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# BUREAU OF MINERAL RESOURCES, GEOLOGY AND GEOPHYSICS

Record 1974/135

# CLONCURRY AREA GEOPHYSICAL SURVEY
# QUEENSLAND 1972



by

N. Sampath and R.D. Ogilvy

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## SUMMARY

The Bureau of Mineral Resources made a geophysical survey in 1972 in the Mount Isa/Cloncurry area of northwestern Queensland to test the response of geophysical exploration methods over known copper mineralization in selected areas in the Marraba Volcanics, Marimo Slate, and Corella Formation. Methods used were magnetic, Turam and transient electromagnetic, induced polarization, and self-potential. In addition to these tests, resistivity depth soundings were made in two areas east of Cloncurry, where Mesozoic sedimentary rocks overlie Precambrian rocks. The objective of this work was to investigate electrical properties of the Mesozoic sedimentary rocks to see what problems would be encountered in penetrating these rocks to map the conductivity of the underlying Precambrian rocks. Rock samples were collected from selected localities and formations in the Mount Isa/Cloncurry area for laboratory tests.

The results in the Marraba Volcanics show that shear zones are easily detectable but that the minor sulphides associated with the shear zones are difficult to detect. The Marraba Volcanics have generally high resistivities and are magnetic. A highly conductive carbonaceous shale in the Marimo Slate was detected easily; this bed was not magnetic. The work in the Corella Formation was a reconnaissance survey and the results are inconclusive. Magnetic and induced polarization anomalies are possibly due to magnetite, and induced polarization anomalies possibly due to sulphides. There is a magnetic anomaly associated with the 'Lakeview Dolerite' dyke and an induced polarization anomaly associated with outcropping mineralization east of the dyke.

The resistivity depth soundings over the Mesozoic sediments east of Cloncurry showed that the Wenner configuration used was probably not the best choice, and that it may be difficult to penetrate highly conductive layers in the Mesozoic sediments.

## 1. INTRODUCTION

The Bureau of Mineral Resources (BMR) made a geophysical survey in 1972 in the Mount Isa/Cloncurry area of northwestern Queensland to test the response of geophysical exploration methods over known copper mineralization in selected geological environments. The areas chosen for survey were in the Marraba Volcanics around the Celestial, Chinaman, and Dawn mines, in the Marimo Slate around the Red Sierra South mine, and in the Corella Formation north of Timberu homestead (Pl. 1). In addition to these tests, resistivity depth soundings were made in two areas east of Cloncurry where Mesozoic sedimentary rocks overlie Precambrian rocks. The object of this work was to investigate electrical properties of the Mesozoic sedimentary rocks to see what problems would be encountered in penetrating these rocks to map the conductivity of the underlying Precambrian rocks. Plate 1 shows all the areas where work was done. Rock samples were collected from selected localities and formations for laboratory tests; the results of these tests are in the Appendix.

The survey commenced on 26 June and ended on 6 October 1972. BMR personnel were N. Sampath (Party Leader), R.D. Ogilvy (Geophysicist), and H.G. Reith (Technical Assistant) plus two field hands and a cook; J.A. Major (Geophysicist) was with the party from 11 September to 6 October. A surveying party of three, led by D.H. Thiedecke, was provided by the Department of the Interior. G.M. Derrick was the geologist associated with the survey. B.R. Spies (Geophysicist) and J.W. Williams (Technical Officer) were associated with the party from 14 September to 6 October to carry out tests with transient-EM equipment.

The parts of this Record dealing with the resistivity depth soundings were written by R.D. Ogilvy and the remainder by N. Sampath.

## 2. GEOLOGY

The areas surveyed, other than the two areas east of Cloncurry, fall within the Marraba 1:100 000 Sheet area, and the geology of this Sheet has been described by Derrick, Wilson, Hill, & Mitchell (1971). Most of the Marraba 1:100 000 Sheet area contains Proterozoic rocks of probable Carpentarian age. The oldest unit is the Argylla Formation, a sequence of acid lava, crystal tuff, and metasedimentary rocks, which forms the core of two broad anticlines along the southern Sheet boundary, and also a narrow belt along the western Sheet boundary. In the centre of the Sheet area it is overlain by basalt (Marraba Volcanics) and quartzite (Mitakoodi Quartzite), but in the west these units are absent and the Corella Formation, a widespread diverse unit of mainly carbonate-rich and calc-silicate granofels, overlies the Argylla Formation unconformably. In the centre of the area the Corella Formation appears to be conformable on the Mitakoodi Quartzite. The Marimo Slate flanks the eastern limb of the Mitakoodi

Quartzite anticline and is considered to be a facies equivalent of the Corella Formation. All these units are intruded by granite and basic rock.

Copper mineralization throughout the Sheet area is related mainly to dolerite dykes and sills, particularly where they intrude the Marraba Volcanics and Corella Formation. Numerous small fissure deposits of copper occur in the Marimo Slate.

The Celestial, Chinaman, and Dawn mines are in the Marraba Volcanics, which consist of basalt, sandstone, siltstone, and minor limestone, agglomerate, and tuff (Derrick et al., 1971, p. 16).

The Celestial and Chinaman mines are about 2 km apart and occur with numerous other small shafts, trenches, scrapings, and pot-holes on a discontinuous quartz vein. The position of this vein is indicated by the mine workings symbols shown in Plate 3. The Chinaman mine occurs near the eastern end of the quartz vein, which trends about 80° to 85° and dips steeply south. The vein cuts cleaved amygdaloidal and massive basalt of the Marraba Volcanics, and appears to be flanked, mainly on its southern margin, by a dolerite dyke (Derrick, pers. comm.).

The Chinaman mine has been used by Mount Isa Mines Ltd as a source of low-grade (2 to 5%) cupriferous silica flux. The mine is an open cut over 100 m long and up to about 20 m deep and 12 m wide. Dolerite occurs along the southern (hanging) wall, and basalt occurs everywhere else in the near vicinity. The main copper mineralization is malachite coatings and thin joint-fillings in quartz-limonite and quartz-chlorite-limonite schist, and small pockets of chalcocite and malachite (Derrick, pers. comm.).

The quartz vein thins to the west and disappears beneath alluvium adjacent to Duck Creek, reappears 600 m west of Duck Creek, and crops out for a further 800 to 900 m to the west, trending about 85° along most of its length. On Traverse 400E of the geophysical grid, at least three closely quartz veins occur, each about 0.5 m thick but pinching and swelling, both laterally and vertically. Zones of chlorite schist border and penetrate the quartz veins. All three veins are mineralized; the southern vein is richest, the central vein poorest. Limonite pseudomorphs after pyrite and/or magnetite occur in parts of gossan developed locally over the veins. Dolerite to the south of the shaft is not extensive. Basalt is the predominant rock type.

On Traverse 200E the quartz vein has a sinistral flexure, near which a narrow shear zone in the metabasics is well developed. Dolerite occurs on the south side of the flexure.

From about Traverse 100E to west of Traverse 0 fine medium-grained dolerite is present to the south of the vein and extends for up to 10 m south before passing into basalt. Near the Celestial mine (Traverse 0) dolerite occurs to the north of the vein and forms both the hangingwall and footwall of the mineralized zone. Gossan after chalcopyrite and pyrite is present at the Celestial mine; malachite, chalcocite, and minor azurite are the main copper minerals. Overall grade is 1 to 3 percent (Derrick, pers. comm.).

The Dawn mine is also in the Marraba Volcanics. Workings extend for about 90 m along a quartz vein trending 60° with steep southerly dip. The vein is almost mined out. The country rock is dolerite and greenstone; on the hangingwall the greenstone is highly chloritic; the footwall consists of massive quartz with small inclusions of chlorite phyllite; malachite coatings are common. The mineralized vein is about 2.5 m thick. Malachite is the main ore mineral; mineralization is sporadic, and is localized in a series of shallow-dipping shears in the quartz vein, which strikes 35° and dips 25° N (Derrick et al., 1971, Appendix 1, p. 4).

The Red Sierra South mine is the southernmost of a series of mines and prospects extending for about 1 km in slate, phyllite, and siltstone of the Marimo Slate. The northernmost mines are the Great Western mines and prospects Nos 5, 6, and 7.

At the Red Sierra South mine the easternmost rocks are siltstone, grey to buff phyllite, and minor interbedded fine-grained sandstone which trend north-northwest. These are flanked to the west by a sequence, 80 to 90 m thick, of black to grey shale, locally carbonaceous and calcareous, which in turn is flanked to the west by massive ridge-forming quartzite. Two zones of mineralization are present on Traverse 180N. One is at the contact between the carbonaceous black shale and grey to buff phyllite to the east, where some shearing and quartz veining are present. The quartz vein dips steeply east, subparallel to cleavage and bedding in the shale, and is discontinuous both along strike and in depth. It is up to about 30 cm thick and contains scattered veinlets of malachite and chrysocolla. No sulphides have been seen in the near-surface workings, but low-grade (0.5%) sulphide mineralization has been reported from drilling results.

A second zone of mineralization occurs in the hangingwall shale, phyllite, and siltstone. This zone extends from a point about 3 m east of the black shale eastwards under the alluvium. It is characterized by numerous small north-northwest-trending shear and breccia zones infilled with quartz veins, some up to 15 cm thick and locally malachite bearing.

On Traverse 480N a mineralized zone (Great Western No. 7) has been exposed by bulldozing. Carbonaceous shale is absent and the mineralization is probably similar to that in the easternmost buff shale on Traverse 180N. The lode is in vuggy grey to buff shale and silt. The ore carried quartz veins and veinlets of malachite and some chalcocite in a gangue of heavily chloritized, ferruginized, and brecciated buff to pale grey shale. Some shallow-dipping quartz-filled fractures to the west of this zone are also mineralized (Derrick, pers. comm.).

About 3 km north of Timberu homestead, small-scale disseminated copper mineralization occurs in a belt of scapolite-bearing limestone, granofels, and calc-silicate rock in part of the lower Corella Formation. The metasediments are steep-dipping to vertical, and locally show minor drag folding along shears. The copper occurs as chalcopyrite blebs one to two mm in diameter (Derrick, pers. comm.).

The Soldiers Cap Formation crops out east of the Marimo Slate in the Cloncurry 1:100 000 Sheet area, and comprises a lower member consisting of metagreywacke schists and pelitic schists, an intermediate member consisting of quartzites, pelitic metasediments, and metabasalts, and an upper member consisting of metabasalts with chert intercalations. The Corella Formation rests unconformably on the Soldiers Cap Formation. The relations between Marimo Slate and Soldiers Cap Formation are unknown (Glikson & Derrick, 1970).

The Mesozoic rocks east of Cloncurry are of Jurassic to Lower Cretaceous age and comprise continental sandstone, overlain in turn by marine sandstone and by the dominantly argillaceous marine Rolling Downs Group (Grimes, 1972).

## 3. GEOPHYSICAL METHODS

Geophysical methods used were magnetic, electromagnetic (Turam), transient-EM, self-potential, induced polarization, and resistivity. Physical properties of rocks collected in the field were measured in the laboratory.

Magnetic. Vertical magnetic variations of the Earth's magnetic field were measured using either a Sharpe MF-1 fluxgate magnetometer or an Askania type Gf6 magnetic field balance.

Electromagnetic. The Turam method was used. This is a fixed-transmitter, moving-receiver system. The primary field is produced by an alternating current passing through a large loop or a grounded cable. In the present survey, rectangular loops were used. The equipment used was an ABEM Turam 2S unit. The generator was an ABEM 220/660 Hz generator driven by a 2-kW Norman T300 motor.

Self-potential. Measurements were made with a Sharpe VP-6 instrument and with an instrument designed and constructed by BMR.

