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MT. LEYSHON ELECTROMAGNETIC SURVEY

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1. INTRODUCTION

In July and August, 1988 an electromagnetic survey was undertaken in the vicinity of the Mt. Leyshon Mine near Charters Towers, Queensland. The aim of the survey was to provide information to assist in the siting of groundwater exploration drillholes by

(i) delineating any electrically conductive zones within and beneath the weathering profile which may represent fracture zones of higher porosity than the surrounding rocks, and

(ii) determining the strike and extent of these, or any other geological features detected by the electromagnetic method.

The survey was conducted over 6 working days, in two parts, the first being from the 25th to the 28th July, and the latter being over the 25th and 26th August; equipment failure was responsible for the enforced break in the survey. For both parts of the survey two personnel were required, these being myself and a field hand supplied by Pan Australia Mining. A total of 20.72 km of traverse was completed, 16.5 km at a 50 m station interval, 1.55 km at a 25 m station interval, and 2.67 km at a 20 m station interval.

2. SURVEY AREAS

Electromagnetic traverses were run along existing grids in three areas near the mine. These areas are referred to as Areas I, II and III and are identified in Plate 1, which also shows the location of all EM lines.

3. GEOLOGY OF THE SURVEY AREAS

Area I overlies granitoids of the Ravenswood Batholith, Area II is underlain by vent breccias, tuff and porphyry of the Mt. Leyshon complex and metasediments of the Puddler Creek Formation, while Area III is underlain entirely by the latter Formation. In all three areas it was anticipated that any significant fracture zones present are likely to dip steeply and strike N to NE, this also being the direction of many of the dykes pervading the areas. Weathering is typically shallow, mostly less than 15 m, with abundant outcrop occuring over large parts of areas I and II

4. SURVEY OBJECTIVES

The aim of the survey was to detect any zones of locally high porosity associated with shearing or faulting within the unweathered rocks, and/or any local associated increase in weathering depth. Such zones, if porous enough, permeable enough and continuous enough may constitute an aquifer, or a means of extracting water from any aquifer that may exist within the wider areas, e.g. within pervasive fracturing at the base of oxidation. Because of their increased water and clay content, such shear zones are expected to be considerably more electrically conductive than the rocks to either side of them; if steeply dipping, their disposition makes for optimum coupling to a horizontal loop electromagnetic system such as was used in the survey.

Also present within the survey areas are dykes, many of which possess a similar trend to the expected shear zones. If more easily weathered then their host rocks, their response may be similar to that of a shear zone, though, as explained below, the survey technique has some ability to distinguish between weak and strong subsurface conductors, with the effect of weathered dykes probably falling into the former category. However, many of the dykes appear to be resistant to weathering, giving rise to semi-continuous outcrop. Such bodies are expected to be electrically resistive compared to the weathered rock surrounding them near the surface but, paradoxically, their electromagnetic response bears certain similarities to that of conductive bodies, as explained below.

5. INSTRUMENTATION

For the first part of the survey a rented APEX "Maxmin II" portable EM unit was employed in the horizontal loop EM (HLEM) mode. Comprising transmitting and receiving coils which can be separated by 25, 50, 100, 150, 200 and 250 metres, the inphase and quadrature (i.e. out-of-phase) components of the secondary magnetic field can be measured at frequencies of 222, 444, 888, 1777 and 3555 Hz.

This unit malfunctioned, requiring that surveying cease until it was fixed. After excessive delays in repairing the instrument on the part of its suppliers, it was decided to finish the survey using a Geonics EM34 system. At coil spacings of 10, 20 and 40 metres, this system measures the quadrature component only of the magnetic field at frequencies of 1600, 800 and 400 Hz respectively. Hence, for a given coil separation, only a single reading can be

It is possible that the last two of the above anomalies represent resistive, rather than conductive bodies. However in these cases, as for any of the other anomalies already discussed, it is also possible that features on the profile curves may be due to both simultaneously, such as may result from fracturing of country rock next to a resistive dyke. Again, a geological inspection of targets prior to drilling may help to resolve the matter.

