Pre-competitive Geoscience for Geothermal Exploration and Development in Australia: Geoscience Australia's Onshore Energy Security Program and the Geothermal Energy Project

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INTRODUCTION

Work conducted at the Bureau of Mineral Resources (now Geoscience Australia) in the early 1990s was instrumental in bringing Hot Rocks geothermal research and development to Australia. Following the announcement of the Australian Government's Energy Initiative in August 2006, a new Geothermal Energy Project has been started at Geoscience Australia. Pre-competitive geoscience previously made available for the minerals and petroleum industries has been extremely useful in assisting the geothermal exploration industry to date. This paper outlines the scope of Geoscience Australia's Onshore Energy Security Program and the development, implementation and progress to date of the new Geothermal Energy Project, including new data acquisition programs specifically aimed at assisting geothermal explorers. Geoscience Australia is the Australian Government's geoscience and geospatial information agency within the Department of Resources, Energy and Tourism.

THE ONSHORE ENERGY SECURITY PROGRAM (OESP)

A program to acquire pre-competitive geoscience information for onshore energy prospects has begun following announcement of the Onshore Energy Security Program. The initiative provides Geoscience Australia with AUS$58.9 million over five years for the acquisition of new seismic, gravity, aeromagnetic, geochemistry, heat flow, radiometric, magneto-telluric and airborne electromagnetic (AEM) data to attract investment in exploration for onshore petroleum, geothermal, uranium and thorium energy sources. The program will be delivered in collaboration with the State and Territories under the existing National Geoscience Agreement. A set of principles has been developed to guide the program. According to these, all proposed work must: (1) promote exploration for energy-related resources, especially in greenfields areas; (2) improve discovery rates for energy-related resources; (3) be of national and/or strategic importance; and (4) data acquisition must be driven by science.

The program is structured with national-scale projects for each energy commodity (geothermal, petroleum, uranium and thorium) and for geophysical and geochemical acquisition. Regional scale projects in Georgetown-Isa, Gawler-Curnamona, Northern WA and the Northern Territory areas will assess the energy potential of these areas in detail. Other regions will be prioritised at a later stage of the OESP. Further information on the OESP can be found at: http://www.ga.gov.au/minerals/research/oesp/index.jsp.

FORMULATING THE GEOSCIENCE AUSTRALIA GEOTHERMAL ENERGY PROJECT

Extensive consultation with State and Territory geological surveys and geothermal companies identified a list of key impediments faced by geothermal companies exploring in Australia. The Geothermal Energy Project aims to address those impediments that may be mitigated through geoscience input.

The greatest identified geological need is an improved understanding of the distribution of temperature in the upper crust of Australia. With no active volcanic systems, geothermal plays in Australia are dominated by conductive Hot Rock systems. There are few surface expressions indicating thermally anomalous areas, and explorers must use indirect methods in such blind systems. The two existing datasets that map temperature and heat distribution - the Austherm05 map of temperature at 5 km depth, and a database of heat flow measurements (Cull 1982) - both suffer from insufficient data points compounded by poor data distribution. Geoscience Australia aims to compile further information for both of these datasets, and acquire new data where possible. Predictions of heat distribution can also be made based on geological models, such as the co-location of high-heat-producing granites with overlying low-thermal-conductivity sediments. These three ways of mapping heat, and the work that the project will do in each of these areas, is described in more detail in later sections.

Other geoscience inputs that will help improve discovery rates and/or reduce risk to explorers and investors include a comprehensive and accessible geothermal geoscience information system, a better understanding of the stress state of the Australian crust, better access to seismic monitors during reservoir stimulation, and a Geothermal Reserve & Resource reporting scheme. Increasing the awareness of Australia's geothermal potential amongst decision makers and the general public may also help to fund the development of industry through Government support and investor confidence. The Geothermal Energy Project has an involvement in all of these activities and this is outlined in later sections.

