

THE BURGEONING AUSTRALIAN GEOTHERMAL ENERGY INDUSTRY

Graeme Beardsmore, Senior Research Fellow, Monash University, Technical Director, Hot Dry Rocks Pty Ltd, Victoria, Australia

INTRODUCTION

Australia has historically been considered a very “cold” country, geologically speaking; not a place that immediately conjures thoughts of geothermal power generation. It is not surprising therefore, that geothermal energy has not historically played a large role in Australia’s energy mix, nor Australia in the global geothermal community. The past decade, however, has seen first a trickle and then a flood of interest in geothermal. This interest has been fuelled by a growing realization that Australia is blessed with world class “hot dry rock” and low temperature hydrothermal resources, coupled with a growing imperative to reduce Australia’s carbon footprint. The result has been new State and Federal legislation, escalating levels of public and private investment, a spate of new companies dedicated to the identification and development of geothermal energy, and a growing number of commercial projects aimed at geothermal power generation.

GEOLOGY OF AUSTRALIA

The impression of Australia as a cold continent comes from the continent’s position in the middle of the Australian Tectonic Plate (Figure 1), and the fact that the continent has large areas of exposed Archaean and Proterozoic crust. There are no plate margins, active volcanoes or surface geothermal manifestations (with the exception of a handful of warm to hot springs) on the Australian continental land mass. In spite of the lack of surface signs, however, there is a significant body of geological evidence to suggest that the continent may not be as cold as initially thought. Some of this evidence is presented below.

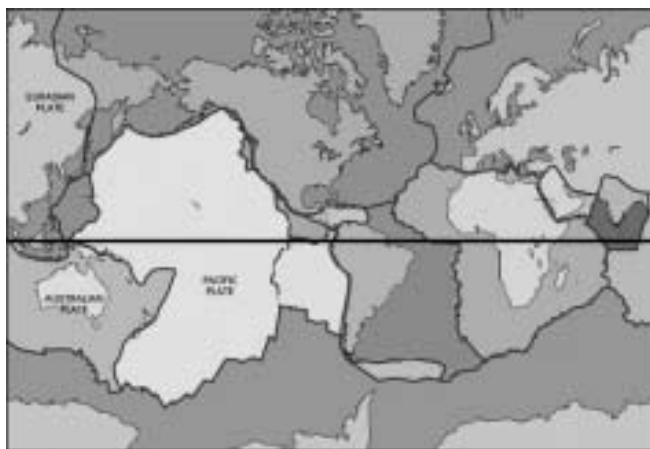


Figure 1. Tectonic plate boundaries, showing the Australian continent in a central position on the Australian Plate. Image modified after USGS.

BOREHOLE TEMPERATURES

An assessment of the thermal resource beneath the Australian continent is hampered by the fact that there are relatively few published conductive heat flow measurements for the continent. The global heat flow data base lists just over 100 measurements across an area roughly equal in size to the 48 contiguous states of the USA. In comparison, there are many thousands of points published for the USA. This paucity of data makes it difficult to quantify the actual energy in the ground, but related data provide a broad indication that heat flow, and potential temperature resource, varies significantly across the continent.

Chopra and Holgate (2005) published a GIS analysis of temperatures reported from over 4,000 boreholes across the continent. They used a simple linear extrapolation method to estimate the temperature of the crust at a depth of 5 km. The results (Figure 2) suggest that large sections of the continent are underlain by relatively hot crust. Temperatures in excess of 200°C have, indeed, been intersected by petroleum exploration wells at depths little more than 3 km in the Cooper Basin in central Australia. In addition, Geodynamics Limited have reported temperatures approaching 250°C at a depth of about 4,400 m in the geothermal exploration well Habanero 1 in the same region. Figure 2 suggests that large tracts of the continent may be underlain by crust of similar temperature, although wells to the appropriate depth have not yet been drilled in any of the other areas.

