Geothermal Exploration in Victoria, Australia

David H Taylor, Ben Harrison, Michelle Ayling, Kate Bassano
GeoScience Victoria, GPO Box 4440, Melbourne, Victoria, Australia

Corresponding author: david.taylor@dpi.vic.gov.au

Geothermal energy is keenly sought as a sustainable, low emissions energy source for Victoria. Exploration companies have been active since 2006 looking for geothermal systems where temperatures of greater than 150 C would allow electricity generation. Initial exploration was largely guided by legacy temperature data in groundwater and petroleum bores but lots of dedicated heat flow data is now being acquired, including a State-wide program by the government. Active volcanic systems are not present but there is good potential for hot sedimentary aquifers already known from the legacy data. Other heat sources such as Palaeozoic radioactive granites or residual magmatic heat from recent basaltic volcanism are possible but data is very limited. As exploration progresses, a number of different geothermal play types across the various heat sources are being investigated. A number of inferred resources have already been declared, in preparation for deep appraisal drilling.

Keywords: Hot Sedimentary Aquifer, Heat Flow, geothermal

Victorian geothermal background

The oil shocks of the 1970's piqued interest into alternate energy sources. Town water supplies being drawn from thick Cretaceous-Tertiary basins along the Victorian coast at that time, showed temperatures of about 50-90 C at 1-2 km depth. The potential of direct use of this hot water was investigated (King et al., 1987). Petroleum exploration in the same area also occasionally intersected deeper basin aquifers with temperatures of about 130-150 C at 3.5-4 km depth (Woollands and Wong, 2001).

Low oil prices throughout the 1990's suppressed interest in alternate energy sources but the return of higher prices and concerns around greenhouse gas emissions have again sparked interest in geothermal energy. Dedicated legislation was put in place in 2005 and a grid of large exploration permit blocks was established across the State. Exploration companies took up many of the permits in two rounds of tenders over 2006 and 2008. About two thirds of the State is now under exploration for the next 3-4 years by seven companies with work plan commitments of approximately $365M.

Victorian Geothermal Data

To support the tender bidding process for permits, a preliminary review of geothermal prospectivity was published by the State government geology organisation (Driscoll, 2006). This report included a compilation of about 300 temperature data points from pre-existing groundwater and petroleum bores but the accuracy and precision of much of the petroleum temperature data for geothermal assessments is questionable.

A handful of heat flow calculations from precision temperature logging and rock conductivity analysis already existed as a result of academic studies since the 1970s. Many of the geothermal exploration companies have started collecting much more of this dedicated type of geothermal data. To accelerate this type of work the State government has undertaken a data collection program for heat flow.

The Victorian Heat Flow Map

In 2009-10 the State government commissioned a one year $500,000 project to generate a State-wide heat flow map. Over the year, this project has compiled the existing academic and company data, plus collected new data, to generate over 100 heat flow measurements that give good coverage over much of the State. Data points are generally close enough together (ideally closer together than the crust is thick: about 40 km) so that interpolation of the point data into a map should still have regional scale meaning.

GeoScience Victoria directly collected borehole temperature profiles in the southern Murray Basin and across the Otway Basin using its own temperature logging unit. As part of the National Geothermal Energy Project (Budd et al., 2009) GeoScience Australia collected temperature data from the northern Murray Basin using their temperature logging unit. GeoScience Victoria is also working collaboratively with Melbourne University who have collect data from the Gippsland basin. The exploration companies in the Gippsland Basin have also collected a fair amount of new temperature data in that region and made it available. Several recent unpublished honours thesis and some additional temperature logging for GeoScience Victoria undertaken by Hot Dry Rocks add further data to the previous handful of heatflow measurements that was all that was available several years ago.

About 200 conductivity analyses have been performed by Hot Dry Rocks on samples from the boreholes measured for temperature. This data allows reasonably precise heat flow calculations to be generated. Heat flow modelling for data from completely new holes was undertaken by Hot Dry Rocks. The various pre-existing honours thesis and company work was remodelled by GeoScience Victoria using consistently applied methodology and better informed conductivities stemming from the new sampling.

This regional scale appraisal of heat flow, when combined with analysis of thickness of basin cover, will help show 'where it is hot and where it is not'. The map will help companies direct their permit scale efforts, as well as informing government policy on geothermal resource potential.

This work is still in progress and thus current assessments of Victoria's geothermal potential still rely on looking at geological factors.

Geological Framework for geothermal potential

Geothermal potential depends on the interaction of a number of geological factors. The best resources are likely to exist in regions where high heat flow passes through rocks of low conductivity (good insulation) to create high temperature at shallow depth (Duffield & Sass, 2003).