MAPPING HEAT

Temperature increases with depth in the crust. Currently drilling technology limits economic development of Hot Rock geothermal extraction systems to about 5 km maximum depth. Temperatures of >200 °C are required at such depths to make the generation of electricity commercially feasible. Temperature is not evenly distributed across the continent, and a temperature of 200 °C at 5 km is anomalous. Therefore it is necessary to find 'hot spots' or areas with above average crustal temperature. There are three ways in which this problem may be approached and each is detailed below. Combined, the ultimate aim of this work is to divide the continent into geothermal provinces with defined geothermal potential in each province.

Temperature at 5 km depth

When bore holes are drilled, temperature measurements are often taken downhole including at the bottom of the hole. This is particularly true for petroleum, as temperature is important information for understanding the maturity and therefore the grade of oil or gas that may be expected. Temperature measurements, combined with other information such as thermal gradient, allow the temperature expected at 5 km depth to be vertically extrapolated. This extrapolated temperature can be horizontally interpolated between drillholes and then contoured to produce a continuous map of temperature at 5 km depth across the entire continent. This technique was pioneered by Somerville et al. (1994 - Geotherm94 database) at the Bureau of Minerals Resources (now Geoscience Australia) and the Energy Research and Development Corporation. Additions and refinements were subsequently made to the database by Chopra and Holgate (2005 - Austherm05 database)

