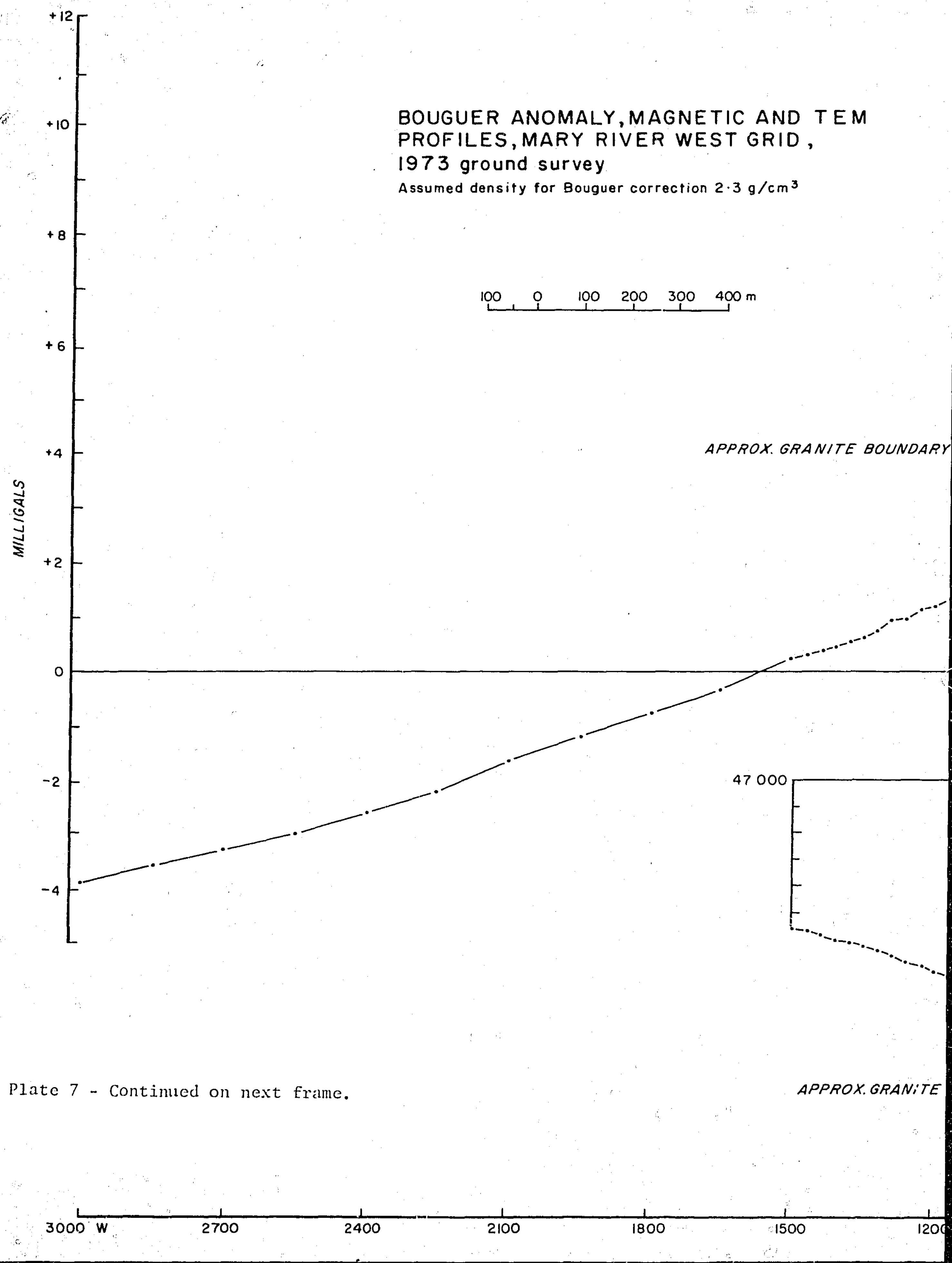


Plate 7 - Continued on next frame.

Bouguer Anomaly, Magnetic and TEM Profiles,
Mary River West Grid, 1973 ground survey.