Induced polarization. The equipment used was McPhar model 2004, using frequencies of 0.3 Hz and 5 Hz. Electrode configuration was dipole-dipole. Results were plotted as pseudo-sections of apparent resistivity, frequency effect, and metal factor.

Resistivity. Resistivity depth soundings were made using a conventional four-electrode expanding Wenner configuration, with the mid-point fixed. A BMR-type direct-current transmitter was used; this consisted of a direct-current power rectifier unit supplied by a 1-kW generator driven by a Norman T300 motor. Receiver potentials were measured with a Sharpe VP-6 self-potential meter.

Transient-EM. Transient-EM measurements were made in all areas except those east of Cloncurry. The method and equipment are described by Spies (in prep.).

## 4. WORK DONE AND DISCUSSION OF RESULTS

### Celestial/Chinaman area

A grid was laid down between the Celestial and Chinaman mines; traverse spacing was 50 m and pegs were 30 m apart along the traverses. Methods used were magnetic, Turam, self-potential, and induced polarization. These were used to determine the response over the known sulphide mineralization and to explore for conductors beneath the surrounding alluvium.

Magnetic. The whole grid was covered by the magnetic survey. Readings were taken every 30 m; intermediate readings at 15-m or 7.5-m intervals were taken in anomalous zones. All readings were referred to a common base station 1000E/0.

In general, magnetic anomalies occur over basalt; their amplitudes vary within small distances (7.5 to 15 m), the variations being of the order of thousands of nT.

Strangway (1967) has interpreted magnetic anomalies occurring over volcanic rocks in the following way: volcanic rocks are, in general, highly magnetic and from a paleomagnetic point of view are magnetically stable. Lavas have a high remanent magnetization acquired at the time that the flow cooled through the Curie temperature of its magnetic minerals. The remanent magnetization is the dominant cause of magnetic anomalies associated with basalt. In the field it is common to find sections of reversely magnetized material intermixed with sections of normally magnetized material.

Three profiles are presented in Plate 2, one across the Celestial mine (Traverse 0), one over an area of no outcrop (Traverse 1000E) and the other across the Chinaman mine (Traverse 1800E). The profiles show anomalies typical of those found over basalt in the area. It was not possible to contour the data. There is no correlation between the magnetic results and the known mineralization or between the magnetic and Turam results.

Turam. Two rectangular loops 900 m wide and 800 m deep were laid on the southern end of the grid. The first loop covered Traverses 0 to 900E and the second Traverses 900E to 1800E. Coil spacing was 30 m; station spacing was 30 m except over anomalous regions where it was reduced to 15 m.

The results are presented in Plate 3 as Turam phase difference contours at 660 Hz, and show four main anomalous zones marked A, B, C and D.

Zone A is along the mine workings from the Celestial mine eastwards. The phase difference anomalies are mostly between $-5^{\circ}$ and $-10^{\circ}$ and the corresponding reduced ratio anomalies are about 1.1, indicating poor conductors.

Zone B extends from Traverse 0 to Traverse 550E. It has large phase difference values; the average value of the reduced ratio anomaly is 1.27. The anomalies are due to medium conductors probably associated with a zone of alteration and shearing in the basalt.

Zone C extends from Traverse 0 towards the eastern end of Zone B and east to Traverse 1150E; east of Traverse 1150E the anomalies become weaker, but the zone probably extends to Traverse 1400E. The phase difference anomalies are generally large with large reduced ratio anomalies, though the reduced ratio anomalies are not as uniformly large as the phase difference anomalies. The conductors in Zone C are medium to good, and are near the surface.

Zone C follows a series of small watercourses from Traverse 0 to Traverse 700E. Beyond Traverse 700E the watercourses turn south but Zone C extends further east. The Turam anomalies in Zone C probably follow subsurface water at a shallow depth in a saturated shear zone. The water table is 10 to 20 m deep (Derrick, pers. comm.).

Zone D extends from Traverse 100E to Traverse 600E. The phase difference anomalies are mostly large and the reduced ratio anomalies are moderate; the anomalies are due to poor to medium conductors, probably in zones of alteration and shearing in the basalt.

Turam anomalies occur on Traverses 1700E and 1800E at the Chinaman mine owing to poor to medium conductors.

Self-potential. Traverses 0, 200E, 400E, 600E, 800E, 1000E, 1200E, 1400E, 1700E, and 1800E were surveyed with a station spacing of 30 m. No significant self-potential anomalies were found.

Induced polarization. Traverses 0, 400E, 1700E, and 1800E were surveyed using 30-m dipoles. Results are presented in Plate 4.

Traverse 0. In general, on the southern part, apparent resistivities are high over the basalt and the frequency effects and metal factors are low. At the Celestial mine (Station 0) a minor near-surface resistivity low coincides in position with the Turam anomaly. Minor increases in frequency effect readings obtained near the Celestial Mine indicate that any sulphides present are in very small quantities and at shallow depths.

An apparent resistivity and frequency effect anomaly farther north, centred about 150N, corresponds to Turam Zone B. The results indicate a shear zone to be the probable source of the Turam anomaly, with clay minerals in the upper part of this shear zone being a possible cause for the frequency effect anomaly.

Traverse 400E. A resistivity low at 60S over the mine workings corresponds to Turam Anomaly A. Another resistivity anomaly corresponds to Turam Anomaly B near 180N. Weak frequency effect and associated metal factor anomalies are apparent also near 60S and 180N. These responses indicate that weak near-surface conductors have little associated sulphide mineralization.

The anomalies between Stations 120N and 210N correspond to Turam Zone B, and indicate a shear zone with clay minerals in it as the most probable cause for the frequency effect anomaly.

Traverses 1700E and 1800E. Apparent resistivity anomalies across the Chinaman mine on both traverses coincide in position with the Turam anomalies. The frequency effects and metal factor values are small, suggesting no sulphide mineralization.

Typical values for frequency effect per decade for basalt is one to two percent (Keller & Frischknecht, 1966, p. 465) and the frequency effects on all four traverses in the Celestial/Chinaman area fall in this range. The induced polarization results indicate that sulphides in the area most probably occur in very small amounts only. No IP work was done over the area in which Turam anomalies C and D were found because these anomalies were interpreted as being due to presence of saline water along creek beds.

Transient-EM survey. This survey covered Traverses 0 to 700E. Weak anomalies were found on the Turam anomalies in Zones B and C. The results are described in detail by Spies (in prep.).

Dawn Area

Magnetic, Turam, self-potential and induced polarization methods were used in the Dawn area. The grid consisted of ten traverses 100 m apart. Station interval was 30 m.

Magnetic. The magnetic results are shown as contours in Plate 5. The magnetic anomalies are localized, and have short strike length. There are no magnetic anomalies over the mines. The anomalies are due to basalt as in the Celestial/Chinaman area. The readings were referred to a base station at 500E/0.

Turam. A loop of 1000 m by 600 m was laid north of the grid with its front edge along 240N, and all ten traverses were surveyed with a station spacing of 30 m; this was reduced to 15 m over anomalous zones. Coil spacing was 30 m and frequency used was 660 Hz. Phase difference contours are shown in Plate 6. An anomaly extends across all traverses; on Traverses 0 and 100E the phase difference anomalies are greater than -21 and the corresponding reduced ratio values are 1.28 and 1.34, respectively. On the other traverses the phase difference values vary between -19.5 and -7 and the reduced ratio values vary between 1.17 and 1.04. The Turam anomalies are due to a medium to weak conductor about 30 m below the surface. The cause of the anomalies is probably a zone of lateration and shearing in basalt, the country rock.

Self-potential. All traverses were surveyed with a station spacing of 30 m. No significant self-potential anomalies were found.

Induced polarization. Four traverses, 100E, 300E, 600E, and 790E were surveyed using 30-m dipoles. Results are shown in Plate 7.

Low apparent resistivities south of Station 0 on each traverse coincide in position with Turam anomalies. Weak frequency effect anomalies occur with these apparent resistivity and Turam anomalies. The mine workings occur about 30 m north of the Turam anomaly axis. The anomalies are due to a shear zone with very minor sulphide mineralization.

Transient-EM survey. A very weak anomaly, barely detectable above the background noise level, was found over the Dawn mine. The results are described in detail by Spies (in prep.).

Red Sierra South

Nine traverses were pegged over carbonaceous shale associated with known copper mineralization in this area, and over the rocks on either side. Traverses 0 to 240N were 60 m apart and Traverses 240N to 720N were 120 m apart.

Magnetic. All traverses were surveyed with a station spacing of 30 m. Observations were reduced to a common base station 360N/300W. No magnetic anomalies were found.

Self-potential. All traverses were surveyed with a station spacing of 30 m in general and 15 m wherever necessary. Results are shown in Plate 8.

A broad self-potential anomaly of up to 450 mV was found over the carbonaceous shale with which copper mineralization is associated. The anomaly is due to graphite in the carbonaceous shale and not to the very minor sulphide mineralization in parts of the shale.

Turam. A loop 900 m by 800 m was laid east of the grid along 150E and a Turam survey attempted. However, no signal could be detected when the receiving coils were over the carbonaceous shale. This was due to the high conductivity of the shale. Highly conductive zones near the surface can cause such large anomalies that the field intensity may approach zero (Keller & Frischknecht, 1966, p. 398). A grounded cable was also tried without success.

Induced polarization. Traverse 120N was surveyed using 30-m dipoles, but with maximum output from the transmitter the voltage at the receiver was too low to be measured. This was due to the high conductivity of the carbonaceous shale. Laboratory measurements of a surface sample of the conductive rock in this area (see Appendix) gave a resistivity of 2 ohm-m, and the resistivity of the unweathered sub-surface rock is probably much lower.

Transient-EM survey. The carbonaceous shale produced a well defined transient-EM anomaly which coincides in position with the self-potential anomaly; it is not as broad as the self-potential anomaly and appears to define better the boundaries of the shale. The transient-EM results indicate a body of high conductivity. The transient-EM contours are in Plate 9 and are discussed in more detail by Spies (in prep.).

## Timberu area

Four traverses, 0, 500S, 1065S, and D were pegged in the Timberu area. Traverse D is about two km north of Traverse 0 and crosses the 'Lakeview Dolerite' dyke. The traverses are of variable length; Traverse 0 extends from 600E to 390W, Traverse 500S from 450E to 390W, Traverse 1065S from 210E to 570W, and Traverse D from 390E to 390W. The traverses were pegged at 30-m intervals.

Magnetic. Observations were taken every 30 m along each traverse and were reduced to a common base station, Station 0 on Traverse 0. The magnetic profiles are shown in Plate 10.

A high magnetic anomaly occurs between Stations 330E and 510E on Traverse 0. The anomaly starts in dolomite on its western side and ends in quartzite with a broad contact zone between. A susceptibility measurement made in situ at 405E gave a susceptibility per $cm^3$ of $3 \times 10^{-2}$ e.m.u., which indicates the presence of magnetite. The susceptibility measurement was made using the method and equipment described by Hood & Sangster (1967). Magnetite bodies to the southwest are associated with faults, and the magnetic anomaly is probably due to disseminated magnetite. The anomaly between 120E and 210E on Traverse 500S is over a fault, and faulting occurs on Traverse 1065S. It is probable that all these magnetic anomalies are associated with disseminated magnetite in faults.

Traverse D crosses the 'Lakeview Dolerite' dyke and the anomaly between 0 and 60E is due to the dyke. The anomalies west of 195W cross a fault and are probably due to magnetite in the fault.

Self-potential. All four traverses were surveyed with a station interval of 30 m. No significant anomalies were found.

