ASEG-PESA 2013
'THE EUREKA MOMENT'
11-14 AUGUST 2013 • MELBOURNE, AUSTRALIA

Magnetotelluric characterisation of the Habanero geothermal EGS project - initial results on fluid injection monitoring and regional geology

Stephan Thiel
University of Adelaide
DP313 Mawson Bldg., Adelaide, SA 5005
Stephan.thiel@adelaide.edu.au

Yohannes Didana
University of Adelaide
DP313 Mawson Bldg., Adelaide, SA 5005
yohannes.didana@adelaide.edu.au

Jared Peacock
USGS, California
USA
jared.peacock@gmail.com

SUMMARY

Magnetotelluric data was collected across the Habanero geothermal site in the Cooper Basin, South Australia, in view of delineating the crustal structure underneath the geothermal area and to monitor fluid injection of the Habanero 3 borehole. Two surveys were carried out. Initially, two perpendicular profiles have been stablished, each about 20 km long, to obtain 2D profiles across the Habanero site. The aim is to estimate the sediment thickness to allow for constrained 3D forward modelling for fluid injection scenarios. Furthermore, the broadband data with periods up to 1000 s allows a view into the crust. Geochemical data from the Mound Springs shows that the seeping water contains a minor component of mantle CO2. MT can be used to image the fluid pathways if such a connection exists. The results will be compared to recent findings from fluid pathways in the Lake From embayment a few hundred km south of the Cooper Basin. Additionally, initial results from the fluid injection monitoring experiment of the Habanero 3 borehole will be shown. In November 2012, fluids were pumped at depth of around 4km for a period of two weeks. The fluids exceed the amount introduced into the Paralana EGS in July 2011, however a pre-existing fluid reservoir from a prior fluid injection exists. We report on surface MT response changes due to the fluid reservoir at depth.

Key words: magnetotellurics, geothermal, fluid injection, resistivity

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 project will focus on the central Cooper Basin where there are extensive datasets that constrain the orientation of the principal stresses, as well as the temperature field and lithological architecture and properties (including permeability and porosity). The gained knowledge will assist in assessing the utility of magnetotelluric data which is comparatively fast and cost effective to acquire as mapping tool for temperature, stress field orientation and permeability potential and will complement the existing borehole information of the Cooper Basin. The applications of such mapping include future geothermal prospects and operations involving fluid monitoring such as fluid fracking in enhanced geothermal systems and coal seam gas plays.

Electromagnetic techniques map the electrical conductivity distribution of the subsurface with decreasing resolution at depth. In sedimentary rocks, the bulk electrical resistivities are empirically related to porosity (Archie, 1942). While this relationship holds well, the uncertainty in the EM models especially across sharp lithological boundaries results in only rough estimates of porosity (Maier, 2011) and following on, of temperature (Spichak et al., 2009) and even permeability (Wright et al., 2009). Furthermore, the distribution of fluid is likely to be strongly influenced by the orientation of fractures and therefore crustal stresses. Up to now, EM geophysics measurements have lacked a suitable "ground-truthing" crustal volume that can effectively be used as a laboratory to link surface derived EM data to subsurface geophysical and material properties. While the work program is specifically designed to understand the utility of EM tools in mapping porosity, temperature, permeability and regional principal stress orientations, the bulk property nature of the MT data will add to the wealth of borehole information from the region.

We propose to use the Cooper Basin in NE South Australia to investigate if surface derived EM geophysical measurements can be used to determine subsurface material properties. Four MT surveys will be conducted in the vicinity of the Habanero site in the central western Cooper Basin. Three broadband surveys will be conducted in a high resolution grid to obtain an optimal 2D and 3D resolution of the electrical structure of the sedimentary rocks and underlying basement. A fourth long-period survey along a >100 km 2D profile will allow signal to be acquired from deeper crustal and mantle features. This may provide constraints on the lithospheric temperature distribution underneath the Cooper Basin, which has undergone recent intracratonic deformation.

Because EM data is comparatively cheap and rapid to collect, it has the potential to cost-effectively map a variety of geophysical and material properties, especially in basins where there are also drill holes that provide calibration points within the "maps". However the Cooper Basin experiment is the crucial first step if this regional mapping is to become a reality.

The work program also has application to resource development. For example in the geothermal sector achieving fluid flow in EGS and HSA prospects is currently a major obstacle for successful energy production. MT measurements showed for the first that time lapse MT can image the movement of fluid at depths of up to 5 km in real time during fluid injection experiments (Peacock et al., 2012). This offers the opportunity to directly monitor the distribution of deeply injected fluids and integrate that information with microseismic data to create a powerful fluid imaging work flow applicable to reservoir (geothermal and shale gas) development. The work program also has application in understanding the utility of MT to investigate deep aquifer integrity during coal seam gas development where permeability depends on the porosity of the sequences, but is also dependent on the connectivity of the pores.

FIELD WORK

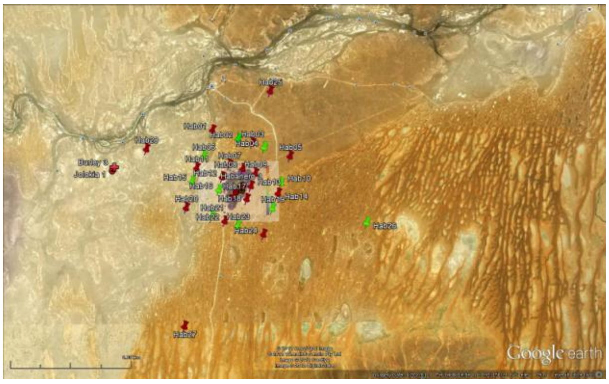

Figure 1: Station layout of the magnetotelluric stations across Habanero. The grid setuip aloows for improved monitoring over the cross-like setup at Paralana EGS in 2011. Red denotes MT stations with green points marking the infill E-field loggers.

So far, two MT surveys have been performed in August 2012 (undertaken by Quantec) and in November 2012 (with ANSIR MT equipment). The first field survey is designed to establish a baseline data set for estimating depth to basement and constrain forward models as knowledge of sediment thickness in the area is crucial for correct analysis. The survey returned good results of impedance estimates for periods of 0.01 to 1000 s. The survey setup followed two perpendicular lines oriented along the main fault strike orientation in the area.

The second survey in November took place around the time of fluid injection of the Habanero 3 by Geodynamics. 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 for infill. The grid is about 4 km along each side to obtain a better spatial resolution than throughout the survey at Paralana (Peacock et al., 2012).

RESULTS

The initial responses of the first experiment show smooth responses with higher noise levels between 1s and 10 s due to local noise sources of pipelines and lower strength in the source field in this period band, also known as the dead-band. The responses are sufficient to warrant accurate estimation of the sediment depth, which will be presented.

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