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RAVENSTHORPE METALLIFEROUS GEOPHYSICAL SURVEY, WESTERN AUSTRALIA 1965

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Note. This Record supersedes Record No. 1966/20

S U M M A R Y

Between June and September 1965 a geophysical survey was made in the Ravensthorpe area of Western Australia. The aim of the survey was to locate copper orebodies and thus extend the life of Ravensthorpe Copper Mines.

The main area surveyed was close to the Ravensthorpe Copper Mine at Elverdton but some tests were also made at The Gap, Marion Martin, and Mount Cattlin. Self-potential, magnetic, electromagnetic, and induced polarisation methods were employed. Anomalies were recorded over known mineralisation making it possible to compare the effectiveness of the various methods.

Several new anomalies were discovered and eight boreholes are recommended to test them. Suggestions for further work include areas where additional routine IP and Turam would be useful, and some difficult areas where experimental work could improve the interpretation.

1. INTRODUCTION

A geophysical survey was made in the Ravensthorpe area in Western Australia between 8 June and 15 September 1965 following representations made by the Director of the Geological Survey of Western Australia and the Technical Director of Ravensthorpe Copper Mines N.L. Initially the geophysical party consisted of A.W. Howland-Rose (Party leader), B. Farrow (geophysicist), N. Ashmore and J. Dymond (field assistants), and two wages hands. The Department of the Interior in Perth supplied a surveyor, A. Rochfort, and two chainmen. The surveyor was relieved during the survey by R. Bishop, who remained in Ravensthorpe until the geophysical work was completed. A.W. Howland-Rose resigned during the course of the survey and left Ravensthorpe on 16 August; he was replaced by R.J. Smith.

During the survey self-potential, E.M. Gun, Turam, induced polarisation (IP), and magnetic methods were used in an attempt to locate new orebodies, or extensions to old orebodies, in order to prolong the life of Ravensthorpe Copper Mines. Several areas were surveyed: Elverdton, The Gap, Marion Martin, and Mount Cattlin (see Plate 1). The methods were tested over known mineralisation in Areas A, B, and C at Elverdton, and at Marion Martin. The other areas had been relatively unexplored previously, and it was hoped to locate new mineralisation.

Some geochemical soil samples were collected in Areas A, B, and C and were analysed for copper.

Previous geophysical work in the area consisted of an airborne magnetic and radiometric survey by the Bureau of Mineral Resources (Wells, 1962) and ground magnetic traversing by Geosurveys of Australia Ltd (at Marion Martin) and by Ravensthorpe Copper Mines (Area C, Elverdton). The ground surveys revealed several anomalies in both areas. These anomalies have been drilled and some copper mineralisation and magnetite have been intersected.

Concurrently with the BMR survey, Pickands Mather and Company International were conducting geochemical and geophysical surveys in the Ravensthorpe area. Soil samples were collected for geochemical analysis and several reconnaissance traverses with induced polarisation were in progress. This work was continued after the completion of the BMR survey.

2. GEOLOGY

The geology of the Ravensthorpe district has been described by Ellis (1953), Sofoulis (1958), and Ellis and Lord (1965). The most detailed account is given by Sofoulis (1958) and the summary included here is based mainly on his work.

Briefly, the area of interest consists of the folded and metamorphosed Ravensthorpe beds surrounded by gneiss and intruded by magmatic granite, all of Archaean age. The regional geology of the Ravensthorpe district and the detailed geology of the Elverdton grid are shown in Plates 2 and 3 respectively.

The Ravensthorpe beds

The Ravensthorpe beds are divided into a 'greenstone' phase and a 'whitestone' phase. Sofoulis has introduced the following subdivision of the 'greenstones'.

Basement metasediments. These are the oldest rocks known in the area, the lower surface of which is granitised forming a fringing gneiss. They are mainly of sedimentary origin, and apparently were not suitable hosts for mineralisation and have no economic significance.

Basaltic lavas and pyroclastics. These rocks are mainly of volcanic origin consisting of basic lavas, agglomerates, and tuffs with minor intercalations of metasedimentary lenses, ultrabasic schists, and acidic volcanics. Varying degrees of metamorphism have generally resulted in alteration to fine-grained amphibolites. This unit includes the most favourable host rocks for mineralisation.

Serpentines. These rocks only appear east of the Ravensthorpe Range; they are the youngest rocks included in the 'greenstone' phase and may be genetically related to ultrabasic dyke rocks in the underlying 'greenstone' units. The serpentines are remote from the granite and are separated from it by the 'whitestones' of the Ravensthorpe Range; they apparently contain no economic mineralisation.

The 'whitestones' are mainly metasediments, primarily argillaceous and graphitic schists with prominent siliceous banded iron formations (jaspilites), which dominate the topography and cause pronounced magnetic anomalies. The 'whitestones' generally have no economic significance, as they have resisted both granitisation and mineralisation, but their influence on the shape of the granite mass may have affected the distribution of mineralisation in the 'greenstone'.

Granitisation

The basaltic lava and pyroclastics unit of the 'greenstone' has been intruded by a magmatic granite (granodiorite), and the Ravensthorpe beds in general are surrounded by a granitised gneiss, which is considered a separate unit.

The emplacement of the magmatic granite has metamorphosed part of the surrounding 'greenstone', introducing schistosity and slatey cleavage and forming parallel and en echelon shear zones, close to the granite boundary. Several sheared remnants of the 'greenstone' enclosed within the granite mass have become important sources of ore (e.g. the Elverdton Mine).

Mineralisation

The mineralisation at Ravensthorpe is copper and gold, both generally occurring together but with a pronounced excess of one or the other in particular deposits. The mineralisation usually occurs in thermally derived shear zones close to the margin of the magmatic granite and follows the margin in parallel or en echelon groups up to 20 chains in length and 100 ft or more in width. Most of the economic zones are 10 to 30 ft wide, either very close to the boundary or in shear zones which have been intruded by granite tongues.

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Greenstone is the usual host rock with a preference for lava amygdaloids, but there are some occurrences in agglomeratic and metasedimentary units. One would expect the serpentine to act as a favourable host but its distance from the magmatic granite has apparently kept it free of mineralisation. Generally, mineralisation has only partly filled the available shear zones, suggesting that insufficient mineralising solutions were available, and the absence of important orebodies below 500 ft depth has prompted several authors to describe the present deposits as the roots of an original ore system. The mineralising solutions may have accompanied the granite magma or they may have been derived from the 'greenstone' and concentrated in shear zones by the action of the granite, but in any case the present ore deposits seem to be genetically related to the emplacement of the granite magma.

The Elverdton and Desmond shafts are situated on a sheared zone of 'greenstone' remnants (the Elverdton-Desmond shear) near the eastern edge of the granite as are several other important deposits (e.g. the Kundip and Mount McMahon Groups; see Plate 2). Extensions or repetitions of the Elverdton-Desmond shear might be expected to contain additional mineralisation. The Marion Martin and Mount Cattlin shafts are near the northern edge of the granite where numerous granite tongues and offshoots from the main mass have penetrated the 'greenstone'. At The Gap a sharp displacement in the strike of the 'whitestones' of the Ravensthorpe Range suggests the presence of a major fault which could possibly be associated with mineralisation in the neighbouring 'greenstones'. All of these areas were considered to warrant investigation by geophysical methods.

Post granite intrusions

There are two main types of post granite intrusions, both having basic components that could be expected to cause magnetic anomalies.

Pegmatites and epidiorites. These are both considered to be late differentiates of the granite magma; the pegmatites are quite shallow and represent the more volatile components of the magma whereas the epidiorite dykes, in and around the granite, are probably late differentiates of the magma which gravitated downwards and then returned to the surface through cooling cracks. These dykes all trend north-west to north-north-west and have no economic importance.

Quartz dolerite. These dykes are quite widespread and occur throughout granite, metamorphics, and gneiss. They trend east to east-north-east and are the youngest of the rocks mentioned in this summary. They are regarded as deep-seated in origin, possibly a differentiate of the granite magma but they are much more widespread than the epidiorite. They have no economic importance.

3. METHODS AND INSTRUMENTS

The methods used were self-potential, electromagnetic, induced polarisation, and magnetic. Some details of the methods and the way they were applied are given below.

Self-potential

Electrochemical action on an orebody extending above and below the water table often produces recognisable negative potential anomalies of the order of a few hundred millivolts which can be used to locate the hidden mineralisation (Parasnis, 1962, p.64). Recent work by Becker and Telford (1965) has shown that the orebody need not extend above the water table, but larger surface anomalies would be expected if it should do so.

