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Developing Large Scale, Base Load EGS Power - The Paralana Project, South Australia.

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ABSTRACT

The Paralana EGS Project, located 600km north of the city of Adelaide in South Australia, provides a natural laboratory for the development of an Engineered Geothermal System. Anomalously high heat production basement rocks cropping out in the Mount Painter Inlier provide the local heat source and are overlain by a thick sedimentary package of Mesozoic to Neoproterozoic age in the adjacent Poontana Sub-basin, within a favourable in situ stress regime. Early exploration drilling indicates an elevated geothermal gradient and heat flow at the project site.

Petratherm Limited in joint venture with a major oil and gas (Beach Petroleum) and power industry energy utilities (TRUenergy) are initially seeking to build a 7.5 MWe commerical power development to supply a local mine. A local microseismic monitoring network has been deployed to record background seismicity prior to drilling of the first deep well into the resource, scheduled to commence in June 2009. An innovative strategy for development of the EGS reservoir is planned, involving massive hydraulic stimulation of multiple target zones within the sedimentary overburden. This paper will provide an update on progress at the Paralana EGS site.

1. INTRODUCTION

The Paralana EGS Project is located east of the Northern Flinders Ranges on the plains area between Lake Frome and the Mount Painter Inlier, within the South Australian Heat Flow Anomaly (SAHFA) (Figure 1). To the east of the Mt Painter Inlier, a system of sub-parallel NE–SW trending faults juxtapose flat-lying sedimentary sequences against the high heat producing Neoproterozoic Mount Painter basement. In this area, 2D reflection seismic survey data and potential field geophysical (aeromagnetic, magneto-telluric and gravity) data delineate a major structure informally termed the Poontana Sub-basin (Figure 2). Based on the interpreted geophysical data, Petratherm postulates that the high heat producing basement rocks observed in outcrop, continue under the insulating cover material, with the maximum thickness of the sedimentary cover in sections of the Poontana Sub-basin being modeled at greater than five kilometres. This favourable arrangement of thick sediments overlying anomalously radiogenic basement suggests that the Paralana area is an ideal location to test the development of an Engineered Geothermal System.

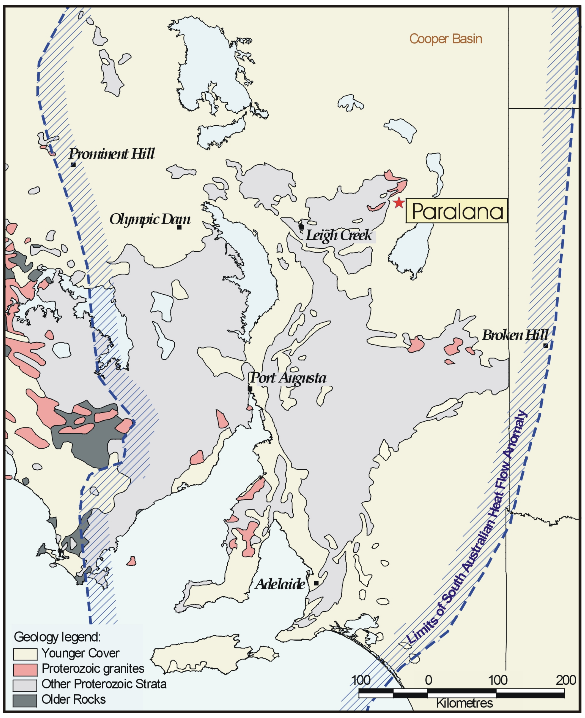

Figure 1: Regional Locality Map of The Paralana Geothermal Project site which is located on the plains between Lake Frome (east) and the northern Flinders Ranges (west) approximately 600 km north of Adelaide

2. GEOLOGICAL OVERVIEW

The Mount Painter Inlier forms the western boundary of the Lake Frome Embayment, and is comprised of multiply deformed, polymetamorphic, Palaeoproterozoic to Mesoproterozoic metasedimentary and volcanic rocks, intruded by granitoids (Drexel *et. al.* 1993).

The basement rocks in the Mount Painter Inlier generally contain elevated uranium and thorium contents resulting in high to very high heat production rates compared to average Proterozoic rocks. For example the average heat production in the Mount Painter Inlier is 10 μWm^{-3}, which is around 4 times that of average granite, with individual granites such as the Yerila Granite producing up to 62 μWm^{-3} (Neumann *et al.*, 2000). These extraordinary basement heat production values point to the existence of a major thermal energy resource domain.

