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Magnetotelluric characterization of the Habanero geothermal EGS project: initial results on fluid injection monitoring

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ABSTRACT

Magnetotelluric (MT) data was collected across the Habanero enhanced geothermal system (EGS) project site in the Cooper Basin , South Australia in view of delineating the crustal conductivity structure of the geothermal area and to monitor fluid injection of Habanero 4 geothermal borehole. Two MT surveys have been carried out. The first MT survey consists of two perpendicular profiles, each about 20 km long. 2D inversion of MT data of the two profiles shows three main resistivity structures to a depth of 10 km: 2 km thick good conducting (< 10Ωm) surface layer is underlain by relatively high resistivity(< 100Ωm) followed by high resistivity(> 100Ωm). The low resistivity surface layer shows areas with poorly consolidated sands, siltstones and clay stones. Below the conductive layer, is a relatively high resistivity zone that can be correlated to consolidated sandstones, siltstones and shale. The high resistivity structure is associated with basement granitic formation. The second MT survey was conducted during fluid injection of Habanero 4 well in November 2012 which lasted for two weeks. Initial results from MT residual phase tensor analysis of the fluid injection at depth of about 4 km show fractures opening in NNE direction. This result is in good agreement with seismic cloud observed in the Habanero area during fluid injection.

1. INTRODUCTION

The aims of this project are to study the relationship between the directions of electrical current flow in the crust and regional stresses, as well as to determine if electrical resistivity of upper crustal rocks can be used to determine temperature, porosity and permeability.

The Habanero EGS project is located in Copper Basin about 1000 km from Adelaide in North Eastern South Australia. The approximate geographical location of the MT studied area as a whole is 140.66° E and 140.85° E longitude and 27.89° S and 27.72°S latitude presented in Figure 1.

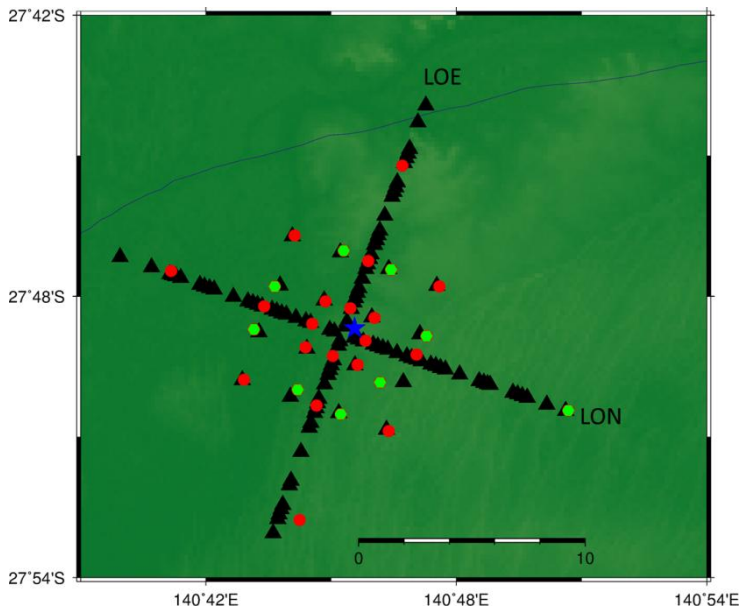


Figure 1: Station layout of MT measurement of the two MT surveys. Black triangles denote MT stations from Quantec survey. The red circles and blue hexagons denote broadband MT stations and E-field loggers from second survey during fluid injection at Habanero 4, respectively. Blue star =Habanero 4 EGS well.

Lemma, Thiel and Heinson.

2. MT DATA ACQUISTION AND PROCESSING

Two MT surveys were conducted at Habanero EGS project site in August 2012 (by Quantec Ltd) and in November 2012 (by University of Adelaide), respectively. The first MT survey consisted of 119 MT sounding along two perpendicular profiles (Figure 1). The MT survey gave good results of impedance estimates for periods of 0.01 s to 1000 s. To remove galvanic distortion in the MT soundings, the method suggested by Bibby et al. (2005) was used. A typical resistivity and phase curve from this survey is shown on Figure 2.