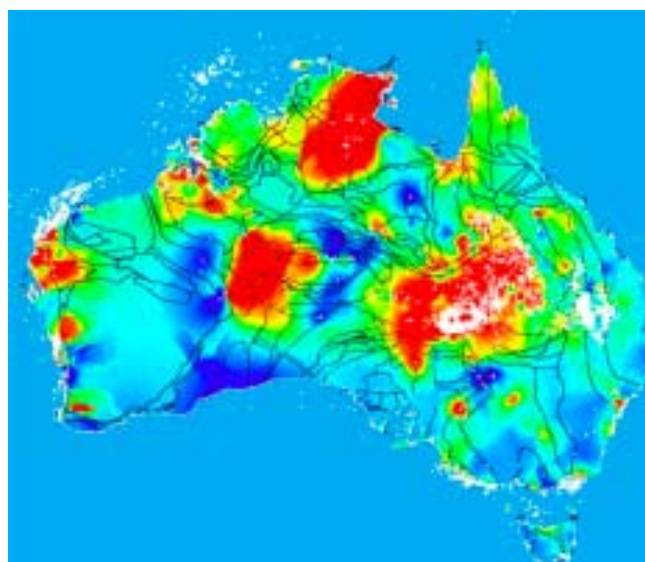


Figure 2. Approximate temperature distribution at a depth of 5 km in the Australian crust, against broad tectonic elements (black lines). Data points shown as white + symbols. Red is relatively hot crust, blue is relatively cold. From Chopra and Holgate (2005)(see cover for colors).