Induced polarization. Two traverses, D and 1065S, were surveyed. No anomaly was found using 30-m dipoles on Traverse D. The traverse was resurveyed and extended using 60-m dipoles; the results (Pl. 11) showed a minor anomaly around Station 120E at n=2 dipole separation and extending to n = 6. Low apparent resistivities and weak metal factors were obtained east of 60E. The position of the induced polarization anomaly on Traverse D is about 100 m east of that of the magnetic anomaly observed between 0 and 60E, suggesting different origins for the two anomalies. The magnetic anomaly is due to the 'Lakeview Dolerite' dyke, and the induced polarization anomaly is considered to be due to minor sulphide mineralization known to occur near 120E.

The induced polarization survey on Traverse 1065S was made using 60 m dipoles. The results (Pl. 11) show a low apparent resistivity and a weak frequency effect zone on the eastern end of the traverse, and this zone may be associated with sulphide mineralization. The traverse needs to be extended east to delineate the anomaly. A weak self-potential anomaly of -25 mV was found at Station 180E which may be associated with minor sulphide mineralization mapped on the surface. A weak frequency effect anomaly and a very weak apparent resistivity anomaly occur on the western end of the traverse and these may also be due to minor sulphide mineralization.

Resistivity depth soundings, Pymurra and Arrolla areas

Resistivity depth soundings were carried out in two areas east of Cloncurry (Pl. 1). A four-electrode Wenner configuration was used; the distance between electrodes was increased in steps keeping the mid-point of the configuration fixed. The expansions were run east-west and north-south to determine the effects of anisotropy.

Plates 12 and 13 show the field results, the initial interpretation of the field results made with a curve-matching technique using asymptotic two-layer curves (Koefoed, 1960), and the computer-interpreted geoelectric cross-sections with the curves from these cross-sections.

In the Pymurra area, the sounding curves indicate the presence of a three-layer sequence with resistivities $\rho_1 > \rho_2 < \rho_3$. The final interpretation (Pl. 12) was:

1. A resistive surface layer (90 to 110 ohm-m) corresponding to a cover of Cainozoic sand and gravel.
2. A second layer of low resistivity (2.3 to 2.8 ohm-m) at a depth of about 8 m. This layer can be attributed to micaceous clay and weathered conductive rock in the Mesozoic strata. The geological log of stratigraphic drill-hole BMR Cloncurry No. 2 (Grimes & Smart, 1970) about 6 km to the south indicates micaceous clay and mudstone at a depth of 8 m.
3. A third layer of moderate resistivity (23 to 27 ohm-m) at a depth of about 30 m. This layer probably represents Precambrian meta-sediments. A resistivity expansion carried out on outcropping Precambrian slate some 3 km to the west indicated a similar resistivity range of 20 to 28 ohm-m.

In the Arrolla area the sounding curves indicate a four-layer sequence with resistivities $\rho_1 > \rho_2 < \rho_3 > \rho_4$. The final interpretation (Pl. 13) was:

1. A resistive surface layer corresponding to a cover of Cainozoic sand and gravel.
2. A second layer of low resistivity (1.5 to 2.2 ohm-m) at a depth of about 7 m. This layer can again be attributed to conductive clay/mudstone within the Mesozoic strata.

3. A third layer of moderate resistivity (15 to 30 ohm-m) at about 25 m. Despite the similarity with the resistivity values obtained for Precambrian slate, bore-hole data indicate that this layer corresponds to Mesozoic shale and mudstone. Nearby bore-holes (Nos 2750 and 2752) intersected blue/black shale at 15 m and 18 m, respectively.

4. A fourth layer of low resistivity at about 120 m. This layer probably corresponds to a sandstone aquifer; bore-hole 2752 about 3 km to the northwest (Pl. 1) intersected a thin sandstone bed under permanent water saturation at 122 m.

The resistivity data obtained in the Arrolla area agree fairly well with those obtained in the Pymurra area about 19 km to the west, indicating uniformity in the near-surface strata. However the similarity in resistivity values of the Precambrian slate and the Mesozoic shale prevents correlation of rock types base on resistivity alone.

East-west and north-south expansions in both areas produced similar curves with little scatter in results, implying horizontal or near-horizontal layering with little lateral inhomogeneity.

The depth soundings in the Arrolla area did not penetrate to the Precambrian basement, assumed to be at 150 to 200 m. This lack of penetration is partly explained by the highly conductive second layer which would have a channelling effect on the current distribution, thereby preventing a sufficient percentage of the current from flowing deeper. With the Wenner configuration, extremely large electrode spacing, a higher-power transmitting system and/or a more sensitive receiver would be needed to overcome the penetration problem. Alternatively, some form of dipole array could be used; this would allow greater depth of investigation and greater operational convenience. The equatorial dipole array has a lower vertical resolution than the Wenner and is more sensitive to near-surface lateral variations. However, because of the uniformity of the near-surface sediments this would not be a serious disadvantage; reliable information could still be obtained on the Mesozoic strata and on the Precambrian basement.

## 5 CONCLUSIONS AND RECOMMENDATIONS

The geophysical results in the Celestial/Chinaman and Dawn areas show that shear zones in the Marraba Volcanics are easily detectable with Turam The sulphide mineralization associated with the shear zones is only minor and not detectable with Turam and self-potential methods, and not easy to detect using induced polarization The Marraba Volcanics have generally high apparent resistivities and are magnetic, in places highly magnetic

In the Red Sierra South area in the Marimo Slate, highly conductive carbonaceous shale produced large self-potential, electromagnetic, and induced polarization anomalies However, the conductivity was too high to allow meaningful Turam and induced polarization results, although the transient-EM method produced good results The sulphide mineralization in the carbonaceous shale is only minor and not detectable in the shale environment The carbonaceous shale is not magnetic

The work in the Timberu area in the Corella Formation was a reconnaissance survey and hence the results are inconclusive Magnetic anomalies are probably due to magnetite in fault zones The sulphides on the surface did not produce significant induced polarization anomalies, and no induced polarization anomalies are associated with the magnetic anomalies on the fault zone Induced polarization anomalies were found on the ends of some of the traverses and were not fully delineated, these traverses need to be extended

On the traverse across the 'Lakeview Dolerite' dyke (Traverse D) a magnetic anomaly was found over the dyke Low apparent resistivities and moderate metal factors were found immediately east of the dyke, these anomalies require further examination

The resistivity depth soundings over the Mesozoic sediments east of Cloncurry showed that the Wenner configuration used was probably not the best choice, and that problems may exist in penetrating highly conductive layers in the Mesozoic sediments

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# APPENDIX

## Laboratory Rock Measurements

The measurements were made by M. Idnurm who supplied the following description of the methods used.

Specimen preparation. The measurements were carried out on cylindrical specimens drilled from the rock samples. The diameters were 2.5 cm and the lengths varied from 2.6 cm to 10.4 cm. Wherever possible the specimens were drilled both parallel and at right angles to the bedding planes or other prominent laminations. The orientations are indicated by the letters P and RA in the table of results.

For water saturation the specimens were first dried overnight in an oven at 100°C and then evacuated in a bell jar for about five hours. Finally tap water was introduced into the bell jar and the vacuum was broken after the specimens were submerged. The specimens were left submerged for several hours before measurements were made.

Porosity measurements. 'Effective' rather than true porosities have been measured. The former is defined as the ratio of total volume of interconnected pores to the total volume of rock.

Resistivity measurements. The resistivities were measured on water-saturated specimens. To minimize surface conduction the specimens were rinsed in deionized water and the surfaces were dried in a blast of air. This was found particularly important for the higher-resistivity samples. The cylindrical sides of the specimens were bound with electrical insulation tape to prevent evaporation losses during measurement. The measurements were carried out in a four-electrode horizontal cell described by Emerson (1969). The electrodes were copper and the electrolyte was copper sulphate. Alternating currents were used; these ranged from 1 mA for the high resistivity samples to 0.5 mA for the lower resistivity samples. The frequencies were varied from 0.01 Hz to 1000Hz in decade steps. The variations of resistance with frequency is indicated in the table of results by the parameter $(P_{0.1} - P_{1000}) \times 100/P_{0.1}$. The measurement temperature was approximately 23°C.

Results. The results (Table 1) show that the resistivities fall reasonably well within the range of resistivities published for the various rock types. The degree of weathering affects resistivity and porosity. In general, igneous rocks and limestone are resistive, and shale and siltstone are relatively conductive. Samples 26, 27, 28, and 29 are from Stations 60W, 120W, 240W, and 600W in the Red Sierra South area in the Marimo Slate and all have low resistivities characteristic of carbonaceous shale. These samples also show high induced polarization effects. Some induced polarization effects are unexplained, and some samples show marked anisotropy.

The specific gravity results are not directly applicable to the survey results but are included to ensure the results are recorded.

The geological descriptions in Table 1 are by G.M. Derrick and the classification into formations by N. Sampath.

TABLE 1

ROCK MEASUREMENT RESULTS

| Lab. No. | Sampler's No. | Lat. S | Long. E | Formation | Rock Type | Specific gravity | Weathering W=weathered M=moderately S=slightly F=Fresh | Porosity % | Resistivity ohm-m at 1000 Hz | $\frac{P_{0.1} - P_{1000}}{P_{0.1}}$ |
|---|---|---|---|---|---|---|---|---|---|---|
| 72/86 | G1 | $20^{0}59'$ | $140^{0}17'$ | Marraba Volcanics | Metabasalt; medium grained | 2.84 | SW | 0.4 | 1000 | Less than 5 |
| 72/87 | G2 | $20^{0}57'$ | $140^{0}14'$ | Argylla Formation | Porphyritic rhyolite; fine grained | 2.69 | F | 0 | over $10^{5}$ | - |
| 72/88 | G3 | $20^{0}51'$ | $140^{0}15'$ | " | Dolerite; coarse to medium grained | 2.98 | F | 0 | over $10^{5}$ | - |
| 72/89 | G4 | $20^{0}57'$ | $140^{0}15'$ | " | Microporphyrite rhyolite | 2.68 | F | 0 | over $10^{5}$ | - |
| 72/90 | G5 | $20^{0}57'$ | $140^{0}16'$ | " | Feldspathic sandstone or quartzite; coarse grained | 2.62 | SW | 0.1 | 20000 | 7 |
| 72/91 | G6 | $20^{0}57'$ | $140^{0}19'$ | Mitakoodi Quartzite | Feldspathic quartzite; coarse grained | 2.63 | SW | 0.2 | 70000 | 9 |
| 72/92 | G7 | $20^{0}54'$ | $140^{0}20'$ | " | Massive basalt | 2.87 | SW | 0 | over $10^{5}$ | - |
| 72/93 | G8 | " | " | " | Amygdaloidal basalt | 2.84 | MW | 0 | " | - |
| 72/94 | G9 P | " | " | " | Laminated micaceous siltstone and fine grained sand-stone | 2.78 | MW | 2 | 6900 | 17 |
| 72/95 | G9 RA | " | " | " | " " " " " " " | 2.85 | " | 0.5 | 5300 | 10 |
| 72/96 | G10 | $20^{0}42'$ | $140^{0}29'$ | Nanaku Granite | Granite; fine to medium grained | 2.63 | SW | 0.2 | 67000 | Less than 5 |
| 72/97 | G11 | $20^{0}44'$ | $140^{0}37'$ | Soldiers Cap Formation | Gabbro; coarse grained | 3.16 | SW | 0 | over $10^{5}$ | - |
| 72/98 | G12 | $20^{0}44'$ | $140^{0}41'$ | " | Dolerite; fine to medium grained | 3.02 | F | 0 | " | - |
| 72/101 | G14 | $20^{0}48'$ | $140^{0}45'$ | " | Probably impure quartzite; fine grained | 2.67 | SW | 0.2 | " | - |
| 72/102 | G15 | " | " | " | " " " " " | 2.97 | MW | 0 | 6300 | Less than 5 |

