

MAGNETOTELLURIC MONITORING

by

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Abstract

Enhanced geothermal systems (EGS) are emerging as an alternative energy supply, though progress has been slowed due to multiple uncertainties in subsurface processes. The most important unknown that needs to be overcome is how to spatially characterize injected fluids. Micro-seismic tomography can locate fractures opening caused by hydraulic pressure, but cannot directly discriminate whether that fracture is fluid filled or connected to other fractures. Magnetotellurics (MT) is sensitive to volumetric electrical conductivity contrasts with depth, specifically thermally enhanced saline fluids in a resistive host rock. Presented in this dissertation are 2 experiments designed for employing MT as a monitoring tool to characterize a fluid injection for the first stage of an EGS at Paralana, South Australia. The first experiment utilizes 11 MT stations set around the injection well continuously measuring 2 days before, 5 days during and 2 days after the fluid injection. Comparing the MT response estimated before the injection with subsequent responses estimated in 24 hour blocks demonstrates a temporal variation associated with injection of an electrically conductive fluid. Residual phase tensor analysis suggests that injected fluids migrated NE of the injection well in a preferred NNE direction, which correlates well with a concurrent micro-seismic array. The second experiment is a time-lapse MT survey that measures the MT response before and after the fluid injection by repeating the same 56 station array. The array contains 2 orthogonal lines of 22 stations each and 2 off diagonal lines of 6 stations each. Multiple pre-injection surveys were collected to ensure data precision and accuracy with a repeatability between surveys being on the order of 0.4 percent for periods above 1 second. However, in the MT dead band (1-20 s) repeatability is on the order of 3-4 percent. This is because of poor source signal and noise from a near by pipeline. The post-injection survey was collected a week after the injection finished and repeatability between pre and post-injection at high frequencies is on the order of 1 percent. Residual phase tensor analysis again suggest fluids propagated NE of the injection well but mostly into an existing fracture network trending NNE. These experiments suggest that MT can be used as a monitoring tool for a fluid injection, but care must be taken in collecting precise and accurate data as well as a detailed analysis of what can cause an anomalous MT response. Residual phase tensor analysis proves to be the most useful representation of the MT response because it provides directionality and is insensitive to near surface distortions. Finally, it is suggested that a dense grid of MT and micro-seismic measurements be collected as complimentary pairs to fully characterize a fluid injection.



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