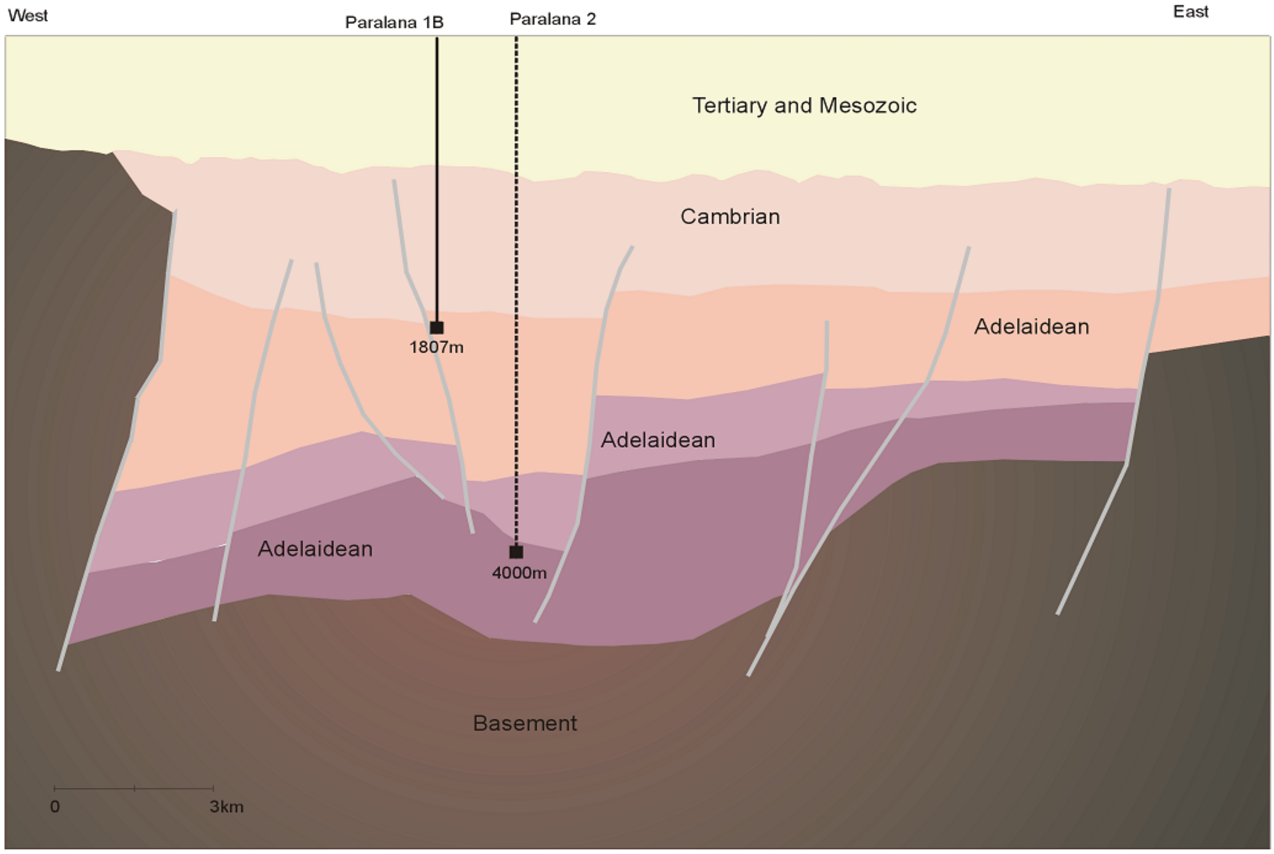

Figure 2: Cross Section of the informally termed Pootana Basin

A long-lived and geometrically complex fracture system known as the Paralana Fault System forms the eastern boundary to the Mountt Painter Inlier. Tectonic activity on this fault system has led to the development of a half graben, known as the Poontana Sub-basin (Figure 2), and juxtaposes the basement rocks against the thick sequence of sedimentary rocks within the sub-basin which represent successive depositional sequences within the stacked Neoproterozoic Adelaide Geosyncline, Cambrian Arrowie Basin and Mesozoic Lake Frome Embayment respectively.

As such the sub-basin has a complex structural history, and comprises sedimentary fill from two distinct depositional times. The first mega-depositional cycle spans Neoproterozoic to early Cambrian periods (~830 Ma. to 520 Ma.) which underwent regional metamorphism to low grade greenschist facies during the subsequent Delamerian Orogeny (~500 Ma. ago). Interpretation of reflection seismic data indicates complex multi-phase extension and faulting of the area, with subsequent reverse movement on re-activated faults during the Delamerian Orogeny. The sequence comprises a highly varied range of lithologies. The Neoproterozoic sediments are dominated by shale-siltstone assemblages, including matrix supported diamictites, with lesser sandstones and dolomites. The Cambrian sediments are comprised of roughly equal proportions of crypt-algal shale, siltstone, sandstone and limestone.

The second depositional period spans Mesozoic to Quaternary sedimentation. These later cycle sediments are comprised of marginal marine mudstones and claystones, overlain by fluviatile silts and Recent colluvium. There is evidence of reactivation of older extensional faults in the early part of Mesozoic and Tertiary sedimentation, and evidence along the eastern margin of the Mount Painter Inlier of continued Neotectonic movements indicating a reverse sense of movement.

