Experimental Controlled Source Audiomagnetotelluric Measurements on the Elura Orebody, NSW

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Introduction

With the permission of EZ Coy. A'asia Ltd., personnel of the Minerals Department of Esso Australia Limited conducted audiomagnetotelluric measurements along one grid line over the Elura ore body. The surveying was experimental in nature and involved the use of prototype equipment. The work was accomplished during January 15 to 17, 1977.

The Audiomagnetotelluric Method

Audiomagnetotelluric (AMT) surveys entail the simultaneous measurement of electrical and magnetic fields over the frequency range 10Hz to 10kHz (Strangway and Vozoff, 1969). The observed values of the electrical field (E volts per metre) and the magnetic field (H gammas) at one locality yield apparent resistivity values which constitute a vertical sounding of the subsurface at that locality over a depth range related to the range of frequencies (f Hertz) studied. The apparent resistivity is calculated by the formula:

$$\rho_a = \frac{1.26 \times 10^5\ (E/H)^2}{f} \text{ ohm metres}$$

Strangway, Swift and Holmer (1973) and Strangway and Koziar (1979) have provided examples of the application of natural field AMT to base metal exploration.

Simultaneous electrical and magnetic measurements may also be made in the vicinity of a loop or grounded dipole source. The utilisation of 'Controlled Source' audiomagnetotelluric measurements is discussed by Goldstein and Strangway (1975). A massive sulphide application of CSAMT in Australia is presented by Smith (1980)

For the work at Elura, the observed signals were created artificially using a 300m long grounded dipole connected to a 5 kw square wave AC transmitter known as the EMT-5000 and manufactured by Geotronics Corporation of Austin, Texas. Currents of the order of 5 to 8 amps were transmitted into the ground over the frequency range 20Hz, 33Hz, 93Hz, 330Hz, 915Hz and 3300Hz. A motor generator provides the transmitter with 120v, 400Hz, three-phase power.

The measuring instrument used for the survey was Esso's own W-1 receiver which is essentially a highly filtered voltmeter calibrated for the specific frequencies emitted by the transmitter. Electrical measurements were made using brass stakes connected to the E input of the receiver which *has an input impedance of 1 megohm.* Magnetic measurements were accomplished using a 50cm long ferrite core coil.

Subsequent to the Elura CSAMT survey the W-1 receiver system has been superseded in toto, while the frequency range of the EMT-5000 has been extended down to 1 Hz.

Field Procedures employed at Elura

All measurements at Elura were of the Ex component of the electric field (E dipole parallel to the transmitter dipole) and of the Hy component of the magnetic field (H coil axis horizontal and perpendicular to the transmitter dipole). A dipole length of 25 metres was used for E observation. All measurements were conducted on line 20100E of the original exploration grid.

The primary field for the CSAMT survey was created using one of two transmitter dipoles established away from the measurement sites as shown in Figure 1.

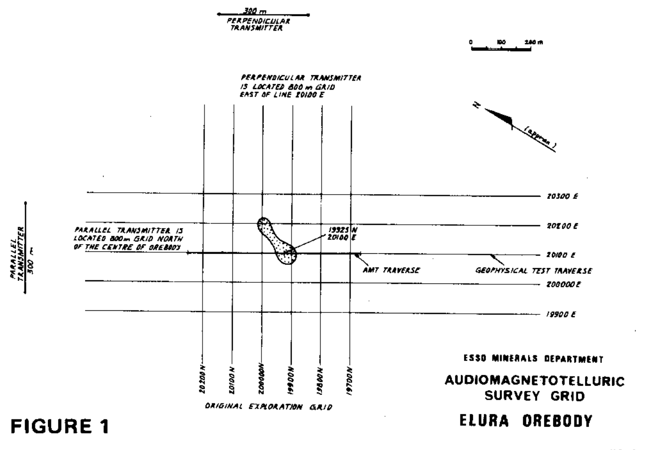

FIGURE 1

One transmitter dipole was set up along line 20725N (i.e. oriented NW-SE), 300 metres in length and centered on station 20725N, 20100E. Thus the centre of the dipole is located 800 metres grid north of 19925N/20100E, the station which is directly above the ore body's southern end on line 20100E. This transmitter is parallel to the baseline and was expected to be parallel to strike. Accordingly, it is referred to as the 'parallel transmitter dipole'. In fact, the exploration grid is oriented about 40° off the true strike of the orebody. With the parallel transmitter, current output was 6 amps.