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| 72/103 | G16 | $20^{0}53'$ | $140^{0}42'$ | Soldiers Cap Formation | Quartzite; medium to fine grained | 2.67 | SW | 0 | 18000 | Less than |
| 72/104 | " | " | " | " | " " " " | 2.65 | " | 0 | 23000 | " |
| 72/105 | G17 P | $20^{0}55'$ | $140^{0}42'$ | " | Siltstone | 2.70 | MW | 2.6 | 3000 | " |
| 72/106 | G17 RA | " | " | " | " | 2.70 | " | 4.1 | 340 | " |
| 72/107 | G18 | " | " | " | Micaceous grey shale | 2.67 | MW | 0.2 | 3900 | 6 |
| 72/108 | G19 | $20^{0}43'$ | $140^{0}32'$ | " | Massive basalt or amphibolite; fine grained | 3.11 | SW | 0.5 | 710 | Less than |
| 72/99 | G13 RA | $20^{0}44'$ | $140^{0}40'$ | Corella Formation | Bedded limestone; coarse grained | 2.73 | F | 0 | 26000 | " |
| 72/100 | G13 P | " | " | " | " " " " | 2.73 | F | 0 | 22000 | " |
| 72/110 | G21 RA | $20^{0}45'$ | $140^{0}31'$ | " | Calc-silicate rock | 2.86 | SW | 0 | over $10^{5}$ | - |
| 72/111 | G21 P | " | " | " | " " | 2.82 | " | 0 | " | - |
| 72/112 | G22 | $20^{0}49'$ | $140^{0}31'$ | " | Calcareous shale with veinlets of limestone | 2.68 | " | 0 | 54000 | Less than |
| 72/113 | G23 | " | " | " | Impure limestone | 2.70 | F | 0.2 | 31000 | " |
| 72/115 | G25 RA | $20^{0}52'$ | $140^{0}30'$ | " | Calc-silicate rock | 2.70 | SW to MW | 0.6 | 1800 | " |
| 72/116 | G25 P | " | " | " | " " | 2.69 | " | 1.6 | 890 | 29 |
| 72/133 | 35 | $20^{0}46'$ | $140^{0}26'$ | " | " " | 2.79 | SW | 0.6 | 13000 | Less than |
| 72/138 | 34 RA | $20^{0}47'$ | $140^{0}06'$ | " | Micaceous silt | 2.63 | MW | 1.6 | 3200 | 8 |
| 72/139 | 34 P | " | " | " | " " | 2.61 | MW | 2.8 | 370 | 7 |
| 72/140 | 34 RA | " | " | " | " " | 2.62 | " | 3.1 | 2600 | 10 |

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| 72/114 | G24 | 20°52' | 140°31' | Marimo Slate | Shale | 2.45 | SW | 9 | 4100 | Less than 5 |
| 72/117 | 26 | 21°00' | 140°26' | " | Slate with quartz veinlets and malachite mineralization | 2.68 | MW to W | 3.3 | 580 | 7 |
| 72/118 | 27 | 21°00' | 140°30' | " | Slate | 2.30 | MW | 13.2 | 2 | 54 |
| 72/119 | 28 | 21°00' | 140°26' | " | " | 2.57 | SW | 6.5 | 240 | 56 |
| 72/120 | 29 RA | 21°00' | 140°25' | " | Siltstone with interbedded sandstone and shale | 1.96 | W | 27 | 1460 | 17 |
| 72/121 | 29 P | " | " | " | " " " " " " | 1.96 | W | 27 | 1000 | 14 |
| 72/122 | 30 RA | 20°59' | 140°26' | " | Chert with ferruginous quartzite interbedded | 2.63 | MW to W | 4.4 | 33000 | 13 |
| 72/123 | 30 P | " | " | " | " " " " " " " | 2.57 | " | 5.8 | 16000 | 10 |
| 72/124 | 31 | 20°55' | 140°25' | " | Manganese limonite concretion | 2.86 | W | 18 | 1400 | 36 |
| 72/125 | 32 RA | " | " | " | Calcareous siltstone | 2.15 | MW | 20 | 410 | 11 |
| 72/126 | 32 P | " | " | " | " " | 2.04 | " | 24 | 210 | 13 |
| 72/127 | 33 RA | 20°54' | 140°25' | " | Silicified slate | 2.55 | MW | 2.7 | 17000 | Less than ! |
| 72/128 | 33 P | " | " | " | " " | 2.60 | " | 1.7 | 46000 | " |
| 72/109 | G20 | 20°43' | 140°30' | Metamorphosed dolerite plug | Dolerite; fine to medium grained | 2.99 | SW | 0 | 26000 | 24 |

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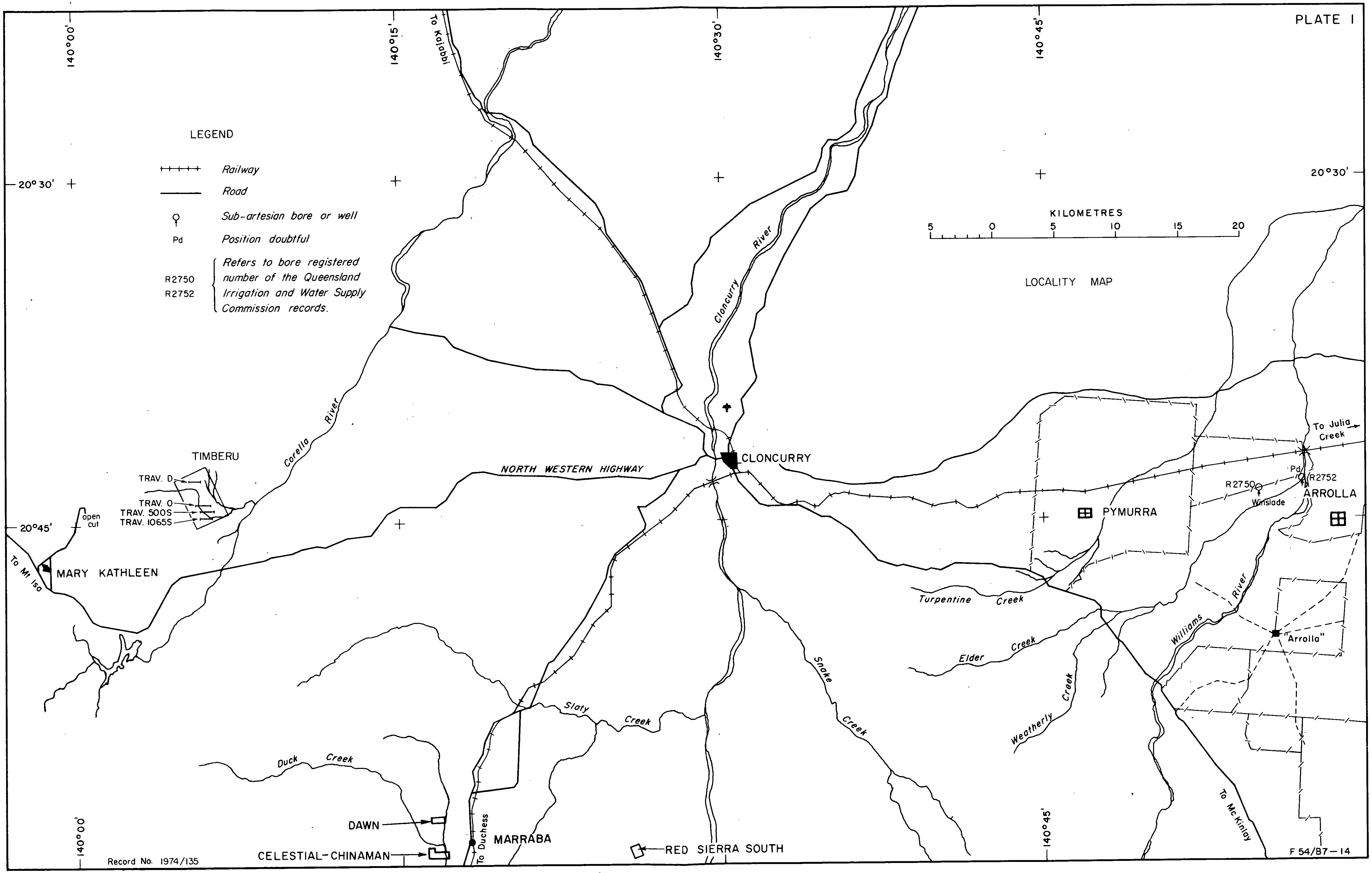
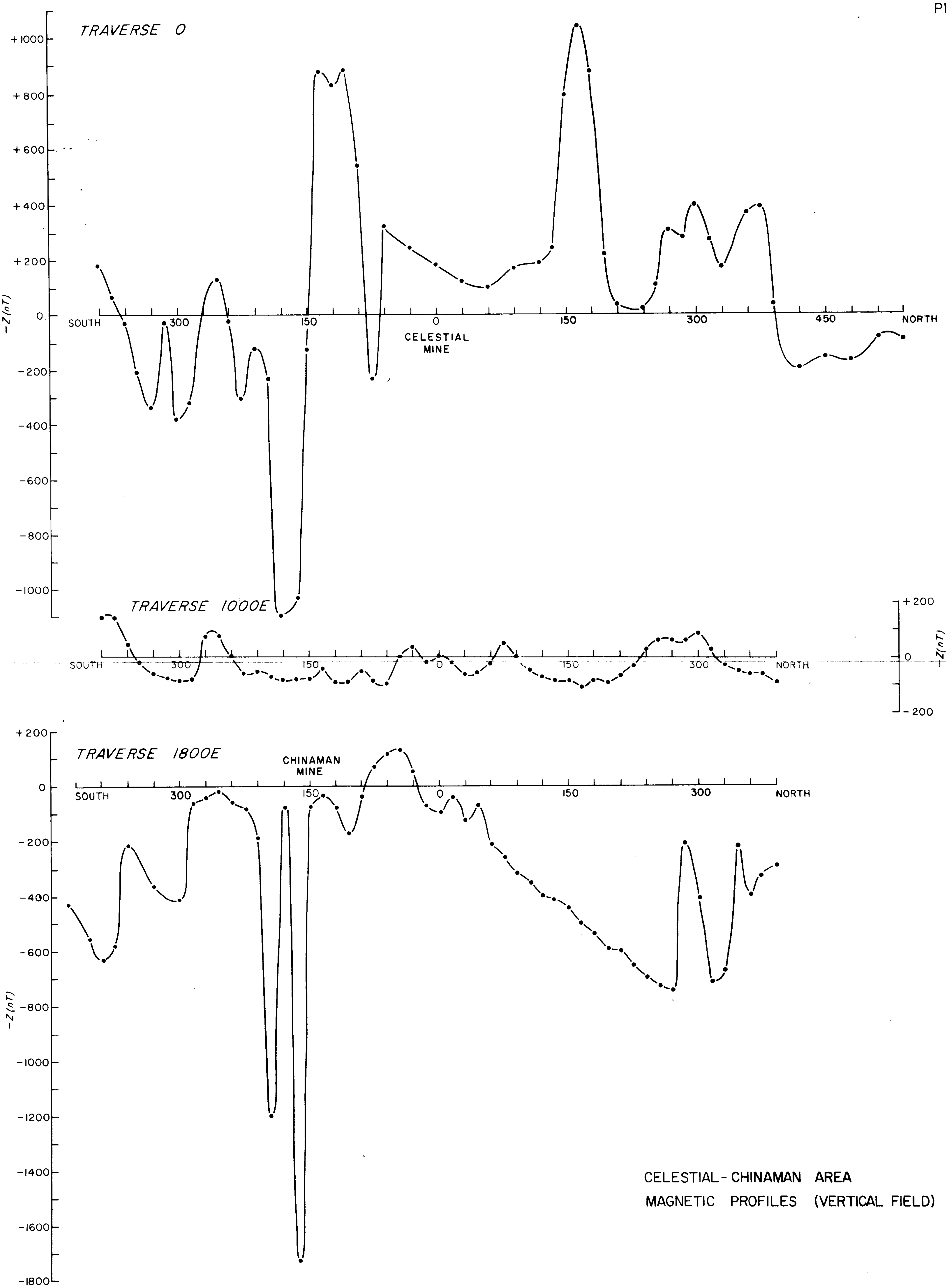


