

Interpretation of TDEM Data Using First and Second Spatial Derivatives and Time Decay Analysis

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Abstract

Current gathering in fixed loop electromagnetic data often dominates responses from large high-grade ore bodies as well as responses from less desirable features such as fault zones, weathering troughs and regional conductors. Through decay curve analysis, current gathering can now be unambiguously recognised.

Many widely used EM interpretation techniques are not applicable to current gathering (channelling) responses. An effective method of deriving the location and shape of the causative source is to study the second spatial derivative, as is shown in several examples.

Key words: Time Domain electromagnetics, spatial derivatives, decay analysis, current gathering, deposits, formational conductors

Introduction

The discovery of the Hellyer orebody in Tasmania by Aberfoyle Resources (Silic *et al*, 1985), has shown that important economic discoveries need not be characterised by long time constant, time domain electromagnetic (TDEM) responses. At the time of the discovery it was recognized that the Hellyer response was largely dominated by current gathering effects, and that other non-economic features such as lithologies or weathering troughs which have a resistivity contrast with their surroundings, may produce responses lasting to similar times. Some authors have reported on some of these problems from case histories as difficulties or limitations of TDEM (Spies and Parker, 1984; Irvine and Staltari 1984).

The purpose of this paper is to show that these problems can be overcome; to discuss decay analysis techniques for recognising responses which are largely dominated by the 'static' interaction between the half spaces electric field and the target, commonly known as current gathering (West and Edwards, 1985), and to illustrate the use of the spatial derivative of fixed loop TDEM data in recognizing the geometry of the conductive targets. Only the 2-D solution for the geometry of the targets will be presented; however, the concept can be extended to 3-D bodies.

Application of the Integral Equation Method

Numerous authors have discussed the generalized frequency domain integral equation for the total vector electric field that is composed of a primary field \underline{E}^p within a half space

perturbed by a secondary field \underline{E}^s from a local conductivity variation within the earth (Hohmann, 1975; Raiche, 1974; Weidelt, 1975). Similar formulations apply to the solutions for the magnetic field (eg. West and Edwards, 1985). San Filippo and Hohmann (1985), and Oristaglio and Hohmann (1984) have successfully obtained solutions for the time domain.

The purpose of this section however is not to discuss the solutions for the 'scattering' or 'anomalous' current $\underline{J}^s(\underline{r}, t)$ within the inhomogeneity, but rather to determine the effect of a conductive half space on the problem of determining the secondary magnetic field from the scattering current. The equation relevant to the problem expresses the secondary magnetic field as

$$\underline{H}^s(\underline{r}, t) = \int_0^t \int_V \underline{G}h(\underline{r}, \underline{r}', t-\bar{t}) \underline{J}^s(\underline{r}', \bar{t}) d\bar{t} d\underline{r}' \quad (1)$$

and only the convolution integral

$$\int_0^t \underline{G}h(\underline{r}, \underline{r}', t-\bar{t}) \underline{J}^s(\underline{r}', \bar{t}) d\bar{t} \quad (1a)$$

needs to be considered. To study this effect the Green's tensor solutions for a line source in a half space were evaluated (Silic, 1989). By assuming that current density with an arbitrary time dependence can be synthesised as a discrete or continuous sum of exponential decay functions $I_n e^{-t/\tau_n}$ it was concluded by evaluating equation 1a for a number of time constants τ_n , that for $\frac{t}{\sigma \mu r^2} \approx 1.0$ (r being the distance to the source, σ the halfspace conductivity) and measuring times up to about $4\tau_n$, free-space approximations may be used to relate the magnetic-field components to the current source, although in some instances a time delay which is largely a function of $\sigma \mu r^2$ may have to be incorporated into the calculation (Silic, 1989).

Identical results are obtained for a current dipole which is relevant to the 3-D problem. As an example, for a 200 Ω m half space, and a distance r of 200 m, $\frac{t}{\sigma \mu r^2} = 1.0$ gives a time of 252 microseconds, a very early time for most TDEM responses.

However the preceding conclusions are not suggesting that the half space is not affecting the current distribution within the inhomogeneity at these 'late' times since the two effects can scale differently in time. It is only suggested that free space approximations may be used to relate the magnetic field to a current source. This concept is vital to the following sections.