Geothermal energy exploration in South Australia

Elinor Alexander (Manager, PIRSA Petroleum Geology Branch)

Geological setting

Geothermal energy is the natural heat found within the Earth — around the globe, temperature increases with depth, typically by 10–50°C/km. The bulk of this heat is generated from the radioactive decay of naturally occurring potassium, thorium and uranium isotopes.

Localised heat sources also occur in active volcanic regions where magma bodies can reach temperatures of 500–1200°C, elevating groundwater temperatures. This sometimes results in geysers and hot springs, which are utilised for hydrothermal energy in over 45 countries, including Japan and New Zealand.

There are four main geothermal energy sources — hydrothermal, geopressured brines, hot dry rock (HDR) and magma associated with active volcanoes. In Australia, the main types of geothermal energy are hydrothermal (from groundwater that has been heated by hot basement rocks) and HDR. Hot fractured rocks (HFR) are also recognised as distinct from HDR. HFR are brine-saturated and naturally fractured hot rocks.

Currently, regions of interpreted high crustal temperature at depths over 3 km form the main exploration targets for HDR energy exploration in South Australia. However, a viable HDR prospect needs both rocks that will generate heat, and cover rocks to insulate and trap the produced heat over geologic time. In South Australia, granites buried by sedimentary cover currently form the main HDR geothermal exploration targets.

HDR energy involves exploring under sedimentary cover for, then drilling, anomalously hot basement rocks, which are then fracture stimulated so that water can be circulated via deep injector wells into the heat source. This heated water is recovered from deep production wells and circulated to the surface to a heat exchanger and used to generate electricity.

The Gawler Craton (late Archaean – early Mesoproterozoic) and Curnamona Province (Palaeo–Mesoproterozoic) are two large complex basement terrains consisting of mafic and felsic igneous intrusions and volcanics, moderate to high–grade metamorphics and minor unmetamorphosed sedimentary deposits (Preiss et al., 2002). Mesoproterozoic granites, felsic volcanics and gneisses in the Gawler Craton and Curnamona Province contain anomalously elevated uranium and thorium concentrations relative to global Proterozoic averages (Neumann et al., 2000), and generate high heat flows (Fig. 1).

Neumann et al. (2000) defined the South Australian Heat Flow Anomaly (SAHFA) based on sparse regional heat flow data (Fig. 2). The SAHFA covers the eastern Gawler Craton, Delamerian Fold Belt (Adelaide Geosyncline) and Curnamona Province. Average heat flow is elevated relative to Proterozoic or younger terrains on other continents — the mean heat flow within the SAHFA is 92±10 μWm^{-2} compared to an average of 51–54 μWm^{-2} in other countries (Neumann et al., 2000). As well as 'hot' granites, Petratherm Ltd has identified that radiogenic iron oxide deposits also occur in the SAHFA (e.g.

