The Penola Project – Australia's First Hot Sedimentary Aquifer Development

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Panax Geothermal Ltd ("Panax") holds the geothermal rights covering four Hot Sedimentary Aquifers (HSA) within troughs or sub-basins in the Otway Basin in southeast South Australia, covering an area of more than 3,000 km^2. The Limestone Coast Geothermal Project is designed to demonstrate that conventional geothermal resources within Australia's hot sedimentary basins can be used to generate large amounts of competitively priced, zero-emission, base-load power. Due to an existing comprehensive database acquired by the petroleum industry, the initial development of its Limestone Coast Geothermal Project is focused on the Penola Trough (GEL223).

The first well, Salamander-1, is the first in a series of wells in the development of a 50 MWe geothermal power plant, which could become the first grid connected geothermal power plant in Australia.

A Pre-Feasibility study has also been completed to assess the total cost per MWh of power produced after taking into account all plant and pump requirements. This study found that electricity can be sustainably generated at a total cost (capital and operating) of AUD$63 per MWh. The Penola Trough has been subjected to intensive oil and gas exploration, including 27 deep petroleum wells with wireline logging and conventional core measurements of reservoir porosity and permeability. In addition, there are 271 km^2 of 3D seismic and a significant amount of 2D seismic data. These data are available as part of the Open File data base and studies have shown that the over 1,000m thick Cretaceous Pretty Hill Formation (sandstones) of the Penola Trough has the capacity to deliver geothermal waters of >140˚C at high volumes, sufficient for the operation of a commercial, medium temperature geothermal power plant. The generating potential is large, as is evidenced by a recent independent Geothermal Resource assessment, which has estimated a "Measured Geothermal Resource" of 11,000 PJ for the Penola Trough.

Introduction

Panax Geothermal Ltd ("Panax") holds eight Geothermal Exploration Licences (GELs), over four Hot Sedimentary Aquifers (HSA) within troughs or sub-basins in the Otway Basin in southeast South Australia, covering an area of more than 3,000 km^2 (see figure 2). The Limestone Coast Geothermal Project is designed to demonstrate that conventional geothermal resources contained within Australia's sedimentary basins have the capacity to generate large amounts of competitively priced, zero-emission, base-load power. The initial development of its Limestone Coast Geothermal Project is focused on the Penola Trough (GEL223, see figure 2), as this trough has a comprehensive exploration database acquired by the petroleum industry.

The Penola Project is located in Geothermal Exploration Licence (GEL) 223, approximately 40 km north of Mount Gambier in South Australia.

The Penola Trough is a sub-basin or trough in the on-shore Otway Basin area of south-eastern South Australia. It is one of several sedimentary troughs and represents an area of thick sediment and relatively recent volcanic activity as indicated by the presence of extinct volcanoes such as those associated with the Mount Gambier region 40km to the south. It is an area of anomalously high heat flow (see figure 3).

The Penola Trough (GEL 223) has been selected for the first deep well because this trough has an extensive data-base of the target productive wells, reservoir, based on more than 20 deep petroleum many of which have intersected the target reservoir, as well as extensive seismic data, including 271 km^2 of 3D seismic.

The Geothermal Reservoir

The target reservoir is the Cretaceous Pretty Hill Formation, a member of the Crayfish Group (see figure 1). The good reservoir quality of the Pretty Hill Formation sandstones has been known from petroleum activities for some time. Gas was first discovered in the trough in 1987 in Katnook-1. These gas discoveries are mainly restricted to the top 25m of the formation, trapped beneath Laira Formation shale. This is relevant and significant because the Laira Formation shale has a low thermal conductivity and is assumed to be a thermally insulating unit, overlying the Pretty Hill Formation target reservoir.

As part of the drilling of the petroleum wells, a significant amount of wireline logging, core sampling and resulting petrophysical evaluation were undertaken in the Pretty Hill Formation. The porosity of the target Pretty Hill Formation section was determined by Panax based on wireline logs calibrated to porosity samples from conventional cores and sidewall cores.

