Multiuse-use ‘triple play’ hot sedimentary aquifer (HSA) potential of Victoria, Australia

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Greenearth Energy Ltd holds geothermal exploration permits to the east and west of Melbourne, Victoria Australia. These permits are located on the Otway and Gippsland basins that straddle the southern part of the State. The basin fills range up to 6 km thick and form an insulating blanket over Palaeozoic basement rocks.

Geothermal gradients are somewhat elevated, with heat flows up to 100 mW/m^2 in places, and projected temperatures of 150 ^{o} C at around 3 kilometres (km) depth.

Sandy units at the base of the basin sequences offer potential for Hot Sedimentary Aquifers (HSA) while longer term Engineered Geothermal Systems (EGS) prospectivity exists in Palaeozoic granites beneath the insulating sedimentary cover. The HSA’s are a triple play with potential for electricity generation, direct heat applications and potential CO_2 sequestration sites.

A geothermal resource has been estimated for the area south of Geelong, encompassing both HSA and EGS geothermal plays. A proposal has been modelled for a 10.7 MW and 48 MW geothermal development accessing part of the HWA geothermal resource.

Introduction

Greenearth Energy Ltd (Greenearth) is a small listed Australian Geothermal explorer. It has geothermal exploration permits near Melbourne Australia (Figure 1) that underlie the industrial hub of southeastern Australia. These areas have a significant greenhouse gas footprint. To the east of Melbourne, in Gippsland, the permits include the Latrobe Valley area, the State of Victoria’s power generation hub with over 6000 MW of brown coal fired electricity generation. To the west of Melbourne a permit covers the Geelong region, the most carbon constrained community in Australia. Major industry includes an aluminium smelter, cement works and a brown coal fired power station.

Greenearth has established inferred resources in both its Geelong and Gippsland permits. To the southwest of Geelong an inferred resource of 260,000 PJ is calculated (Beardsmore, 2008), encompassing both a hot sedimentary aquifer resource (HSA) and a deeper engineered geothermal system (EGS), while in the Gippsland area a small inferred geothermal resource of 39,000 PJ is estimated (Beardesmore, 2009).

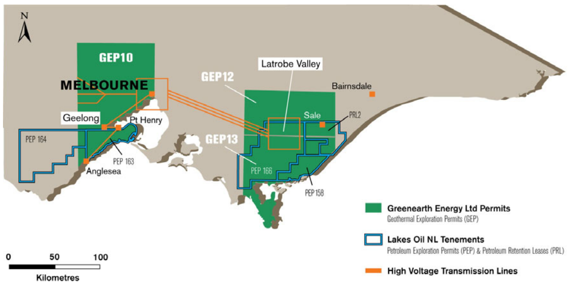

Figure 1: Greenearth Energy Ltd permits.

The Australian Government has set a target that 20 % of all energy generation by 2020 will be from renewable sources (Department of Climate Change, 2008). This could mean that approximately 45,000 gigawatt-hours from renewable energy sources will be required by 2020.

The thick sedimentary basins running east and west of Melbourne, the higher than normal heat flows in the basin margin areas and the potential for thick sandy sequences in the temperature depth widow of 3-4 km make the Greenearth permits prospective for geothermal development of hot sedimentary aquifers.

Geological and geothermal description

A Mesozoic rift basin established along the south-eastern margin of Australia during Gondwana separation. To the west of Melbourne is the Otway Basin, stretching 500 km, while the Gippsland Basin is located to the southeast of Melbourne.

Both basins have undergone significant petroleum exploration with the offshore part of the Gippsland Basin being a major hydrocarbon province.

While the detailed stratigraphic nomenclature varies between the two basins, the overall sedimentary history is similar. Sedimentation commenced in the early Cretaceous with fluvial sediments (Pretty Hill/Rintouls Creek) deposited onto the rifting basement. This is overlain by thick non-marine volcanogenic sandstones and siltstones. These sediments are in turn unconformable overlain by a series of marine sediments spanning the late Cretaceous to mid Tertiary (Duddy, 2003; Holdgate and Gallagher, 2003).