The second transmitter dipole was set up along line 20900E, 300 metres in length and centred on station 20000N, 20900E. Thus this dipole is located 800m grid east of the point where line 20100E crosses the orebody. This dipole is perpendicular to the baseline and was intended to be perpendicular to strike. It is referred to as the 'perpendicular transmitter dipole'. Current output with this dipole was 7.8 amps.

The formulae for calculating E and H values are as follows:

$$E = \frac{\text{Wave Analyzer Reading}}{\text{Gain x Stake Spacing}} \quad \text{volts/m}$$

$$H = \frac{\text{Wave Analyzer Reading}}{\text{Gain x H-Sensor Sensitivity at each frequency}} \quad \text{gammas}$$

(1 gamma = 794 micro-ampere turns per metre)

Signal Strength & Background Noise

Prior to commencing the survey, measurements of the natural magnetotelluric fields (background noise for the *a) Electric Field* (E voltage recorded with 25m dipole, Gain-100)

Parallel Transmitter:Receiver at 19975N

	20 Hz	33 Hz	93 Hz	330 Hz	915 Hz	3.3 kHz
Signal	82 mv	66 mv	35 mv	5.4 mv	18.5 mv	18.0 mv
Noise	<60 μv	<60 μv	<90 μv	<0.1 mv	< 0.3 mv	< 0.3 mv

Perpendicular Transmitter:Receiver at 19950N-19975N

	20 Hz	33 Hz	93 Hz	330 Hz	915 Hz	3.3 kHz
Signal	298 mv	248 mv	68 mv	42 mv	93 mv	64 mv
Noise	<30 μv	<40 μv	<60 μv	< 0.1 mv	< 0.1 mv	<0.7 mv

b) Magnetic Field (H voltage recorded with Gain-1000)

Parallel Transmitter:Receiver at 19975N

	20 Hz	33 Hz	93 Hz	330 Hz	915 Hz	3.3 kHz
Signal	3.7 mv	5.7 mv	9.0 mv	9.5 mv	26 mv	12 mv
Noise	1.4 mv	0.7 mv	0.3 mv	0.26mv	0.22 mv	0.12 mv

Perpendicular Transmitter:Receiver at 19950N-19975N

	20 Hz	33 Hz	93 Hz	330 Hz	915 Hz	3.3 kHz
Signal	6.9 mv	8.6 mv	18.7 mv	21.5 mv	50 mv	22 mv
Noise	1.2 mv	0.8 mv	0.3 mv	0.35 mv	0.45 mv	0.35 mv

CSAMT survey) were made with the receiver in both parallel and perpendicular receiving modes. These noise levels are compared with the actual signal observed at the same station in the tables following.

It is apparent that the signal to noise ratio is excellent for the E measurements and satisfactory for the H measurements at high frequency. The greatest source of error will occur with magnetic measurements at 20 Hz and 33 Hz.

Presentation of Results

The AMT measurements at Elura have been presented as contoured pseudo-sections of apparent resistivity employing a linear horizontal scale and a logarithmic frequency scale: These plots are contoured at logarithmic intervals of apparent resistivity. The data are also analysed presented as profiles of apparent resistivity for each frequency plotted on a logarithmic resistivity scale against a linear distance scale. The profiles are not included in this text.

Discussion of Results from the parallel Transmitter

The contoured pseudo-section of apparent resistivities obtained on line 20100E using the parallel transmitter is shown in Figure 2.

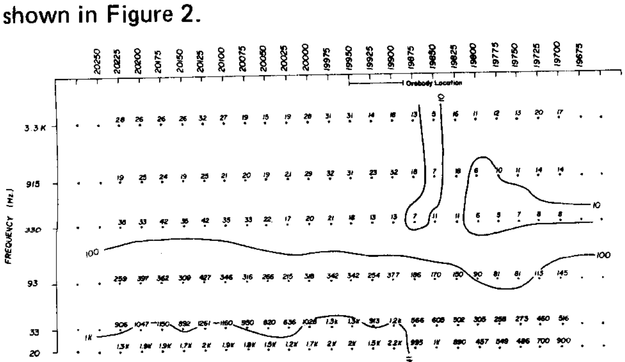

FIGURE 2

Near-surface resistivities (330 Hz to 3.3 kHz) range from 5 to 40 ohm-metres and probably indicate the upper zone of oxidised rock. This weathered zone appears slightly more conductive to the south. At lower frequencies, higher resistivities are observed. This increase may reflect the influence of fresh bedrock.

However, theoretical studies by Goldstein (1971) have shown that an increase in apparent resistivity is observed with decreasing frequency when the transmitter is close to the receiver line. Thus an apparent layering may be produced in the resistivity pseudo-section to an extent related to the proximity of the transmitter and to the resistivities of the subsurface.