PLATE I
LEGEND
Railway
Road
Sub-artesian bore or well
Pd
Position doubtful
R2750
R2752
Refers to bore registered number of the Queensland Irrigation and Water Supply Commission records.
KILOMETRES
5 0 5 10 15 20
LOCALITY MAP
140°00'
140°15'
140°30'
140°45'
20°30'
20°45'
To Kajabbi
Cloncurry River
Corella River
TIMBERU
TRAV. D
TRAV. 0
TRAV. 500S
TRAV. 1065S
open cut
To Mt Isa
MARY KATHLEEN
NORTH WESTERN HIGHWAY
CLONCURRY
To Julia Creek
Pd
R2750
R2752
Winslade
ARROLLA
PYMURRA
Turpentine Creek
Elder Creek
Williams River
"Arrolla"
Weatherly Creek
Snake Creek
Slaty Creek
Duck Creek
DAWN
CELESTIAL-CHINAMAN
To Duchess
MARRABA
RED SIERRA SOUTH
To McKinlay
Record No. 1974/135
F 54/B7-14

PLATE 2



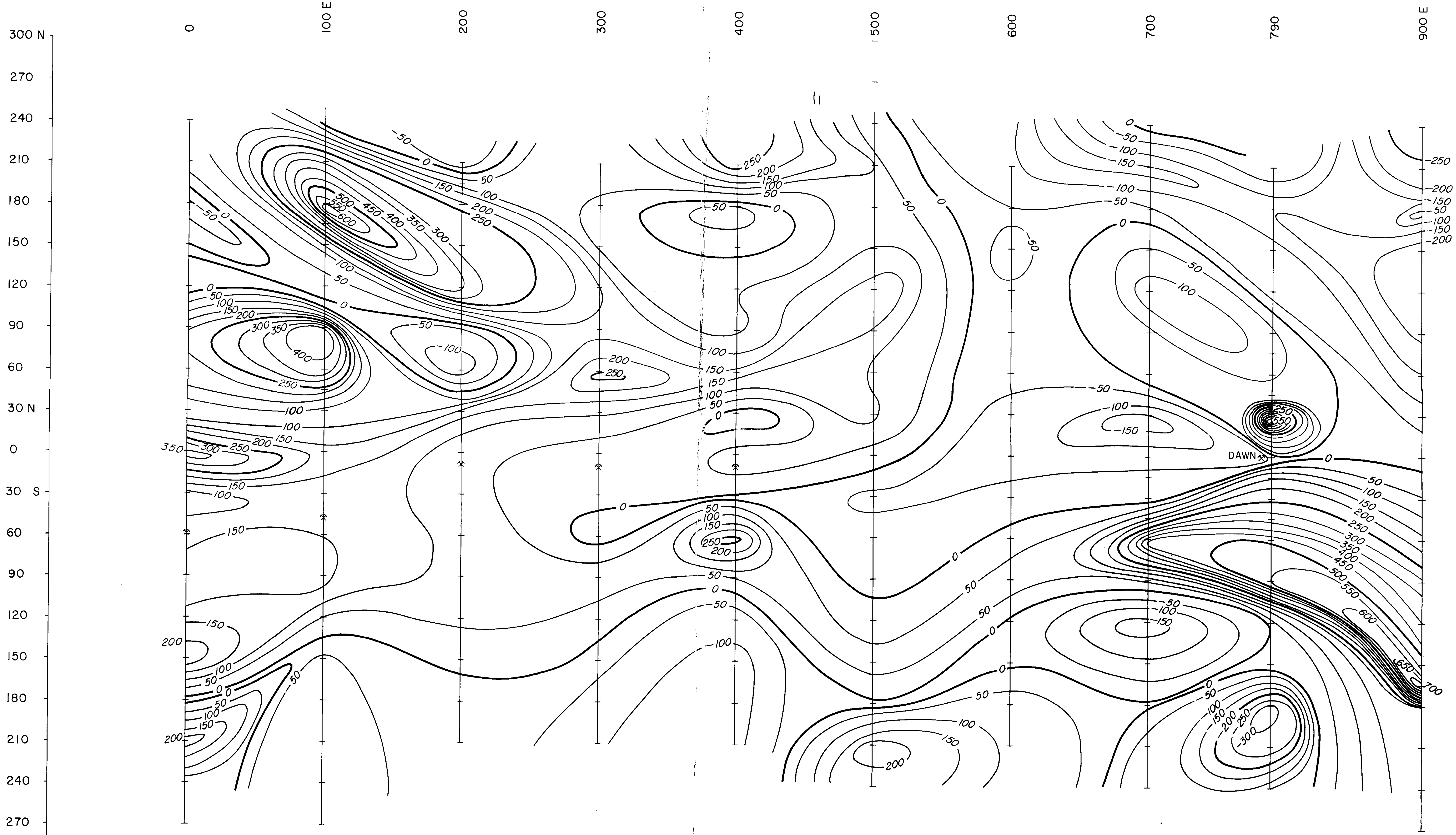

CELESTIAL-CHINAMAN AREA
MAGNETIC PROFILES (VERTICAL FIELD)


PLATE 3 011932

011932


PLATE 4
TRAVERSE 0
APPARENT RESISTIVITY (Ohm-metres)
CELESTIAL MINE
FREQUENCY EFFECT (%)
METAL FACTOR
Celestial Mine
Alluvium
SIMPLIFIED GEOLOGICAL SECTION ACROSS CELESTIAL MINE
TRAVERSE 400 E
MINE WORKINGS
GEOLOGICAL LEGEND
LENTICULAR QUARTZ VEIN
DOLERITE
BASALT
ℓ Dipole length
IP transmitter or receiver
Electrode
Plotted position of reading
n = 2, 3, 4, etc.
TRAVERSE 1700 E
CHINAMAN MINE
TRAVERSE 1800 E
CELESTIAL - CHINAMAN AREA
INDUCED POLARIZATION RESULTS
Record No 1974/135
F54/B7-16

PLATE 5




100 0 100 200 metres

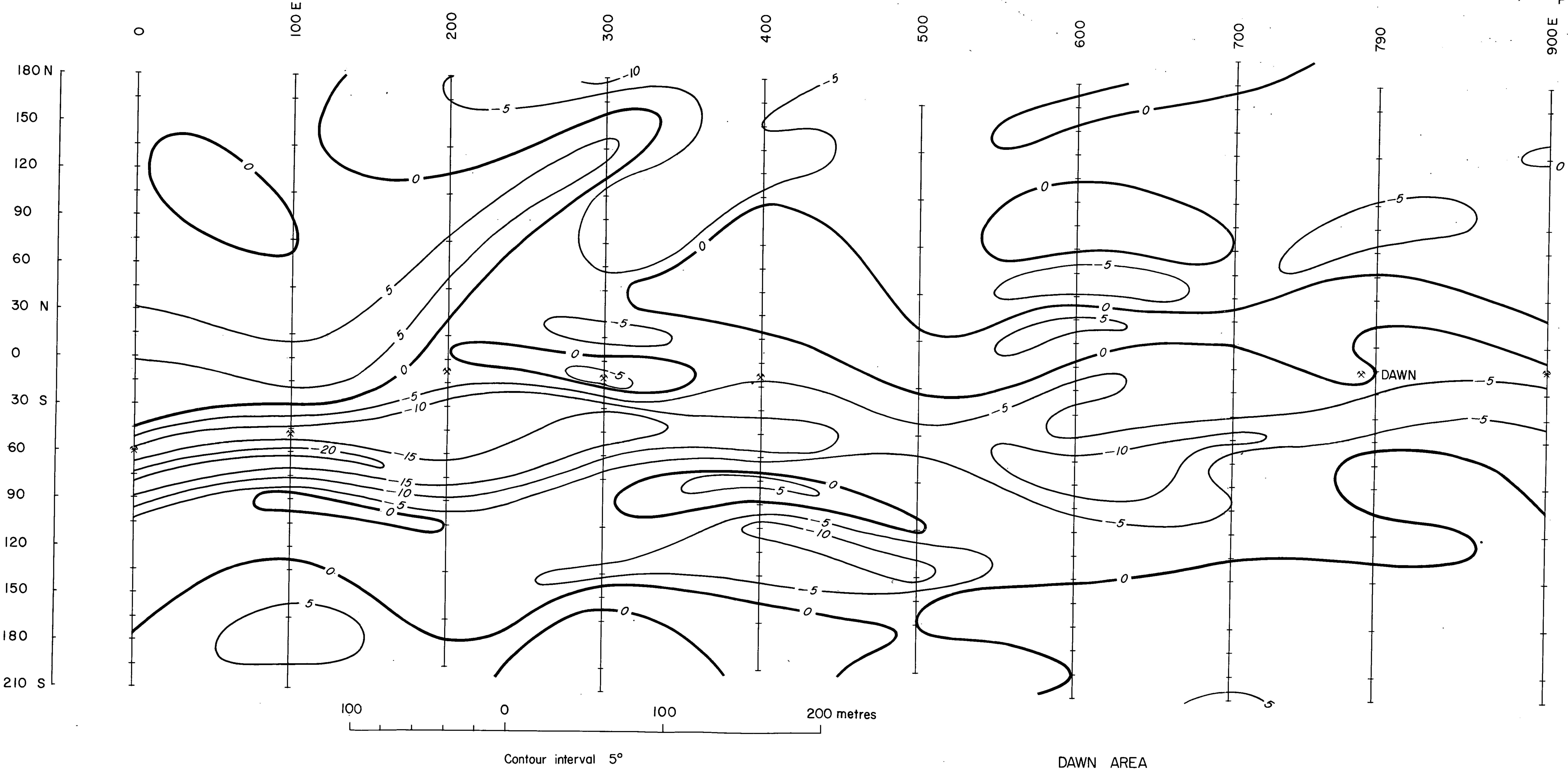
Contour Interval 50 gammas

DAWN AREA

MAGNETIC CONTOURS (VERTICAL FIELD) (-ZnT)