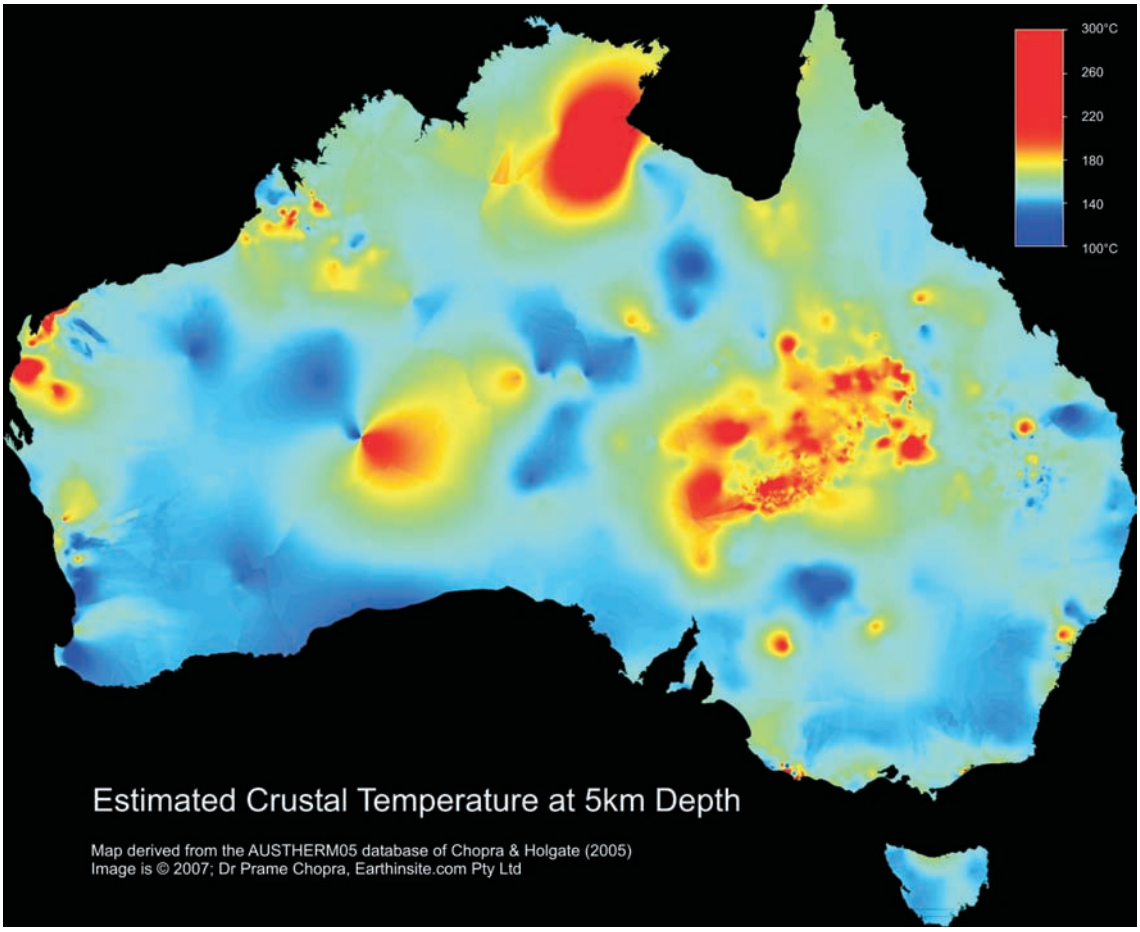

Figure 1. Modelled crustal temperature at 5 km depth using data from the AUSTHERM05 database (Chopra & Holgate 2005). The temperature data contained in this image has been derived from proprietary information owned by Earth Energy Pty Ltd ABN 078 964 735.

(Figure 1). In 2007 Geoscience Australia purchased the Austherm05 database from Dr Chopra (Earth Energy Pty Ltd) and has been making further improvements. These include utilising the OZ SEEBASE™ [1] sediment thickness data to better constrain the depth at which geothermal gradients change from those typical of sedimentary basins to the lower gradients typical of crystalline basement rocks, and dividing the continent into areas of different temperature gradient based on recognised heat flow provinces.

The Austherm05 database has also been used in a new way to estimate the geothermal energy contained within the Australian crust. The 5 km economic drilling depth was used as a lower depth extent: in the USA a similar estimation was based on a depth of 10 km (Tester et al. 2006). The database was interrogated to provide the depth at which 150 °C would be predicted to form an upper depth layer. Grids with 5 km x 5 km cells were made and the average temperature, volume and an estimation of the contained heat was calculated for each cell (Figure 2). This provides an estimate of 1.9×10^{25} Joules of energy contained in the upper 5 km of Australia's crust, which is the equivalent of about 2.6 million years energy supply at 2004-2005 consumption levels[2]. Not all of this energy will be accessible for extraction: but even if a low estimate of 1 % were taken, geothermal sources could still provide 26,000 years of energy supply. Future drilling and extraction

[1] OZ SEEBASE™ available as a free download from www.frogtech.com.au.

[2] 2004-2005 gross energy consumption = 7258.1 PJ: ABARE Energy in Australia 2006.

