Applying Lessons Learned in Borehole Seismology to the Paralana Geothermal Development in South Australia

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ABSTRACT

The Institute of Earth Science and Engineering (IESE), at The University of Auckland, will be applying borehole seismology for a variety of investigations in Australia, including geothermal exploration. In the development discussed here, working with Petratherm Ltd of Adelaide, IESE will provide both seismic monitoring and advanced data analysis for the Paralana Geothermal Development. The objective is to monitor and analyse the seismicity produced by the hydrofracturing program in order to create a tomography of the fracture zone. The project will proceed in 3 phases. The initial phase was begun in June 2008 with the deployment of a preliminary shallow "post-hole" microearthquake net. This net is aimed at establishing the local background seismicity for comparison to induced events, and we expect the first data from it to be available at the AGEC meeting. The subsequent phases will focus on monitoring the geothermal development, with initial EGS drilling and, hopefully, power production.

Introduction: Improvements in geothermal exploration and monitoring using borehole seismology

The primary advantage of placing seismographs underground in borehole is summarised in Figure 1. As this plot shows, surface and shallow seismograph network have both a cut off in high-frequency signal detection and a significant loss in Signal-to-Noise ratio with decreasing sensor depth. These affects result from strong near surface attenuation and trapped wave noise. The result is that surface nets miss the much more numerous small earthquakes because much of their energy is contained in the higher frequencies. Yet these events can be used to tell much about the surface conditions and their changes during geothermal exploration and monitoring.

In this presentation we will cover the first results of our efforts to begin geothermal development in the Paralana area in the right way, seismologically speaking. This way is to establish the background seismicity before any development takes place so natural events can be separated from those induced by geothermal production. We also describe the plans for developing the monitoring array that will be installed once the best configuration for observing the background and induced events has been established.

These phases are described below, along with mention of advanced data analysis techniques that will be applied to assist both the well targeting and field management aspects of the Paralana development.

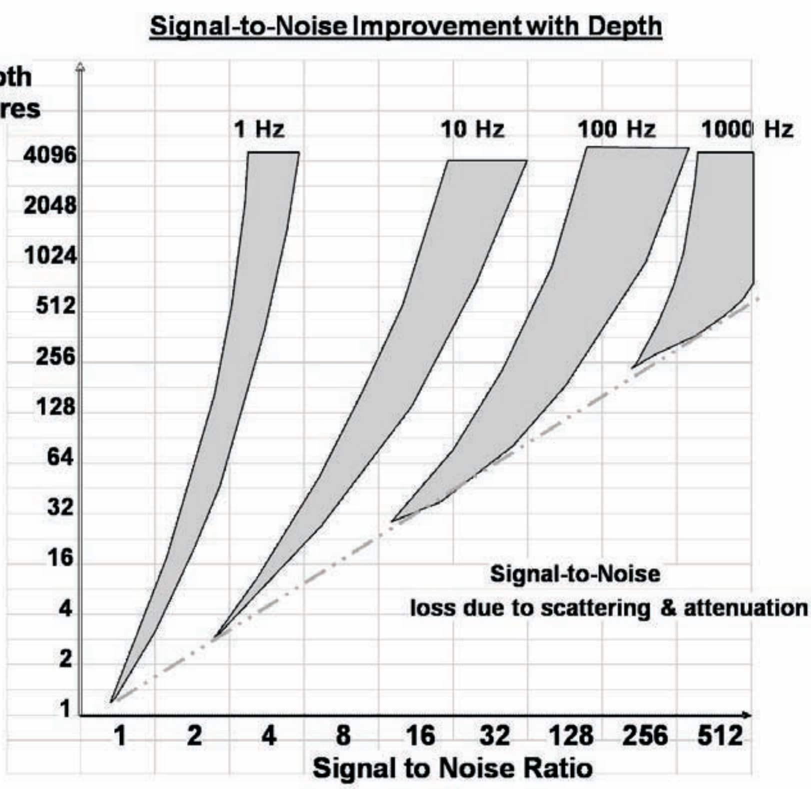

Figure 1. Signal-to-Noise improvement with depth of seismograph, showing cut-off in high frequency detection and loss of high frequency signal with decreasing depth.

