

Chapter 1

1 INTRODUCTION

"I believe that we cannot live better than seeking to become still better than we are."

(Socrates)

1.1 General overview

The Time Domain Electromagnetic (TDEM) method, also referred to as Transient EM (TEM), has been used in mineral exploration since the late 1950's. The basic theory of this method is defined in totality by four differential equations, known as Maxwell's equations. These equations describe the relationships between electric and magnetic fields and sources, enabling the geophysicist to derive the electric field (E) in the earth through measuring the magnetic field (B), or its time derivative (dB/dt) on, above or below the surface. The electric field in the earth is a function of the electromagnetic (EM) source and of the earth's conductivity distribution. If the source is known, the geophysicist should be able to derive the conductivity distribution of the subsurface (and therefore be able to isolate and interpret zones with contrasting conductivities).

- The success of this procedure is dependant on three factors:
- Choosing a source (transmitter) of appropriate dimensions and magnetic moment to induce currents in the subsurface volume of interest
- Measuring the induced magnetic field and/or its derivative with the required accuracy and resolution in time and space (receiver) to resolve the target
- Accurately solving Maxwell's equations

The first two factors are concerned with the design of the measuring instrument and data acquisition parameters. Survey costs are the largest limiting influence on these factors and increases in cost can only be justified by producing increasingly accurate geological models leading to savings in other stages of exploration expenses, e.g. drilling.

Theoretically, within some engineering constraints, one can choose to measure or "know" the whole field exactly. This is a scenario utilised very effectively through

forward modeling and is the reason why synthetic data is normally used as a first run to test new interpretation algorithms.

The third factor proves to be the most difficult – accurately solving Maxwell's equations. These equations can only be solved analytically for a few very simple geometrical models and only if assumptions regarding homogeneity, isotropy, frequency dependence, and frequency and conductivity ranges are made. Kaufman and Keller (1983) makes use of asymptotic equations based on even more assumptions and terms like “far away”, “late time”, “early time” and “large loops” are found extensively in EM literature. Solutions are calculated for these very special instances of system geometry and conductivity models, but the results are applied and compared to real earth situations, not complying with these assumptions. Following this reasoning it is understandable why geophysicists sometimes experience frustration in terms of knowing that there is a conductive unit but not being able to say exactly what or where, leading to simply drilling anomalies – also known as “bump-hunting”.

Accepting that Maxwell's equations cannot be solved analytically for a general situation, the next option would be to solve them numerically making use of standard numerical solutions for differential equations. The complexity of these equations, numerical instabilities under certain conditions (e.g. high conductivity contrasts), and the very long computer calculation times, imply that full three dimensional solutions (and especially inversion) of realistic geological models are not yet reaching industry expectations as an efficient interpretation tool.

The only option left at this stage is to develop time- and cost efficient algorithms to find solutions based on some of these assumptions and apply these *only* to geological settings and data *satisfying* those assumptions. An example of this is the mathematical assumption of one dimensionality of the earth, which is met when horizontally layered geology is investigated. This approach implies a number of different interpretational procedures and algorithms to be developed. It is of course possible to apply one algorithm or procedure to all data acquired over a range of different geological settings, but the obtained results would only be reliable if the inherent assumptions of the algorithm are met.

One of the most common assumptions is that the host rock containing the ore body of interest is very resistive. This implies a significant decrease in computational effort, but unfortunately is one of the assumptions not always met in true field conditions. The non-compliance of this assumption is of great importance in the closely related field of landmine detection where small pieces of metal are looked for, often in very conductive and magnetite rich top soils (Butler, 2003).

1.2 Objective

The objective of this work is to find an efficient, preferably automated, algorithm or interpretational procedure that can be applied in real time to scenarios of conductors buried in a resistive and/or conductive host rock or half space. This will not provide the ultimate answer, but can be considered another useful tool available to the geophysicist to reduce some assumptions. Real-time conductor location and imaging (i.e. estimating size, depth and conductance) can attribute significantly to reduction of processing and interpretation cost in the mineral industry and might also encourage the development of new instruments. For example, a multi-channel metal detector with real-time processing and conductivity imaging of data might prove to be very valuable in the field of landmine detection, especially in conductive top soil regions where traditional metal detectors sometimes prove to be inadequate (Butler, 2003).