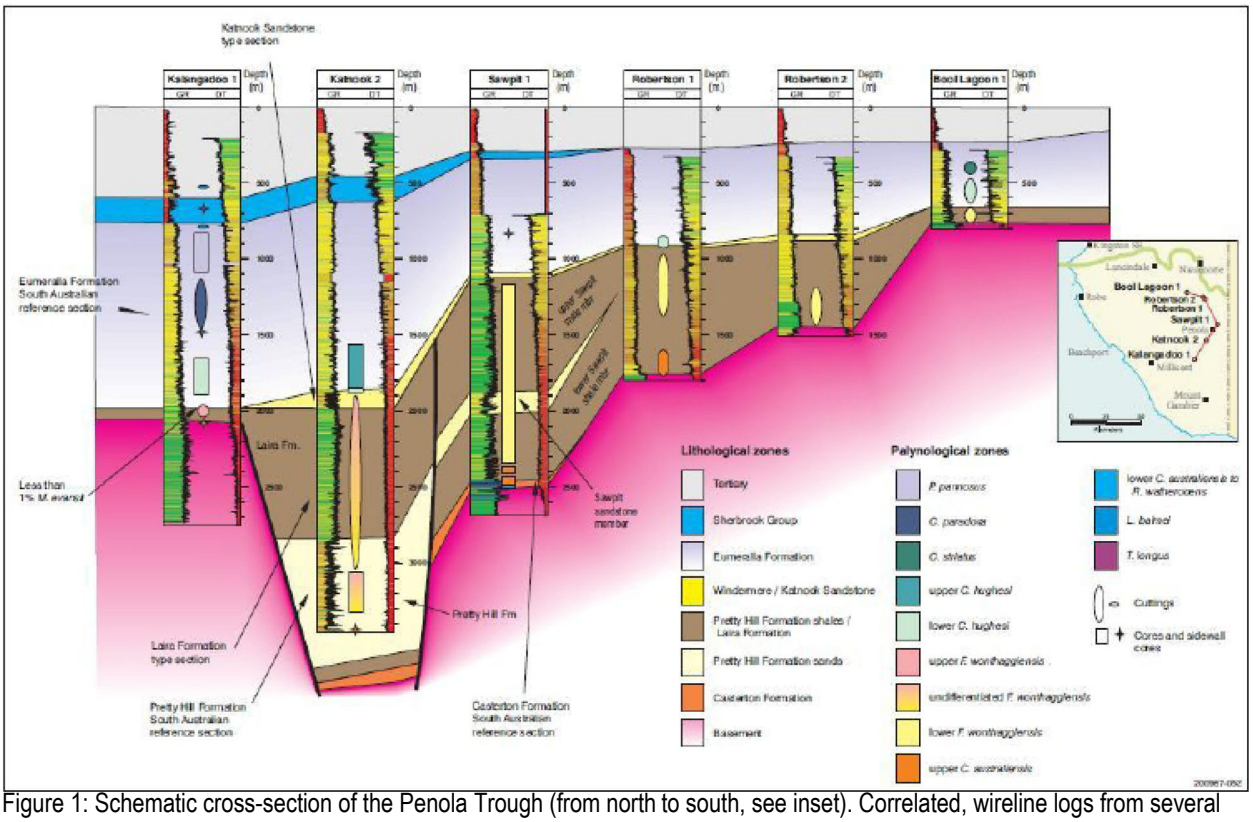

Figure 1: Schematic cross-section of the Penola Trough (from north to south, see inset). Correlated, wireline logs from several wells are also shown. The target reservoir formation, the Pretty Hill Formation, attains maximum thickness in the Katnook Graben (near the Katnook 2 well). After Boult et al. (2002).

We have estimated a total transmissivity (permeability thickness product) of 10-50 Darcy.metres (D.m) depending on well and thickness of Pretty Hill Formation penetrated.

The availability of well data, combined with the available 3D seismic data gives the Penola Geothermal Project a significant degree of credibility and reduced technical uncertainty in regards to the existence of suitable geothermal reservoirs.

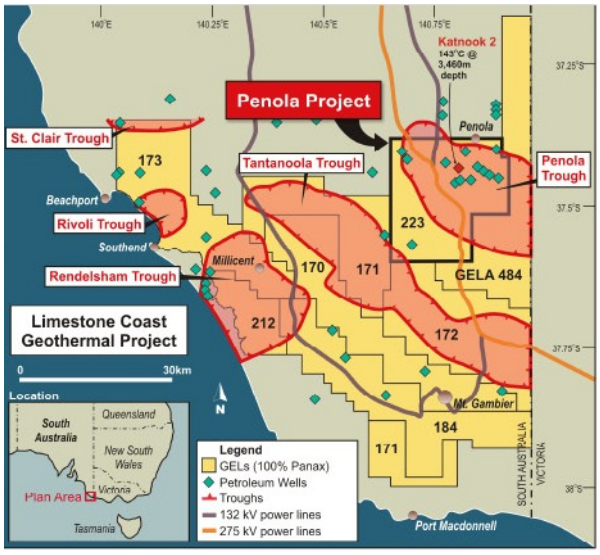

Figure 2: Outline of Sub-basins or troughs of the Limestone Coast Geothermal Project.