There is no bedrock conductor indicated in the lower frequency results. The Elura ore body is located at station 19925N and was not detected using the parallel transmitter.

On line 20100E, it is necessary to conduct measurements close to the collars of three diamond drill holes which contain varying amounts of metal casing. This culture appears to have had no effect on the AMT results obtained with the parallel transmitter.

Discussion of Results from the Perpendicular Transmitter

The contoured pseudo-section of apparent resistivities obtained on line 20100E using the perpendicular transmitter is shown in Figure 3. Again, near-surface resistivities (those observed at 300 Hz to 3.3kHz) are generally between 5 and 40 ohm-metres and these values reflect the weathered zone.

At lower frequencies, higher resistivities are observed. This increase may reflect the influence of fresh bedrock. Again, however, it is also possible that this apparent horizontal layering is partly due to the relatively close proximity of the transmitter to the receiver line.

An anomalous contrast in apparent resistivities is evident

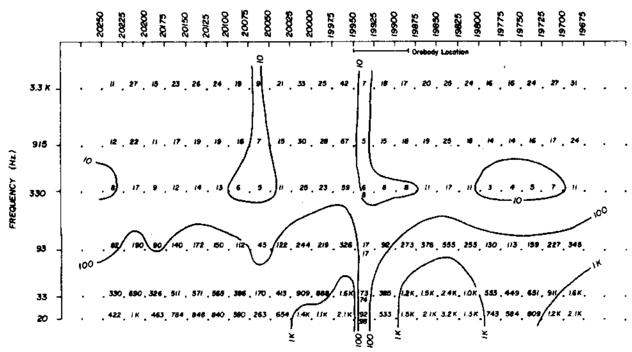

FIGURE 3

at station 19925N-19950N. The contrast exists very weakly at frequencies 2.2kHz to 300 Hz.

It is a significant contrast at 93 Hz and it is a strong contrast at both 33 Hz and 20 Hz. This contrast is also present whether the apparent layering of resistivities is a direct reflection of bedrock or whether this layering is related to the transmitter receiver separation. The resistivity anomaly at 19925N-19950N indicates a more conductive zone within the deeper portions of the subsurface (since the response is strongest at the lowest frequencies). The position of the conductor coincides with the southern end of the Elura ore body and may well be caused by this massive sulphide mass.

The AMT conductor delineated over the Elura deposit is narrower than might be expected from such a wide body occurring at fairly large depth. It seems improbable that the observed conductor is due to culture, such as drill hole casing, since no such anomaly is associated with drill hole collars to the south of the conductor, nor was any anomaly obtained from the drill hole collars when the parallel transmitter was employed. Similarly, the conductor is unlikely to be due to noise even though the measurements most susceptible to error are the H measurements at 20 Hz and 33 Hz. The H values observed over the ore body were 7.1 mv at 20 Hz and 9.2 mv at 33 Hz, and these are well above the noise level. Moreover, the Elura anomaly is defined primarily by the E field data and both the E and H data were repeatable to better than 15%.

Having attributed the CSAMT conductor to a geological source, the question arises as to the depth of the anomaly source. No algorithms are readily available for CSAMT modelling or interpretation. The anomaly coincides with massive sulphide mineralisation and could be substantially due to the high conductivity of this sulphide assemblage.

The anomaly also coincides with a conductive portion of the overburden delineated by Hone (this volume). The limited width of the conductor together with its evidence in the high frequency data suggest a near surface source for at least part of the CSAMT conductor. There is no obvious explanation for the much better definition of the anomaly with the 'perpendicular' transmitter than with the 'parallel' transmitter when both transmitters were actually oriented about 40 to 50 degrees to the strike of the ore body.

Conclusion

Audiomagnetotelluric *surveying* using a perpendicular dipole transmitter has yielded a distinctive conductor coincident with the Elura ore body. Both surficial and bedrock conductors related to the ore body present the likely explanation for this conductor. No anomaly was obtained using a parallel dipole transmitter.

The Elura CSAMT survey line was located over the southern end of the ore body and was not oriented perpendicular to the strike of the deposit. It is possible that a more definitive response might have been obtained if the transmitter dipole and receiver line were better disposed with respect to the ore body. In addition, it is probable that additional measurements with different trasnmitter locations, as well as extended coverage along strike, would have assisted in resolving the ambiguity between the shallow overburden conductor or the massive sulphide deposit as the dominant source for the CSAMT anomaly.

Despite the interpretation uncertainties, the results from this single line should encourage the further evaluation of controlled source audiomagnetotellurics in the Cobar area, and in similar areas of deep oxidation and conductive overburden.

References

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