The recent publication of a more complete geothermal systems assessment framework (Cooper & Beardsmore, 2008) outlines that in addition to (1) the heat producing basement (2) an insulating blanket; there needs to be (3) a fluid available to extract and move the heat; and (4) a reservoir to accommodate the fluid.

Applying this four factor analysis to the major geological provinces of Victoria gives some idea of their relative geothermal prospectivity. The broad diversity in the age and types of rocks across Victoria (Figure 1) gives some potential for all three types of geothermal systems: Hot Rock; Hot Sedimentary Aquifer; and Magmatic.

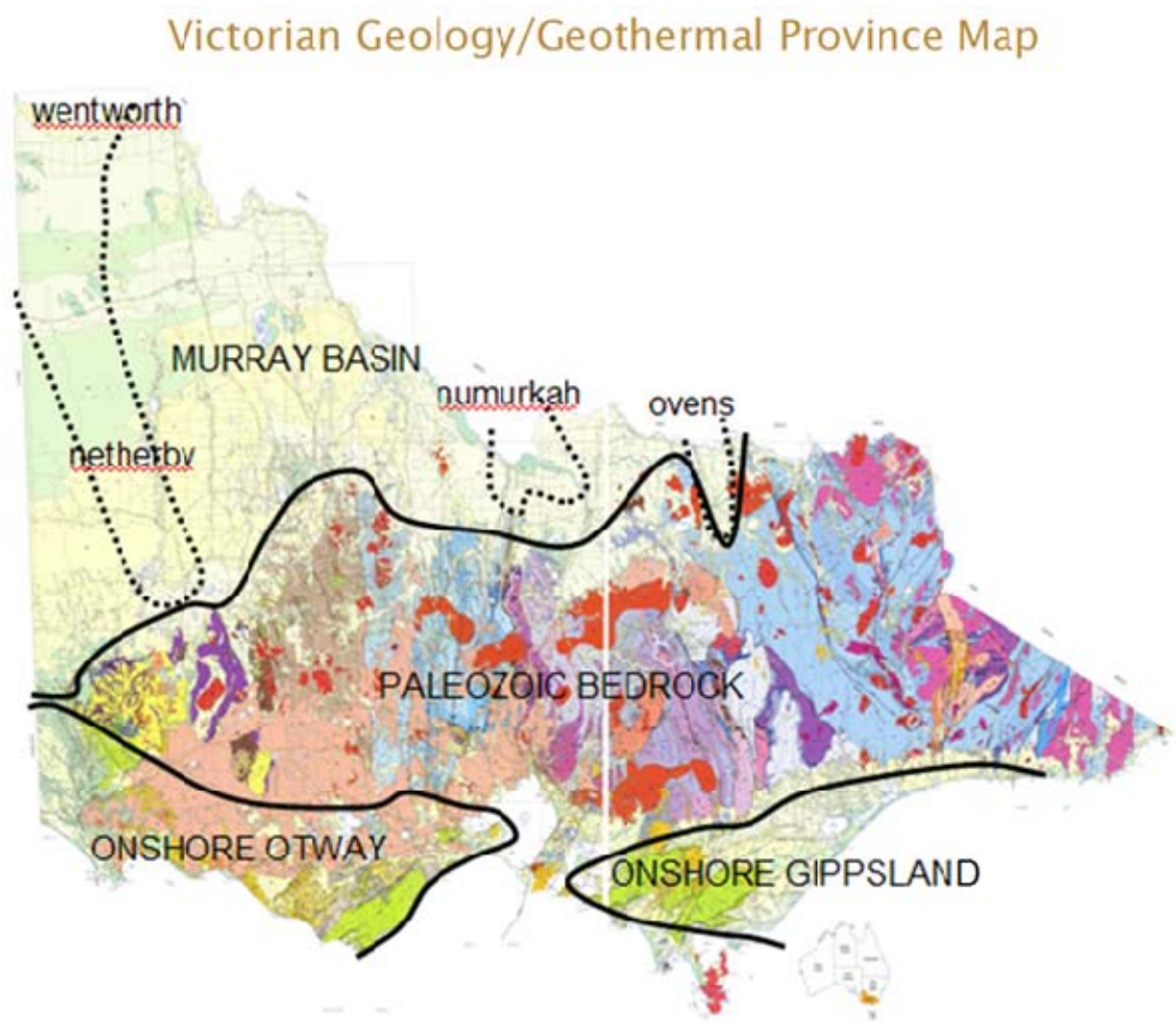

Figure 1: Geological geothermal province map

Three broad geological/geothermal provinces can be delineated across Victoria: (1) The Palaeozoic bedrock (2) the onshore Otway and Gippsland Basins and (3) the Murray Basin.

