ductive, bedrock sources. This problem holds for both one-loop and two-loop configurations, but is further complicated by the sign changes in a two-loop configuration.

Such two-loop sign changes are evident in the Pulse-EM data from Cobar shown in Figure 1, for loop separations, L, of 50, 100, 200 and 300 m (Crone, 1978). For L = 50 m, the profiles at all sample times are negative. As the loop separation is increased, the response at early times changes to positive values. Variations in the conductivity of the overburden can cause large changes in response for sample times about that of the sign change. The vertical bars in Figure 1 for L = 100 and 300 m are the changes in response which would be caused by a variation of 10 percent in the overburden conductivity. For a one-loop configuration the change in response with variations in conductivity exhibits a gradual variation with sample time.

Interpretation of two-loop data is further complicated because the response of a finite conductor in a resistive host-rock also exhibits sign changes, which depend on depth of burial or conductivity. Thus for ease of interpretation, a one-loop configuration is recommended; this can be approximated in a two-loop system by locating the receiver in the cnetre of the transmitter loop (sometimes called "in-loop" or "frame-loop" configuration).

The concept of limits of detection has been investigated by studying the modelled response of the Elura and Roxby Downs deposits using an interactive mini-computer analogue model system (Spies, unpublished data). The TEM response is determined for a variety of loop sizes, depths of burial, and conductivities of the deposits and host rocks. An example of this study is shown in Figure 2, for a model of Elura (conductivity = 4.8 S/m) at a depth of 125 m, with and without a conductive host with conductivity 0.16 S/m. At early times the response of the body is screened by the host or overburden. The body is not detected until about 6 ms, which corresponds to $t = 10^{-6} \sigma h^2$, where h is the depth of the body. At late times the response of both one-loop and two-loop systems was found to be fairly similar.

The Roxby Downs study consisted of modelling tabular bodies with a range of sizes, at a depth of 350 m. The limits of detection of this type of target depend mostly on its size and the conductivity contrast between the deposit and host rock. A model 1500 m long, 300 m wide and 150 m thick can be detected with a conductivity contrast as low as 50:1, but a smaller model, 900 m by 180 m by 90 m requires a conductivity contrast of 100:1. For optimum detectability, the loop size should be of the same order as the target.

For both the Elura and Roxby Downs model studies, it was found that the optimum time range for measurement was between 1 and 50 ms. Measurements at earlier and later times, however, give useful information on conductive host rock or overburden.

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THE APPLICATION OF SIROTEM IN WEATHERED TERRAIN

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I. Introduction

SIROTEM is an instrument developed for multichannel TEM measurements. Details of characteristics of this instrument are described by Buselli and O'Neill (1977). Over the past two years SIROTEM has been applied widely in many different terrain types. In particular, considerable success has been achieved in detecting mineral deposits occurring under conductive overburden of thickness up to 100 metres.

Data collected with SIROTEM along a given traverse line can be represented in the form of a profile of the response for each channel. To interpret these profiles in terms of target geometry, conductivity and host rock properties, a system has been set up at CSIRO to model responses from thin dipping dykes, using a SIROTEM unit to collect the modelling data. The dykes are modelled both in air and in conductive media, using both separated and coincident loops configurations.

The apparent resistivity output of SIROTEM provides a means for producing in-field pseudo-sections of apparent resistivity. The apparent resistivity for each channel is plotted vertically as a funciton of station position, which is plotted horizontally.

II. Geological Data

The following gives a brief outline of the geological environment for each of the case studies to be presented in this paper.

Case Study No 1: The Elura deposit near Cobar NSW

Massive sulphide mineralisation occurs at a depth of approximately 100 m below conductive overburden with a resistivity of the order of 15 Ωm. The deposit is a near-vertical pipe-like structure, oval in horizontal section with maximum dimensions of the order of 200 m by 100 m in horizontal section at a depth of 200 m.

Case Study No 2

A thin steeply dipping conductor lies below conductive overburden of thickness 70 m and resistivity approximately 10 Ωm.

Case Study No 3

This massive sulphide deposit is a thin lens dipping at approximately 50°. It occurs in association with conductive sediments in the hanging wall. The electromagnetic response of these sediments could interfere with that of the target. The deposit occurs under conductive overburden of resistivity less than 10 Ωm, and the depth to the top of the lens is ~100 m.

III. Examples of results and data interpretation

1. SIROTEM Profiles

Fig. 1 shows the results of one of four traverses carried out with 100 m coincident loops across the Elura deposit described. For this north-south profile there is no significant indication of an anomaly in the early channels, which contain mainly conductive overburden response as high as 2 to 3 mV/A. Beyond channel 6 (a delay time of 3.4 ms) there is a clear indication of an anomaly which persists out to at least channel 20 (33.4 ms), and for the west-east profile out to channel 24 (59 ms). The extent of this anomaly is ~500 m for both the east-west profile and the north-south profile (shown in Fig. 1). The position of the centre of the deposit can be accurately located from these profiles. As a further guide to drilling, the single symmetrical peak at any given delay time indicates the response is caused by a near-vertical thick dyke or a sphere at depth. The width of the anomaly is consistent with that predicted theoretically (Kamenetskii, 1976) for a sphere of radius 50 m, the top edge of the sphere being 100 m below the earth's surface.