8. CONCLUSIONS

In all three areas covered, features on the EM profile results can be correlated from line to line, thus establishing strike for the causative bodies. However in no area is a strong conductor present. The conductors that are present have a variable response from line to line indicating changes in conductivity and/or thickness along strike.

In each area, targets have been ranked in order of apparent thickness-conductivity product, this being reflected in the amplitude of the anomaly as the coils cross it, the extent to which the real component responds, and the change in the anomaly amplitude with frequency. For some anomalies, it is possible that a resistive, rather than conductive, body is the causative agent. However complex geology and irregular bedrock surface often make it difficult to separate the effects of any one geological feature; the resultant contamination of the anomaly curve resulting from one feature by that resulting from another makes it difficult to glean too much information about an anomaly's source from the shape of its response. Furthermore it is not unlikely that resistive and conductive bodies may lie in juxtaposition, as explained above, complicating the position further.

In giving the position of targets above, some attempt has been made to interpolate between measuring points so that, in general, the target has been described as closer to the lower reading of two neighbouring anomalously low readings. Most anomalies are defined by two such consecutive low readings; this is because, at a sampling interval of half the coil separation, the array subtends the conductor for two readings. When making final selections of the drilling point, the latter should be kept between these two low readings. (This does not apply to EM34 results taken at a 25 m station interval as 25 m exceeds half the coil separation).

taken at each station. However because of this instrument's ability to cancel the primary field through careful positioning of the receiving coil, the reading is highly accurate, permitting high repeatability and resolution of earth conductor response. For display, the reading is converted to apparent conductivity, the relationship being

$$\sigma a = \frac{4}{\omega \mu r^2} \frac{Hs}{Hp}$$

where

σa is the apparent conductivity
ω is the angular frequency of transmission
μ is the magnetic permeability
r is the coil separation
$\frac{Hs}{Hp}$ is the normalized quadrature secondary field

6. SURVEY TECHNIQUE

In all areas survey lines had been pegged at 50 m or 100 m intervals, though electromagnetic surveying was often made difficult because pegs had been knocked over or were missing. Traverses were run in an E-W direction.

A coil spacing of 100 m was used for traversing with the Maxmin system, and readings at every station were taken at three frequencies, viz 222 Hz, 1777 Hz and 3555 Hz. A reading interval of 50 m was used, so that rapid coverage could be achieved. It was intended to re-survey any interesting zones with a smaller sampling interval, and perhaps a smaller coil spacing, at the end of the survey but, as was mentioned, the Maxmin was no longer available. During surveying operations the transmitter lead the receiver so that the operator of the former could search visually for the next station while the receiver operator was taking the measurements. The transmitter-receiver distance was maintained at 100 m using marks on the cable connecting the coils, while the grid pegs were used to determine each reading site. The axes of the transmitter and receiver coils were kept vertical for each reading.

A coil spacing of 40 m was used for traversing with the EM34. On one line, readings were taken at 40 m intervals; otherwise the station interval was 25 m or 20 m, mostly the latter. Again, the transmitter led the receiver; distances were measured in the course of profiling using marks on the wire, and the 20/25 m sampling interval was tied into the 50 m pegging interval at each peg. The transmitter-receiver distance was kept accurate by the in-phase nulling procedure of the EM34 which requires that this distance be adjusted until the measured secondary in-phase magnetic field component at the receiver is zero.

7. RESULTS

All results are presented in Plates 2, 3 and 4. These are plotted to a scale of 1:5000, the same as the map of Plate 1. Note that the plotting point for results is halfway between the transmitter and receiver.

Discussion of Results - General

The Maxmin results plotted in Plates 2-4 all contain an instrumental offset of a constant amount, this offset depending on the frequency and whether the inphase or quadrature component is being considered. However the shape of anomalous responses is not affected by this offset. In the present context of shallow groundwater exploration this does not present a problem, as the system's ability to detect conductivity variations along the profile line and to allow judgments as to the magnitude of these variations is unaffected.