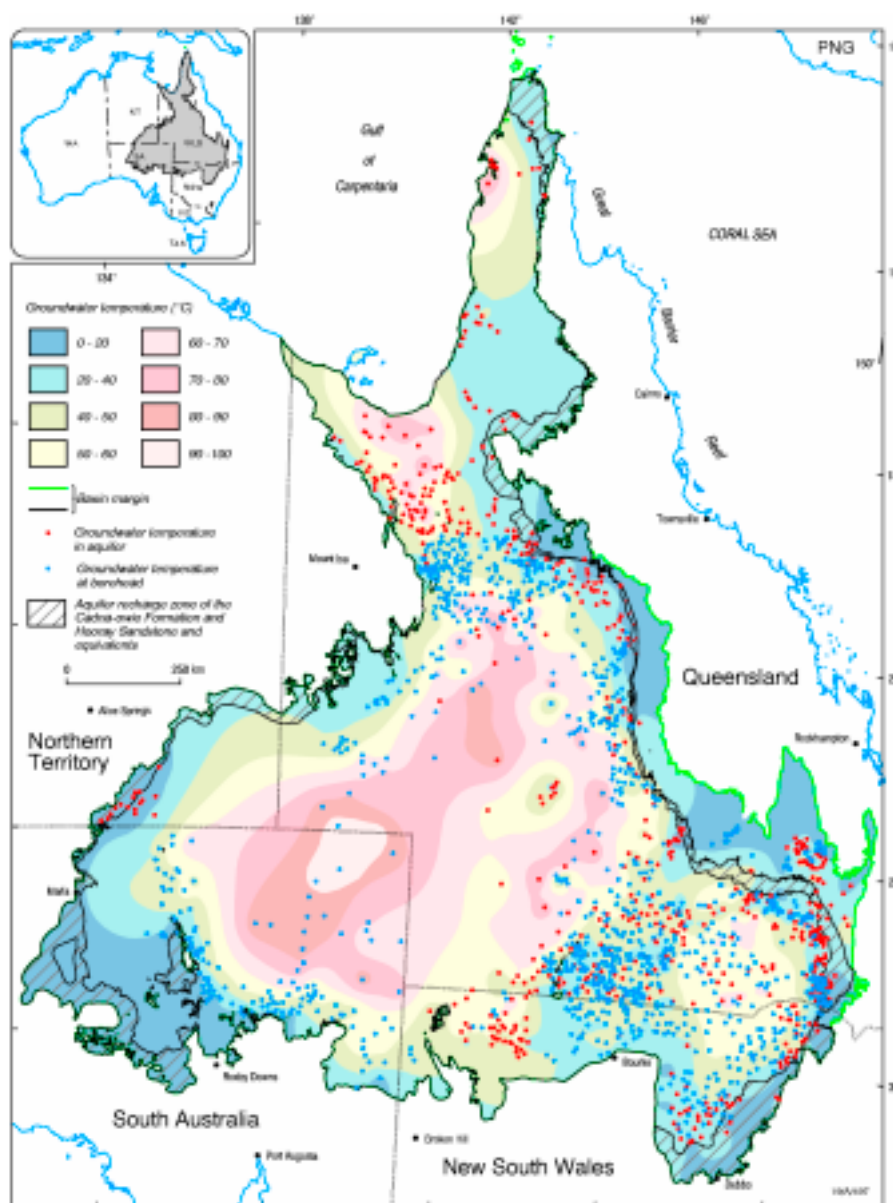


Figure 3. Groundwater temperature from the Great Artesian Basin. From Habermehl and Pestov (2002).

TERTIARY ERUPTION CENTERS

Australia is not generally considered an active volcanic region, but the eastern side of the continent, from the state of Queensland in the north to Tasmania and South Australia in the south, plays host to a large number of relatively young basaltic eruption centers. The state of Victoria in the southeast of continental Australia, for example, shows evidence of intermittent volcanism over the past 190 Ma (million years), with volumetric peaks between 5,742 Ma and 50 Ma (Price et al., 2003). The most recent event, at Mount Gambier just over the border in South Australia, has been dated at less than 5,000 years (Sheard, 1995). These volcanic features appear to be related in some manner to a series of rifted marginal basins along the same coast. The exact relationship is far from obvious, but with such a long, and potentially ongoing history of volcanic activity throughout the region, it is tempting to conclude that there may be young intracrustal igneous bodies or areas of elevated mantle

heating, though no direct evidence of such phenomena has yet been found.

The most tantalising evidence that young volcanic features are associated with geothermal energy sources lies in the northern part of the state of Queensland, in the northeast of the country. A number of hot springs in the area known as the Atherton Tablelands discharge water at temperatures in excess of 70°C. The same area hosts some very young volcanic rocks (on the order of 10,000 years), including some spectacular lava tubes.

GREAT ARTESIAN BASIN

The Great Artesian Basin (GAB) is the world's largest artesian groundwater basin, underlying about 22% of the Australian continental landmass. Groundwater from the GAB comes out at wellheads at temperatures ranging from 30°C to 100°C (Figure 3), and in most cases has to be cooled before it can be used as town or stock water. The sheer size and temperature of

the underground water resource makes it an attractive geothermal target. In fact, the geothermal potential of the GAB was highlighted in the June 2002 edition of this very Bulletin (Habermehl and Pestov, 2002).

CURRENT USES OF GEOTHERMAL ENERGY IN AUSTRALIA

Chopra (2005a) described the state of the geothermal industry in Australia in 2005. Little has changed between then and now in the number of commercial operations, but governments and organizations across the country are beginning to recognize the potential of geothermal resources, and are exploring new possibilities for utilization. Geothermal utilization in Australia is currently restricted to a single small binary cycle power generator, and a handful of direct uses. Some examples follow.

Birdsville Geothermal Power Plant

Ergon Energy, the state-owned electrical power company in the state of Queensland, owns and operates the Birdsville Geothermal Power Plant. Birdsville (25°54'S, 139°22'E, population 100) is a small town in southwest Queensland, near the border with South Australia.

The town lies over 1,500 km from the nearest state capital city and many hundreds of kilometers from the nearest point on the national electricity network, so all electrical power is locally generated. A simple binary cycle geothermal generator supplies a net 80 kW of electricity, sufficient to supply Birdsville's off-peak demand. Diesel generators cut in at times of higher demand. The heat source for the geothermal plant is the town's water supply bore, which flows 98°C water at 27 liters per second. (see also Chopra, 2005b).