Self-potential measurements were made in Areas A and B using a self-potential meter, RL 807B No.3, designed by the BMR.

Electromagnetic

Both electromagnetic methods (E.M. Gun and Turam) detect the presence of hidden conductors by inducing eddy currents in them. These eddy currents produce distortions in the magnitude and phase of the total electromagnetic field (primary inducing field plus secondary induced field) which can easily be detected by search coils. Although both methods detect the same type of phenomenon there will be differences in sensitivity and depth penetration owing to their different geometries. Both instruments suffer from the limitation that they cannot discern between ionic conductors (e.g. saline solutions) and electronic conductors (e.g. metallic sulphides). With both methods, depth penetration is affected by frequency, lower frequencies giving greater depth penetration (Parasnis, 1962, Chapter 5).

The E.M. Gun (ABEM E.M. Gun No. 82) was tested in Areas A and B using a high frequency (1760 c/s) and a 150-ft coil separation.

All other electromagnetic work was done with the Turam equipment ABEM No.41) using both frequencies (220 c/s and 660 c/s). Initially all the traverses were surveyed using 100-ft coil separation but when some anomalies gave readings off scale they were re-surveyed using 50-ft coil separation and, in exceptional cases, 25-ft coil separation. The Turam equipment was used with grounded primary cables throughout the survey; these cables were laid out parallel to the general strike of the country rock and grounded at least 800 ft past the last traverse. Generally, very good contacts were obtained using two or three iron spikes, and the low contact resistance made it possible to use a higher primary current (2.5 A) than is usually obtainable. The higher primary current made it possible to cover larger areas than usual from one cable position. Readings were frequently obtained up to 2000 ft from the primary cable and in some cases as far as 2500 ft from it. Areas A, B, D, The Gap, and Marion Martin were each read from one grounded cable but three cable positions(1500 W, 1500 E, and 2100 E) were used to cover Area C.

Induced polarisation

The IP method gives measurements of both resistivity and frequency effect. The resistivity measurements indicate the presence of conductive zones which may be caused in particular by saline solutions or metallic sulphides. Frequency effects are usually caused by the presence of an electronic conductor (e.g. graphite or metallic sulphides) and should provide a means of distinguishing between electromagnetic anomalies caused by saline solutions and those caused by sulphide mineralisation. For further information on the IP method the reader is referred to several recent publications (e.g. Forwood & Roberts, 1965; Hallof, 1964; Madden & Cantwell, 1963).

The Geoscience IP equipment was used on selected traverses and as a test of selected Turam anomalies. A dipole-dipole array was used with 100-ft and 200-ft dipoles, and measurements were made using 10 c/s and 0.3 c/s. With 100-ft dipoles, measurements were made at six dipole separations (n = 2 to 7) and with 200-ft dipoles measurements were made at five dipole separations (n = 2 to 6). Initially most traverses were covered using 200-ft dipoles but later, more detailed work was done using 100-ft dipoles. The dipole-dipole array is illustrated in Plate 4 where the various parameters are defined.

Magnetic

The magnetic method detects the presence of magnetic minerals. It could assist in the search for copper mineralisation at Ravensthorpe, either by delineating the geological structure of the area and indicating favourable host rocks, or by detecting magnetic minerals that are frequently associated with the copper mineralisation (e.g. magnetite).

Magnetic measurements were made at 25-ft intervals along all traverses. Initially some measurements were made with an ABEM Torsion Magnetometer (No. 4503) but this was later replaced by a Sharpe Fluxgate Magnetometer (MF1No. 30749). The fluxgate magnetometer was much faster to use and the measurements made with it could still be repeated within the required accuracy. The Sharpe magnetometer was checked during the survey by repeating measurements on a traverse that covered a wide range of magnetic values (Traverse 40N area B) and no appreciable variations were noted.

The magnetic readings in Areas A, B, C, and D at Elverdton were tied in to a base at 0E/1600N in Area B. Magnetic work at The Gap was tied in to a base near 600N on traverse 400E.

Geochemistry

Soil samples were taken at 50-ft intervals on several traverses from 1 ft below the surface. They were dried and seived by the geophysical party and then forwarded to Pickands Mather and Co. International in Perth for copper analysis. The results are discussed in Chapter 5.

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4. TESTS OVER KNOWN MINERALISATION

Initially all the methods were tested over known mineralisation in the Elverdton - Desmond shear in the hope that characteristic anomalies would be recognised which could assist in the interpretation of results from new areas. Later, similar tests were made with IP and Turam methods over known mineralisation at Marion Martin.

Elverdton - Desmond Shear (Plates 3 and 4)

Self-potential measurements were made along several traverses (A, B, C, and E in Area A) crossing the Elverdton - Desmond shear and along other traverses (4N, 8N, 12N, and 16N in Area B) crossing the suspected extension of the shear. No significant anomalies were detected; the profiles were almost featureless and the small irregular variations that were observed were erratic and difficult to repeat. It seems likely that the known sulphides were all below the water table and any surface anomalies due to them were reduced sufficiently to be masked by the effects of small near-surface bodies. The self-potential method was evidently not a useful tool in the Ravensthorpe area and its use was discontinued. No self-potential results are illustrated in this report.

E.M. Gun measurements were made over the Elverdton - Desmond shear (traverses A, B, C, and D in Area A and traverse 00 in Area B) but all the profiles were affected by the presence of a pipeline and a power line close to the shear. These conducting bodies produced strong anomalies, which occurred close to the mineralisation and which prevented the detection of any anomalies that the sulphide orebodies may have produced. Some E.M. Gun results over known mineralisation are illustrated in Plate 4.

Magnetic work over the Elverdton - Desmond shear was affected seriously by a large water pipe from the Elverdton shaft to the Desmond shaft parallel and close to the shear and by sheds and machinery near the Desmond shaft. In spite of these disturbing influences there appeared to be an anomaly of 200 to 300 gammas over the shear on traverse B., A similar, but stronger anomaly, of approximately 1000 gammas was detected over the workings on traverses 8S, 9S, 10S, and 11.37S in Area C.

Turam work over the Elverdton - Desmond shear was affected similarly by the presence of water pipes, etc. In particular, a zone of very strong Turam anomalies in Area A, attributed to the presence of the large water pipe, masked any anomaly associated with the shear. This water pipe and other conductors around the Desmond shaft prevented the detection of any anomaly on traverse 0 in Area B but a small anomaly was observed on traverse 2N in line with the shear. In Area C there was no Turam anomaly coinciding with the magnetic anomaly and the workings but some small anomalies were observed 400 to 500 ft east of the workings close to a two-inch water pipe.

IP tests over the Elverdton - Desmond shear detected anomalies on each traverse where the method was used. In particular, on traverse D (Area A) and traverses 0 and 2N (Area B) well-defined frequency effect anomalies were obtained over the shear. Small, but recognisable, frequency effect anomalies (>5%) were also obtained over the shear on traverses A and B (Area A). On traverses 7S, 8S, and 10S (Area C), IP tests detected extremely high frequency effects (greater than 40% in some cases) over a wide area. The anomalies on traverses 7S and 8S were attributed to the presence nearby of houses, iron fences, and water pipes, and these may also partly explain the anomaly on traverse 10S. 9

On all of these test traverses in areas A, B, and C, wide ranges of apparent resistivity values were encountered. Values ranged from approximately 10 ohm-metres to between 2000 and 3000 ohm-metres along the traverses, and values over the position of the shear varied from 10 to 500 ohm-metres. Generally the resistivity values associated with mineralisation appeared to be in the range 50 to 300 ohm-metres, but the sharp variations resulted in quite complex resistivity patterns, which were difficult to interpret. The metal factors also closely followed the complex resistivity patterns but values over the mineralisation were generally in the range 100 to 300. The main difficulty in the interpretation of metal factors was the existence of many metal factor anomalies without associated frequency effects. These metal factor anomalies were caused entirely by zones of low resistivity and often dwarfed the anomalies associated with mineralisation.

Marion Martin

Turam work at Marion Martin detected a small but recognisable anomaly that could be traced through the area from traverse 150W to traverse 750E and coincided with the position of the known mineralisation. This anomaly was overshadowed by a large anomalous zone attributed to a shallow, horizontal conductor - possibly salt water - immediately to the south of it (see Plate 9).

