Surface-Borehole Electromagnetic Method - A Review on the Technology Development and Potential for Geothermal Applications

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Summary

Electrical resistivity of subsurface formations has proven to be the most useful geophysical property in the search and characterization of geothermal resources. Surface based Electromagnetic (EM), primarily Magnetotelluric, is the preferred method to map the resistivity structure and anomalies associated with a geothermal reservoir. Resistivity models are so obtained via regularized inversion of surface-based data, resulting in low-resolution images of the subsurface structure, as expected, owe it to diffusion of the fields traversing the medium. Recent developments of simultaneous joint inversion methods of multiphysics data has shown to significantly reduce the uncertainty in defining exploration and monitoring targets. Yet, sensitivity of the measured response is rather related to frequency of excitation and proximity to the target, which are to be addressed in data acquisition. DeepLook EM technologies, including single borehole high frequency, mid TX-RX separation and low frequency surface to borehole measurements, have proven very efficient in providing mid to high resolution images, in reservoir characterization, monitoring and well placement application in the O&G industry. This paper presents a brief overview of these technologies, further focusing on the capabilities and limitations of the recently deployed surface to borehole system for oil-water contact mapping and its potential applications in Geothermal problems.

Introduction

Electrical resistivity of subsurface formations has proven to be the most useful geophysical property to be determined in the search and characterization of geothermal resources. In turn, surface based Electromagnetic (EM), specifically Magnetotelluric (MT), and Electrical (to a lesser degree), are traditionally the preferred methods to map the subsurface resistivity structure and anomalies associated with geothermal reservoirs. However, it is well known that diffusion of the EM fields renders effectively a filtered response on the measurements carrying information related to the secondary fields arising due to the presence of subsurface resistivity inhomogeneities. At the outset regularized inversion of a surface-based EM dataset is expected to result in a low-resolution image of the subsurface structure. Recent developments in integrated interpretation, specifically via simultaneous joint inversion of multiphysics data, has contributed to significantly reduce the uncertainty in defining the targets in O&G exploration and monitoring problems. However, the problem of low-resolution of EM images persists and it is rather related to resistivity contrast, frequency of excitation and proximity to the targets of interest. Of these, frequency of excitation is dominated by the requirements of depth of penetration vs signal to noise ratio. Indeed, increasing the frequency of excitation yields stronger attenuation and thereby effectively shallow penetration of those measurable signals.

Recent development of DeepLook EM technologies, including single borehole-high frequency, mid TX-RX separation and low frequency surface-borehole measurements, have proven very efficient in providing mid to high resolution resistivity images, in problems of reservoir characterization, monitoring and well placement for O&G applications. In this paper a brief overview of these technologies is presented, followed by more detailed discussion on the capabilities and limitations of the surface to borehole EM method. Results are then presented on the survey carried out in the Middle East with the objective of mapping of the oil and water contact in 3D around a single well. At the outset a brief discussion is presented for the potential applications of the technology in Geothermal problems.