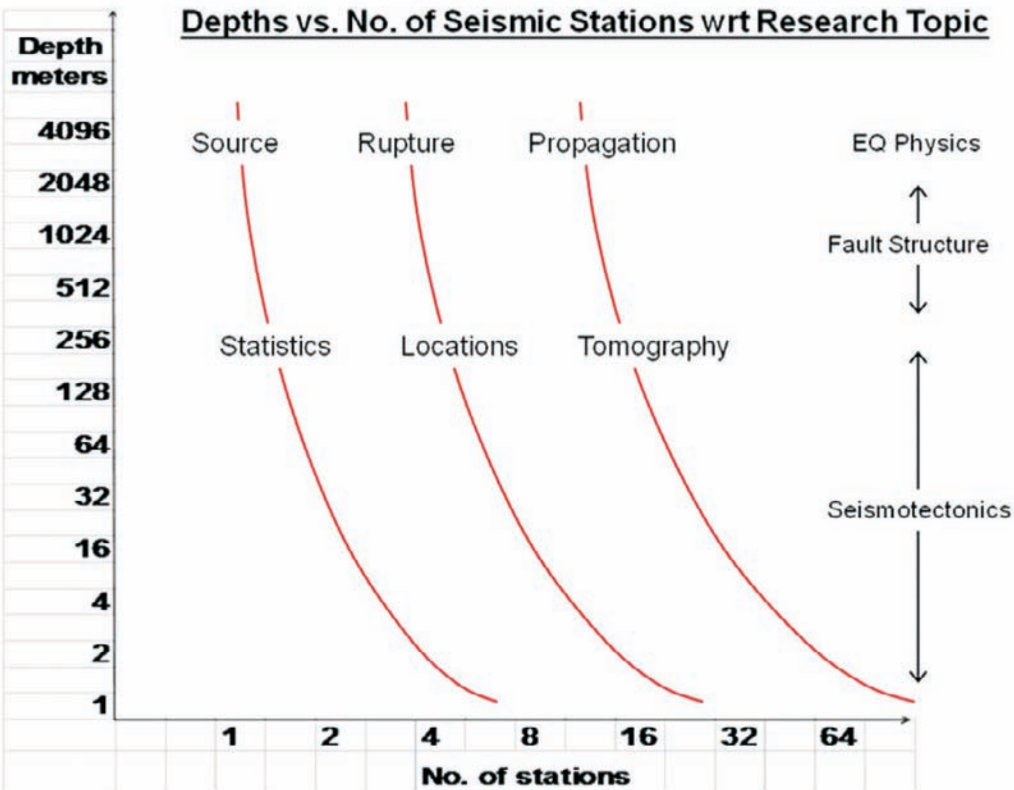

Figure 2. Engineering diagram summarising Number of Stations vs. Depth. The deeper and greater number of stations gets us closer to understanding the physics of the rupture process.

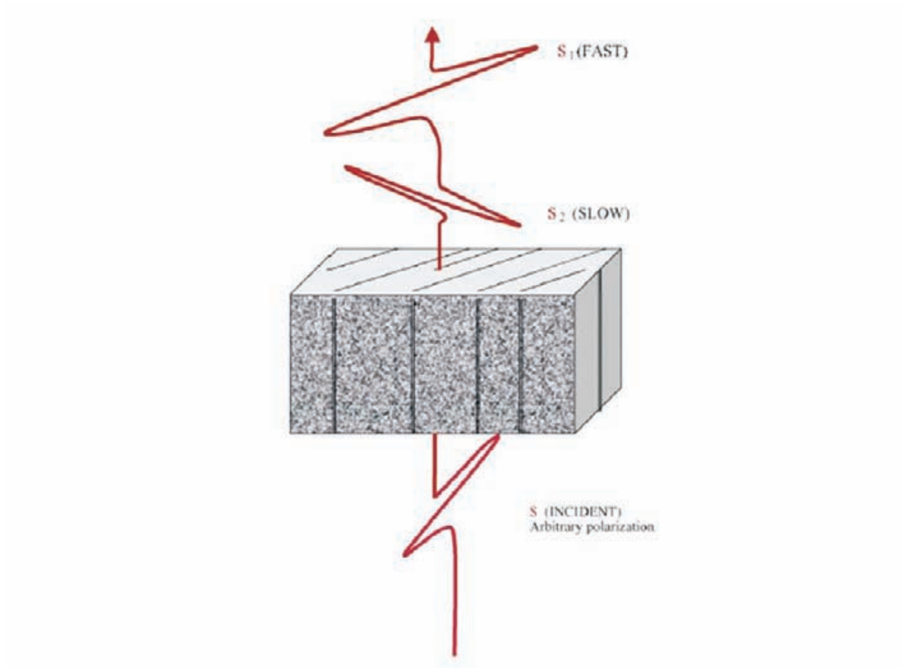

Figure 3. Shear wave propagation in a fractured medium. From Rial et al. (2005).