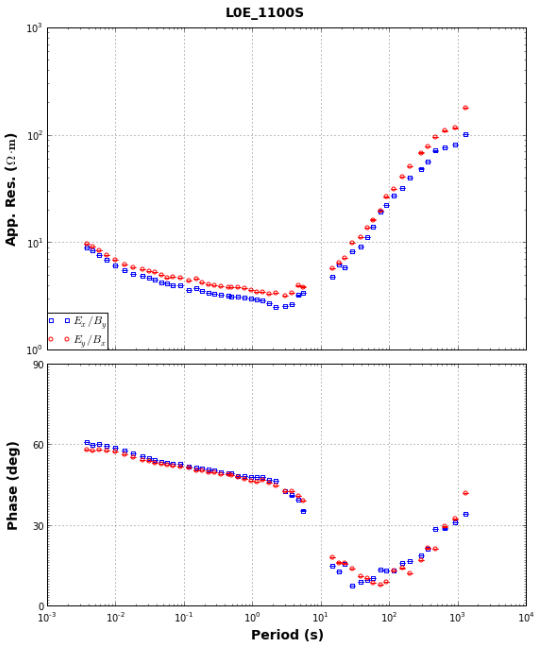


Figure 2: Resistivity phase plot site LOE_1000S from Qunatec survey.

The second MT survey was conducted concomitantly with fluid injection of Habanero 4 well by Geodynamics (Figure 1). Based on the findings of Peacock et al (2012), the survey has been expanded to include 19 broadband MT sites and 10 new E-field loggers. The grid is about 4 km along each side to obtain a better spatial resolution. The time series processing resulted in good impedance estimates for periods of 0.01s to 300s. Some MT sites were affected by cultural noises from fluid injection operation and gas pipeline generators.

Phase tensor residuals give information about geoelctric strike transformation during fluid injection and help to infer direction of change in current flow (Heise et al, 2006 and Peacock et al, 2013). The tensor residual are calculated as a percent change and given by:

$$\Delta\Phi_{oj} = I - (\Phi_o^{-1}\Phi_j) \quad (1)$$

Where Φ_o, Φ_j, I, Φ^{-1} are phase tensor pre-injection, phase tensor during injection, identity matrix of rank two and the inverse, respectively.

3. RESULTS

2D MT cross section LOE (Figure 1 and Figure 3) consists of a total of 48 MT station with a total distance of about 20 km. 2D inversion of MT data of profile LOE shows three main resistivity structures to a depth of 10 km: 2 km thick good conducting (< 10Ωm) surface layer is underlain by relatively high resistivity (< 100Ωm) followed by high resistivity (> 100Ωm). The low resistivity surface layer shows areas with poorly consolidated sands, siltstones and clay stones. Below the conductive layer, is a relatively high resistivity zone that can be correlated to consolidated sandstones, siltstones and shale. The high resistivity structure is associated with basement granitic formation.

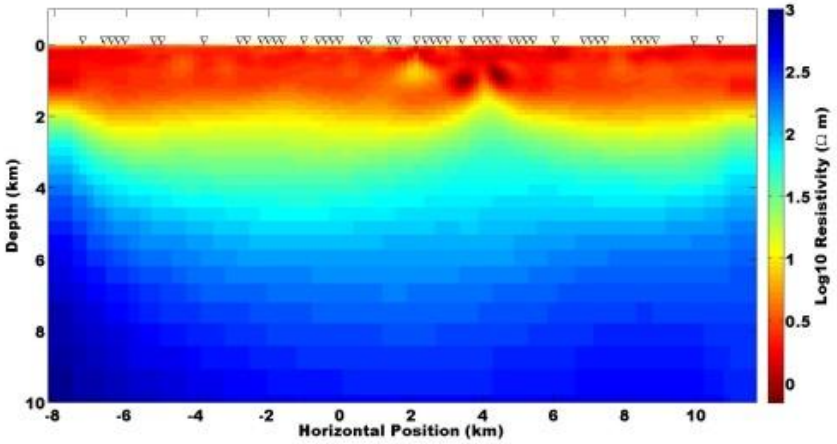


Figure 3: 2D resistivity model of profile LOE.