The geothermal potential is associated with the initial sedimentary basin fill which offer permeability potential. Faulting is extensive in the basins with major faults bounding half grabens, originally normal and then subsequently reactivated as reverse faults. Faulting in or adjacent to any sandy basal units, in particular fracture zones, should provide access to broader reservoir areas (Figure. 2).

Latrobe Valley and Gippsland

In the Gippsland area the base of the sedimentary basin is in the range 3000-4000 m or deeper. The basal units (Rintouls Creek Sandstone and Tyers Conglomerate) have known porosity and offer a geothermal target where they are most deeply buried.

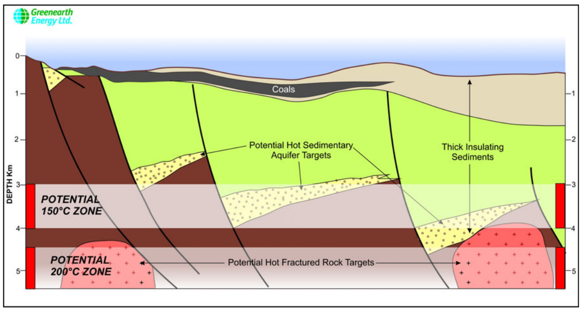

Figure 2: Schematic geological model for Hot Wet Aquifer, Otway and Gippsland basins.

Heat flow investigations show that there is a trend of elevated heat flow through the Latrobe Valley area. Measurements on 10 wells returned estimates up to 101 +/- 26 mW/m^2 (Figure. 3) (Walsh, 2009a). One of the most significant temperature projections is that at the Loy Yang-2 well, drilled in 2005 to 1443 m and re-entered in 2008 for precision temperature logging to 713m. From the original well composite log, measured and fair estimates of conductivity were applied to different layers. The resulting thermal conductivity profile yielded a heat flow of 90 mW/m ^{2}.

Based on this information a heat flow model was used to predict the temperature beneath the well. Well log data from the adjacent Loy Yang-1 well was able to give the stratigraphy to a depth of 1735 m. and a scenario was modelled down to

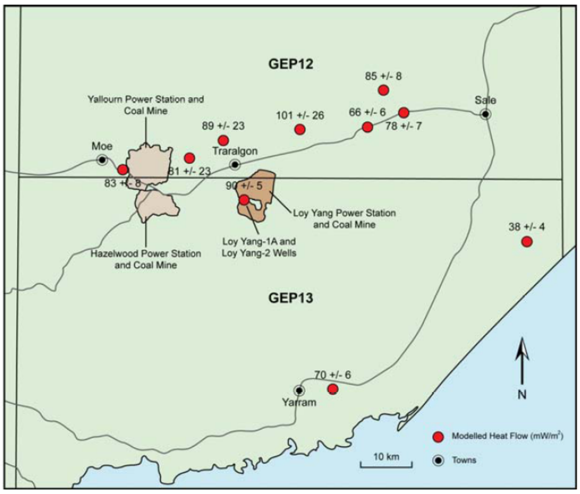

Figure 3: Summary of heat flow investigations. The Latrobe Valley area shows heat flows well above the global average.

3500m. An estimated temperature of 150 ^{0}C was achieved at a projected depth of 2900m +/- 400m (Fig. 4) (Walsh, 2009b, Greenearth Energy Ltd, 2009).

Any porous sandy sediment at that depth in the Latrobe Valley area provides an exploration target for hot wet sedimentary aquifer style geothermal resources. In the Latrobe Valley brown coal generation hub opportunities exist for both electricity generation as well as direct heat application for drying brown coal or pre-heating boiler feed water.

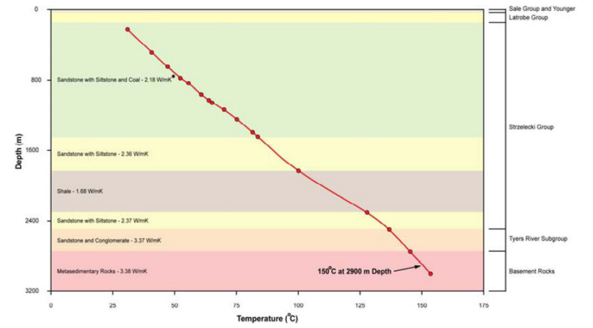

Figure 4: Modelled temperature of Loy Yang-2 Well

These same units also offer potential targets for investigation as CO_2 sequestration reservoirs. The brown coal electricity generation in the Latrobe Valley area produces around 60 mtpa of CO_2. The sandy units, located at depths of 2.5 km or deeper beneath the power generation area, warrant further investigation of their ability to act as onshore CO_2 storage sites.