011932

PLATE 6




DAWN AREA

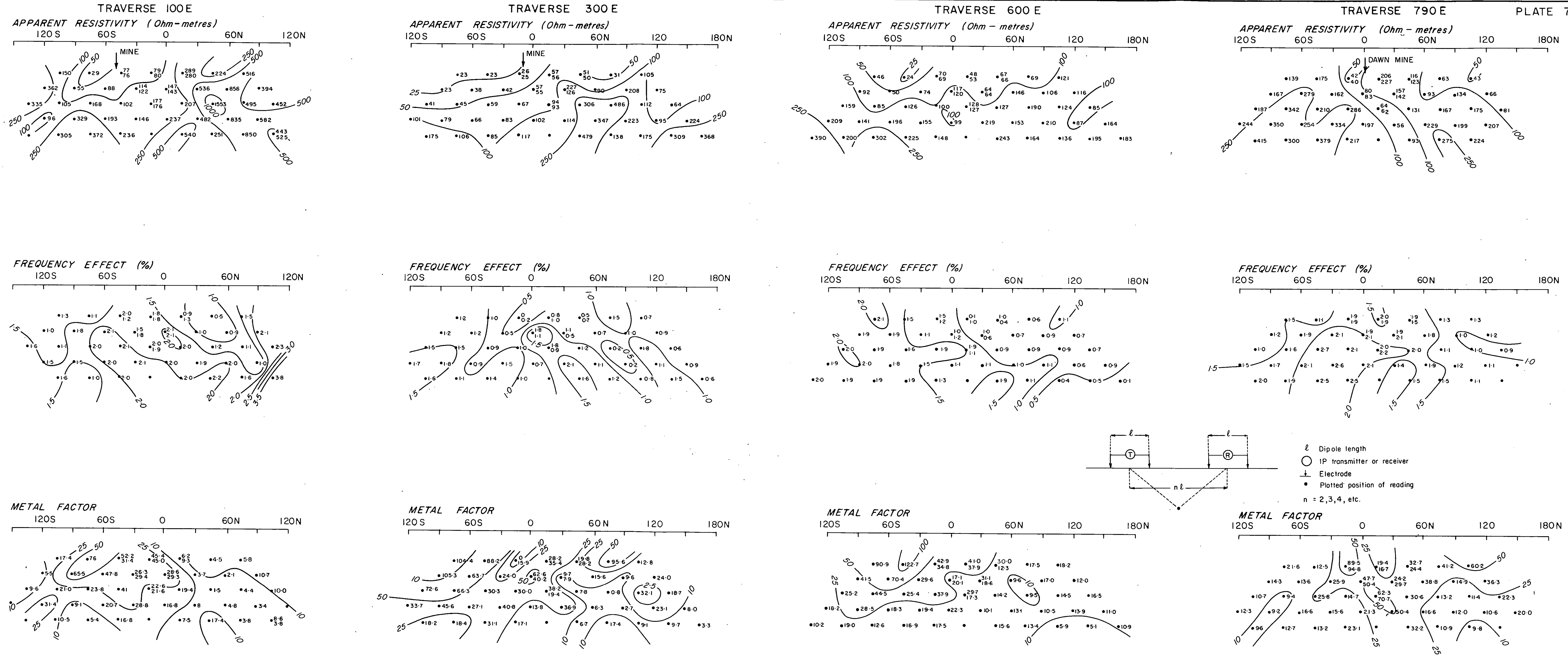
TURAM PHASE DIFFERENCE CONTOURS (660 Hz)