At the time of writing, Ergon Energy is funding a study into the feasibility of improving the capacity and efficiency of the geothermal plant. The study is looking at such things as improving the temperature and flow rate of the resource, potential for reinjection (currently most of the spent fluid is discharged to a surface stream), and decreasing the parasitic load from the cooling fans (current parasitic cooling load is on the order of 30% of gross power output).

Portland Space Heating Facility

Portland (38°20'S, 141°36'E, population 8,800) is a town on the west coast of the state of Victoria. It was host to Australia's only geothermal district heating system, operated by the Glenelg Shire Council. Bore water at 58°C was drawn at a rate of 90 liters per second from 1,400 meters in the Dilwyn Formation aquifer of the Otway Basin. The water was used between 1985 and 2006 to heat council buildings, a hospital, a police station, a motel and a public swimming pool. The capacity of the facility was 10.4 MWt. Initially, the geothermal water was used as Portland's drinking water after passing through the heating system, but this practice was discontinued in 1997 due to water quality concerns. Ironically, between 1997 and 2006 the spent geothermal water was air-cooled (with energy intensive fans which contributed a net positive amount of greenhouse gas to the atmosphere) and discharged to surface drainage. The system has been decommissioned since January 2006 because

of the poor condition of the bore, the energy intensive cooling system, and because it was no longer deemed environmentally sustainable to discharge the spent geothermal water into surface drainage. There is growing political pressure to recommission the system, but it will require significant investment to drill a new production bore, and redesign of the system to incorporate reinjection.

Innot Hot Springs

The Innot Hot Springs (17°40'S, 145°14'E) lie in the Atherton Tablelands inland from Cairns in the state of Queensland. It is one of a handful of natural warm to hot springs that are utilized around the country for tourism purposes. The Innot Spa Resort is primarily a trailer and camping park, with an outdoor heated spa pool and three indoor heated spa pools (Figure 4). The source of the geothermal water is a 50 meter deep bore from which 70°C water is drawn. Natural hot water (also about 70°C) discharges along a short section of stream bed about 100 meters from the bore, and this natural warm "beach" has been used by visitors and locals alike for relaxation since being discovered by European settlers in the late nineteenth century. The source of the water and the heat is poorly understood, and the subject of a current research project by the Geological Survey of Queensland.

Other commercial hot spring operations are located at Maree in New South Wales, Hastings in Tasmania, Rye in Victoria (Davidson, 2006), and a new, multi-million dollar development is underway at Warrnambool in Victoria. This is not an exhaustive list, and there are early indications that a geothermal spa industry may develop.



Figure 4. The spa house at the Hot Springs Resort, Innot Hot Springs, Queensland.

Robarra Pty Ltd

Barramundi (giant perch, or Australian seabass) is a very popular eating fish native to northern Australian fresh waters. The optimum growth temperature for barramundi is about 28°C, typical of the tropical inland waters of the north. A thriving barramundi farm operates on the south coast of South Australia, however, where the average surface water temperature is around 12°C. Robarra Pty Ltd operates the farm at Robe (37°09'S, 139°45'E), utilizing warm water flowing at 30°C