I.P. work at Marion Martin detected frequency effect anomalies (>5%) coinciding with the mineralisation, but the apparent resistivities and hence the metal factors were extremely variable and difficult to correlate with the mineralisation. Values of apparent resistivity ranging from 50 to 500 ohm-metres were observed close to the known mineralisation, and corresponding large variations in the metal factor were noted.

The shallow zone of very low resistivities south of the mineralisation gave very high metal factors and distorted any anomaly that might have coincided with the mineralisation. Metal factor values over the mineralisation were still close to 100 - 300, the values obtained over the Elverdton - Desmond shear.

General

Although some of the tests, particularly in the Elverdton - Desmond area, were hampered by spurious effects, it seems that all three methods can assist in locating further orebodies. The magnetic method detects magnetite, which is often associated with the ore and can serve as a useful prospecting tool. The absence of a magnetic anomaly, however, need not detract from the value of other anomalies, as magnetite is not always present. Magnetic anomalies can occur over many other minerals not associated with economic mineralisation, so that a magnetic anomaly unsupported by Turam or IP anomalies would not be sufficient to warrant drilling.

Turam anomalies were expected over all mineralised shears but they were sometimes absent (e.g. Area C). Anomalies over orebodies were often obscured by the presence of large disturbances, probably due to mineralised water in shears and shallow pools.

Since the measured values of apparent resistivity in the Ravensthorpe area varied from 10 ohm-metres to several thousand ohm-metres and mineralisation has been shown to coincide with apparent resistivities of 50 to 500 ohm-metres in the areas tested, there seems little point in looking for resistivity or metal factor anomalies as a guide to mineralisation. A large proportion of these anomalies define low resistivity zones not associated with mineralisation; they are much more pronounced than the anomalies associated with the known orebodies. Frequency effect anomalies always accompanied known mineralisation but often were absent from the low resistivity zones nearby. It appears that the presence of a frequency effect anomaly (>5%) accompanied by metal factors of 100 to 300 (or perhaps higher) is the best indication the IP method can give of mineralisation in the Ravensthorpe area.

Frequency effect anomalies are necessary to distinguish between genuine mineralisation and the low resistivity zones associated with saline solutions. Since the frequency effect itself is a function of the resistivity of the surrounding rocks (Hallof, 1964) the metal factor can be used to distinguish the different types of frequency effect anomalies. For example, frequency effects greater than 5% were frequently measured over the granite containing sparsely disseminated mineralisation on the western ends of the traverses in Area B. The resulting frequency effect was enhanced by the high resistivity of the granite but the resulting small metal factors caused these anomalies to be discarded.

5. RESULTS, INTERPRETATION, AND DRILLING RECOMMENDATIONS

Elverdton

Areas B and C adjoining the Elverdton - Desmond shear were explored in the hope that extensions or repetitions of the mineralisation in the Elverdton - Desmond shear might occur there. Further north, Area D enclosed the Ironclad workings, and similar mineralisation was sought there. All three areas were mapped magnetically and several large anomalies were revealed (see Plate 5). The E.M. Gun was tested on several traverses but results were not encouraging and the method was finally discarded in favour of Turam. Turam work in all three areas located a large number of anomalies but many of these were probably caused by water-filled shears (see Plate 6). IP work revealed a wide range of resistivities but no large frequency effect anomalies. Several small frequency effect anomalies were observed and although not as large as those obtained over the Elverdton - Desmond shear they are considered to warrant further investigation by drilling.

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The magnetic contours are illustrated (Plate 5) and show a close correlation with the known geology (Plate 3). The most pronounced magnetic feature is the 'high' (with adjoining 'lows') running from approximately 250E on 10N to 1300E on 4N in Area B, and corresponding to a quartz gabbro (dolerite) dyke. Other magnetic 'highs' with similar strike and magnitude occur at 1000E on 16N and 400E on 20N in Area B. The 'high' at 400E on 20N corresponds with an epidiorite dyke and the one at 1000E on 16N is probably a similar feature (i.e. a basic intrusion, either dolerite or epidiorite and unlikely to have any economic significance). The strongly disturbed magnetic field in the eastern half of Area B corresponds to expected greenstone schists on the geological map, and similar features were observed in the north-east corner of Area C. Magnetic contours in these areas have been obtained from smoothed profiles and are approximate only.

Several very narrow, steep anomalies were observed in Area A (due to the presence of iron water pipes, etc.) and around 800E on traverse 00 in Area B (due to sheds and heavy machinery around the Desmond shaft). These anomalies have been smoothed and generally do not appear on the contour map.

In the eastern half of Area C there are several small magnetic 'highs' trending north-west to north-north-west with amplitudes of several hundred gammas. The direction of strike is consistent with the many epidiorite dykes in the area and these are the most probable causes of the anomalies. In the absence of IP or Turam anomalies these magnetic anomalies are not expected to have any economic significance. A series of magnetic 'highs' extending from 400E on traverse 7S to 400E on traverse 16S (Area C) appears to be associated with mineralisation at least on traverse 11.37S, where drillhole ES25 revealed the presence of chalcopyrite and pyrrhotite. Several other small magnetic anomalies in Area C (at 1100E on 17S, 1250E on 24S, 950E on 25S, and 0 on 28S) could be associated with mineralisation or with the epidiorite and dolerite intrusions observed elsewhere in the area. The first of these anomalies is not associated with any Turam anomaly and was therefore discarded, the second and third are close to weak Turam anomalies, and the fourth is close to a pronounced Turam anomaly. None of these magnetic or Turam anomalies has any associated IP anomalies. The second, third, and fourth magnetic anomalies, if connected, have a strike consistent with the dolerite dykes, and a small dolerite intrusion could explain them. This possibility and the absence of any IP indications caused the anomalies to be discarded as drilling targets.

The E.M. Gun profiles obtained on traverses 4N, 8N, 12N, 16N, 20N, 24N, 32N, 36N, and 40N in Area B show several small anomalies, but they are generally ill defined and difficult to separate from background noise. The anomalies that were detected were later found to agree in position with Turam anomalies, which were more pronounced and easier to identify. Since the Turam method detected the same anomalies and was more sensitive it was decided to discontinue using the E.M. Gun method.

The Turam phase contours (220 c/s) are shown together with the main IP anomalies in Plate 6. It must be stressed that IP anomalies shown in this way (shaded parts of the traverse) are a summary only and much more information is available on the two-dimensional pseudo-sections used in the interpretation. Some selected pseudo-sections are illustrated in Plates 4 and 7 but most are not included with this report. 12

The Turam results revealed many anomalies indicating the presence of conductors but probably most of these anomalies are due to mineralised solutions in shear zones. In general, the results using 660 c/s are seriously affected by conducting surface layers; the effect is still apparent at 220 c/s but is somewhat reduced. The presence of a Turam anomaly alone was not considered significant and a supporting IP anomaly was generally required before recommending drill sites. Several of the Turam anomalies (e.g. 200W to 400W on traverse 12S in Area C) are typical of the response obtained over a shallow horizontal conductor during Turam model tests (Langron & Sedmik, in preparation). The anomalies are probably due to saline solutions near the surface, which caused large Turam anomalies and low resistivities and reduced the depth penetration of both the Turam and IP methods. The most pronounced Turam anomalies are roughly parallel to the primary cable and probably outline shear zones which do not necessarily contain sufficient mineralisation to warrant drilling (see Chapter 2).

The main IP anomalies are shown in Plate 6 and drilling is recommended on several of them. Those anomalies not recommended for testing are, generally, poorly defined with barely significant frequency effects (>5%) and relatively high resistivities. They are not supported by magnetic or Turam anomalies and were not considered important.

In Area B a Turam anomaly was observed near the Desmond shaft. This anomaly decreases in magnitude to the north but can be detected as far as traverse 14N, which it intersects at 950E. Another similar anomaly can be traced from 650E on traverse 4N to 520E on traverse 14N. IP anomalies (both frequency effect and metal factor) were detected on traverses 10N, 12N, and 14N near the P.L.P. workings and are possibly associated with the western Turam anomaly on traverse 12N. A small magnetic anomaly was also detected, intersecting traverse 12N at 650E close to the centre of the IP anomaly but possibly not connected with either the IP or Turam anomalies. None of the anomalies is especially pronounced but since all three methods gave anomalies close together a drillhole is recommended to test them. One drill hole is recommended, drilling west along traverse 12N from 1000E, depressed at 40° and extending at least 700 ft. This should test both Turam anomalies and the main target (based on IP results) which is 300 ft below 650E.