Record No. 1974/135

F54/B7-18

011932

PLATE 7

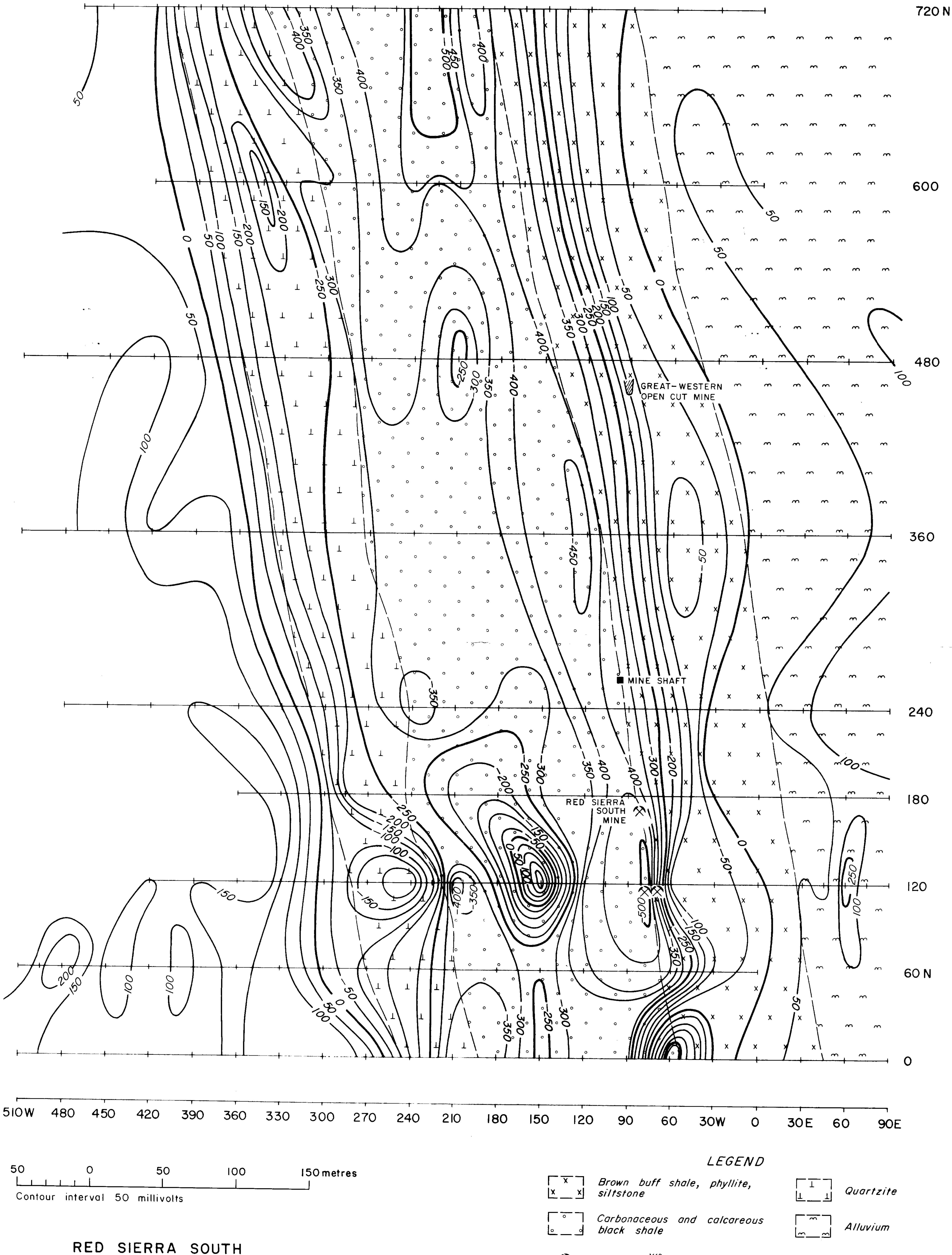



DAWN AREA
INDUCED POLARIZATION RESULTS

Record No. 1974/135

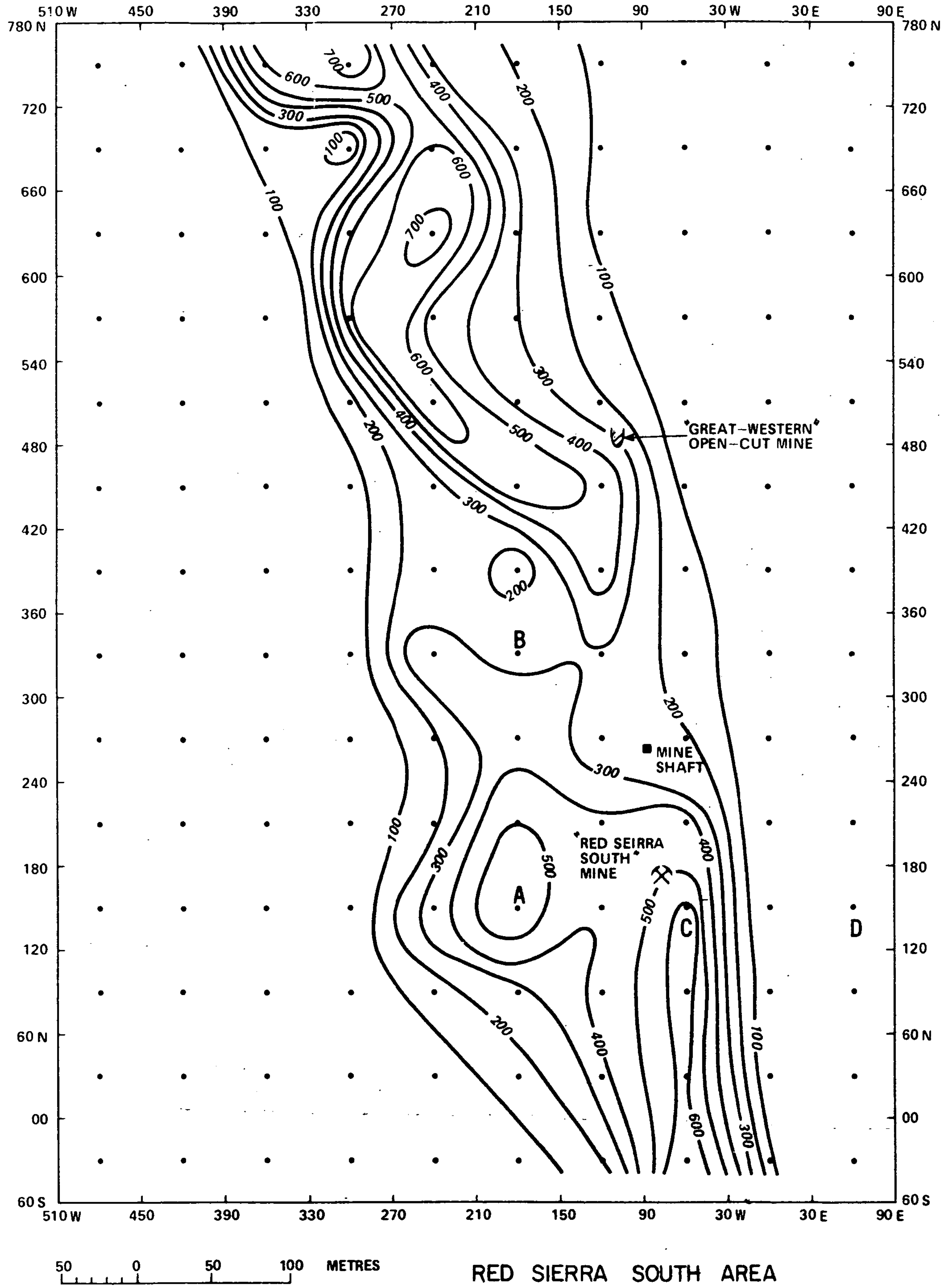
F 54/B7-19

PLATE 8




RED SIERRA SOUTH
SELF POTENTIAL CONTOURS
AND SURFACE GEOLOGY

PLATE 9




RED SIERRA SOUTH AREA

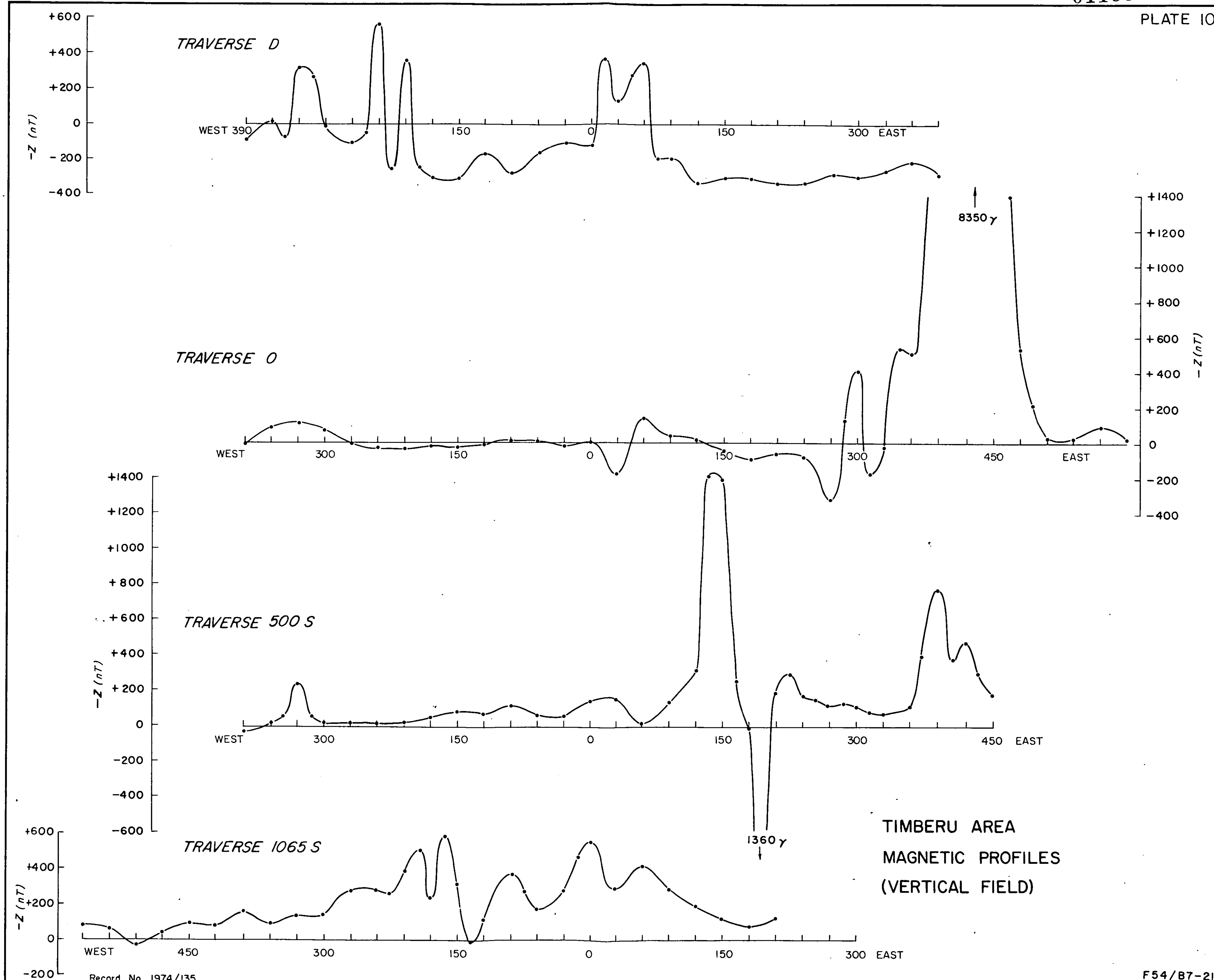
Contours of $\frac{e(t)}{I}$ in $\frac{uV}{A}$ for t=1·1ms (60m Loops)

Record No. 1974/135

F54/B7-27 A

011932

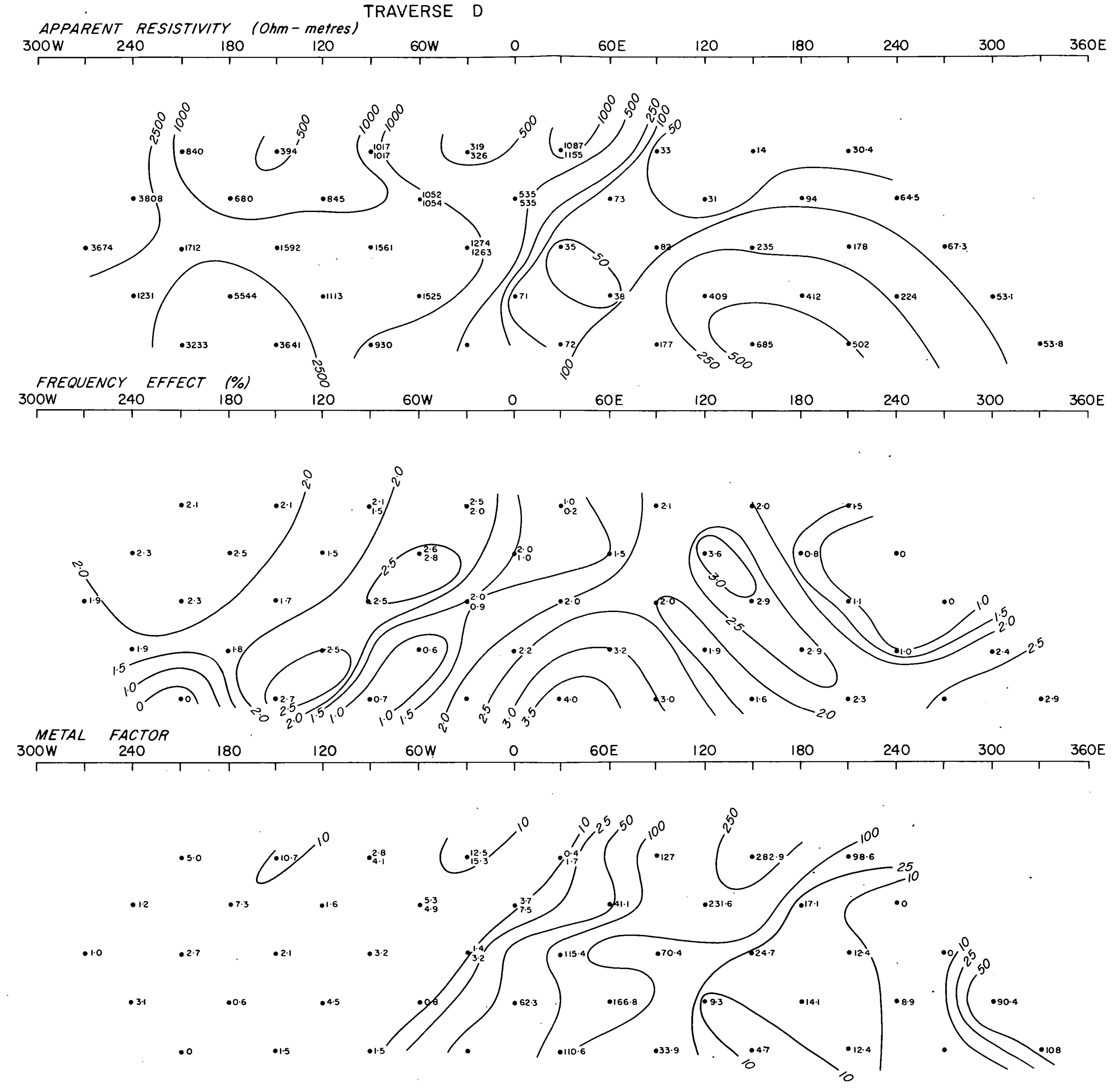
PLATE 10

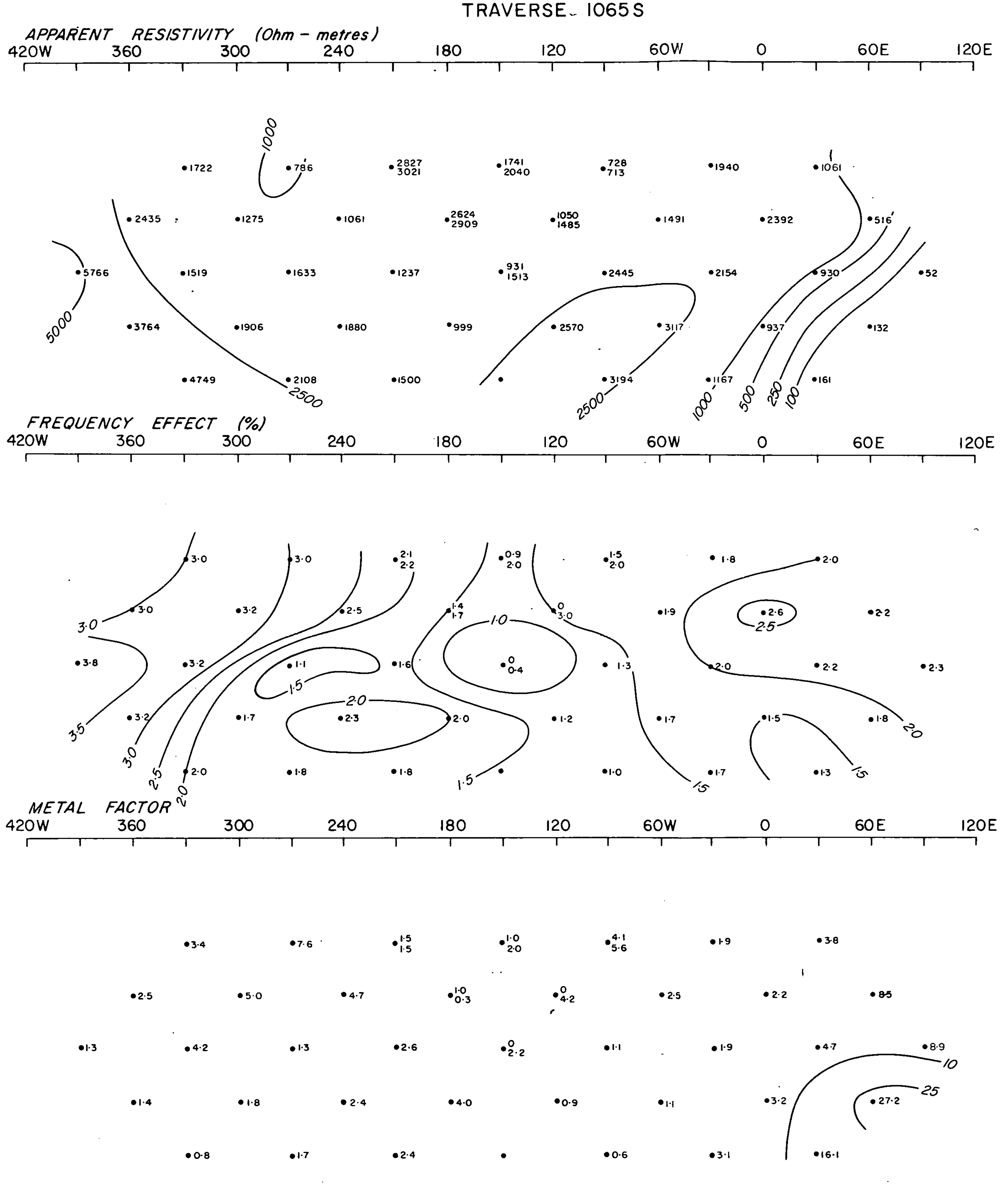



TIMBERU AREA
MAGNETIC PROFILES
(VERTICAL FIELD)