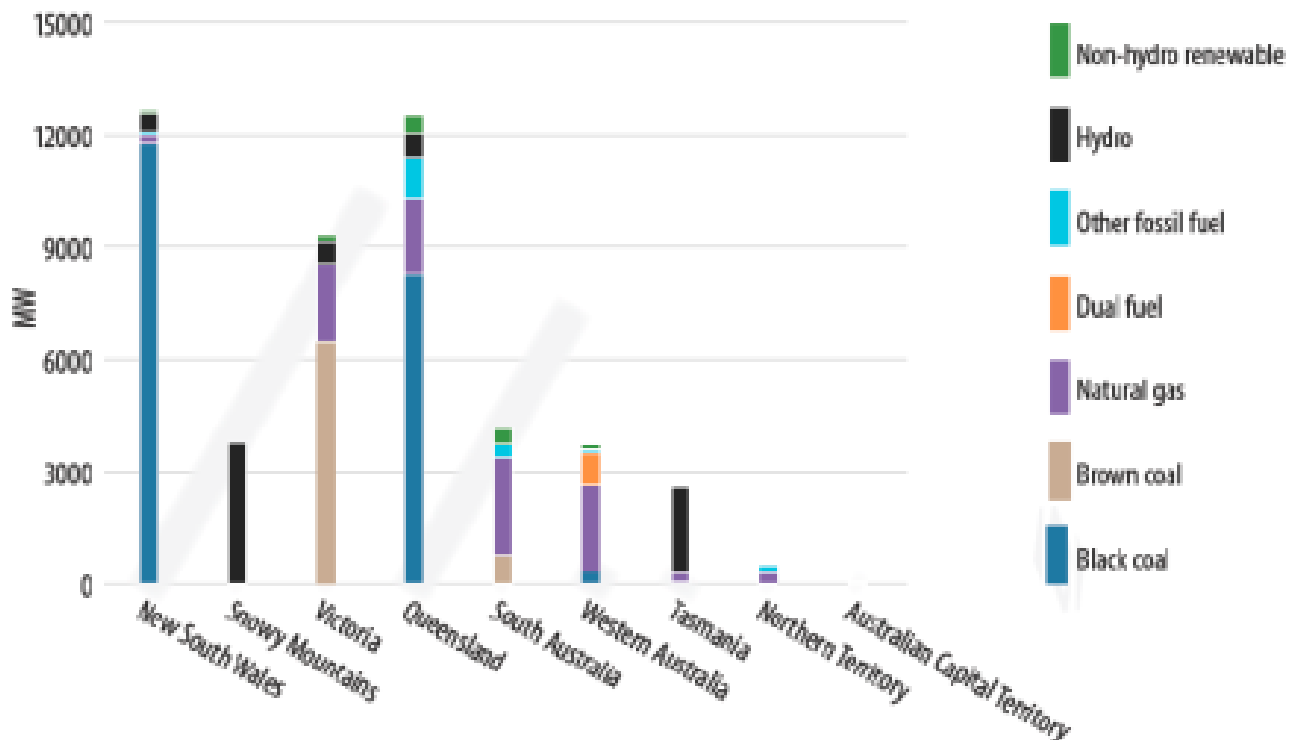


Figure 5. Sources of Australia's electricity generation, listed by state. Source CSIRO (2006).

from several hundred meters down in the Dilwyn Formation of the Otway Basin. The fresh geothermal water passes through adjustable boom jets directly into the grow out tanks. The operation provides employment for about 22 local people, and turns over about AU\$2 million annually.

SOURCES OF ELECTRICAL POWER

In spite of the majority of geothermal energy being directly utilized at present, most attention is currently on developing new sources of electrical power.

Australia's electricity demand is about 50,000 MW (CSIRO 2006). About 7,000 MW is generated from renewable sources (mostly hydro and bio-waste from sugar processing facilities), but the great bulk of demand is met by fossil fuel sources; dominantly black and brown coal, but with a significant proportion of natural gas (Figure 5). This great reliance on fossil fuels for electricity generation is the primary reason that Australia rates as one of the most greenhouse gas polluting countries in the world. At 17.35 tonnes CO₂ per capita per year in 2003, it ranked fourth amongst Organization for Economic Co-operation and Development (OECD) countries (Source: OECD), behind Canada (17.49), the USA (19.68) and Luxembourg (21.96). The state of Victoria, where about 70% of electricity is generated from brown coal, is a particularly noteworthy polluter.

Australia's domestic supply of coal and natural gas is sufficient to provide electricity at current levels for over 500 years. Under the current pricing regime, the cost of electricity production from coal, in particular, is significantly lower than any current alternative. The current Federal Government, however, aims to introduce a carbon trading scheme by 2012, and such a scheme will force the coal-fired power in-

dustry to internalize the cost of carbon emissions. Several economic studies (e.g. McLennan Magasanik Associates Pty Ltd, 2006) have concluded that in a carbon-constrained economy, geothermal energy could provide the lowest cost base-load power. With demand increasing, therefore, there is scope for geothermal power to provide a significant portion of base load electricity capacity into the future.