Geothermal Resource Estimation and Temperature Determination

Hot Dry Rocks Pty Ltd (HDRPL) undertook a geothermal resource assessment across geothermal tenements owned by Panax, adhering to the Australian Code for Reporting of Exploration Results, Geothermal Resources and Geothermal Reserves, 2008 edition (the Code) (Beardsmore, 2009). The geothermal resource summary in table 1 shows the relatively large overall potential of the Limestone Coast Geothermal Project.

The Penola Trough stands out as being the only trough with indicated and measured resources, courtesy of reservoir information derived from previous petroleum wells and 3D and 2D seismic data. The outline of the measured resource in the Penola Trough is shown in figure 4.

Within most of the Penola Trough, consistent with observations in well Katnook 2, modelling predicts that the temperature is relatively constant around 160°C at 4,000m.

Location and Infrastructure

GEL 223 is located within 50km of Mt Gambier, close to the township of Penola (figure 5). GEL 223 is transected by a transmission network of 275kV and 132kV power grid lines. Indications are there is sufficient capacity at two local substations to facilitate a low cost option (AUD$1-$2 million) for connecting the Demonstration Plant of the Penola Project

Limestone Coast Geothermal Resources					
Trough	**Measured (PJ)**	**Indicated (PJ)**	**Inferred (PJ)**	**Total (PJ)**	**Report Date**
Penola	11,000	32,000	89,000	132,000	18/02/2009
Rivoli & St. Clair			53,000	53,000	28/01/2009
Rendelsham			17,000	17,000	28/01/2009
Tantanoola			130,000	130,000	31/03/2009
Total	**11,000**	**32,000**	**289,000**	**332,000**	

Table 1: Estimated Geothermal Resource within the Pretty Hill Formation and deeper reservoir units for the Penola Geothermal Play. Resource estimates rounded to two significant figures (Beardsmore, 2009; for full reports please refer to the Panax website: www.panaxgeothermal.com.au)

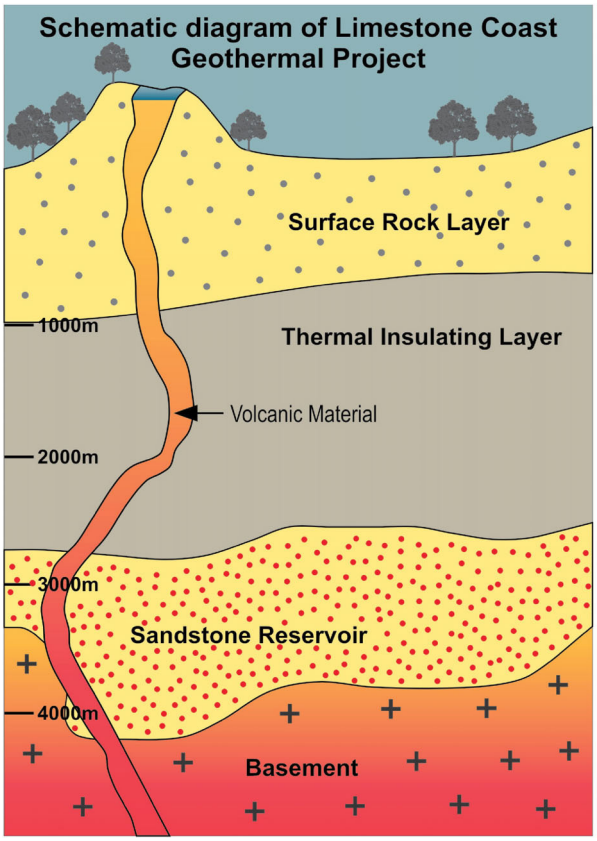

Figure 3: Schematic diagram of the Limestone Coast Geothermal Project.

Seismic Interpretation

Seismic interpretation of the 3D seismic datasets has allowed a confident delineation of the top of the Pretty Hill Formation and the base of the rift. The seismic data was also processed to provide more information on the reservoir quality than from the well data alone. An 'acoustic impedance' inversion of the 3D seismic was undertaken to better identify the prospective reservoir section.

Pre-Feasibility Study

Panax compiled a Pre-Feasibility Study of the Penola Project to determine the total costs per MWh of power generated from brine produced from the Pretty Hill Formation reservoir to provide an assessment of the economic viability of this project. The total cost per MWh is considered to be the cost per MWh of power generated after taking into account all plant and pump requirements.