An additional drill hole in Area B is recommended to test the Turam and IP anomalies near 2500E on traverse 24N (Plate 7). Both Turam and IP anomalies are weak but definite, and one drill hole, drilling west along the traverse from 2560E, depressed at 60°, could test both targets. Depth estimates based on the Turam anomaly are difficult because of its irregular shape, but a target 120 ft below 2490E has been selected. IP results only permit an approximate depth estimate to be made and in this case the target is 200 ft below 2450E. If the drill hole is continued for at least 400 ft it should test both targets adequately. Further geophysical work, both Turam and IP, could help to delineate this anomaly more completely and assist in selecting a better target, but present results are sufficient to warrant testing with one borehole.

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In Area C two very pronounced Turam anomalies dominate the contour map (Plate 6). One of these extends from about 400W on traverse 10S to 50E on 32S and the other from about 2200E on traverse 1S to 2600E on 16S. Both appear characteristic of a shallow, horizontal conductor and therefore are not considered important. The second of these anomalies coincides with a sludge dump containing pyrite and other sulphides, which probably explains it's presence. However, extensions of the anomaly can be traced to 1850E on 5N and 2600E on 30S with a shape typical of a deeper, vertical conductor. It seems likely that a near-vertical shear (with or without mineralisation) extends from 1850E on 5N to 2600E on 30S passing underneath the sludge dump between 1 S and 16S.

On traverse 10S there are two distinct peaks in the Turam profile (220 c/s), one at 2250E and one at 2450E (Plate 7). The peak at 2450E is interpreted as being associated with the suspected shallow horizontal conductor, the peak at 2200E is assumed to be due to a near-vertical conductor at a minimum depth of approximately 150 ft. IP work on this traverse with 200-ft dipoles detected a frequency effect anomaly extending from 2200E to 2500E exhibiting metal factors of 50 to 100. The anomaly suggests a body at approximately 400 ft, but the presence of the shallow low resistivity layer (coinciding with the sludge dump) would distort the profile and give exaggerated depth estimates. Although the resistivity at depth is quite high, the Turam results suggest a major feature and the presence of a small frequency effect anomaly is considered sufficient to warrant testing.

Magnetic work on traverse 10S detected a narrow, steep-sided anomaly at approximately 2400E. The anomaly is evidently caused by some very shallow feature and is most unlikely to be connected with the Turam and IP anomalies.

One drill hole is recommended to test the Turam anomaly at 2200E. It should be drilled west along the traverse from 2400E, depressed at 45°, and continued for at least 500 ft.

IP work between 0 and 1500E on traverse 10S, using 100-ft dipoles, revealed a very pronounced frequency effect anomaly near 200E (see Plate 7), approximately 200 ft deep and accompanied by resistivities of 100 to 200 ohm-metres. This anomaly appears similar to the anomalies detected on traverses 7S and 8S (which seem to be associated with the houses, fences, water pipes, etc. indicated in Plate 6) but it is at least 300 ft from the houses etc. and therefore unlikely to be caused by them.

A magnetic anomaly detected on the same traverse, from 350E to 550E, coincides with underground workings, but the nearest Turam anomaly is at about 700E.

An existing drill hole, ES 25, on traverse 11.37S, should have tested the magnetic anomaly adequately and in fact it located some copper mineralisation, coinciding reasonably well with the anomaly. Although the IP results are possibly affected by artificial disturbances, the anomaly is very pronounced and occurs close to the present mine and therefore should not be ignored. One drill hole is recommended to test the IP anomaly. If the hole is drilled west along traverse 10S from 400E, depressed at 45 , and continued for at least 500 ft, it should intersect the target 200 ft below 200E.

IP work on traverse 12S, with 200-ft dipoles, revealed a frequency effect anomaly (see Plate 7) accompanied by metal factors of 200 to 300 near 300W, and opposite a house, fences, pipes, etc. The source of the anomaly is apparently 200 to 300 ft away from the traverse, horizontally or vertically; it could be the house and associated surface conductors or it could be an orebody at depth.

There is a broad magnetic anomaly, with several narrow fluctuations superimposed on it, extending from 400W to 100E on 12S. Part of the anomaly may be due to the house and associated magnetic material but the main effect is some distance from the house and not likely to be associated with it.

The pronounced Turam anomaly (typical of a shallow, horizontal conductor) discussed earlier dominates the Turam profile and prevents the detection of any possible anomaly due to a deeper conductor which could be correlated with the IP and magnetic anomalies. Although both the IP and magnetic anomalies could be caused by surface conductors the evidence for this is far from conclusive. The anomalies are close to the present mine and potentially are too valuable to be ignored. One borehole is recommended to test the anomalies. It should be drilled west along the traverse from 150W, depressed at 60°, and continued for at least 500 ft. The main target is 260 ft below 300W.

In Area D, several Turam anomalies were detected (see Plate 6). The most interesting of these appears to fork near 950E on traverse 00, and the eastern fork passes close to the Ironclad shaft, intersecting traverse 2N at 1000E, and probably follows the mineralised shear on which the shaft is situated. The western fork crosses traverse 2N and 4N near 860E and can be traced through to 850E on traverse 10N. The minimum depth to the current concentration on traverse 4N has been estimated at 100 ft (see Plate 7).

IP work on traverse 4N detected a small but recognisable frequency effect anomaly centred on 900E (see Plates 6 and 7) associated with metal factors of 100 to 150. This is the most pronounced IP anomaly in Area D and its source is apparently more than 200 ft below the surface.

Disturbed magnetic results in Area D are evidently due to small, shallow, magnetic bodies and no magnetic anomaly from a deeper source coinciding with the IP and Turam anomalies could be distinguished.

One drill hole is recommended to test the Turam and IP anomalies. The target should be 250 ft below 860E on Traverse 4N. A borehole drilled west along the traverse from 1000E, depressed at 60°, and extending for at least 500 ft should intersect the target.

In recommending drill holes in the Elverdton area it has been assumed that an easterly dip is prevalent. This appears to be the case from limited geological evidence and all the suggested holes are drilling west. If a closer inspection of the drill sites reveals that this assumption is unwarranted the suggested holes should be changed accordingly while retaining the same targets.

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The recommended drillholes and accompanying geophysical profiles in the Elverdton area are illustrated in Plate 7.

Geochemistry (see Plates 11 and 12)

The geochemical samples taken on traverse D in Area A and traverse 00 in Area B both showed increases in copper concentration over the Elverdton - Desmond shear. Traverses 2N and 4N in Area B show similar anomalies in line with the shear but decreasing in amplitude to the north. Other anomalies of several hundred ppm (against a background of 100 to 200 ppm) were observed but it is difficult to correlate them with any known mineralisation.

Samples on traverses 5S, 6S, and 14S in Area C generally had a lower background and the profiles show less pronounced anomalies. Small anomalies (about 400 ppm against a background of approximately 100 ppm) were observed near 2800E to 3000E on traverses 5S and 6S. These correspond to a small IP anomaly and a suspected weakly mineralised shear. Other small anomalies were observed near 1700E and from 3100E to 3200E on traverse 1400S. Both these anomalies are near small mineralised shears visible on the surface but not expected to continue in depth and not associated with IP anomalies.

The geochemical samples detected several anomalies that could generally be correlated with mineralisation. The presence of many small shafts and the main Elverdton concentrator, with resulting surface contamination, necessitates a great deal of care in soil sampling in this area. The results appear to be a useful auxiliary tool but tests were not sufficiently comprehensive to assess the value of geochemistry as a reconnaissance method.

The Gap

The most notable features of The Gap area (see Plate 8) were the extremely low resistivities encountered. Resistivities of 1 to 10 ohm-metres were common and on none of the traverses tested did the resistivity reach 100 ohm-metres. This low resistivity made all IP measurements difficult to obtain as the received signals were very small and difficult to distinguish from telluric noise. The frequency effect measurements were probably rather inaccurate and possibly influenced by inductive coupling. Frequency effect anomalies were obtained on all three traverses surveyed, particularly on traverse 400E and close to the shaft on traverse 0. High frequency effect and metal factor values were observed along the entire length of traverse 400E with the highest values at the southern end. The increase of frequency effect with increase in "n" observed on all three traverses is characteristic of the effect of inductive coupling. Frequency effects due to inductive coupling have been calculated in several places assuming a uniform earth and using the method outlined by Madden and Cantwell (1963). Although the calculated values are quite significant they are not sufficient to explain the observed values and it appears likely that a real IP anomaly distorted by inductive coupling effects exists on all the traverses surveyed.