As a general principle, when inspecting HLEM results in an environment where no geological feature has an outstanding conductivity, the quadrature component is the most sensitive to local increases in conductivity. As the conductivity of a target body increases, the in-phase component then starts to respond. Hence two conductors detected with the quadrature response can be ranked according to how much the in-phase response varies simultaneously.

For steeply dipping conductors of the type expected at the present locality, the response is expected to be negative relative to the response of the surrounding countryside; this negative will be flanked by broad low peaks on either side. So, in general, "lows" on the graphs of Plates 2-4 represent possible targets. However the situation is somewhat confused by the fact that resistive bodies also give rise to a response that is negative compared with that of the surrounding country. This is illustrated in Fig. 1 which shows the response of the EM34 to two models of the type typically of interest in groundwater exploration. In part (a) of this figure the traverse crosses a buried local deepening of bedrock as may represent a subcropping shear zone; in part (b) the traverse crosses a resistant dyke. It can be seen from these diagrams that in area of complex geology and irregular bedrock topography, a valley and a ridge in bedrock may be difficult to distinguish on the basis of field profiles run with a discrete sampling interval.

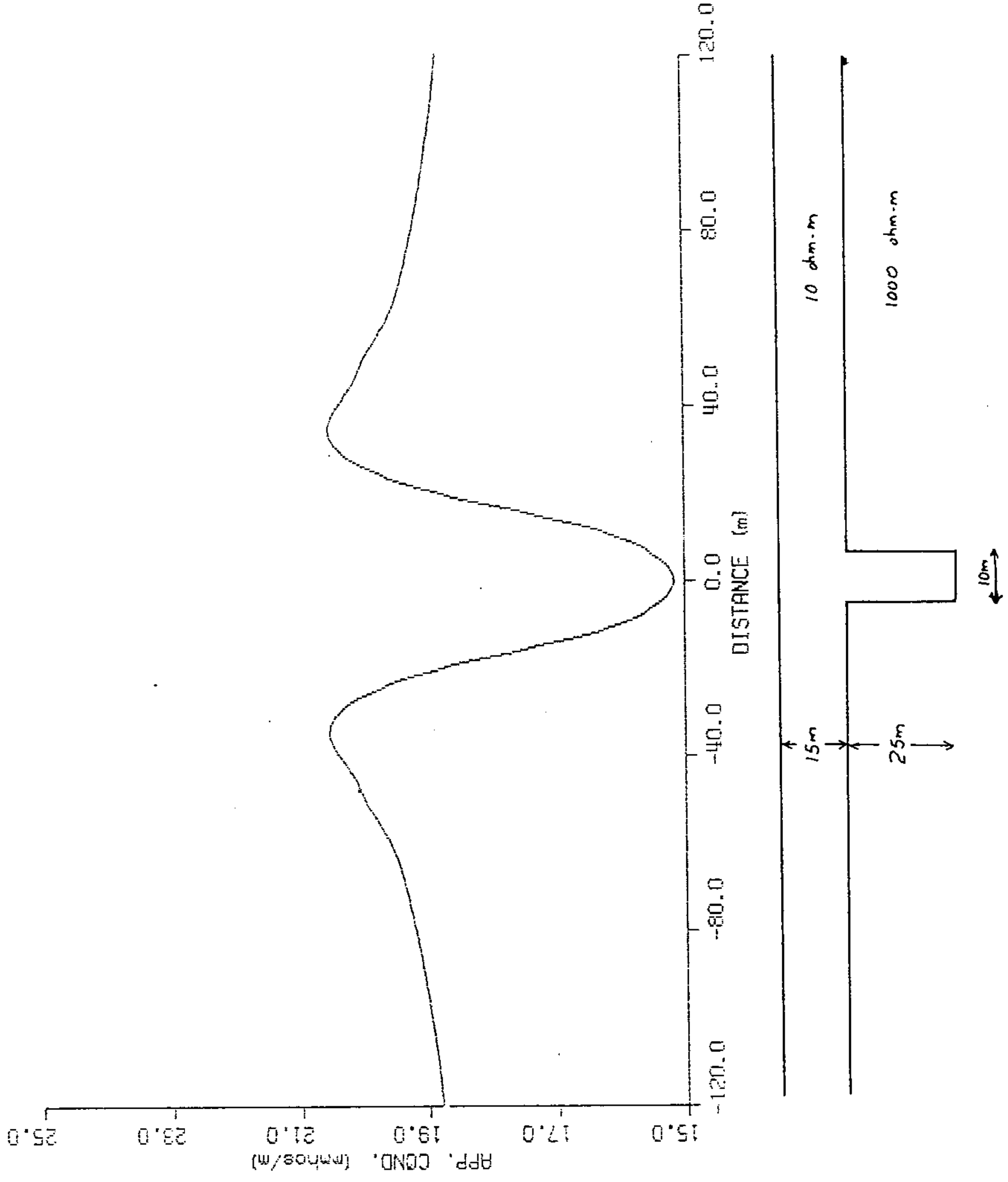

Figure 1a. EM34 traverse over a basement trough

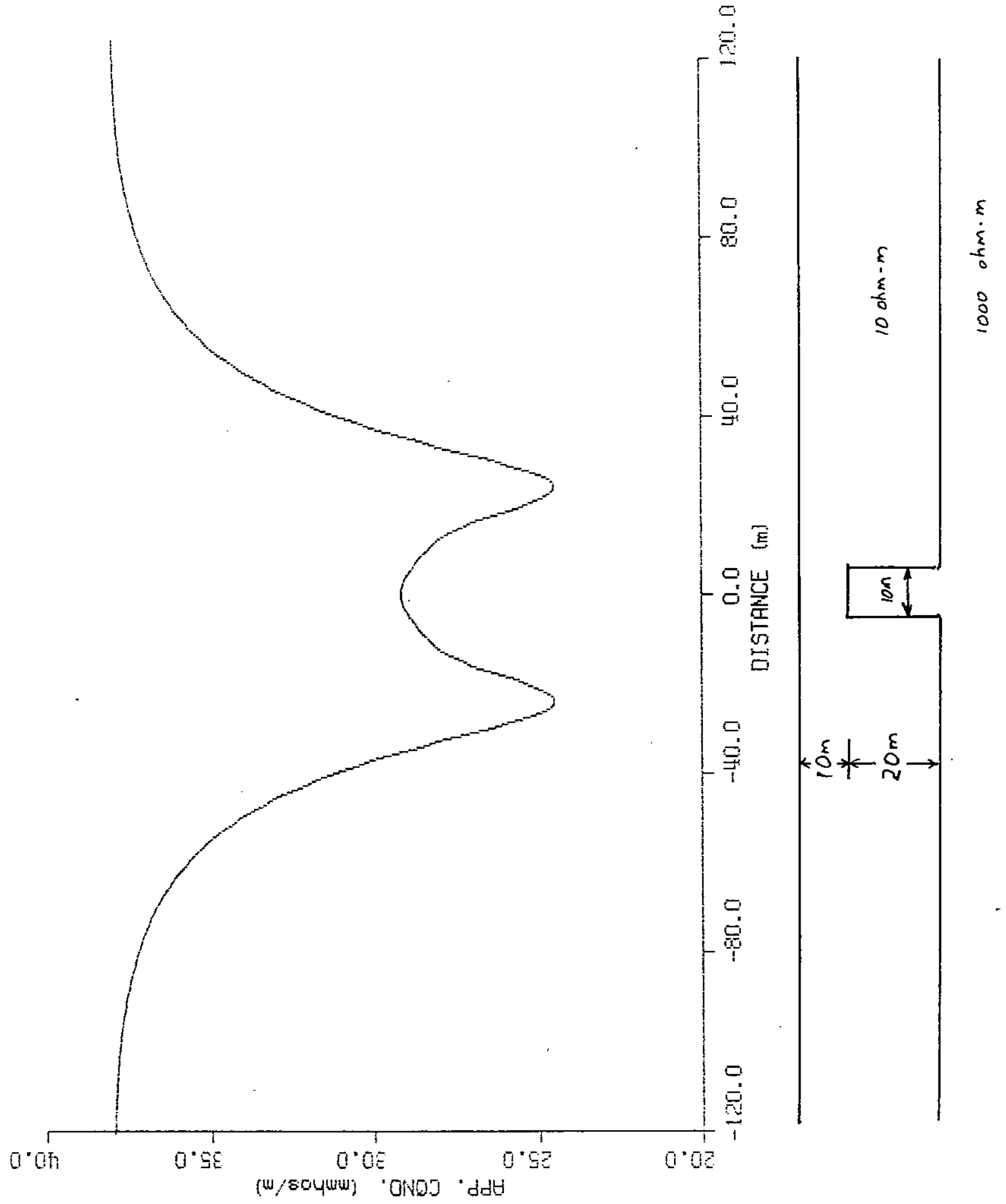

Figure 1b. EM34 traverse over a basement ridge

