Interpretation of Ground VLF-EM Data in Terms of Inclined Sheet-Like Conductor Models

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Abstract—The response of two-dimensional, inclined, sheet-like conductors with low conductance values to plane wave electromagnetic fields in the very low frequency (VLF) range has been evaluated by using a numerical technique. The conductance values of the conductors considered are appropriate for those produced by water and/or clay-filled fracture and shear zones in the Precambrian crystalline rocks of the Canadian Shield. The surrounding host rock was assumed to be resistive with resistivities in the 1–10 k\(\Omega\).m range to reflect the high resistivities over the shield areas. No overburden was assumed in this analysis.

The results of the computations are presented in the form of characteristic interpretation diagrams to interpret ground VLF data in the field, where facilities for direct numerical modelling may not be available. A method for interpreting ground VLF data using such characteristic diagrams has been proposed in this paper which requires a prior knowledge of the host rock resistivity and the inclination of the conductor. These two parameters may be derived from a VLF resistivity survey and from appropriate filtering of the VLF tilt angle response. The interpretation method was applied to a ground VLF anomaly obtained at a research site near Atikokan in NW Ontario, which yielded an interpretation compatible with information from geological mapping.

Key words: VLF-EM, interpretation, ground, inclined, conductor, sheet-like.

Introduction

The very low frequency electromagnetic (VLF-EM) method is a widely used geophysical technique for detection of shallow conductors with applications in mineral exploration and engineering geophysical studies. The method uses plane EM waves transmitted by Navy communication transmitters located strategically around the earth in the frequency range of 15–30 kHz. The ground VLF method therefore requires only one operator for measuring the VLF field response at various positions on the ground using a portable receiver. The combination of low operational cost, simplicity of field operation and ease of qualitative interpretation of the data has made the system popular as a reconnaissance technique.

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for mapping and exploration of shallow targets in the last two decades (FISCHER et al., 1983).

The ground VLF method has been used extensively for site characterization studies of plutonic rocks of the Canadian Shield in the Canadian Nuclear Fuel Waste Management Program by the Atomic Energy of Canada Ltd. (AECL). Fractures and shear zones in the plutonic rocks, which contain water and/or clay, behave like weak conductors (conductances in the range of 0.1 to 0.7 S) and hence can be detected by VLF surveys. VLF anomalies are also produced by conductive overburden (quaternary glacial and glaciolacustrine sediments) which can fill up depressions in bedrock structures and produce anomalies which may be stronger than those produced by fractures and shear zones. The task of detecting weak fracture-type conductors becomes even more difficult if the overburden thickness is variable, making the interpretation of VLF anomalies very difficult. However, when the overburden is absent, or relatively thin, resistive, and uniform in thickness, semi-quantitative interpretation techniques may be applied to interpret ground VLF data.

In spite of the extensive use of the ground VLF method in exploration, development of interpretation schemes for the method has not progressed significantly. Most routine VLF interpretations are qualitative, frequently limited to determining the locations of conductors and sometimes using simple "rules of thumb," to determine their depths. However, such rules can produce large errors since the influences of factors like host rock resistivity, finite depth extent and inclination are ignored. In recent years, theoretical and scale model studies have been undertaken by several investigators (BAKER and MYERS, 1979; OLSSON, 1980; KAIKKONEN, 1979) to understand the VLF response of the conductors of simple geometries and provide a better understanding of the influence of various parameters on the observed VLF field data. A convenient and widely used model for VLF interpretation is the two-dimensional (2-D), sheet-like conductor placed in a more resistive host rock. Numerical results on the VLF response of thin, sheet-like models placed in a conductive host rock were reported by VOZOFF (1971) and SWIFT (1971) using the network solution technique. Similar results on 2-D sheet-like conductors and half-planes in a host rock of finite resistivity were published by KAIKKONEN (1979), OLSSON (1980), SAYDAM (1981) and PODDAR (1982).

KAIKKONEN (1979) used the finite-element technique to obtain the response of vertical and 45° dipping conductors of different resistivities under a conductive overburden, assuming fixed values of host rock and overburden resistivities and fixed depth, depth extent and width of conductors. The computed values of tilt angle and ellipticity variations provided interesting insight of the effects of the conductivity contrast between the conductor and the host rock and that of the overburden on the VLF response. But the effects of other parameters, such as the host rock resistivity, depth and depth extent of the conductors were not discussed. OLSSON (1980) and PODDAR (1982) presented analytical results on the VLF response of perfectly conductive half-planes beneath a layered half-space and