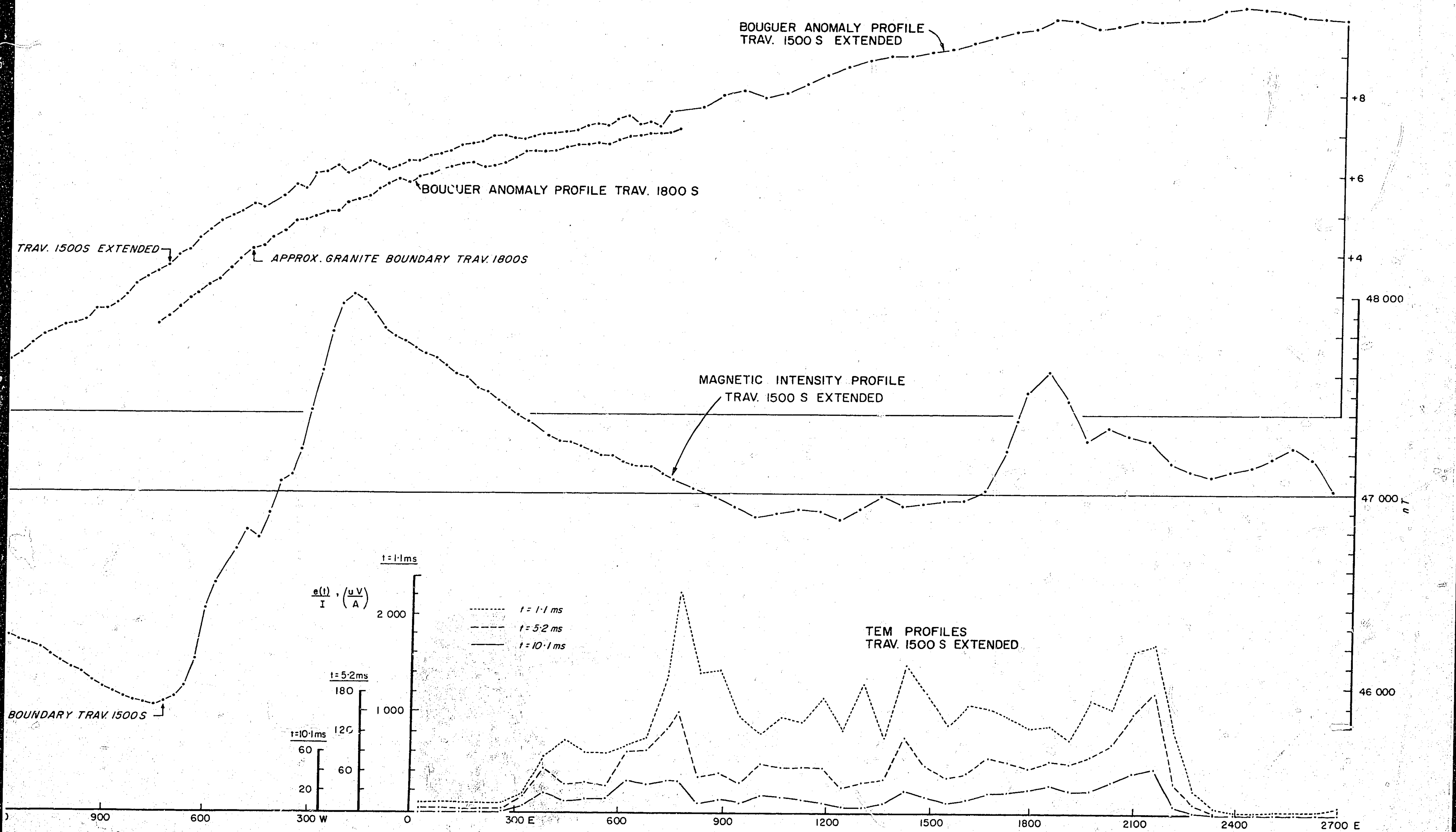


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