Turam measurements were made on all three traverses at The Gap, and many large anomalies were found. The profusion of anomalies, possibly due to mineralised solutions, made the interpretation of this area very difficult and a great deal more field work is necessary before a complete analysis can be made. 16

Magnetic profiles at The Gap were very disturbed and many steep, narrow anomalies were observed. One anomaly was observed at 450N on traverse 0, near the abandoned shaft, between two Turam anomalies. A similar anomaly was observed at 400N on traverse 400E between two Turam anomalies similar in shape to those on traverse 0.

The most favourable location for testing the geophysical results is on traverse 400E. The IP results on this traverse show the strongest anomaly at 100N (but further IP work to the south could possibly modify this conclusion); the Turam anomaly is centred between 200N and 300N and the magnetic anomaly at 400N. One borehole from 400N, drilling south along the traverse, depressed at 40°, and extended for at least 700 ft should test the IP and Turam anomalies. It must be stressed that such a recommendation is not based on very conclusive geophysical evidence. Furthermore no detailed geological information is available on the area. This drill hole should have a low priority and if any further information, either geological or geophysical, becomes available, it should be reconsidered.

Marion Martin

No magnetic work was done in the Marion Martin area by the 1965 survey party but it was understood that the area had been surveyed previously by Geosurveys of Australia Ltd and magnetic anomalies had been used to locate drill sites. The holes drilled as a result of the magnetic work had located chalcopyrite orebodies, and subsequent mining, still active during the geophysical survey, had confirmed them.

The Turam results (see Plate 9) show a pronounced anomaly extending across the area between 600N and 100N. It is typical of a shallow horizontal conductor and is not considered important. Another pronounced anomalybetween 2000N and 2200N on traverses 600E, 750E, and 900E coincides with a wire fence and is most probably caused by it. The anomaly extending from traverse 150W to traverse 750E at about 1200N, which coincides with the position of the known mineralisation, has already been mentioned (Chapter 4). A similar anomaly occurs at about 1800N on traverses 450E to 900E close to several old shafts and suggests the presence of another similar line of mineralisation.

IP work at Marion Martin detected frequency effect anomalies on several traverses coinciding with the position of the Turam anomaly and shafts near 1100N - 1200N. In general, the metal factor anomalies are displaced slightly to the south, in the direction of a low resistivity zone coinciding with the suspected shallow, horizontal conductor between 600N and 1000N. It is difficult to say whether the metal factor anomaly has been distorted by the low surface resistivities to the south or whether it is a genuine anomaly caused by sulphide mineralisation; drilling or underground development would be necessary to resolve these possibilities. The highest metal factor anomalies are between 900N and 1000N on traverses 300E and 450E, at a depth of approximately 200 ft. Although this does not necessarily indicate the best mineralisation, the zone has not been adequately explored and further underground exploration seems justified.

The second line of anomalies near 1800N contains similar frequency effect and metal factor indications and probably similar mineralisation. No drilling is recommended on the present results but further geophysical work would be useful. Both Turam and IP methods could be used to trace this line of anomalies to the east, but the IP method appears to be the most sensitive.

Mount Cattlin

Two traverses were surveyed at Mount Cattlin and frequency effect anomalies were observed on each (see Plate 10). Metal factors in the range 100 to 500 were observed but they did not form well defined anomalies.

On traverse 00 a shallow frequency effect anomaly occurs at about 800N, very close to a shaft, probably indicating shallow mineralisation. A similar, deeper frequency effect anomaly was detected on both traverses: at 1100N to 1200N on traverse 00, and 1000N to 1100N on traverse 200E. The source of the anomaly appears to be at least 200 to 250 ft deep and almost too deep to be detected using 100-ft dipoles. One borehole is recommended to test this anomaly, aimed at a target 250 ft below 1050N on traverse 200E. If the borehole is drilled from 1200N, south along the traverse, depressed at 60°, and extended for at least 600 ft it should test the anomaly adequately.

The apparent success of the IP method in the Mount Cattlin area is most encouraging and even if the recommended borehole is unsuccessful, further IP work on parallel traverses is warranted.

6. CONCLUSIONS

The geophysical methods in use at Ravensthorpe were tested over known mineralisation in several places (Desmond, Elverdton, and Marion Martin) and in all cases recognisable anomalies were obtained. Turam measurements and resistivity profiles obtained from IP measurements apparently were seriously affected by the presence of saline solutions, and the frequency effect appeared to be the most diagnostic parameter. In some cases metal factor anomalies were better defined and easier to recognise than frequency effect anomalies but the possibility of serious distortion owing to the presence of non-mineralised conducting zones made great care necessary in their interpretation.

In the Elverdton area several boreholes are recommended to test the geophysical anomalies. It must be emphasised that none of the anomalies to be tested is as pronounced as any of those obtained over known mineralisation, but they should be tested as all are reasonably close to the present mine and plant and any new ore discoveries would be extremely important. Turam results using a grounded cable were possibly affected by galvanic currents and tests using a large loop may give more regular anomalies and enable a more accurate interpretation to be made.

IP measurements at The Gap gave encouraging results but the low resistivities encountered limited the accuracy of measurements. Results suggest that inductive coupling may have affected the observed frequency effects; further tests using different frequencies or time domain IP equipment should help to give a more definite interpretation. One borehole is suggested to test results at The Gap. However, if any other exploratory work in the area is envisaged, the borehole should be delayed until this information becomes available.

IP and Turam anomalies were detected in the Marion Martin area. No boreholes are recommended at present but further geophysical work is recommended (particularly IP) in the area between Marion Martin and Mount Cattlin.

IP results at Mount Cattlin were encouraging. One borehole is recommended and further geophysical work may reveal more targets.

Details of the drilling recommendations are given below:

Drill Hole No.	Location	Angle of Depression	Bearing along traverse	Approximate minimum length (ft)	Position of target and depth (ft)
DDH 1	1000E/12N Area B	40°	West	700	650E/12N (300)
DDH 2	2560E/24N Area B	60°	West	400	2450E/24N (200) 2490E/24N (120)
DDH 3	2400E/10S Area C	45°	West	500	2200E/10S (200)
DDH 4	400E/10S Area C	45°	West	500	200E/10S (200)
DDH 5	150W/12S Area C	60°	West	500	300W/12S (260)
DDH 6	1000E/4N Area D	60°	West	500	860E/4N (250)
DDH 7	400N/400E The Gap	40°	South	700	see text
DDH 8	1200N/200E Mount Cattlin	60°	South	600	1050N/200E (250)

For the first six drill holes, in the Elverdton area, no order of priority is given, all should be tested as any discoveries would be of great value to the mine. The borehole at The Gap should have the lowest priority. Supporting evidence, particularly from geological mapping, would be required to allow it to be sited with confidence. The drill hole at Mount Cattlin is based on the best IP anomaly obtained during the survey (apart from those over known mineralisation) and has the best chance of success.