POLITICAL SUPPORT

The Australian political system is divided into three levels; local, state and federal. Geothermal energy development is receiving significant support at all three levels. Local councils increasingly view sustainability and renewability as important parameters for development, often giving more weight to these over and above purely financial arguments. As an example, in 2006, Melbourne City Council opened Council House 2 ("CH2"), a ten story building in the heart of Melbourne (a city of three and a half million people) with energy and water efficiency as its core design feature. 22.1% of the construction cost was directly attributed to efficiency features (Melbourne City Council, 2004). While geothermal energy was not utilized in CH2, the same council incorporated geothermal heat pumps into the air conditioning system of the East Melbourne Library during a refurbishment in 2005, in spite of the premium cost of the system compared to natural gas systems.

At the state level, the Victorian Government introduced the Victorian Renewable Energy Target (VRET) scheme in late 2006. The VRET scheme requires energy retailers to purchase a minimum of 10% of their total power purchases from renewable sources by 2016. Since then, several other states have introduced equivalent schemes, with some setting

more aggressive targets (e.g. South Australia's target is 20% renewable power by 2014). For geothermal energy, some states are matching legislation with financial support. South Australia and Queensland, for example, offer cost-sharing schemes to offset the cost of drilling.

The Australian Federal Government introduced the Mandatory Renewable Energy Target (MRET) in 2004. MRET requires that 9,500 GWh per year of new renewable electricity be online by the year 2010. The country is well on track to achieve this goal, largely due to strong growth in the wind energy sector. Other Federal Government schemes offering financial support to the geothermal energy sector include the Renewable Energy Development Initiative (REDI), which provides grants for renewable energy innovation and commercialization; Renewable Remote Power Generation Programme (RRPGP), which supports renewable energy in remote areas; Renewable Energy Equity Fund (REEF), which provides venture capital for small renewable energy companies. At the time of writing, six geothermal energy companies have received in excess of AU\$21 million total in REDI grants alone. The current Federal Government has been a strong and vocal supporter of the geothermal energy industry, and, with a Federal election due by the end this year, the current Opposition Party has also indicated that, if elected, it will continue support for the industry, with AU\$50 million earmarked for direct cost-sharing of deep drilling programs.

The Federal Government's geoscience institution, Geoscience Australia, operates out of a building in Canberra that utilizes geothermal heating and cooling.

COMMERCIAL GEOTHERMAL INDUSTRY

At the time of writing there are six companies listed on the Australian Stock Exchange (ASX) with geothermal energy development as one of their core activities. A seventh company is currently in the middle of an IPO, and several others are preparing to follow suit. The money is being raised through the public markets primarily to fund desktop analyses, surface exploration and shallow drilling programs designed to shed light on the nature of the geothermal resource in different parts of the country. About 25 individual companies hold exploration rights or have made application for over 170 exploration licenses across five states (Queensland, New South Wales, Victoria, Tasmania and South Australia.) The size of the exploration licenses range from about 100 km² to over 12,000 km². At the time of writing, the remaining two states of Australia (Western Australia and Northern Territory) are in the process of developing legislation to allow geothermal energy exploration and development.

Many geothermal companies have sprung from parent companies engaged in mineral or petroleum exploration, and almost without exception the focus is on electrical power generation. The distribution of activity, in terms of numbers of exploration licenses applied for and granted, is strongly influenced by state boundaries, with by far the most activity in South Australia (99 licenses granted, 39 current applica-

tions, and 10 retention licenses). This is due in equal parts to attractive geology and an accommodating State Government. The Department of Primary Industries and Resources, South Australian (PIRSA), has actively encouraged the growth of a geothermal industry centered on South Australia; with generous drilling subsidies, a simple application procedure for licenses, easily and freely accessible data packages, and by assuming a leadership role in coordinating the growth of the industry.

The range of exploration and development strategies is almost as wide as the list of companies in the industry is long, but a small number of case studies will serve to illustrate the different strategies being pursued. Listed companies Geodynamics Limited, Petrathern Limited, Green Rock Energy Limited and Torrens Energy Limited each have very different development strategies. The following summaries also highlight the international expansion of a number of Australian companies.