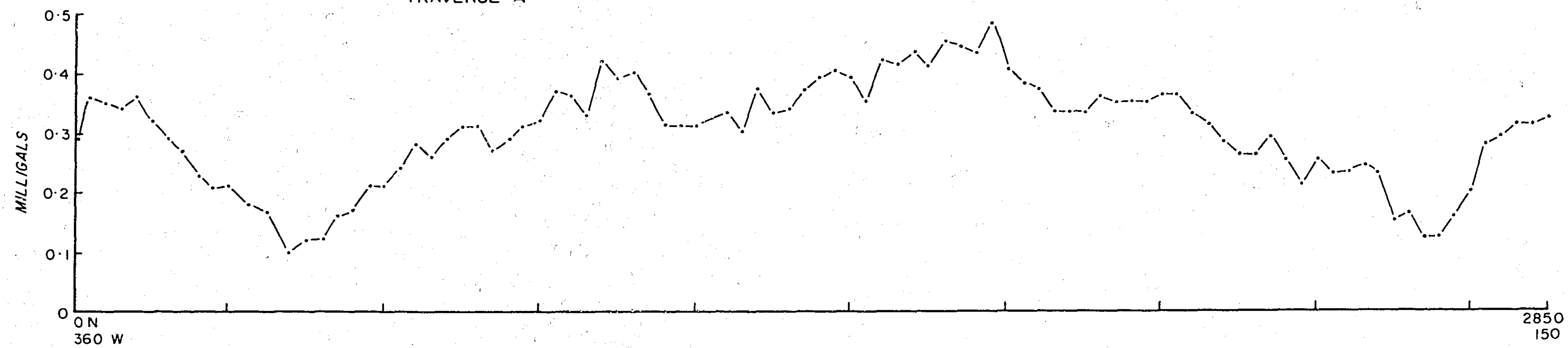
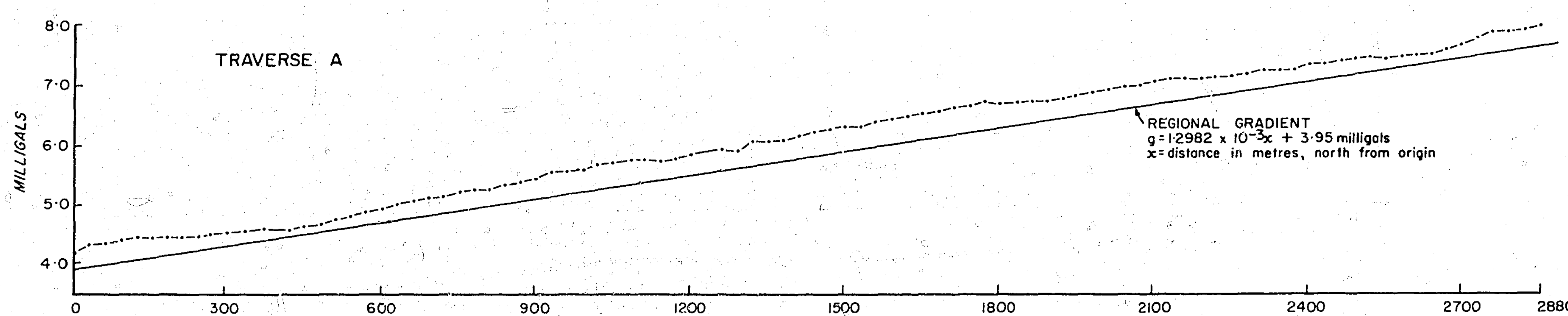
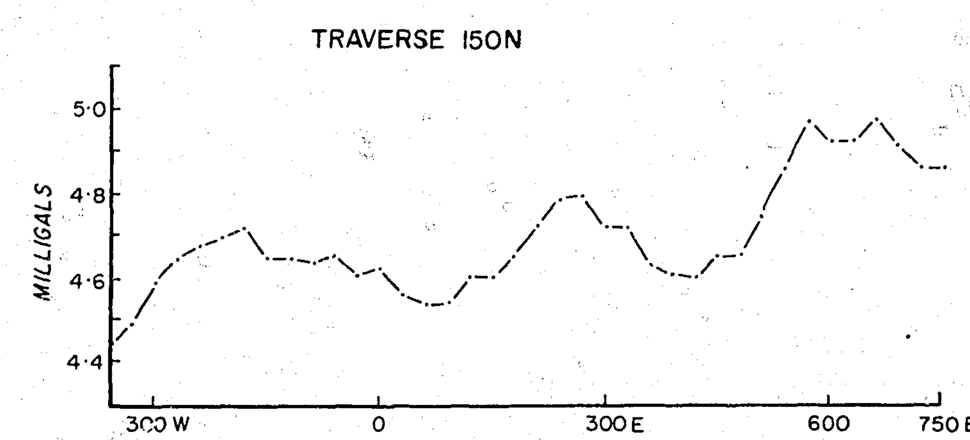
PLATE 8