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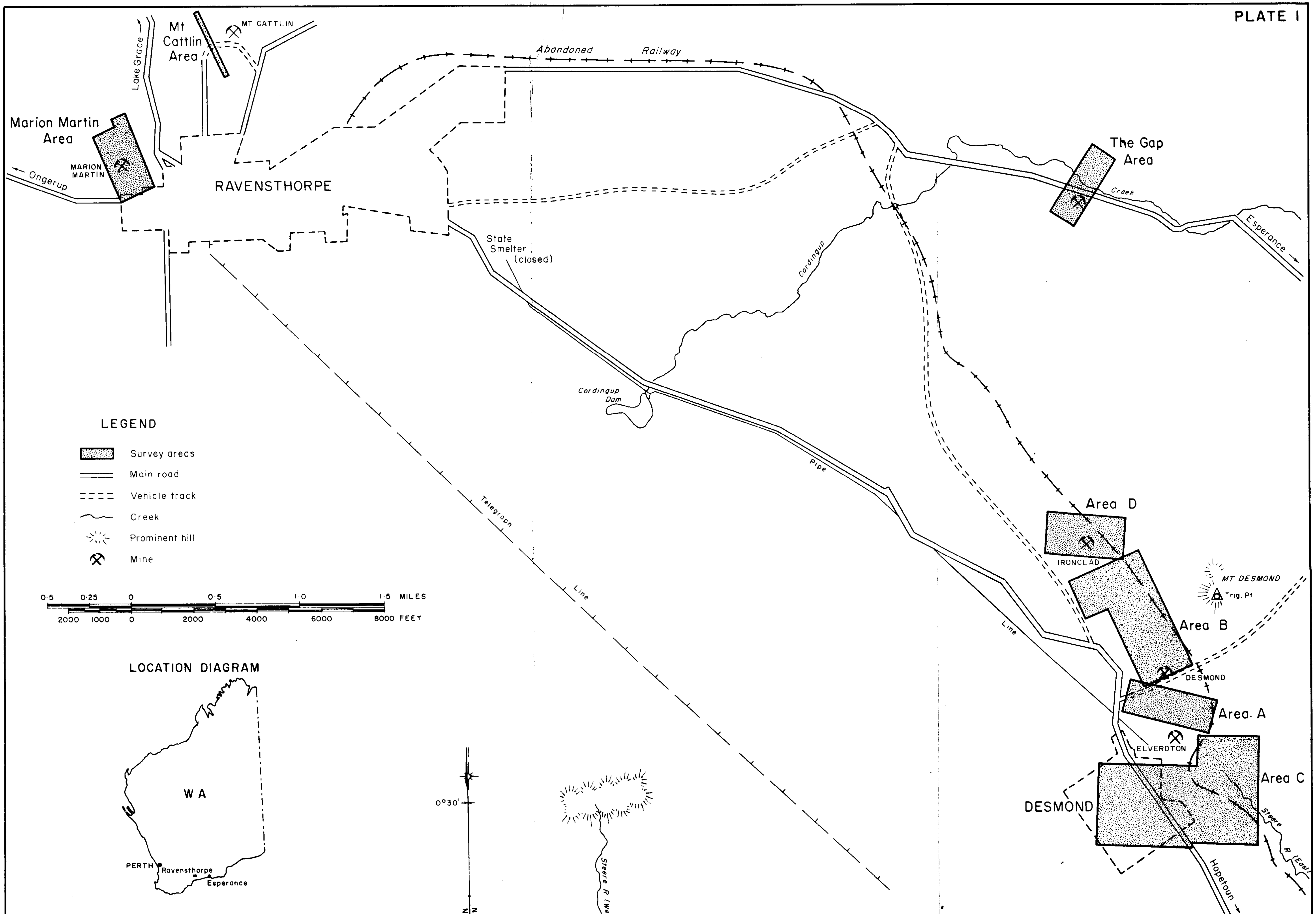

METALLIFEROUS SURVEY, RAVENSTHORPE, WA, 1965

LOCALITY MAP

TO ACCOMPANY RECORD No. 1967/64

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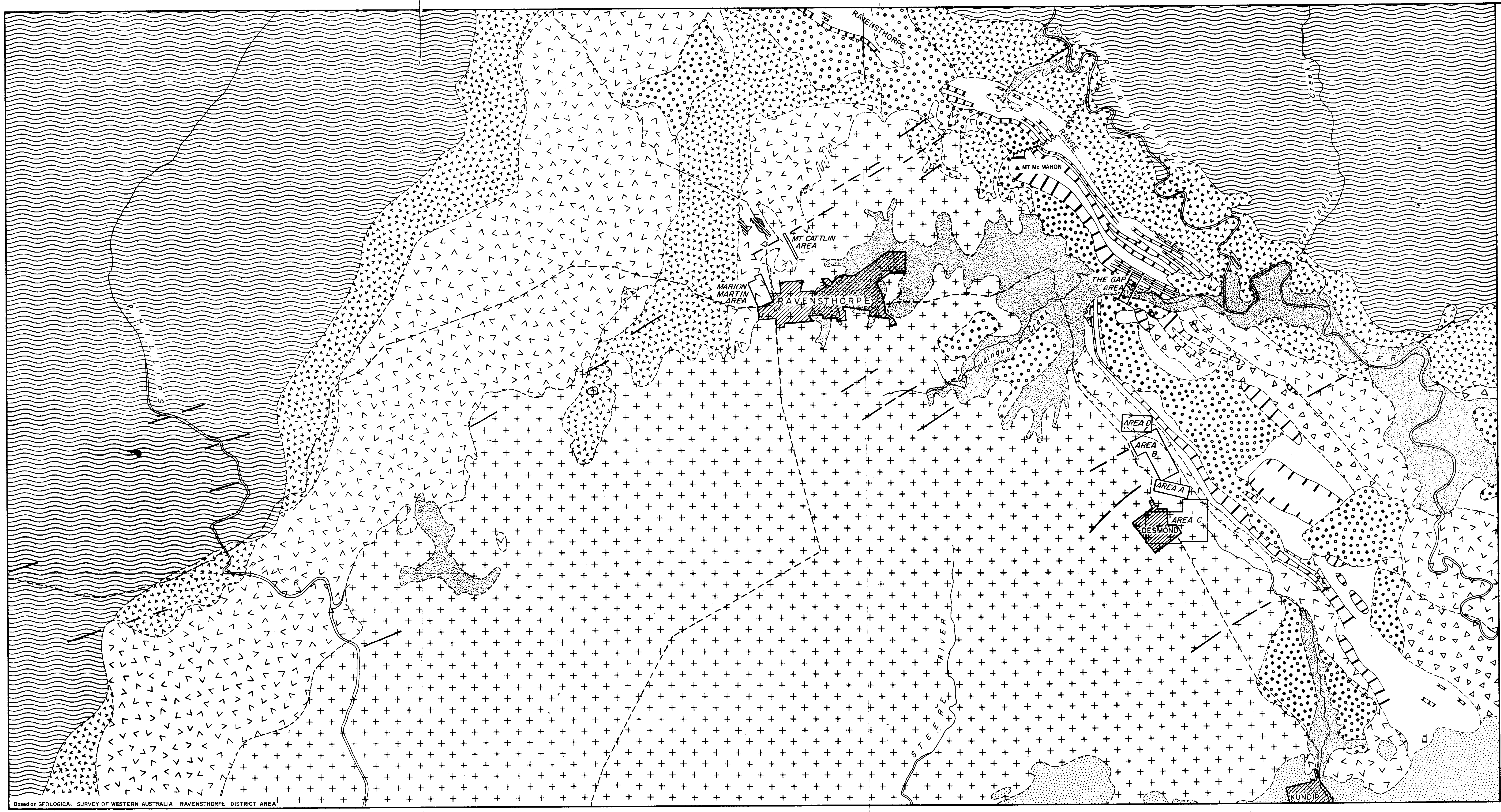
151/B7-14

PLATE 2



LEGEND

- Sand, Alluvium.
- Superficial sandy and lateritic soils, thin sedimentary skins, cements, boulder deposits.
- Undifferentiated quartzites, phyllites, shales etc.
- Quartz-dolerite
- Pegmatite
- Granite
- Gneiss, Granitised meta sediments.

RAVENSTHORPE BEDS

WHITESTONES

- Undifferentiated meta sediments, schists, slates, quartzites etc.
- Jaspilite

GREENSTONES

- Serpentine.
- Undifferentiated basic amygdaloidal, massive porphyritic lavas etc.
- Undifferentiated basement metasedimentary schists, quartzites etc. Agglomeratic lava. Metasedimentary quartzite.