Geelong area

In the Geelong area the basal parts of the insulating sedimentary cover (Crayfish Group/ Pretty Hill Sandstone) reaches depths of 4000-5000 m (St John, 2007). Just to the west of the permit boundary the Pretty Hill Sandstone is 615m thick.

This area has potential for both Hot Sedimentary Aquifers(HSA) geothermal plays in the shallower sand-prone beds of the early Cretaceous Crayfish Group as well as Engineered Geothermal Systems (EGS) geothermal plays in the Palaeozoic basement.

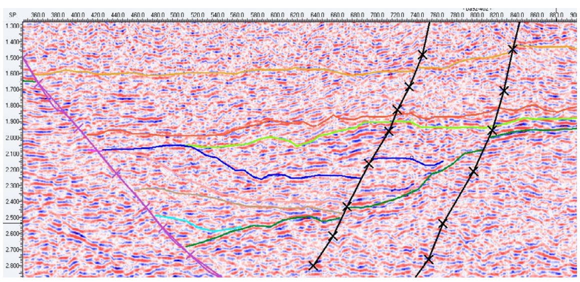

Figure 5: Seismic line OGF 92-402 showing distribution of possible sand prone units. Yellow – top E1, blue – top F, brown – base F, light blue – top Casterton A.

Seismic mapping has identified the distribution of two possible sand-prone units in the early Cretaceous CrayFish Group. These two sequences are described as units F and E1 (Figure. 5) and may constitute viable sedimentary aquifers. Both units show characteristic syn-dypositional growth towards the major bounding faults with unit F reaching a maximum thickness of about 600 m and unit E1 reaching a maximum thickness of about 700 m (Cooper and Waining, 2008; Cooper, Waining and Pollington, 2008) (Figure 6).

Inferred Resource estimates have been made on three reservoir targets. The targets fall into two categories of geothermal reservoir-:

- buried sedimentary aquifers (Hot Sedimentary Aquifers –HSA) type plays, targeting sandstones units in the Crayfish Group (E1 and F reservoirs); and
- Engineered Geothermal System (EGS/HDR), targeting Palaeozoic basement.

The HSA targets were defined via sequence stratigraphic methods incorporating 2D seismic with local and regional well data from the Otway Basin. The EGS target has been defined by the seismic data and constitutes the basement beneath the insulating Otway Basin sediments.

A stored heat method was used to estimate a HSA inferred geothermal resource of 40,000 PJ and the EGS inferred resource of 220,000 PJ. The resource covers an area of 462 km^2 and is contained in 656 km^3 volume of rock. The resource estimate complies with the Australian code for reporting exploration results geothermal resources and geothermal reserves (2008 edition).

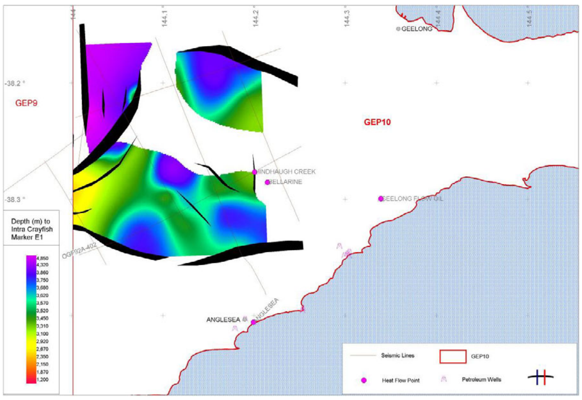

Figure 6: Depth map of the E1 marker, the top of the potential reservoir unit in the Crayfish Group. Distribution is controlled by early Cretaceous growth faults.

This work has led to the development of a HSA commercial model for geothermal based electricity generation southwest of Geelong.

This model assumes that a portion of the inferred HSA geothermal resource of 40,000 PJ present in Geothermal Exploration Permit (GEP) 10 is available to utilize for power generation.