Record No. 1974/135

F54/B7-21




TIMBERU AREA

INDUCED POLARIZATION RESULTS

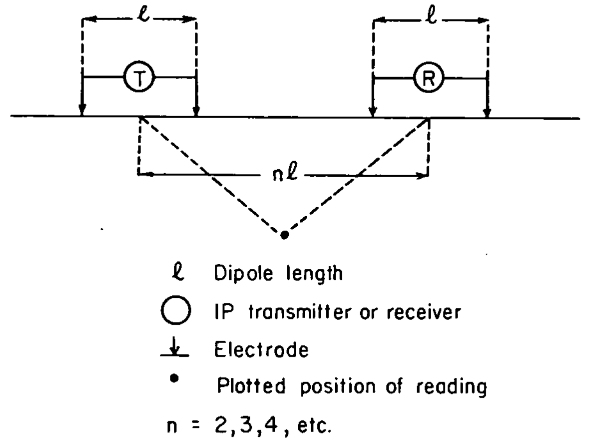


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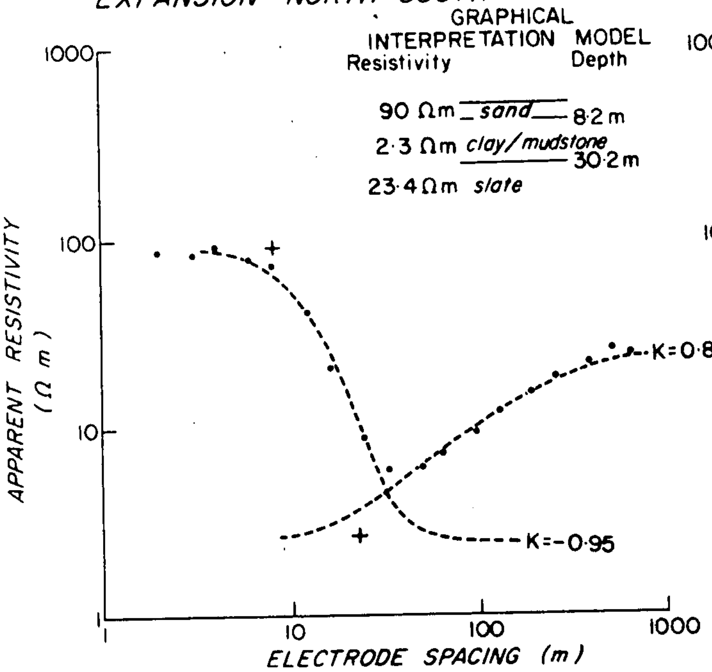
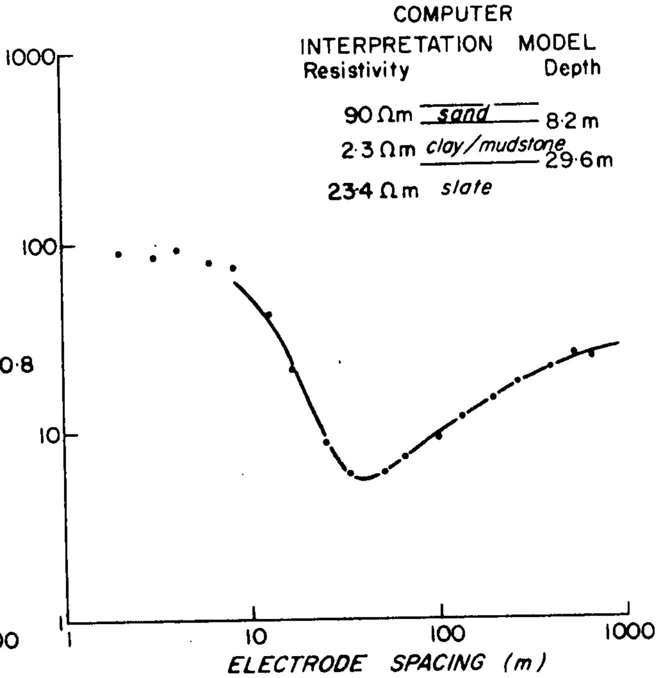
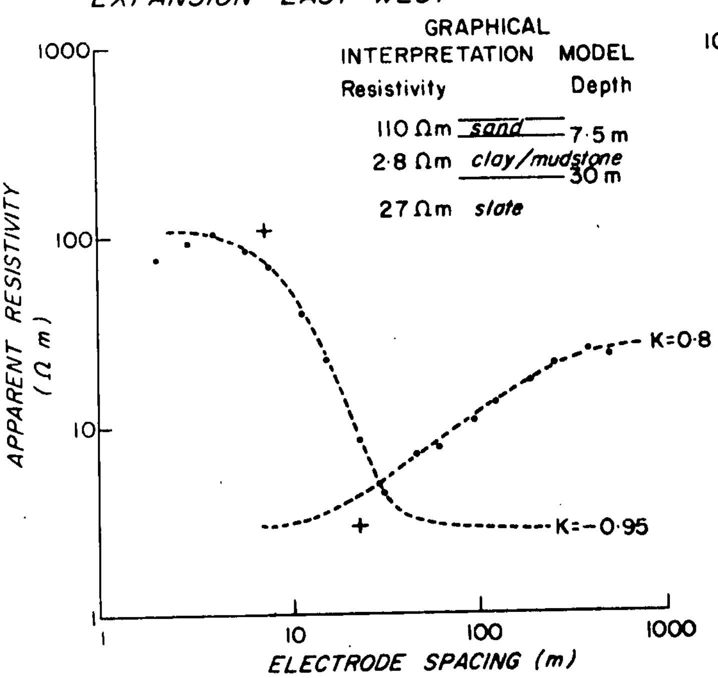
PLATE 12

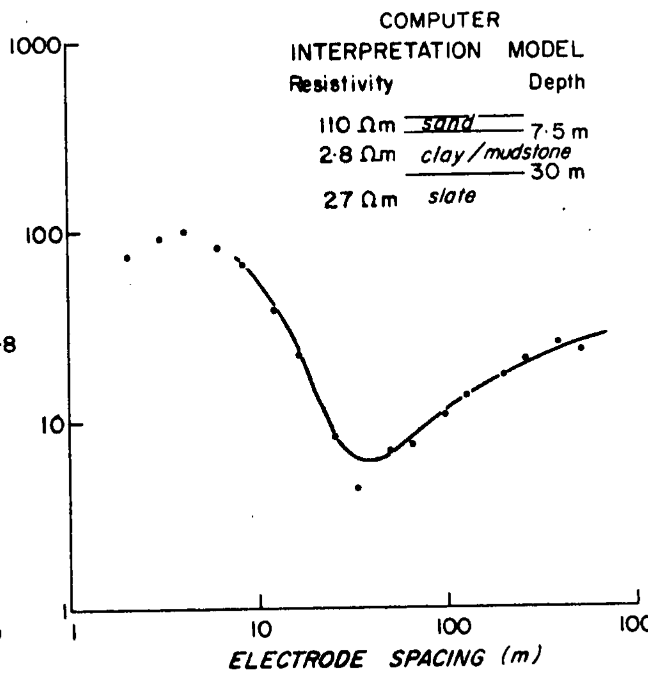
*EXPANSION NORTH-SOUTH*




*EXPANSION EAST-WEST*




LEGEND

------ *Theoretical 2-layer standard curves*

—— *Theoretical computer curves*

\+ *Origin of standard curves*

• *Field readings*

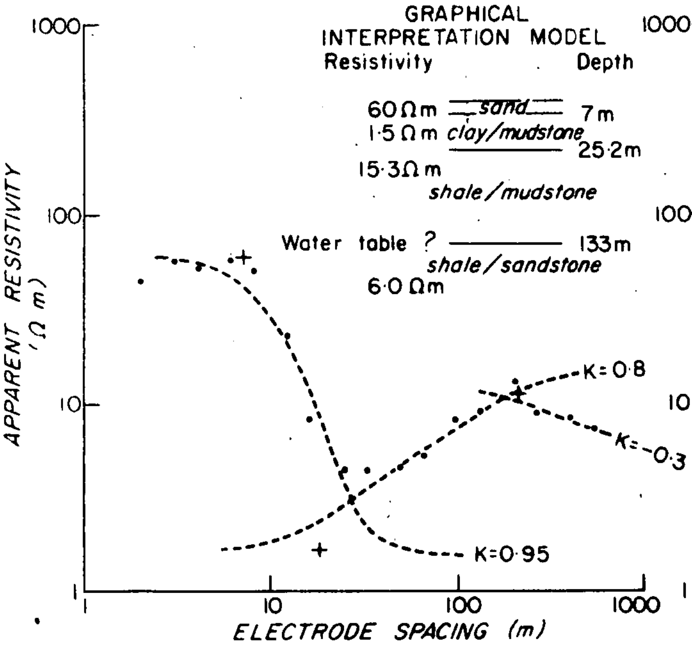
## PYMURRA AREA

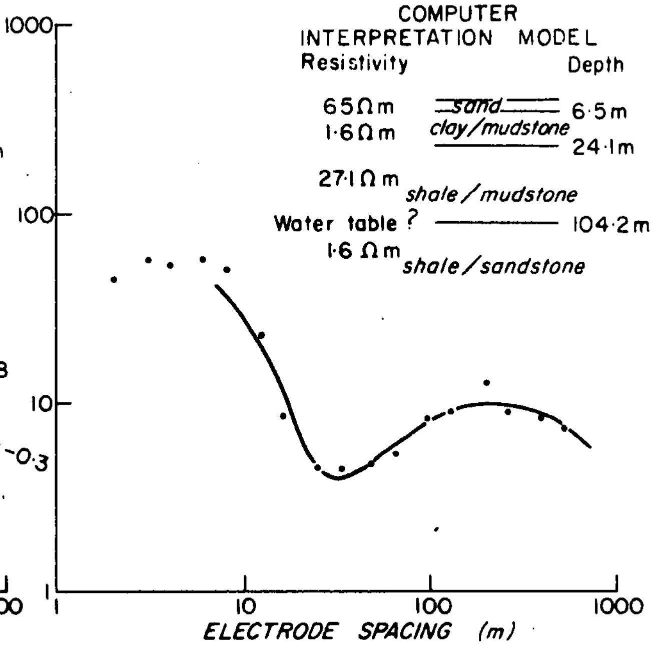
## RESISTIVITY DEPTH SOUNDINGS

Record No. 1974/135

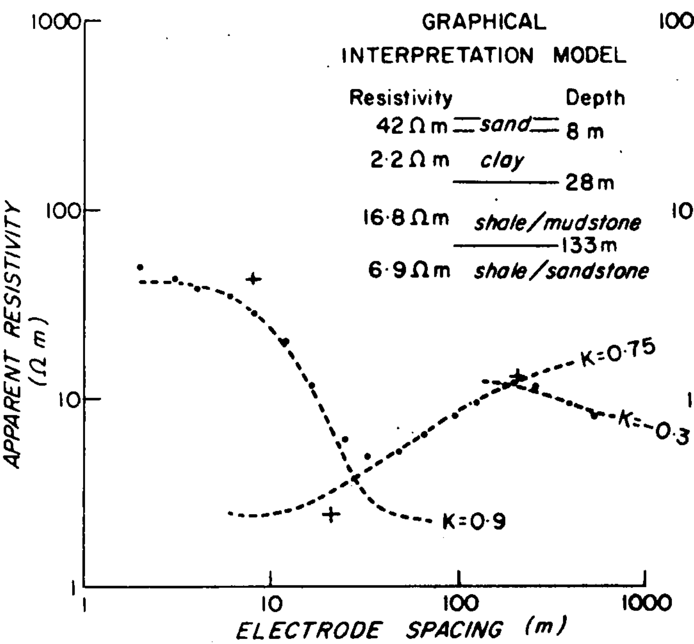
F54/B7-23A

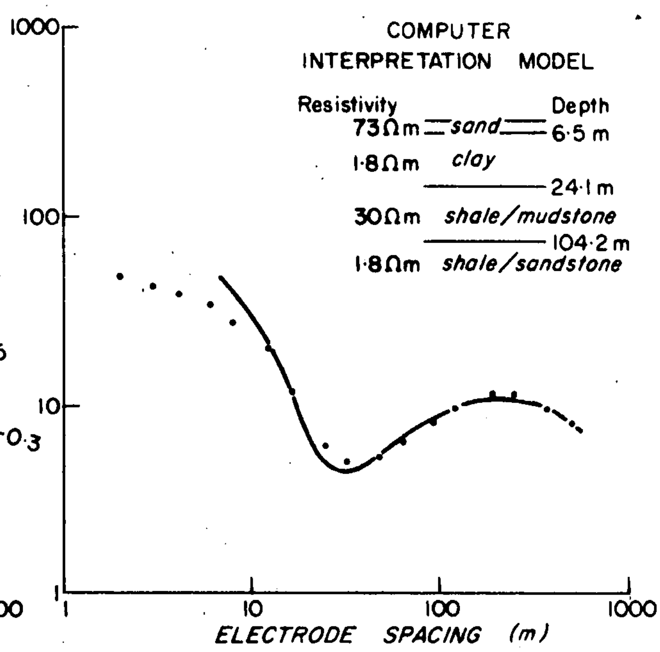
## EXPANSION NORTH-SOUTH




## EXPANSION EAST-WEST




LEGEND

- - - - - *Theoretical 2-layer standard curves*

——— *Theoretical computer curves*

\+ *Origin of standard curves*

• *Field reading*

## ARROLLA AREA

## RESISTIVITY DEPTH SOUNDINGS