6 The transient electromagnetic method

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6.1 Introduction

6.1.1 Historic development

The transient electromagnetic (TEM) method has been developed and refined most intensively since the mid-1980s. This makes the method relatively “young” compared to the frequency domain method, the magnetoteluric method and the geoelectric method. The reason is twofold: firstly the TEM response covers a very large dynamic range, which makes it difficult to measure without sophisticated electronics. Secondly, the interpretation of TEM data is approximately 50 - 100 times more computer intensive compared to interpretation of frequency and geoelectric data. Though, with modern computers the interpretation of TEM data can be done interactively, which was not possible 15-20 years ago when large computers were only available to research institutions and a few large companies.

The inductive methods (TEM and frequency domain methods) were originally designed for mineral investigations. Back in the 60s and 70s frequency domain methods were dominating being very sensitive to low resistivity mineral deposits settled in a high-resistive host rock (>100000 Ωm). This is a typical mineralogical setting in North America. However, most of Australia is covered with a relatively thick layer of Rhyolite (up to 100 m) with low resistivity. Frequency domain methods have difficulties penetrating this layer because of the resistivity. This fact pushed the development of the TEM method in Australia in spite of the electronic difficulties. At that time only qualitative interpretations were possible, but they gave indicative information on mineralizations.

Over the last two decades the TEM method has become increasingly popular for hydrogeological purposes as well as general geological mapping. The frequency domain methods have found extensive use using a helicopter (see Chap. 5) whereas ground based frequency methods are used only very limited for hydrogeological purposes.

A key point in using the TEM method for hydrogeological purposes is the requirement for accurate data with high spatial density. The accuracy
must be met by instrumentation, data processing and the interpretation al-
gorithm, in order to have an optimum basis for the geological and hydro-
geological interpretation. Most often it is not enough to map the ground-
water reservoir, but also the internal geological structures, aquifer size,
volumetric parameters and the geophysical character of cover materials
must be mapped.

Fig. 6.1. Comparison of the responses of a base metal mineral exploration and a
hydrological target as approximated by a vertical thin sheet and layered-earth
model, respectively. The mineral exploration target is a vertical sheet measuring
90 m by 30 m at a depth of 20 m, with a conductance of 100 S, in a 100 Ωm half
space. The parameters for a three-layer hydrological model with a layer represent-
ing a sandy aquifer are: \( \rho_1 = 50 \ \Omega m, \rho_2 = 100 \ \Omega m, \rho_3 = 10 \ \Omega m, t_1 = 30 \ m, \) and
\( t_2 = 50 \ m, \) where \( t \) is the layer thickness. The parameters for the background model
(without an aquifer or a sheet) are: \( \rho_1 = 50 \ \Omega m, \rho_2 = 10 \ \Omega m \) and \( t_1 = 80 \ m \)

To illustrate the need for accurate data, Fig. 6.1 displays sounding
curves from typical TEM soundings over a mineral deposit and over a
groundwater reservoir. A thin-sheet model is used to compute the response
of a mineral exploration target and compare it to the layered-earth response
of a hydrological model. For both models the same central-loop TEM ar-
ray is used. The response with the aquifer layer differs from that of the
background response by a factor of approximately 1.2 or 20%, whereas the