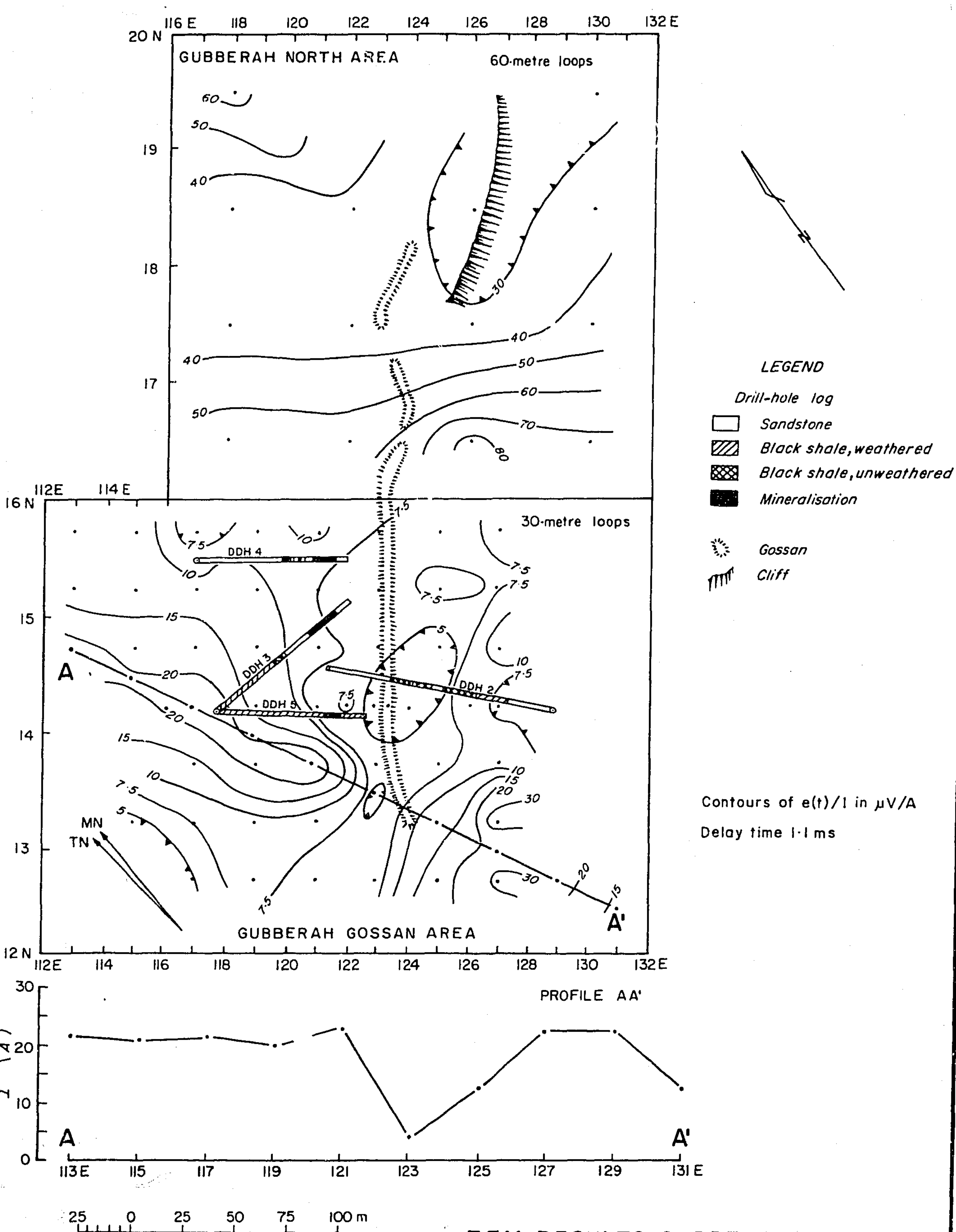




100 0 100 200 300 400 m

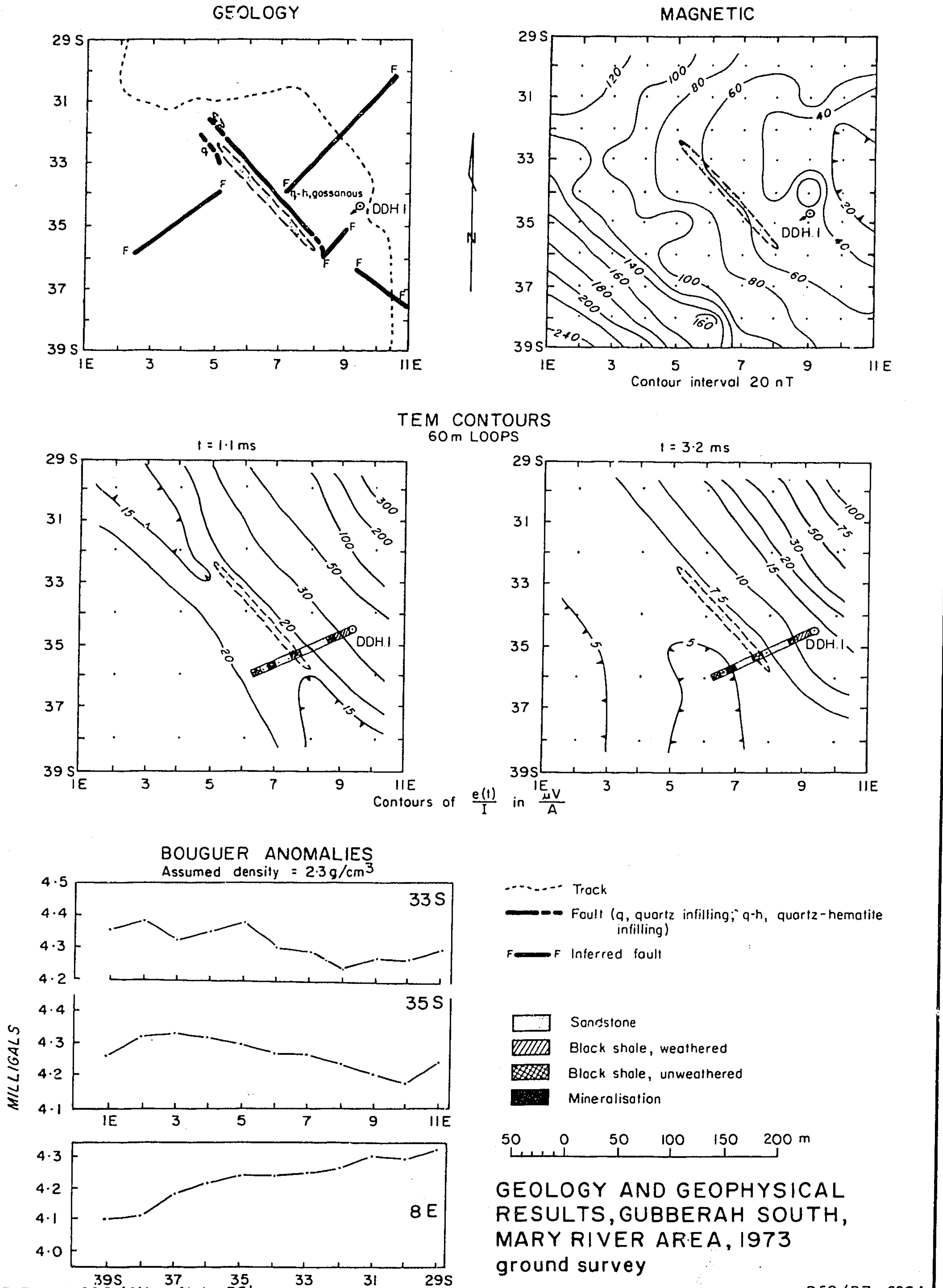
BOUGUER ANOMALY PROFILES, MARY RIVER WEST GRID, TRAVERSES A AND 150 N, 1973 ground survey