Profiles for Case Study No 2 and No 3 show a high conductive overburden response in the early channels. This response obscures the target response in the same manner as observed for the Elura deposit Case Study. The target

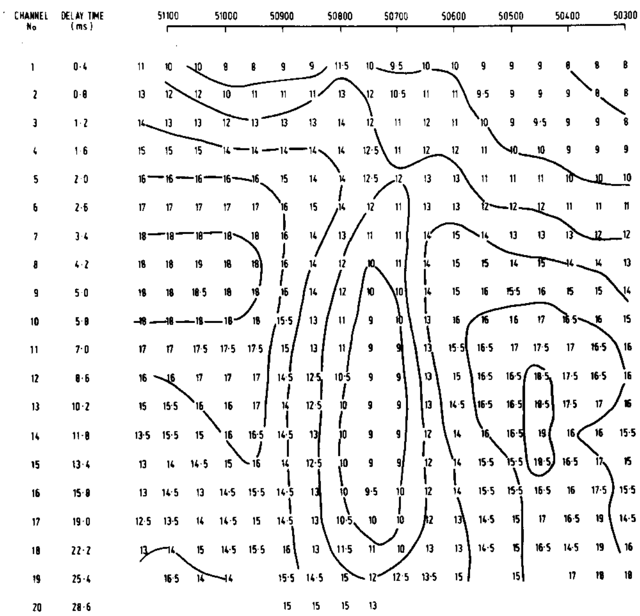

FIG. 2. EXAMPLE OF APPARENT RESISTIVITY PSEUDO-SECTION FOR CASE STUDY No 1

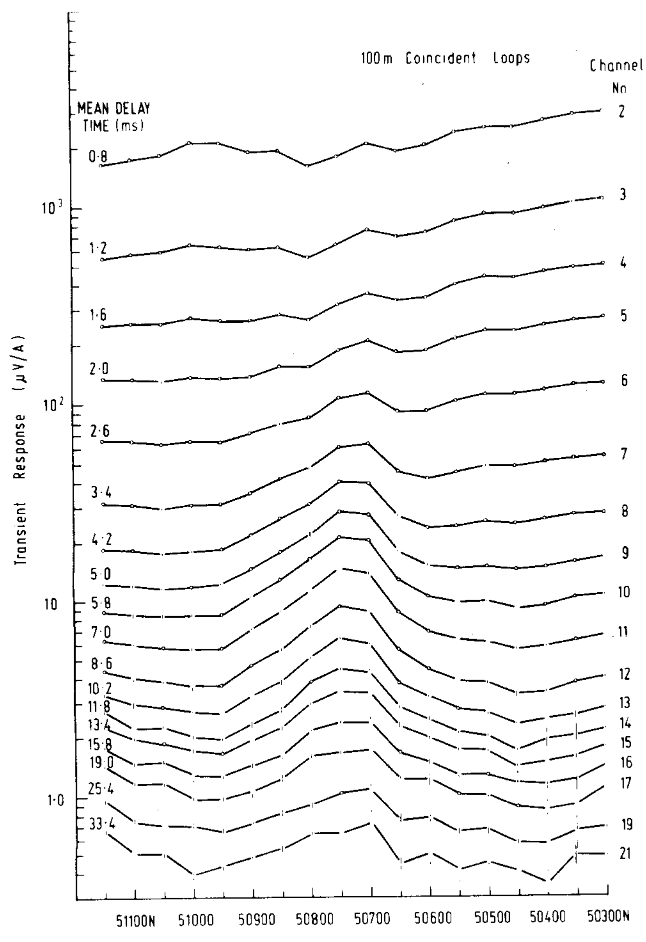

FIG. 1 EXAMPLE OF TEM PROFILE FOR CASE STUDY No 1

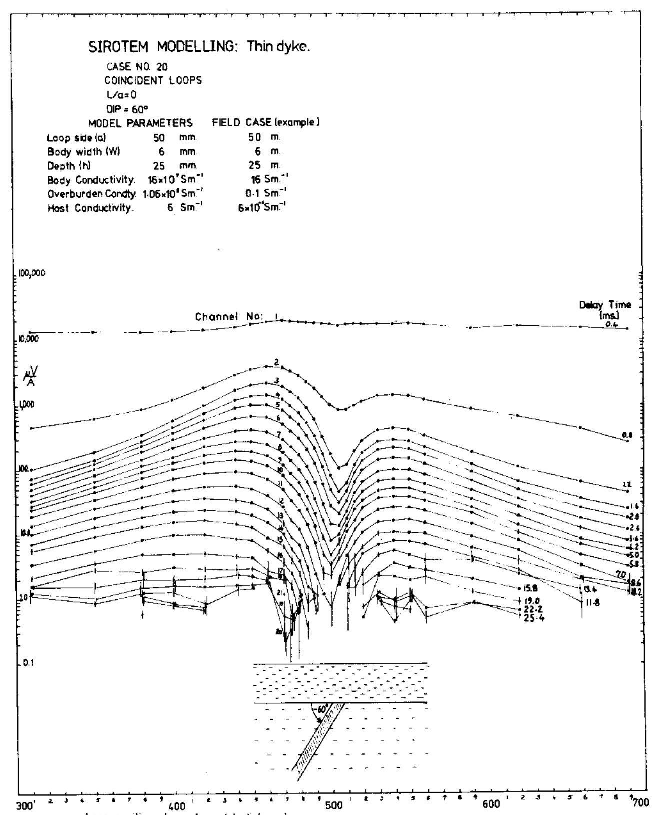

FIG 3: Example of results from modelling the TEM response of a dipping dyke in host covered by conductive overburden.