Geology after Sofoulis (1958)

REGIONAL GEOLOGY OF THE RAVENSTHORPE DISTRICT

MILES

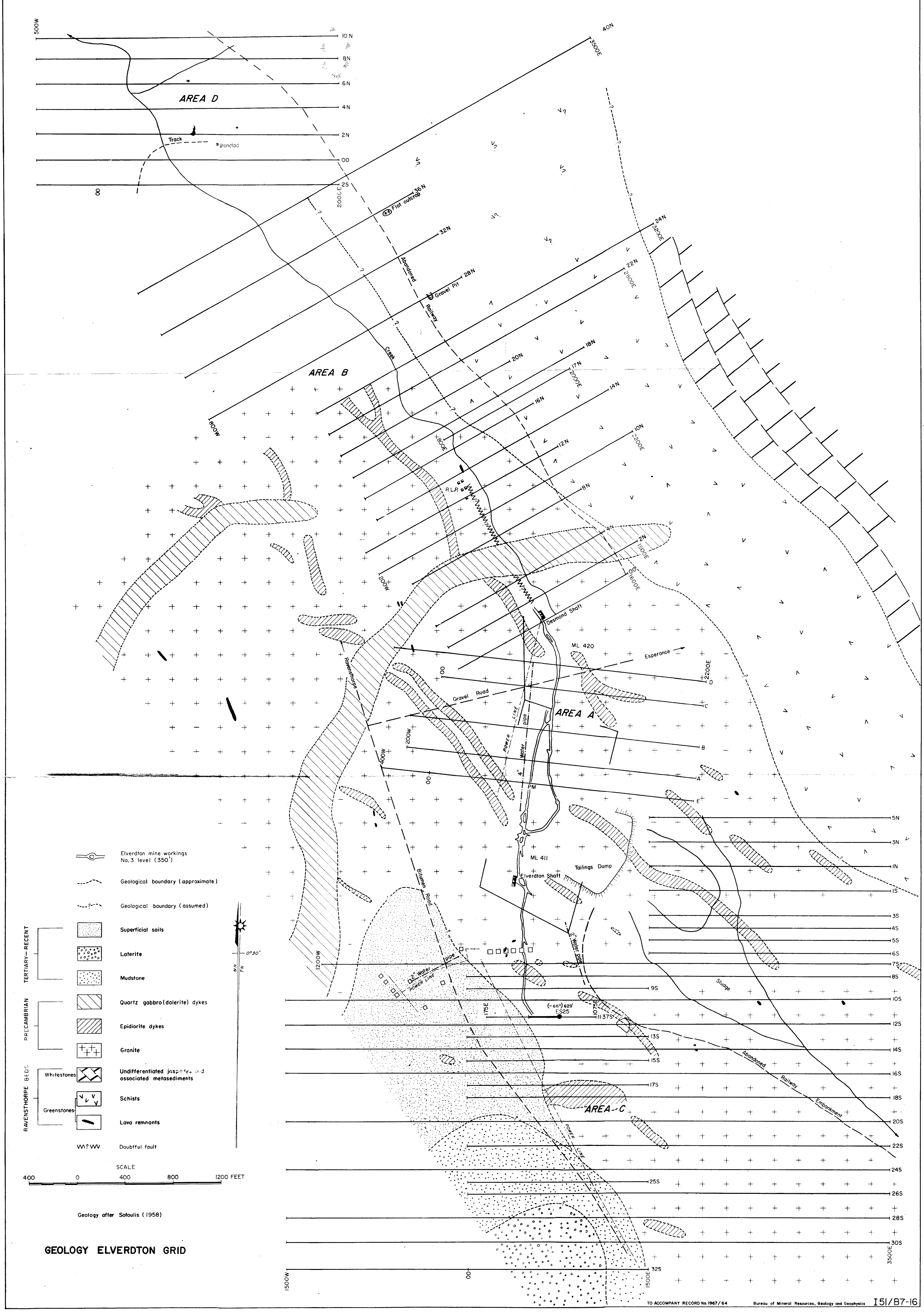
1 0 1 2

TO ACCOMPANY RECORD No. 1967/64

Geophysical Branch, Bureau of Mineral Resources, Geology and Geophysics.

I51/B7-22

PLATE 3



GEOLOGY ELVERDTON GRID

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Bureau of Mineral Resources, Geology and Geophysics

I51/B7-16

I51/B7-16 RAVENSTHORPE (Elverdton)

GEOPHYSICAL PROFILES OVER KNOWN MINERALISATION

PLATE 5

ELVERDTON AREA

VERTICAL MAGNETIC FIELD CONTOURS

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151/B7-13-1

PLATE 6

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I51/B7-19

RAVENSTHORPE METALLIFEROUS SURVEY WA, 1966

PLATE 7

ELVERDTON AREA

GEOPHYSICAL PROFILES OVER DRILLING TARGETS

FEET
200 0 200 400 600
(Vertical scales as shown)

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PLATE 8

THE GAP AREA
TRAVERSE PLAN AND GEOPHYSICAL RESULTS

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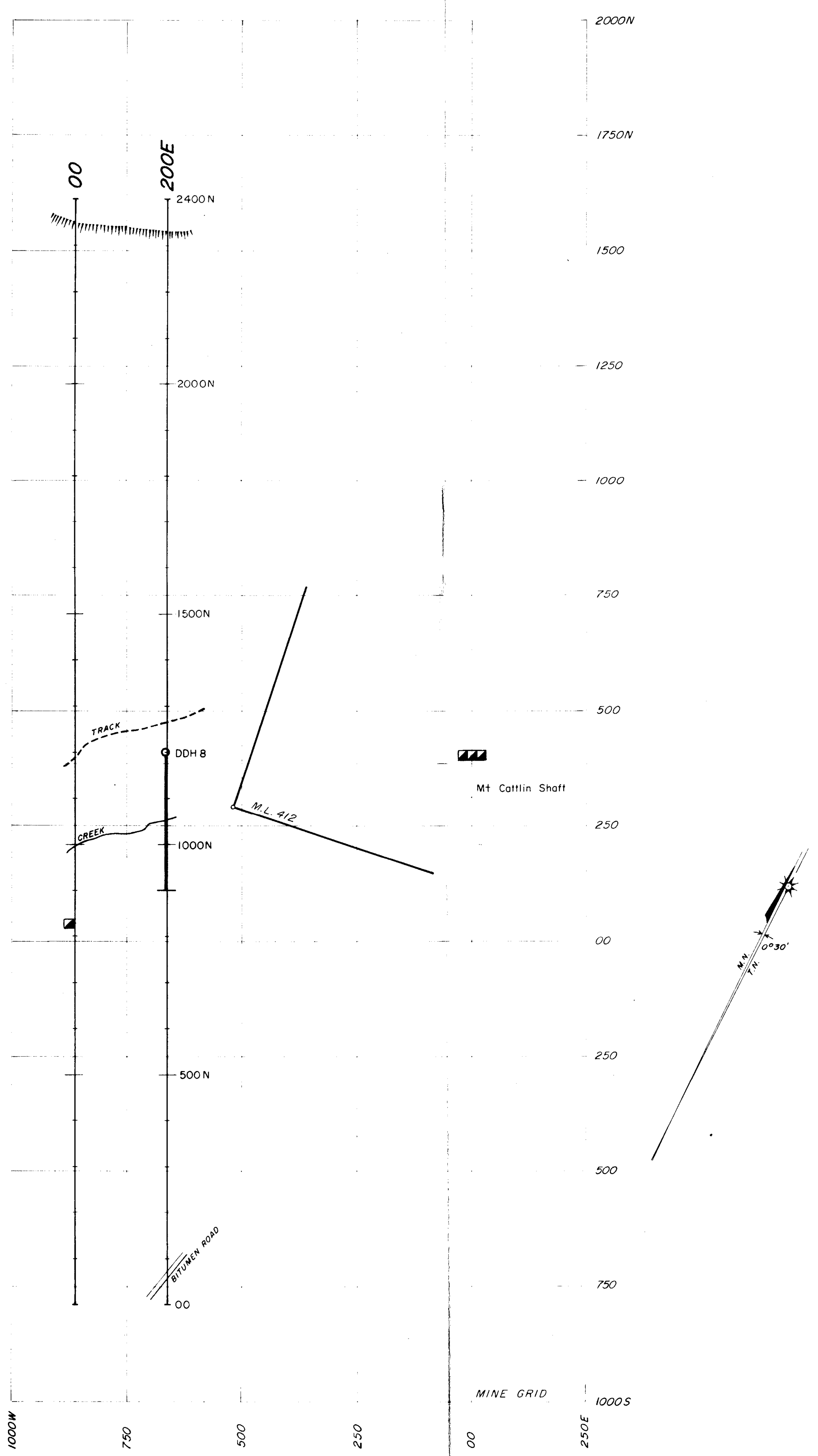
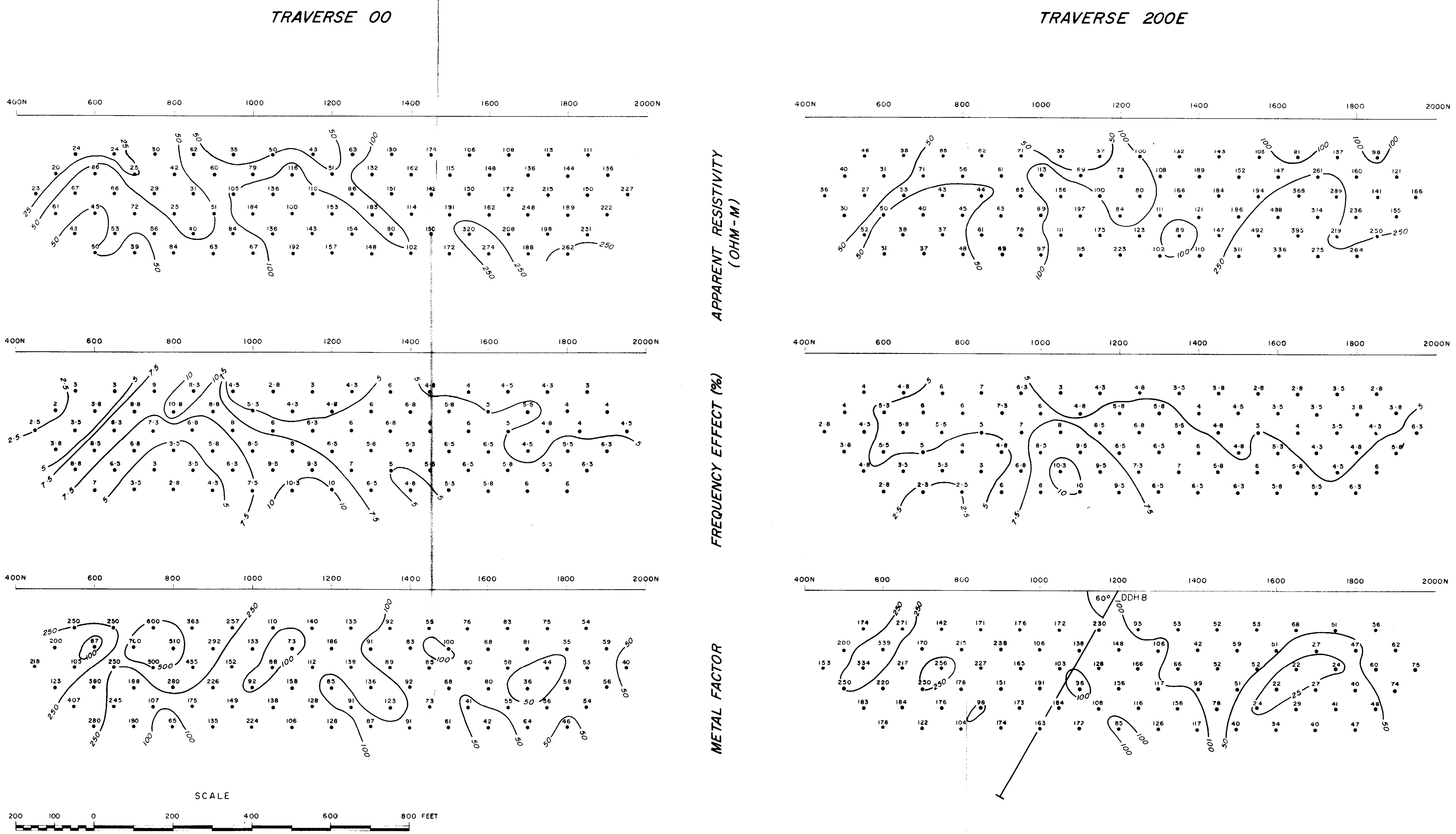
I51 / B7 - 17