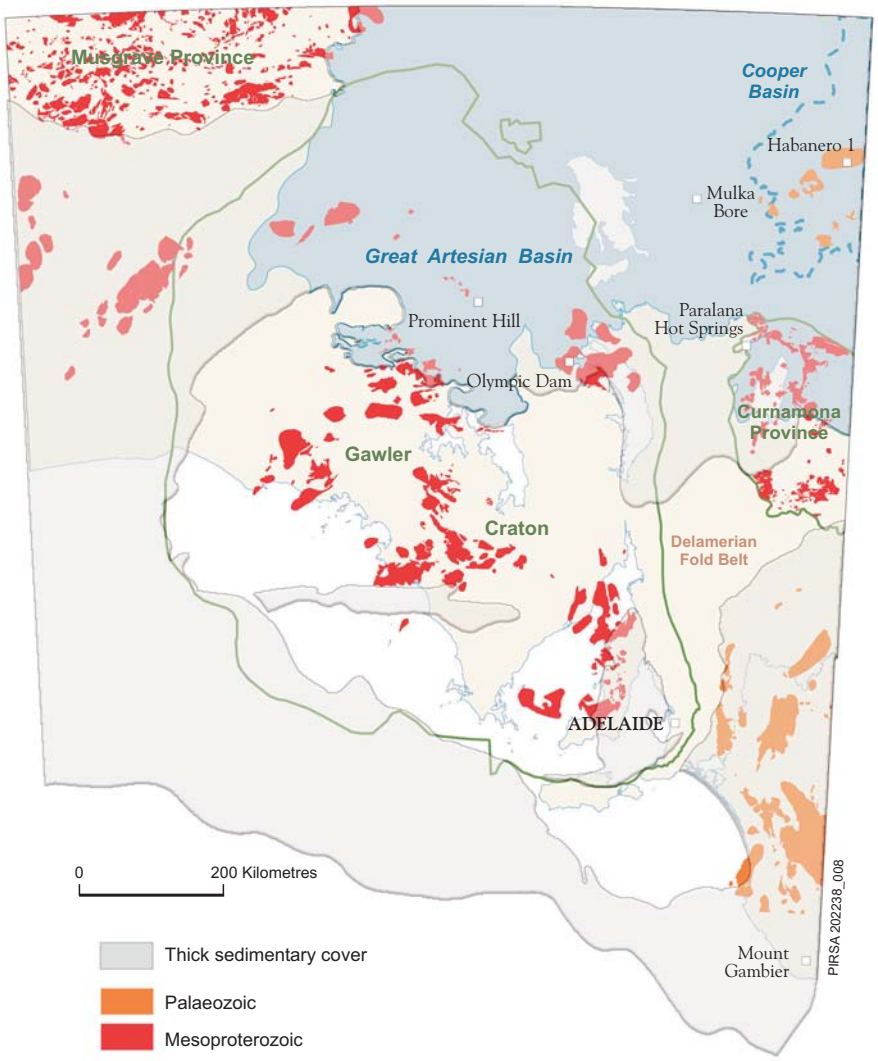

Fig. 1 *Distribution of potential high heat flow rocks in South Australia.*

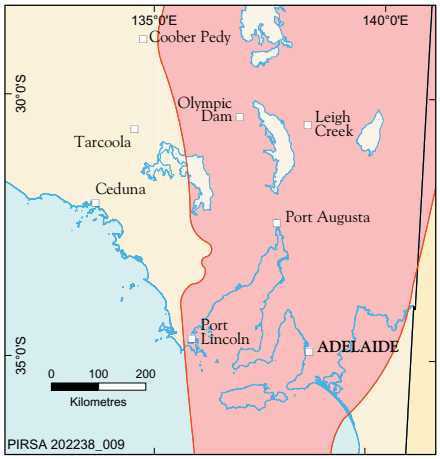

***Fig. 2** The South Australian Heat Flow Anomaly (Neumann et al., 2000).*

Olympic Dam, Prominent Hill) and may have even higher heat flow than the granites, although over a smaller volume of rock. The central and northern part of the SAHFA is overlain by Neoproterozoic, Palaeozoic, Mesozoic and Tertiary sediments in a number of stacked basins.

At Paralana Hot Springs in the central SAHFA, naturally occurring faults and fracture systems have provided migration pathways for hot (>60°C) groundwater to reach the surface. Petratherm predicts high heat production rocks at depth. The maximum heat flow measured within the SAHFA, 126 μWm^{-2} (Neumann et al., 2000) occurs at Parabarana Hill, ~30 km northeast of the Paralana Hot Springs, in the Paralana Fault Zone.

Younger (Cambro-Ordovician) granitoid rocks occur in the Delamerian Fold Belt, which lies on the eastern margin of the SAHFA. Many of these granites occur at depth and have been overlain by the Murray Basin; however, heat production data are limited.

In the state's northeast, mid-Carboniferous granite (Big Lake Suite) has been overlain by the Cooper, Eromanga and Lake Eyre Basins. While this granite has lower heat production compared to older Mesoproterozoic Gawler Craton and Curnamona Province granites, it is blanketed by >3 km of insulating Late Carboniferous – Recent sandstone, siltstone, shale and coal. This has effectively trapped heat generated from the granite, and temperatures of 250°C occur at 4.5 km depth.

Figure 3 shows estimated temperatures at 5 km depth for Australia, and indicates that much of central and northeastern South Australia, corresponding to the SAHFA, is anomalously hot at depth. Higher temperature outliers occur under the Murray and Otway Basins.

