ELECTROMAGNETIC INDUCTION IN GEOTHERMAL FIELDS AND VOLCANIC BELTS

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Abstract. This review covers electromagnetic studies in geothermal and volcanic regions presented in the literature since 1983. It has been arranged by geographical areas, emphasizing where possible the data gathering, the interpretation techniques and the results of each study. The main conclusions of this review are: In all the surveys, people are measuring the complete MT impedance tensor. However, in general, this information is not being used in the interpretation mainly because of the poor quality of the data. This unfortunate situation originates by the presence of strong noise in the surveyed area and generally, by the lack of use of the remote reference technique. Crews with equipment and techniques that can gather data of very good quality, generally perform very detailed interpretations using most of the gathered information. Other groups that collect noisy data oversimplify the interpretation by using only one mode or averaging the resistivity of both modes and interpreting the results using simplified 1-D interpretations. At the interpretation stage, most of the mid-crustal conductors identified are being associated to the presence of trapped water of magmatic origin. In general, magma chambers are not being detected, probably because either they are absent or because there is a lack of resolution of the electromagnetic methods to detect them.

Introduction

This review is intended to cover the period since Berktold's (1983) paper on electromagnetic studies in geothermal regions. He presented a thorough review of the physical characteristics of geothermal fields, and covered technical aspects on the use of electromagnetic methods in these regions. Wright et al. (1985) has also reviewed geophysical exploration of geothermal resources. Chave and Booker (1987) gave a complete review on the general subject of electromagnetic (EM).

Since 1983, there has been an impressive improvement in EM instrumentation used worldwide, particularly in the development of better sensors and advances in electronics and hardware. It has become less expensive to have access to portable computer-controlled equipment everywhere. Also, there has been substantial progress in the processing and interpretation of EM data (Booker, 1988). Perhaps due to global economic restrictions, there has also been a tendency for groups to work together and integrate different techniques to study interesting areas in the world. This approach has gained support by funding agencies, both in America and Europe.

I have arranged the presentation by geographical areas. I have tried to emphasize, where possible, the data gathering and the interpretation techniques used, together with the major findings from each area. As it always happens in papers...
of this kind, I may have inadvertently missed some important work. Therefore, I apologize for any omissions I may have made.

**North America**

Kurtz *et al.* (1986, 1990), collected magnetotelluric MT and geomagnetic depth sounding (GDS) data at 25 locations across Vancouver Island, Canada, over the subducting Juan de Fuca Plate, along the line where the Canadian Lithoprobe Program obtained detailed seismic profiles. A one-dimensional (1-D) inversion of the data shows a conducting layer whose top coincides with a seismic reflector interpreted as the upper surface of the Juan de Fuca Plate. They also present a two-dimensional (2-D) model consistent with the MT and GDS data, and relate the conductor to substantial amounts of sediment filled with saline fluids. Stanley *et al.* (1987) used MT and geomagnetic variation results to map a high conductivity anomaly in the southern part of the Washington Cascades. The MT data were fitted using a 2-D model derived by trial and error using a forward modeling algorithm. The anomaly is located within the triangle formed by the volcanos Mt. Rainier, Mt. St. Helen, and Mt. Adams. The anomaly is associated with conductive strata with resistivities in the range of 1–4 Ω·m and thickness of more than 15 km. These conductive rocks are found 2–8 km beneath the overlying, more resistive, volcanic and sedimentary rocks of the upper crust. This conductive anomaly is interpreted by the authors as a compressed forearc basin/accretionary prism complex of probable Eocene time, caused by the accretion of a large seamount complex (Siletzia).

The Electromagnetic Study of the Lithosphere and Asthenosphere Beneath Juan de Fuca Plate (EMSLAB-Juan de Fuca) experiment was designed to investigate the electrical structure of the entire Juan de Fuca Plate and the adjacent continental section under which it has been subducted. The experiment had a broad international participation from eight countries. Its main phase took place during the summer of 1985. Eighty soundings were measured in 1986 on an E–W 200 km profile, known as the Lincoln line, running across Central Oregon from the Pacific coast to the Basin and Range area, as shown in Figure 1a.

The measurements were made using four wide band MT systems using remote reference and in-field processing, and with long period equipment at several sites. Data from 39 representative sites on this profile have been modeled, inverted and interpreted. Wannamaker *et al.* (1989b), Jiracek *et al.* (1989), Livelybrooks *et al.* (1989) and Martínez *et al.* (1987), gave a full description of the field operation, the data characteristics, and presented 2-D interpretations of the data. In spite of the very careful site selection to place the line across a 2-D structural setting and probably because of finite strike length effects in the N–S TE data, it was not possible to find a 2-D model that would fit both modes in a satisfactory manner. Wannamaker *et al.* (1984) have shown that two-dimensional modeling of TM data across simple, elongated three-dimensional structures yields accurate resistivity