Wells intersecting the Pretty Hill Sandstone in the wider Otway Basin show variable porosity and permeability. Based on this limited data, it is feasible that the Pretty Hill Sandstone may have porosity in the range 10-15 % and average permeability of 50-150 mD at the target depth of 3450 m (Fig. 7). It would be expected that the reservoir unit would need to have a thickness of > 100 m of permeable rock to achieve a permeability-thickness function (Darcy-metre) required for commercial flows.

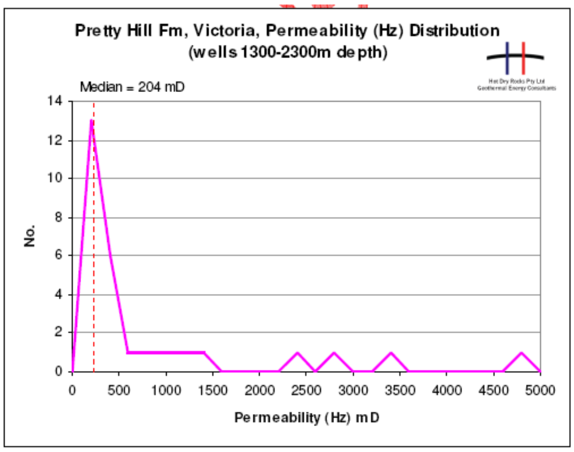

Figure 7: Frequency distribution of horizontal permeability from core samples for the Pretty Hill at Waracburunah-2, Hawkesdale-1, Garvoc-1, Pretty Hill-1, and Woolsthorpe-1. The distribution is strongly log-normal with a median 204mD

A 1D conductive heat flow model on data from the Bellarine-1 well and extrapolated to basement from seismic data illustrate that the geothermal working fluid (150 ^{o} C) is intersected at about 3040m with a heat flow of 90 +/- mW/m^2 (Fig. 8).

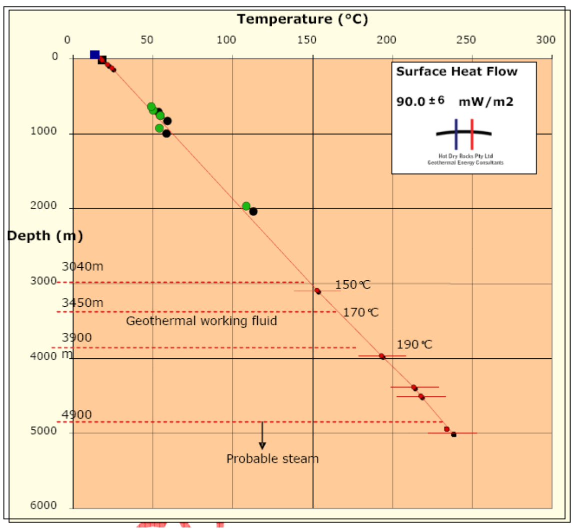

Figure 8: Sample conductive 1D heat flow model based on temperature data from Bellarine-1 and measured thermal conductivity data for all major lithologies in GEP 10. The model has been extrapolated on based on seismic depth grids.

A target geothermal resource temperature of 170 degrees centigrade at the modest target depth of 3,450 metres with an assumed flow rate of 100 litres per second, should yield sufficient heat flow to build an operating geothermal power plant.

There are several possible sites for a geothermal power plant in GEP 10 and a potential site was selected approximately 10 kilometres north-northwest of the Anglesea Coal Mine, 9.5 kilometres from the Anglesea– Point Henry electricity transmission line.

A commercial study modelled the costs and outcomes that may reasonably be expected for developing a 10.7 megawatt (MW) geothermal power plant. Similarly the study modelled an expansion to establish a 48 MW geothermal plant (Cooper, Waining and Pollington, 2008).

Borrowing costs were amortised over the life of the projects (20 years). Costs were discounted as has the generation (MWhr) to calculate the levelised cost (LEC) of both scenarios.

The commercial model shows that over a 20 year life for the proposed geothermal power plant:

- The levelised cost of electricity (LOCE) would be in the range of $96-114 per MW hour.

Generation of attractive pre-tax revenue and discounted cash flows for the project.