The large temperature anomaly in Queensland and South Australia (Fig. 3) coincides with granitic intrusives into the Warburton Basin, overlain by the Cooper, Eromanga and Lake Eyre Basins. In this region, Great Artesian Basin groundwater within rocks of the Eromanga Basin has been heated to >100°C at depth. Hydrothermal energy utilising hot groundwater from the Great Artesian Basin has been harnessed on a small scale in both South Australia and Queensland. In South Australia, an experimental 20 kW Organic Rankine Cycle generator was installed at Mulka Bore in 1986 and generated electricity from hot (85°C) groundwater. At Birdsville, Queensland, a 150 kW demonstration plant has been operating using 99°C groundwater from the town bore since 1999.

The most recent volcanic activity in South Australia occurred in the southeast ~4–6000 years ago at Mount Gambier and Mount Schank, producing locally elevated heat flows (Neumann et al., 2000). Over the border in Victoria at Portland, hot groundwater from the Portland Trough (which has elevated geothermal gradients) has been used since 1985 to heat municipal buildings, the town swimming pool and a motel.

Geothermal exploration activity

The Government of South Australia is leading Australia with expeditious and effective processing of activity approvals for geothermal energy. In fact, the last few months have seen a rush for licences to explore a variety of geothermal energy plays in the state.

Companies or individuals wishing to apply for a Geothermal Exploration Licence (GEL) need to provide the following:

- a map of the application area (currently the area must be <500 km^2)
- a proposed five-year work program for evaluating the prospectivity of the licence area (including the expected annual cost of operations)
- evidence of their technical and financial resources
- pay the application fee of A$2736.

Currently, there are 11 GELs with four proponents of generating electricity from hot dry rock geothermal energy — Geodynamics, Scopenergy, Minotaur's affiliate Petratherm, and the Perilya – Green Rock Energy Joint Venture. The GELs cover 5177 km^2 (*see Figs 1 and 2 under 'Tenement activity — petroleum'*).

In addition, 15 applications for GELs covering 6718 km^2 had recently been lodged with PIRSA up to the end of June 2004 by Scopenergy, Petratherm and a new geothermal explorer, Tasman Resources.

Geothermal licences and applications cover a diversity of geological provinces so a range of potential new energy sources and exploration models are being targeted and tested. If initial exploration is successful, the total potential investment in geothermal energy in the state over the next five years could reach over $310 million. Just one of the 11 current GELs has potential to contain hot rocks able to yield emission-free electricity equivalent to 40 Snowy Mountains Hydro Schemes.

Geodynamics has progressed exploration the furthest so far, in GEL 98, having successfully drilled Habanero 1 exploration well in 2003 to 4421 m depth to access hot Big Lake Suite granites buried under the central Cooper

Aerial view of Habanero 1 in the Cooper Basin. (Photo 049548)

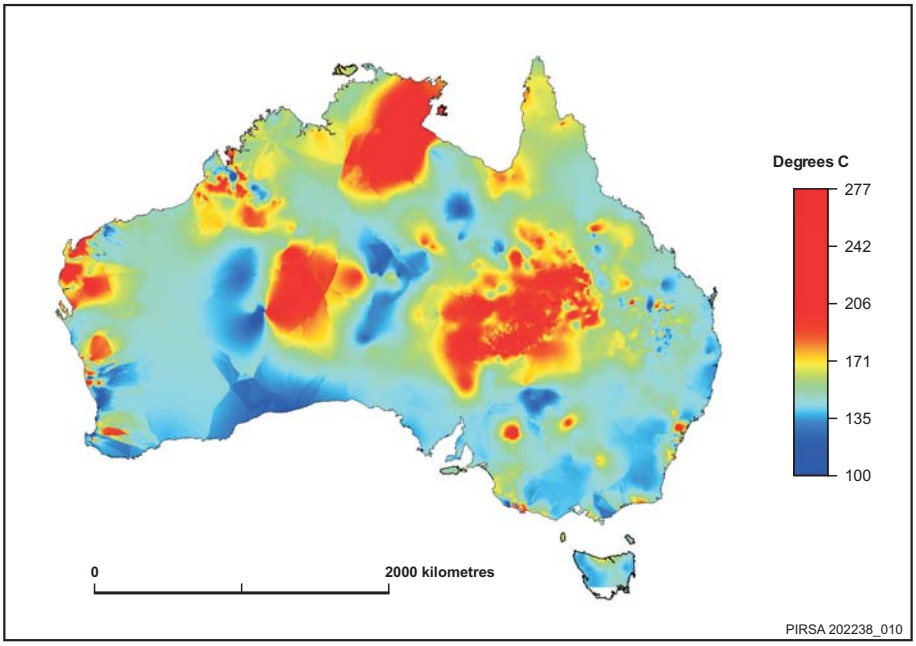

Fig. 3 *Australian estimated crustal temperature at 5 km depth, generated from the Austherm database (Holdgate and Chopra, 2004).*