Finally it should be noted that the in-phase response of the HLEM technique is sensitive to topographic effects. Thus on hilly country such as was encountered over some of the lines, the in-phase response can become quite low, giving the impression of a conductive anomaly beneath the traverse. However the quadrature component is only affected slightly by topography, and should be referred to in order to ascertain whether anomalous readings taken on hills are due to conductors or not. Also, if the anomalous in-phase readings are due to anomalous earth conductivities, the response will become more pronounced at higher frequencies, whereas the magnitude of the anomaly will remain constant with frequency if the anomaly is a topographic effect.

In general, the effect of subsurface conductivity variations is greater at higher frequencies, the extent to which the anomaly magnitude increases being a measure of the causative feature's conductivity contrast with its surroundings.

Discussion of Results - Area I

The most prominent feature on all lines in Area I is the response of the buried telephone cable beside which all other anomalies pale. Matching other responses from line to line is possible, with correlations indicated on Plate 2.

The results show that no features stand out as being particularly hopeful targets; however the better-looking ones were followed up using the EM34. Ranked in decreasing order of likely conductivity-thickness product, the best features in the area are at

(i) 3230 E on line 7800 N
(ii) 3490 E on line 7400 N
(iii) 3375 E on line 7400 N
(iv) 3100 E on line 7800 N