The Palaeozoic bedrock consists predominantly of Cambrian to Devonian deep marine muddy siliciclastics that have been tightly folded and cleaved at various times in the Palaeozoic (blues, browns and purples of Figure 1). This bedrock also underlies the other provinces and thus gives good insight into the potential of their heat producing basement. Numerous granites intrude this bedrock (red blobs on Figure 1). In west and central Victoria some of them have felsic, fractionated geochemistry with mild enrichment in heat producing elements, so Hot Rock plays may be possible where granites lie buried within the bedrock or beneath the adjacent basins. In the southwest, an extensive province of young basalts has erupted onto the bedrock in the last few million to tens of thousands of years (the light pink in Figure 1). Teleseismic data suggests a mantle hot spot still underlies this recent volcanism (Graeber et al., 2002). In addition to an increased mantle heat flow contribution across this region, there may be some residual magmatic heat in the crust from the volcanic activity to allow Magmatic geothermal plays.

The Onshore Otway and Gippsland Basins are Cretaceous rift basins associated with Gondwana break-up (greens and yellow along coast in Figure 1). These basins are well characterised thanks to a long history of petroleum exploration with many deep wells. They contain several kilometres of muddy sediments overlying a coarser grained basal unit. This basal unit provides a natural reservoir already charged with hot water beneath an insulating blanket to create an attractive fairway for Hot Sedimentary Aquifer plays. In the Otways this basal unit has been intersected upon the basin floor but in the Gippsland basin this unit has yet to be tested away from the margins, at the depths necessary for a geothermal play. Beneath these basins there is also potential for Hot Rock plays in places where they are floored by granites.

The Murray Basin is a Tertiary intracratonic sag basin (light greens and yellow inland in Figure 1). It generally contains only a few hundred metres of sandy marly cover. This is insufficient cover to act as a heat blanket but in some places deeper troughs – such as the Wentworth, Netherby, Numurkah and Ovens - exist and can contain up to a couple of kilometres of sediment that is poorly known since there has been limited petroleum exploration here. Alignment of favourable factors over the deeper troughs may allow Hot Rock or Hot Sedimentary Aquifer plays but the favourability of the geothermal factors in this province has yet to be validated.

Pathways to Resource Development

In the absence of detailed, dedicated geothermal data, most of Victoria can be viewed as ‘blue sky’ or perhaps ‘green fields’ at best, in those areas where some legacy petroleum data exists. The new heat flow map and better characterisation of rock thermal insulation (conductivities) will provide a new level of interpretation on prospectivity.

Most of the Victorian geothermal explorers are small companies with limited amounts of capital and cash-flow to fund their 5 year exploration programs. Ideally, as these companies collect information and decrease risks and unknowns, they could call for more capital through either debt or equity raisings until it becomes probable that a major backer would farm-in for development. The Global Financial Crisis has badly affected this traditional venture capital pathway through to resource development.

At the national level the Federal government has committed a significant amount of funds into a geoscience investigation program and also put up money for co-funding deep appraisal drilling. If these drilling appraisals lead to early success, then perceived risks around geothermal energy may be reduced and allow easier funding for the whole industry from the more traditional pathway. The State government has also offered substantial funds towards industry assistance for shallow and deep drilling plus contingent money for demonstration power plants.

Company announcements around Inferred Resources and/or conceptual targets suggest that several thousand MW of electricity generation may be possible but it is still early days for the geothermal industry in Victoria.

References

Budd, A.R., Holgate, F.L., Gerner, E.J., Ayling, B.F. & Barnicoat, A.C., 2009, Pre-competitive geoscience for geothermal exploration and development in Australia: Geoscience Australia's Onshore Energy Security Program. Proceedings, Australian Geothermal Energy Conference, Brisbane, Australia.

Cooper, G.T. & Beardsmore, G.R., 2008, Geothermal systems assessment: understanding the risks in geothermal exploration in Australia. Proceedings, Eastern Australian Basins Symposium III, Sydney, Australia.

Driscoll, J., 2006, Geothermal propsectivity of onshore Victoria, Australia. VIMP Report 85. GeoScience Victoria.

Duffield, W.A. & Sass, J.H., 2003, Geothermal energy: Clean power from the earth's heat. Circular, U. S. Geological Survey 1249.

Graeber, F.M., Houseman, G.A. & Greenhalgh, S.A., 2002, Regional teleseismic tomography of the western Lachlan Orogen and the Newer

Volcanic Province, southeast Australia. Geophysical Journal International, v. 149, 249-266.

King, R.L., Ford A.J., Stanley, D.R., Kenley, P.R., & Cecil, M.K., 1987, Geothermal Resources of Victoria, Department of Industry, Technology and Resources and Victorian Solar Energy Council, Melbourne.

Woollands, M.A., & Wong, D., (eds.) 2001, Petroleum Atlas of Victoria, Australia, Department of Natural Resources and Environment.