Basin. The well was subsequently tested and overpressures were discovered in the granite, which was unexpected and significantly increased the likelihood of the resource being successfully exploited. Geodynamics will test the heat exchange capacity of the granite by drilling the Habanero 2 production well later this year. Additional capital has been raised for its proof-of-concept pilot plant in the Cooper Basin. Geodynamics has also acquired South Australia Geothermal Energy Pty Ltd, the licensee of neighbouring GEL 97.

Scopenergy is still negotiating with a number of companies to obtain financial and technical support for a proposed HDR development program in GEL 99. It has also proposed that the work program is to be carried out under a joint venture agreement. Scopenergy has just applied for four GELs (GELA 170, 171, 172 and 172) in the state's southeast.

Perilya – Green Rock, WMC and PIRSA's Petroleum Group entered into negotiations that resolved a mutually acceptable outcome which enables the partial grant of GELs 128, 129, 161, 162 and 163 in proximity to WMC Resources' Mining Lease and Occupational Licence at Olympic Dam (and Roxby Downs). Negotiations are continuing on grant of licences for GELAs 164 and 165 over the Olympic Dam area.

Minotaur has been successful in raising capital for its geothermal venture through an initial public offering of a newly formed company named Petratherm Ltd, which closed on 17 June 2004. The University of Adelaide will be assigned ~2% of the initial capital in Petratherm in return for its intellectual inputs to projects. Petratherm is operator of GELs 156, 157 and 158 and has applied for GELAs 178 and 179 to test a range of geothermal exploration plays. Petratherm is targeting hot geothermal source rocks >220°C but no deeper than 3500 m, close to electricity infrastructure and markets. The company plans shallow drillholes (600–750 m) to test temperature, stress environment and fracturing characteristics of target rocks to determine the capacity of prospects to sustain economic geothermal energy. On successful completion of the geothermal evaluation phase, injection and production holes are planned, a heat-exchange system would be established and a grid drilling program undertaken to establish a commercial power plant.

Tasman Resources has recently lodged applications for GELAs 166, 167, 168, 169, 175, 176 and 177 across the state and established a wholly owned subsidiary, Eden Energy Pty Ltd, in June 2004. Eden has a focus on hydrogen and geothermal energy.

The embryonic HDR industry in South Australia has been well supported by share market investors, including major petroleum exploration and production companies (Woodside Petroleum and Origin Energy).

The Prime Minister released a white paper (*Securing Australia's energy future*) on 15 June which sets out policies and principles to guide the production and use of energy in Australia well into the 21st century. The white paper aims, amongst other things, to improve electricity and gas markets, improve energy efficiency, enhance energy security, improve air quality and manage the environmental impact of large projects. Two key aims of direct relevance to the budding geothermal exploration industry are lowering Australia's long-term greenhouse emissions signature and the role of energy innovation in delivering prosperity, security and sustainability.

Securing Australia's energy future also includes a number of major new initiatives of relevance to geothermal energy exploration. Investment of at least $1.5 billion to demonstrate break-through technologies with significant long-term greenhouse gas reduction potential will be driven through the establishment of a $500 million fund to leverage private sector investment of at least $1 billion in the demonstration of low-emission technologies; and the provision of $134 million to support commercialisation of renewable technologies. Eden Energy has announced that it will be looking at this new source of potential funding for 'clean and green' geothermal energy exploration. White Paper details are available at <www.pmc.gov.au/energy_future>.

If the state's geothermal energy potential is successfully realised, South Australia will become a major electricity exporting state and be on track to be justifiably called the 'Geothermal State'.

References

Holdgate, F. and Chopra, P., 2004. New temperature maps of the Australian crust. *Preview*, 109:24-25.

Neumann, N., Sandiford, M. and Foden, J., 2000. Regional geochemistry and continental heat flow; implications for the origin of the South Australian heat flow anomaly. *Earth and Planetary Science Letters*, 183:107-120.

Preiss, W.V., Alexander, E.M., Cowley, W.M. and Schwarz, M.P., 2002. Towards defining South Australia's geological provinces and sedimentary basins. *MESA Journal*, 27:39-52.