Geodynamics Limited

Geodynamics (GDY) is the leading geothermal energy development company in Australia by any objective measure. The company was the first to list on the ASX, is most advanced in its development, has the highest market capitalization on the ASX (AU\$286.5m), and receives (arguably) the most media attention. The company holds two exploration licenses and 10 retention licenses (allowing them to maintain development rights for up to 15 years) in South Australia, but GDY's only project is near Innaminka in northeast South Australia. It is an engineered geothermal system project to extract power from 250°C granite at a depth of about 4,500 m. The company has successfully drilled a well (Habanero 1) into the granite to target depth, performed hydraulic stimulation to enhance the natural fracture network, and drilled a second well (Habanero 2) to intersect the fracture network. Unfortunate engineering difficulties resulted in the effective loss of Habanero 2 and set the project back almost two years. At the time of writing, however, drilling has commenced on Habanero 3 and the company is confident about achieving hydraulic connection with Habanero 1 within a few months. Their business plan calls for 40 MW of electrical power generation by 2010, with rapid expansion to at least 500 MW.

The major perceived barrier to commercial success for GDY lies in the geographic location of their project. Innaminka is at least 400 km from the nearest point on the national electricity grid, and substantial capital will be required to transmit generated electricity to the market.

This dictates that GDY's development will ultimately need to be several hundred megawatts capacity if they are to operate profitably, but the size of their resource will comfortably accommodate such output if the technology can be proven. GDY also has a subsidiary company (Exorka International Limited, now based in Germany) dedicated to the commercialization of the Kalina Cycle technology that will be utilized in the Habanero project.



Figure 6. Drilling of Haanero I in the Cooper Basin (Geodynamics, Ltd.)

Petratherm Limited

Petratherm Limited (PTR) holds nine exploration licenses in South Australia, has a subsidiary company exploring development opportunities in Spain, and has been endorsed by both the Australian and Chinese governments to investigate the development of hot rock technology in China. PTR was the second geothermal company to list on the ASX and has a market capitalization of AU\$46m. Their main project lies at a locality called Paralana in South Australia. Their single test hole to this stage (Paralana 1) is about 1,800 m deep, and they have demonstrated levels of heat flow more than sufficient to generate attractive geothermal temperatures at depths less than 4 km. PTR aims to deepen Paralana 1 and use it to stimulate the development of an underground heat exchanger within the sediment column.

Paralana, like Innaminka, lies off the national electricity grid, but close to a major energy user in the Beverley uranium mine. PTR have signed a power purchase agreement with the operators of the Beverley mine, which values electricity generated at Paralana at a higher price than the normal national electricity price. This will allow PTR to receive a premium rate for generated electricity during their early commercialization stage, which will help them fund growth to the point where they can connect to the grid and compete on the national market.

Green Rock Energy Limited

Green Rock Energy Limited (GRK: market capitalization AU\$20 million) holds a range of geothermal exploration tenements in South Australia; around the world's largest Urani-

um mine at Olympic Dam, around the top of the Spencer Gulf, and in the Cooper Basin. An early entrant into the geothermal industry in Australia, GRK is geographically positioned to take advantage of the enormous power requirements of a proposed four-fold expansion of the Olympic Dam mine. The company has drilled a 1,900 m deep hole into a granite body in their Olympic Dam area and demonstrated an attractive heat resource and stress regime for the development of an engineered geothermal system within the granite.

As well as its Australian interests, GRK also holds 32% equity in a combined heat and power development in Hungary. There, they are seeking high flow rate fluids of about 140°C. The company's initial drilling operation in Hungary achieved disappointing results from the point of view of observed fluid flow rates, but the project was the inaugural recipient of World Bank geological risk insurance for geothermal development in Eastern Europe. As such, GRK should receive much of their invested capital back, to reinvest in further exploration in Hungary.