The Penola Project power generation is based on the production of 175kg/sec of brine (=166.4k gallons/hr (US)), at a temperature of 145˚C (293˚F) from each production well, and an injection temperature of 70˚C (158˚F). This Base Case using a standard binary organic rankine cycle binary geothermal power plant, has an estimated Gross output of 6.7 MWe and Net output of 5.9 MWe and a net/net output of 4.5 MWe.

The development is divided up in three stages:

- a **Demonstration Plant** based on one production well
- the **Phase 1 Plant** based on a total of three production wells; and
- the **Phase 2 Plant** based on a total of ten production wells.

A summary of the output and total cost per MWh for the three stages and a summary of the total capital and operating costs per MWh is listed in tables 2 and 3 below:

	Output MW	$ MWh
Gross	67.0	42
Net Plant	59.0	48
Net Plant/Net Pumps	45.0	63

Table 2: Penola Project Summary of Base Case Output Gross, Net Plant and Net Plant/Net Pumps, Total Costs per MWh

The cost per MWh produced after plant and pump power demands (i.e. net plant, net pumps) is estimated at AUD$63 per MWh. The cost of connecting the Penola Project power generation to the grid (based on independent expert advice) adds approximately AUD$2 to the total cost per

MWh generated, a direct reflection of the excellent infrastructure location of this project.

Capital & Operating Costs per MWh (Phase 2 Plant, AUD$'s)	
Capital Costs	$51
Operating Costs	$12
Total Costs	**$63**
Grid Connection	$2
Total	**$65**

Table 3: Penola Project Capital and Operating Costs per MWh Phase 2 Plant (67 MW).

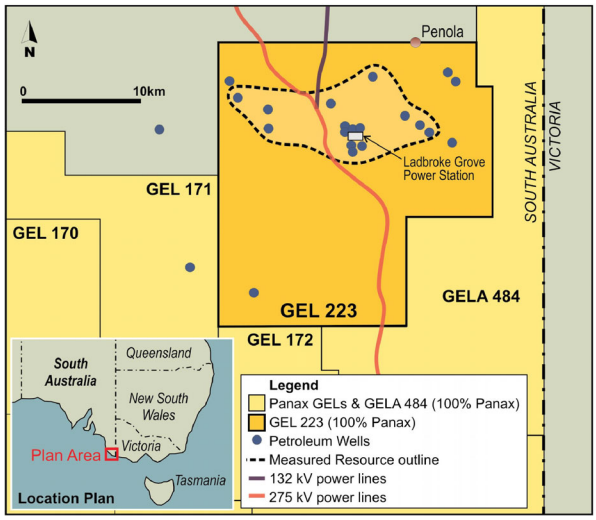

Figure 4: Surface outline of the Measured Geothermal Resources of the Penola Project.

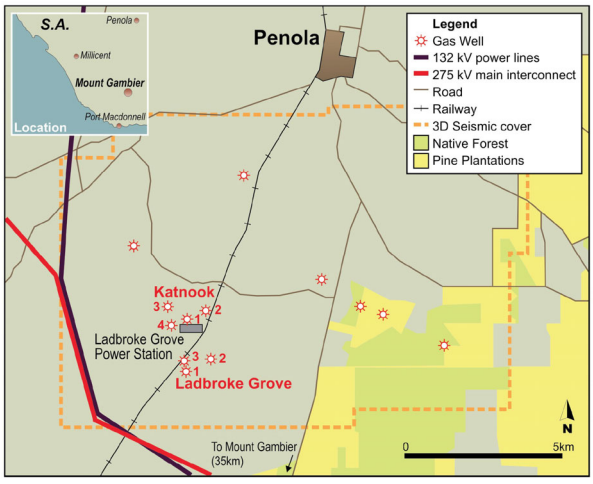

Figure 5: Penola Project – Location & Infrastructure.

Conclusion

It can be concluded that the Penola Project represents a commercially attractive geothermal development proposition targeting a hot sedimentary aquifer which is well known from previous petroleum exploration. A pre-feasibility study indicates that a competitive total cost per MWh of AUD$63 can be achieved. Further, the plans for drilling the first well in the project, Salamander 1, are well advanced. Overall, the Penola Project has the scope to be of national significance in the quest to reduce carbon emissions through providing competitively priced, zero emission, base-load power, and to be the first grid connected geothermal electricity generator in Australia.

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