Assumed density for Bouguer correction 2·3 g/cm^3



TEM RESULTS, GUBBERAH GOSSAN AND GUBBERAH NORTH, MARY RIVER AREA, 1973 ground survey

PLATE 10



GEOLOGY AND GEOPHYSICAL RESULTS, GUBBERAH SOUTH, MARY RIVER AREA, 1973 ground survey

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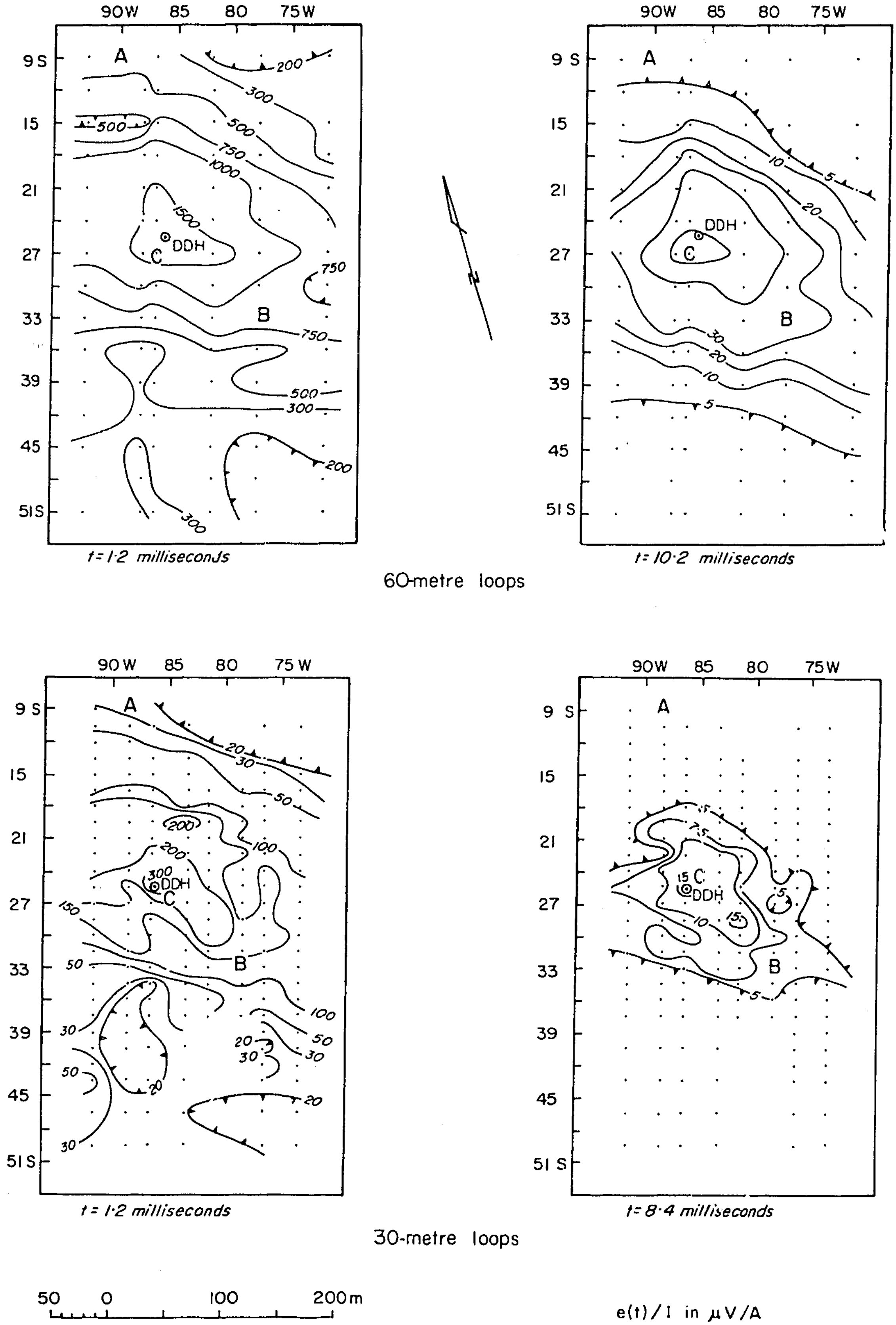
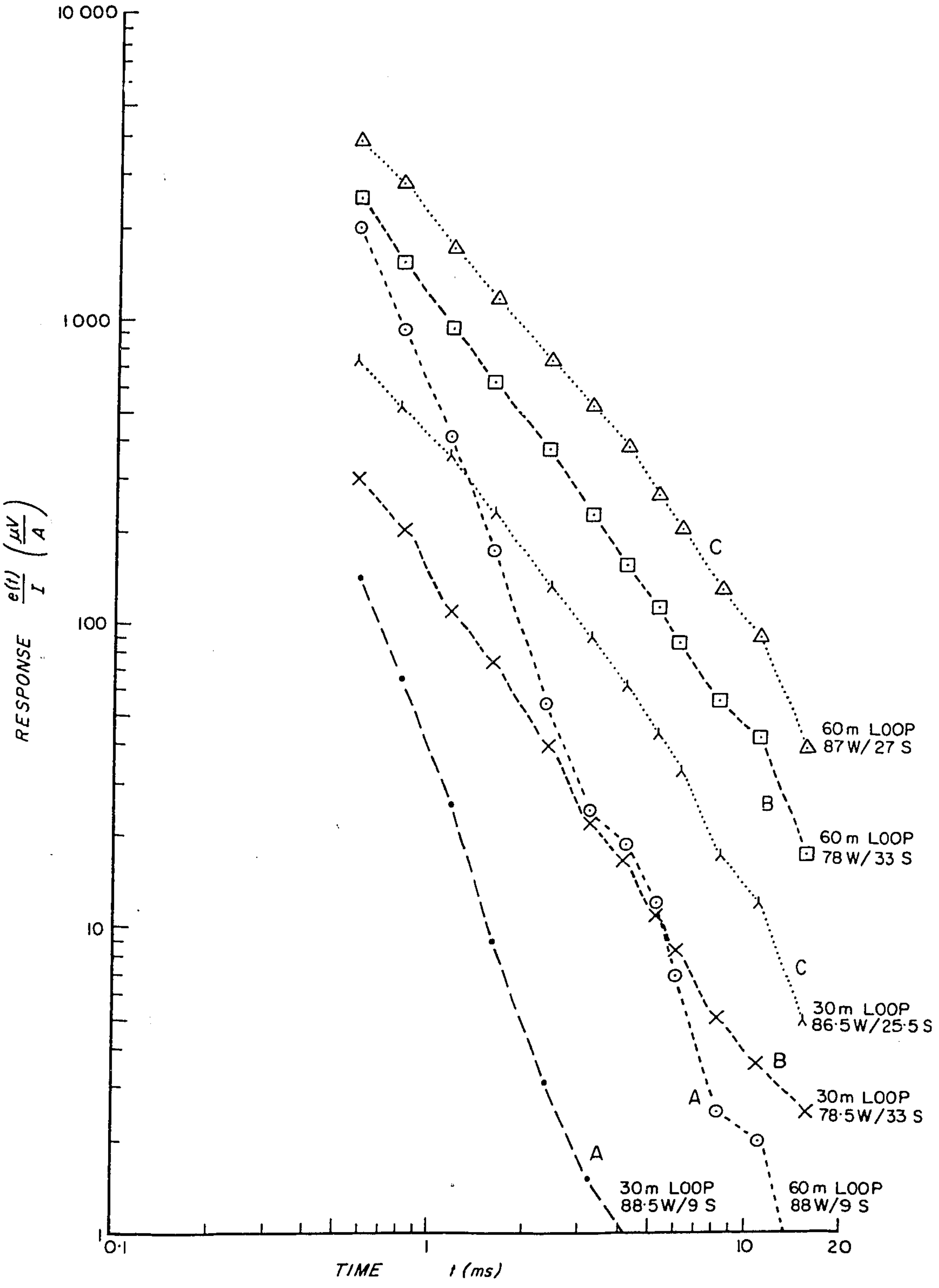
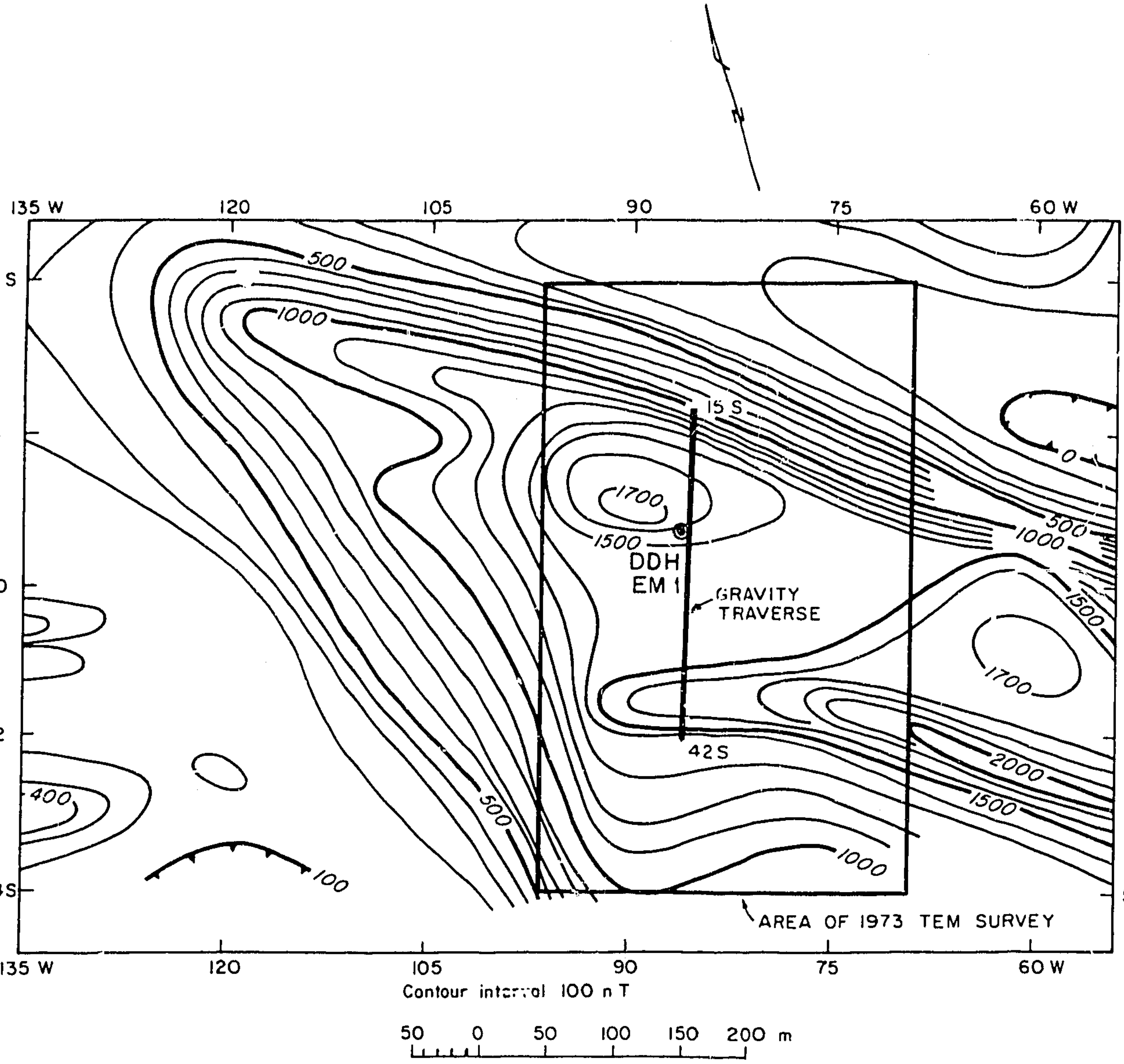
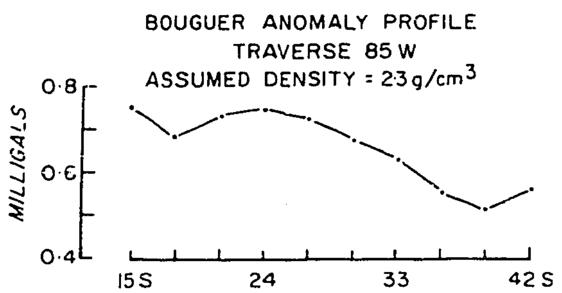