Result in a displacement of at least 1.2 million tonnes and up to 7.3 million tonnes of carbon dioxide “greenhouse gases” emitted by conventional power stations.

Conclusion

Greenarth Energy Ltd has geothermal exploration permits that underlie the industrial hub of southeastern Australia. The permits contain in excess of 6000 MW of brown coal fired electricity power generation with the Latrobe Valley power stations alone having a greenhouse gas footprint in excess of 60 mtpa.

The southern Victorian Cretaceous-Tertiary sedimentary basins that straddle the permits have substantial seismic and well data from previous petroleum exploration. Heat flows vary, however, in places values of up to 100 mW/m^2 were recorded. In the Geelong and Latrobe Valley area temperatures are estimated to reach 150 ^{o}C at around 3 km depth. The basal units of the sedimentary pile, where they occur in the 3-4 km depth range have potential to contain hot sedimentary aquifers that may be suitable for power development using organic rankin cycle technology.

The high moisture content of the brown coals used for electricity generation may present opportunities for direct heat application using geothermal fluids to dry coal. Given the high level of greenhouse gas emission in the permit areas, these same units are a target for further research as to their capacity to also act as reservoirs for greenhouse gases.

In the Geelong area good seismic coverage has enabled the calculation of an inferred geothermal resource. A site was selected near the Anglesea power station for a conceptual geothermal development. At this location the potential reservoir is interpreted to be 1000m thick commencing at around 3.5 km depth.

The costs and outcomes for conceptual 10.7 megawatt (MW) and a 48 MWgeothermal power plant were modelled. The plants would produce 1.65 and 7.41 GWh of renewable electricity. The levelised cost of electricity (LOCE) would be in the range of $96-114 per MW hour.

Acknowledgements

Much of this paper has drawn extensively upon reports to Greenearth Energy Ltd by Graeme Beardsmore, Gareth Cooper, Denis Walsh and Ben Waining of Hot Dry Rocks Pty Ltd. They are duly acknowledged for their contribution.

References

Beardesmore, G., 2008, Greenearth Energy Ltd, statement of estimated geothermal resource, Anglesea, GEP 10 as at 04 December 2008. (Release to the Australian Stock Exchange by Greenearth Energy Ltd), 9pp

Beardesmore, G., 2009, Greenearth Energy Ltd, statement of estimated geothermal resource, Wombat, GEP 13 as at 18 December 2008. (Release to the Australian Stock Exchange by Greenearth Energy Ltd), 9pp

Department of Climate Change, Australian Government, 2008, Fact Sheet, Australian Government renewable energy target (December 2008), 1p

Duddy, I. R., 2003, Mesozoic, in Geology of Victoria, (Ed W.D. Birch). *Geological Society of Australia, Victorian Division Special Publication* ***23,*** pp239-286.

Cooper, G. T. and Waining, B., 2008, Interpretation of selected 2D seismic reflection lines in the Otway Basin (GEP 10) and related sequence mapping. Report prepared for Greenearth Energy by Hot Dry Rocks Pty Ltd., 63pp

Cooper, G. T., Waining, B. and Pollington, N. J., 2008, Renewable energy Project: concept development for geothermal power plants, GEP 10, Geelong area Victoria. Report prepared for Greenearth Energy by Hot Dry Rocks Pty Ltd, 31pp

Greenearth Energy Ltd., 2009, High modeled temperatures benearth the Loy Yang power stations, Latrobe Valley, Victoria. Australian Stock Exchange Release, (27 May 2009), 2pp

Holdgate, G. R., and Gallagher, S. J, 2003, Tertiary, in Geology of Victoria, (Ed W.D. Birch). *Geological Society of Australia, Victorian Division Special Publication* ***23,*** pp289-335.

St John, P., 2007, Independent geological expert's report. In Greenearth Energy Ltd Prospectus, pp32-47

Walsh, D, 2009a, GEP 12 & 13 temperature logging and heat flow investigation. Prepared for Greenearth Energy Ltd by Hot Dry Rocks Pty Ltd (unpublished), 43pp

Walsh, D, 2009b: Loy Yang-2 temperature correction and projection. Prepared for Greenearth Energy Ltd by Hot Dry Rocks Pty Ltd (unpublished), 5pp