Torrens Energy Limited

Torrens Energy Limited (TEY: market capitalization AU\$18 million) has the stated objective to find the hottest rocks possible close to population centers and on the national electricity grid. TEY achieved first mover advantage in recognizing the geothermal potential of a geological feature known as the Adelaide Geosyncline, part of which lies under the city of Adelaide, capital of South Australia. TEY were recently awarded a AU\$3 million REDI grant to undertake a drilling program and develop computer software to accurately model the temperature resource beneath their tenements. TEY also holds an exploration license under the northeastern suburbs of Melbourne, Australia's second largest city. They also intend to investigate the possibility of using geothermal energy to desalinate seawater.

The Australian Geothermal Energy Group

The geothermal industry in Australia is in the process of forming one or more collaborative organizations. At the time of writing, over forty companies, organizations and institutions are involved in a loose collaboration called the Australian Geothermal Energy Group (AGEG). AGEG has coalesced from a broad range of interested parties under the umbrella of Australia's involvement in the International Energy Agency Geothermal Implementing Agreement (IEA-GIA). The group is Chaired by PIRSA and includes commercial entities, state and federal government organizations, universities and research institutions.

To date, the geothermal sector has been unofficially represented in Canberra by the Renewable Energy Generators Association (REGA), but this situation is now considered unsustainable with geothermal's increasingly high profile and number of commercial participants. At the time of writing, the commercial partners within AGEG are exploring the possibility of incorporating an industry association with a full time secretariat and political lobbying as part of its role.

Australian company Geodynamics Limited leads the Enhanced Geothermal Systems Annex of the IEA-GIA, at least three Australian companies have interests overseas, and the first Australian (the author) has just been elected to the Board of Directors of the International Geothermal Association. As

a country, Australia looks set to play an increasingly important role in geothermal energy development on the global stage.

Note: AU\$1 = 0.827 US\$ = 0.600 Euro

REFERENCES

Chopra, P.N. 2005a. Status of the Geothermal Industry in Australia, 200-2005. *Proceedings World Geothermal Congress 2005*. Antalya, Turkey, 24–29 April 2005. 8p.

Chopra, P.N. 2005b. Hot Artesian Water Powers an Outback Town in Australia, Geo-Heat Center Quarterly *Bulletin*, Vol. 26, No. 2 (June), Klamath Falls, OR. pp. 25-26.

Chopra, P.N. and F. Holgate, 2005. A GIS analysis of temperature in the Australian crust. *Proceedings World Geothermal Congress 2005*. Antalya, Turkey, 24–29 April 2005. 7p.

Davidson, C., 2006. Peninsula Hot Springs – A Developers Story, Geo-Heat Center Quarterly *Bulletin*, Vol. 27, No. 3 (September), Klamath Falls, OR. pp. 15-18.

CSIRO, 2006. Energy Futures Forum Report.

Habermehl, R. and I. Pestov, 2002. Geothermal resources of the Great Artesian Basin, Australia. Geo-Heat Center Quarterly *Bulletin*, Vol. 23, No. 2 (June) Klamath Falls, OR. pp. 20-26.

Melbourne City Council, 2004. CH2 in facts and figures. PDF fact sheet, 2p.

McLennan Magasanik Associates Pty Ltd., 2006. *Renewable energy—a contribution to Australia's environmental and economic sustainability*. 131p.

Price, R.C., Nichols, I.A. and C.M. Gray, 2003. Cainozoic igneous activity. In: Birch, W.D. ed. *Geology of Victoria*, pp.361-375. Geological Society of Australia Special Publication 23. Geological Society of Australia (Victoria Division).

Sheard, M.J., 1995. Quaternary volcanic activity and volcanic hazards. In: Drexel, J.F. and W.V. Preiss, eds. *The Geology of South Australia, Vol. 2, The Phanerozoic*. South Australian Geological Survey Bulletin, 54, pp. 264-268.



GEO-HEAT CENTER
Oregon Institute of Technology
Klamath Falls, OR 97601-8801

Non-Profit
Organization
U.S. Postage
PAID
Klamath Falls, OR
Permit No. 45