Phase 1: Initial data monitoring period and preliminary data analysis to ensure optimal network capabilities

The project will begin with the recording of a six month catalogue of background micro-seismicity for the region around the Paralana site. To record the background seismicity a network of four surface sensors, four 30-metre posthole stations and one deep 1,442 m borehole station have been deployed. The advantage of placing seismographs in boreholes to explore geothermal areas is their ability to quickly determine the level of local seismicity, often picking up events several orders of magnitude below the sensitivity of regional networks. Such installations also greatly increase the frequency bandwidth of the microearthquake observations, improving event location and signal analysis. Figures 1 and 2 summarise these advantages.

Phase 2: Re-locate individual stations or network as advised from Phase 1. Additional stations and telemetry links maybe added to the network during this phase

During the hydro-frac program, scheduled for early 2009, 4 to 6 additional surface stations will be installed and the network will be upgraded with real-time telemetry, and linked to a remote data acquisition and analysis computer system in the field. The 30 m deep stations may also be redeployed into 250 m boreholes to provide higher resolution data. Real-time data analysis will be performed on the waveforms to determine event locations during the fracturing program, and to monitor the directional "move-out" of the fracture front in real-time so as to provide feedback to the operators.

Phase 3: Continued monitoring and Analysis of data and summary report

The primary technique IESE will apply is shear-wave splitting analysis. These methods are based on the principle that shear-waves travelling along fractures travel at a different velocity to those travelling perpendicular to the factures (Figure 3). Facture densities and orientations can be calculated from maps of travel-time delays (Figure 4). After the completion of the hydro-fracturing program, the data will undergo a detailed analysis focused on the pre- and post-seismic travel times in order to detect shear-wave splitting events. These results will be used to create a map of the fracture density and direction. A detailed tomographic velocity inversion of the data will be created

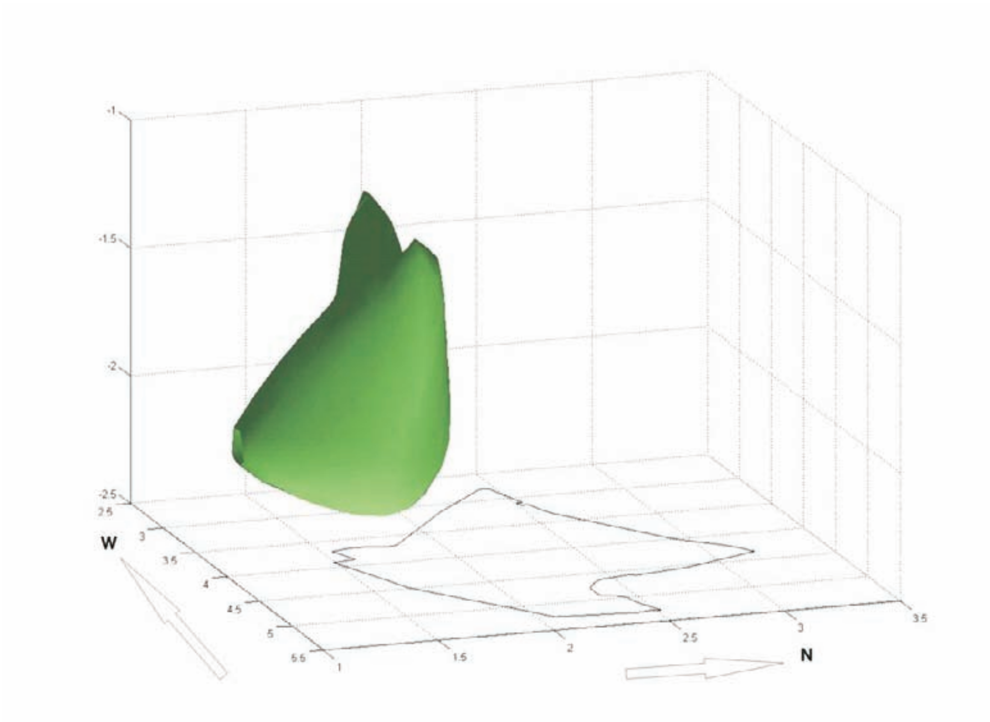

Figure 4. 3-D crack density map produced as a result of passive seismic monitoring of an Example Geothermal Field. The green area represents the area most likely to have high fracture density and permeability. The lease boundary is plotted at the bottom for orientation. Scale is in km. (From unpublished consultancy report).

to develop a high-resolution map of the velocity field and detect any changes that may take place as a result of hydro-fracturing. Furthermore, a double-difference event location will be performed for each of the events in the data set to develop a better image of the fracture patterns created by the hydro-fracturing.

REFERENCES

Rial, J.A., Elkibbi, M. and Yang, M. (2005) Shear wave splitting as a tool for the characterisation of geothermal fractured reservoirs: lessons learned. *Geothermics*, **34**. 365 - 385.