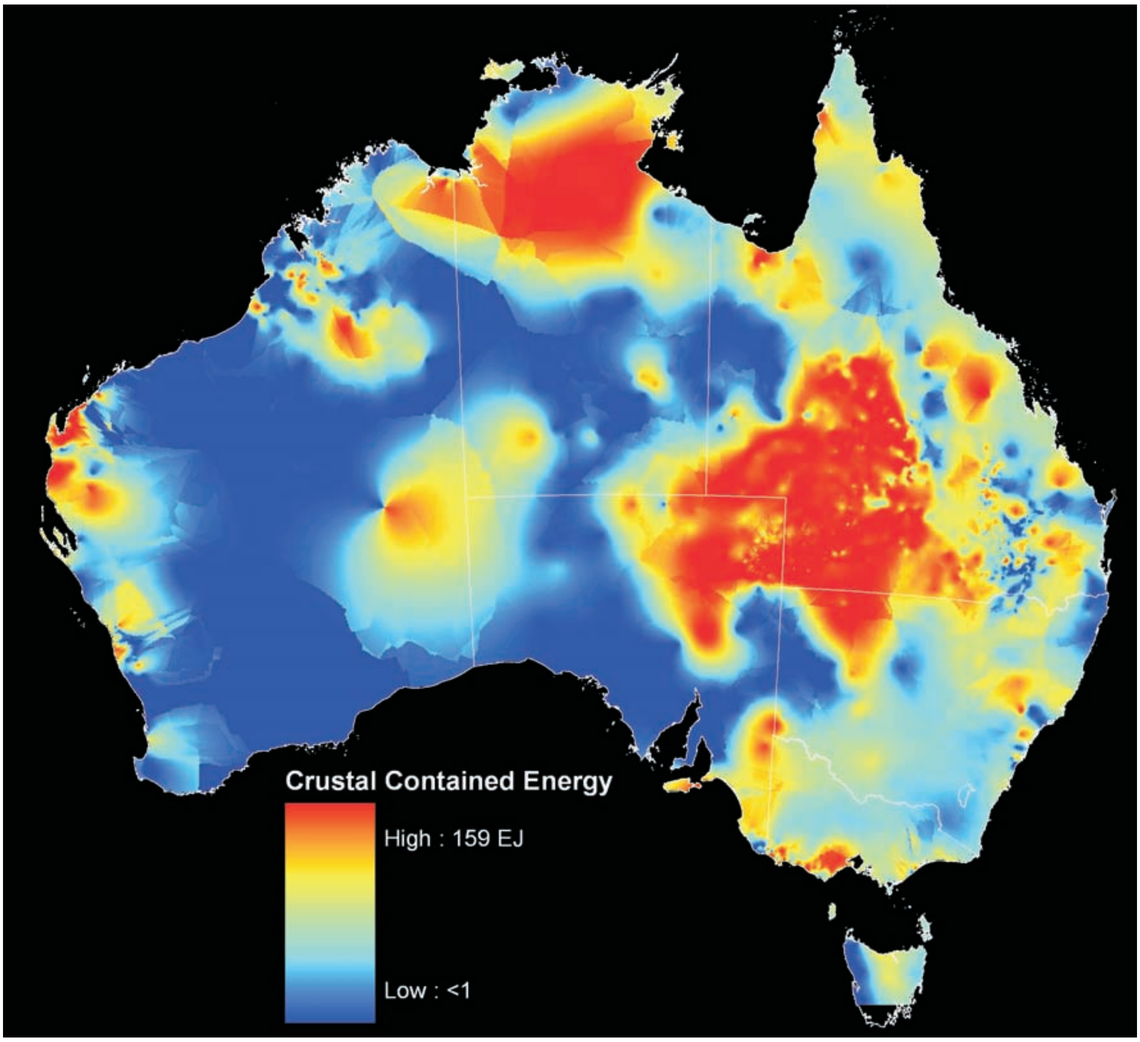

Figure 2. Map of distribution of contained crustal energy. See text for calculation method. The total resource is 1.9 x 10^{25} J, equivalent to 2.6 millions times the gross energy consumption in Australia during 2004-2005. The temperature data used in this image has been derived from proprietary information owned by Earth Energy Pty Ltd ABN 078 964 735.

technologies will undoubtedly allow extraction of heat at depths greater than 5 km, meaning that this figure is conservative.

Heat flow measurements

Heat flow is the preferred method of quantifying the amount of thermal energy that is available at a particular geographic location. Heat flow is the product of thermal gradient and thermal conductivity, and may be measured in the crust via drill holes. There are approximately 200 heat flow measurements throughout Australia, a coverage that is far too sparse to provide a meaningful map of heat flow on a continental scale. Geoscience Australia has purchased a thermal conductivity meter and downhole logging equipment in order to acquire new heat flow measurements to improve the definition of heat flow provinces throughout the continent. The project will operate a field crew full-time to measure the temperature gradient in selected holes across the continent and will also sample drill core from State and Territory core libraries to make new thermal conductivity measurements.

