**Characterizing Geothermal Resources with Passive and Active Electromagnetic Methods in Challenging EM Environments**

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Within the frame of the French Research Project founded by the group of scientific interest GEODENERGIES for a greater understanding of geothermal reservoirs in fault zones (REFLET), our research efforts have been focusing on improving electromagnetic methods for resistivity mapping in environments with a high level of electromagnetic noise. Indeed, the Magneto-Telluric (MT) method has been traditionally used for exploration in geothermal areas. The challenge is that such a passive method is severely affected by electromagnetic noise induced by anthropogenic activities such as in cities and industries. In particular, MT exploration is almost not feasible in countries where trains are powered by DC-current (such as in many countries in Europe). As an alternative, we propose to deploy active source EM techniques (Controlled Source EM) using surface and borehole high power emissions to improve the EM signal to noise ratios and allow mapping resistivity variations at the depth of the geothermal targets.

Over the last few years, we have performed several combined MT and CSEM surveys to demonstrate the benefits and limitations of such methods for geothermal exploration in different geological settings, e.g. volcanic areas in the Caribbean, in sedimentary basins in France, Czech Republic, Belgium, and Switzerland. When possible, we have also deployed Long Electrode Mise-à-la-Masse (LEMAM) setups utilizing the casings of the geothermal wells as source electrodes to improve even more the CSEM signal to noise ratio. To process and interpret the large diversity of data acquired (near-field, far-field, plane wave, borehole etc.), we have developed our own processing and 3D modelling and inversion routines.

In this paper, we will share the results and learning from these different surveys and show the complementarity of the different techniques for retrieving realistic resistivity measurements at the depth of the geothermal reservoirs. We will also show that in very noisy environments, despite the use of remote references and robust processing, some frequency bands of MT data are still corrupted by permanent anthropic noise sources and CSEM data must be preferred. Finally, we will illustrate with the different examples the need and benefits of developing more advanced acquisition, processing, modelling and inversion techniques to ensure EM techniques are considered as exploration techniques of prime choice to reduce the cost and uncertainty associated with geothermal resource assessment.