Although the existing data is sparse, indications are that the present-day stress environment in this region is compressional to strike-slip (Hillis *et. al.* 2008), which will favour development of fractures in a horizontal to sub-horizontal plane in response to hydraulic stimulation. This creates an ideal environment for HDR developments (Swenson *et. al.*, 2000)

3. EXPLORATION OPERATIONS UNDERTAKEN AT PARALANA

Based on the recognition of high heat production basement rocks cropping out in the Mount Painter Inlier, and supporting evidence of radiogenic heating of groundwater at the Paralana Hot Springs, Petratherm began exploration activities in the Paralana region with the drilling of a shallow test well (Paralana 1B) to 491m. The well penetrated poorly consolidated Tertiary to Mesozoic sediments and yielded a high geothermal gradient measurement (ave. 77^{o}C/km). Paralana-1B was subsequently deepened to 1807m in 2006 through Cambrian and Adelaidean aged strata of the Adelaide Geosyncline, which comprise the remainder of the basin fill. The equilibrium bottom hole temperature recorded at this depth was 109^{o}C and a measured heat flow of 129 +- 3.6 mWm^{-2} calculated. Thermal modeling studies using data gathered from the Paralana-1B well, indicated temperatures in excess of 200^{o}C were possible at less than 4000 metres depth (Hand 2006).

Due to the structural complexity of the basin architecture a 2D reflection seismic survey was shot over the area in 2007, coincident with trial magneto-telluric studies, and a microseismic monitoring network was deployed in the area to record background seismicity prior to the commencement of drilling and stimulation operations. Subsequent geological and thermal modeling was used to site Paralana 2, the first deep geothermal well to be drilled into the inferred resource. Drilling of Paralana-2 is due to commence in June 2009, and is planned to target Adelaidean sediments at 4000 metres depth.

4. PROPOSED HEAT EXCHANGE DEVELOPMENT PLAN – THE HEWI MODEL AND MULTIZONE STIMULATION

4.1 The HEWI Model

One of the principle limiting factors towards the commercialisation of EGS has been the in-ability to manufacture a heat exchanger of sufficient size and fluid production rate. Existing technical difficulties in achieving a robust sub-surface heat exchanger in EGS applications generally relate to the practice of developing the sub-surface heat exchanger within the heat producing granite rock. Granite is by nature an impermeable and mechanically strong rock. As a result it is inherently difficult for fluid to flow through granite, or to mechanically fracture the rock to develop an effective reservoir artificially. By comparison, the rocks which make up the overlying insulating sediments tend to have greater naturally occurring porosity and permeability, are mechanically weaker, and more susceptible to induced chemical and mechanical stimulation if enhancement of the reservoir is required.

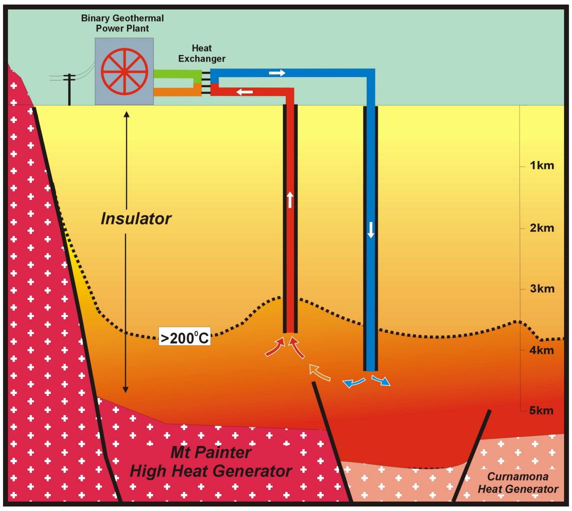

Figure 3: Schematic diagram demonstrating the basic concept of an Enhanced Geothermal System using the HEWI (Heat Exchanger Within Insulator) model

The Heat Exchanger Within Insulator (HEWI) model (Figure 3) aims to exploit naturally permeable and porous insulating sedimentary rocks above the granite heat source, or where intrinsic permeability is inadequate, deliver greater control over the development of the reservoir via hydraulic stimulation of these units. This strategy more closely approximates the systems successfully used in petroleum reservoirs and conventional geothermal projects, enabling the application of techniques for stimulation and geochemical mitigation developed and successfully used on a routine basis in these industries.

4.1 Multi-Zone Stimulation

Historical hydraulic fracture stimulations have generally been single massive stimulations in an open hole. The limitation of this method is that the operator has minimal control over the location and distribution of the developing fracture network, with most fractures propagating at the base of the casing shoe near the top of the open hole section. The inability to selectively initiate propagation of fractures in the remaining open hole section means the development of the heat exchanger has been severely compromised.

Given that the development of a complex, thick, interconnected fracture network is the optimal configuration for the engineered reservoir, it follows that undertaking multiple stimulation operations initiated at different levels in the well could achieve the desired outcome. Such an operation would enable greater control; both in terms of the location of initiation of fracturing in the well bore, and the potential to develop stacked multiple fracture horizons within suitable single or multiple geological units.

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