The residual phase tensor analysis of the MT station taken during fluid injection (shown as red circles on profile LOE on Figure 3) gave a direction of maximum change in geo-electric strike in NNE direction as shown on Figure 4. The inferred change in the phase tensor residual ellipse occurs at period of about 10 s which is equivalent to the targeted fracture at depth of 4 km during the injection.

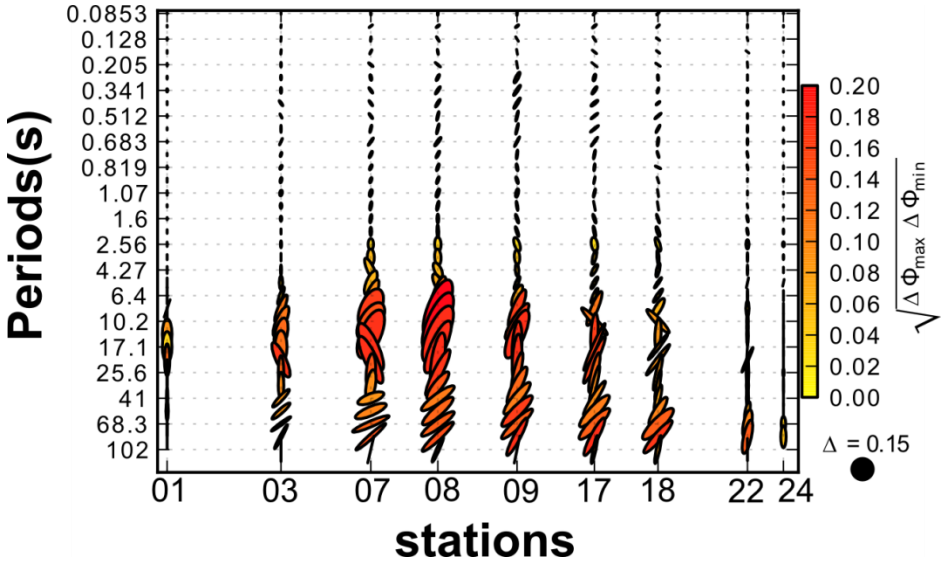


Figure 4: phase tensor residual ellipse pseudo-section calculated using (1) and colored as geometric mean of (1).

3. CONCLUSION

The preliminary 2D inversion of MT data showed thickness of the sedimentary formation over the granitic basement. The residual phase tensor analysis showed the period at which the maximum change in the direction of current flow occurred during the fluid injection. The preliminary result indicated the requirement of further work to confirm the change in permeability occurred in the EGS system.

REFERENCES

Bibby, H. M., T. G. Caldwell, and C. Brown: Determinable and nondeterminable parameters of galvanic distortion in magnetoteurics: Geophysical Journal International, 163, 915–930. (2005)

Heise, W., T. G. Caldwell, H. M. Bibby, and C. Brown: Anisotropy and phase splits in magnetotellurics: Physics of the Earth and Planetary Interiors, 158, 107–121 (2006)

Peacock, J. R., S. Thiel, P. Reid, and G. Heinson: Magnetotelluric monitoring of an enhanced geothermal system fluid injection: Example from an enhanced geothermal system: Geophysical Research Letters, 39, L18403. (2012)

Peacock, J. R., Thiel, S., Heinson, G. S., & Reid, P.: Time-lapse magnetotelluric monitoring of an enhanced geothermal system. Geophysics, 78(3), B121-B130. (2013).