Note that these locations are susceptible to a ± 10 m error due to the 20 m station interval, and may need to be shifted by something less than that amount on geological or topographic considerations. Also, some of these features may be due to resistors rather than conductors as explained above, so that geological information should be taken into consideration when deciding where to drill.

Discussion of Results - Area II

The correlation of the responses from line to line is not definitive, though it is likely that the connections shown in Plate 3 represent the disposition of the causative bodies. Again, anomalies are not outstanding. On four lines anomalies were followed-up with the EM34; note that a 25 m sampling interval was used with the latter instrument in this area.

The best targets, ranked in order of decreasing suspected conductivity-thickness product are as follows:

1. 4425 E on line 5400 N
2. 4530 E on line 5300 N
3. 4270 E on line 5400 N
4. 4520 E on line 5000 N
5. 4595 E on line 5000 N

or 4795 E on line 5000 N
or 4720 E on line 5100 N

Note that a ±12.5 m uncertainty exists for all of these locations, this being half the sampling interval.

Apart from the first anomaly on the above list, there is little to separate them in terms of strength of response, so that geological and topographical considerations should be significant in choosing between them. (Note also, it is not impossible that any of them may be spurious, being due to bedrock "highs" of the type shown in Fig. 1b).

Discussion of Results - Area III

Line-to-line correlations are not obvious, but it is suggested that they are as indicated in Plate 4. Anomalies ranked in order of decreasing thickness-conductivity product, are as follows:

1. 3125 E on line 3700 N
2. 3330 E on line 3700 E
3. 3505 E on line 3700 E and 3255 E on line 3700 E
4. 3300 E on line 4400 N
5. 3240 E on line 4400 N