response becomes clearly discernible at a delay time beyond approximately 2 ms. However, in contrast with the anomaly observed for the Elura deposit, the TEM profiles for both Case Study No 2 and No 3 show an asymmetrical double-peaked anomaly. This indicates the target is a thin dipping dyke. Hence, results can be interpreted with the aid of the analogue modelling results for thin dipping dykes described below.

2. Apparent Resistivity Pseudo-sections

Transient voltage levels at any given delay time can be transformed to apparent resistivity values via the asymptotic formula for a half-space (Fokin, 1971 and Lee and Lewis, 1974), or via a more accurate formula involving a series of terms (Spies and Raiche, 1979). The first term of this series yields the asymptotic formula.

Fig. 2 shows an example of a pseudo-section for the Elura deposit. The apparent resistivity values have been obtained by transforming the voltage values of the profile presented in Fig. 1. The resistivity of the overburden is approximately 15 Ωm, while that of the localised anomaly at 50750N is approximately 9 Ωm.

3. Analogue Modelling Results

A TEM modelling programme has been initiated at CSIRO to model responses from thin dipping dykes, occurring in conductive media. A SIROTEM unit is used to collect the data. Fig. 3 shows an example of results obtained from a model of a thin dipping dyke occurring in conductive host rock covered with conductive overburden. Any scaling factor can be applied to this model. For example, with a scaling factor of 1000, the model corresponds to a field case of 50 m coincident loops over a conductive overburden of 25 m thickness covering of body of width 6 m and dipping at 60°. The model results show an asymmetrical double-peaked anomaly, as is observed in the field.

IV. Conclusion

The results presented here show that the high signal-to-noise ratio of SIROTEM measurements enables effective location of conductive targets, even in weathered terrain where considerable conductive overburden covers the target. In conjunction with extensive data interpretation aids provided by modelling, the parameters of the target can be deduced. The ability to produce apparent resistivity values from the transient voltages indicates the potential use of SIROTEM for stratigraphic mapping.

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THE EFFECT OF HOST ROCK ON TRANSIENT ELECTROMAGNETIC FIELDS

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The presence of a conducting material about an orebody modifies the transient electromagnetic field in two ways. First, at the early stages by strongly directing the primary field and secondly, at the later stages by swamping the secondary field.

Figure 1 shows an arrangement for a transmitting loop that is capable of being able to control the direction of the fields in the ground. Figure 2 shows the variation in the locus of the maximum when the, f, parameter is varied, a, is set to 20.

The swamping of the secondary, electromagnetic transients can best be understood in terms of the singularity expansion of the primary and secondary transients. We show that the swamping occurs because both the primary and the secondary fields are both controlled by the same singularity — a branch cut from the origin and along the positive imaginary axis. We also argue that much more attention should be paid to the early stages where other singularities are know to be important.

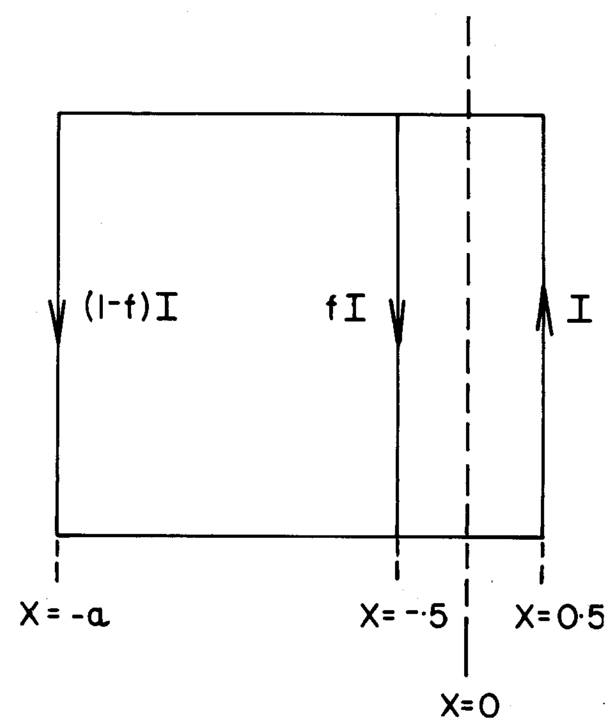

FIGURE 1

Arrangement for the transmitting loop so as to direct the electromagnetic transient.