PLATE 9


MARION MARTIN AREA
TURAM PHASE CONTOURS AND I P ANOMALIES
220 c/s, 100 ft separation
Cable at ON
Traverse
Drill hole
Shaft
Fence
100 FT DIPOLES
200 FT DIPOLES
I P Traverses
Frequency effect anomaly (>5%)
Metal factor anomaly (100-500)
Only areas where metal factor and frequency effect anomalies coincide or overlap are shown.
Turam phase contours
FEET
200 150 100 50 0 200 400 600
(Contour interval 5 degrees)
MARION MARTIN
ML 410
Creek
Ravensthorpe
Ongerup
MMS1
MMS2
MMS3
MMS4
MMS5
MMS6
MMS7
MMS8
MMS9
MMS10
RS1
RS2
0°30'
TN
MN
150W
0
300E
450E
600E
750E
900E
2500N
2000N
1500N
1000N
500N
ON
(BASED ON 151/B7-15)
TO ACCOMPANY RECORD No. 1967/64
GEOPHYSICAL BRANCH, BUREAU OF MINERAL RESOURCES, GEOLOGY AND GEOPHYSICS
151/B7-23





MOUNT CATTLIN AREA

TRAVERSE PLAN AND IP RESULTS

100' DIPOLES

PLATE II

AREAS A AND B
GEOCHEMICAL PROFILES

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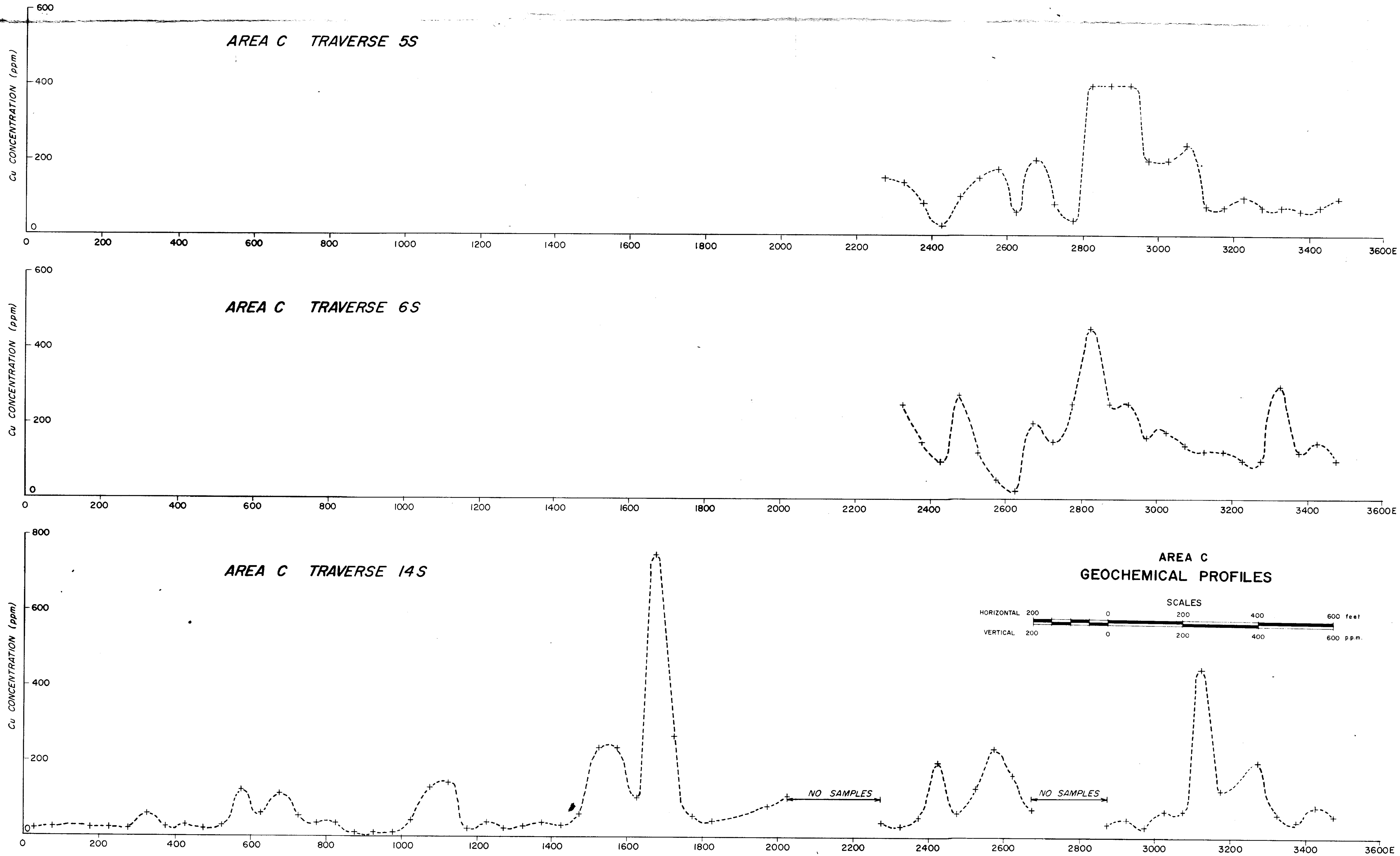
RAVENTHORPE W.A. 1965

PLATE 12



RAVENSTHORPE W.A. 1965

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