TEM CONTOURS, MINGLO 2, MARY RIVER AREA, 1973 ground survey



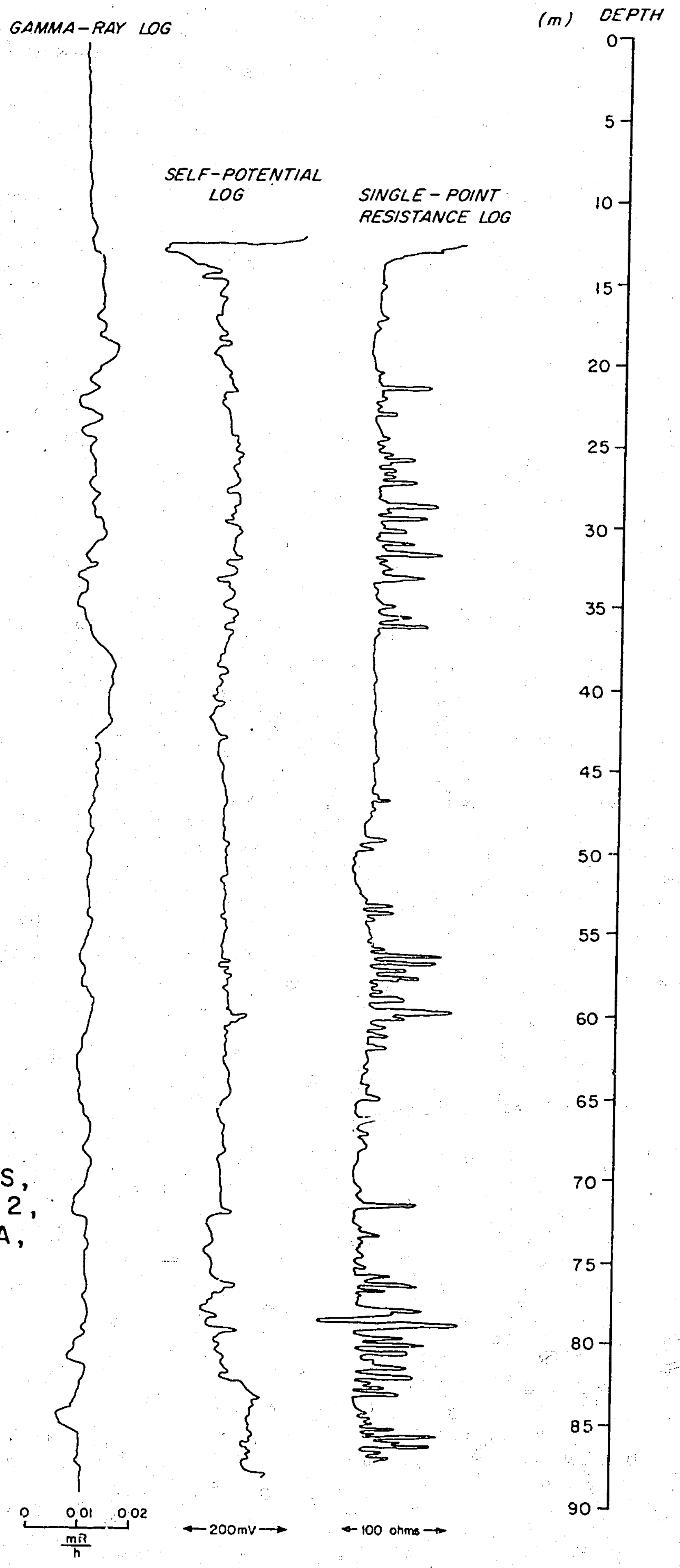
TRANSIENT DECAY CURVES
(at A, B, C; see Pl.11), MINGLO 2,
MARY RIVER AREA, 1973 ground survey





BOUGUER ANOMALY PROFILE, TRAVERSE 85W, MINGLO 2, MARY RIVER AREA, 1973 ground survey

Vertical magnetic intensity contours after Michail (1974)



GEOPHYSICAL LOGS, DDH EM1, MINGLO 2, MARY RIVER AREA, 1973 ground survey

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