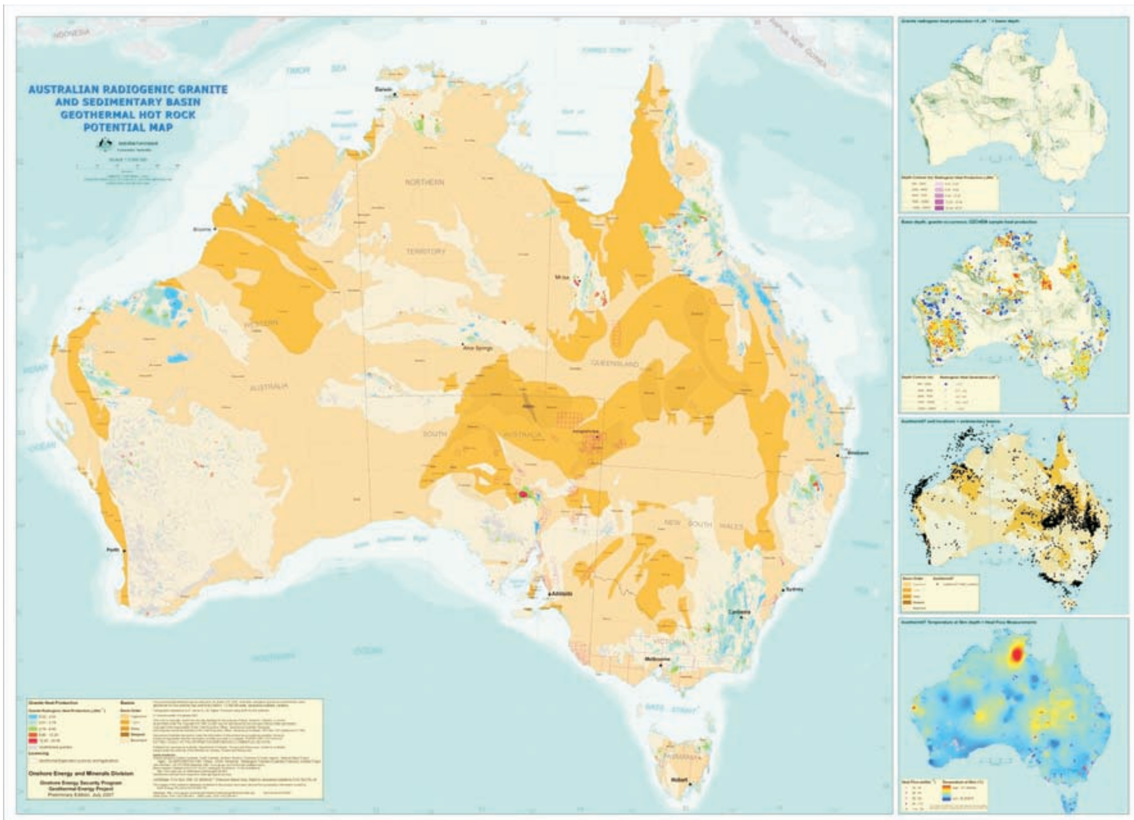

Figure 3. Map showing distribution of granites and their radiogenic heat production, combined with location and depth of sedimentary basins (main panel). Right-hand panels include information on the distribution of geochemical samples and their U-Th-K contents, distribution of downhole temperature measurements, depth of sedimentary basins, and temperature at 5 km depth. The map can be downloaded at http://www.ga.gov.au/minerals/research/national/geothermal/index.jsp.

Granite + sediment map

The key geological ingredients of the Hot Rock geothermal model are high-heat-producing granites overlain by thick accumulations of low-thermal-conductivity sediments. The decay of low concentrations of radiogenic elements (mostly uranium, thorium and potassium) over millions of years produces heat in the granite. This heat may be trapped at depth within the crust by the sedimentary cover which, lying above the granite, acts like a blanket. By mapping out deeply buried granites and having knowledge of both their chemistry and the thermal conductivity of any overlying sediment, it will be possible to make predictions about crustal temperature. Unfortunately most of the available granite chemistry comes from samples at surface, rather than from those that are buried. It is possible however to identify buried granites using remote sensing methods such as gravity and magnetics. By mapping granite outcrops it is also possible to make predictions of the composition of buried granites as they trend from outcrop areas to beneath sediments. In this way the heat production beneath sedimentary basins may be estimated. With information about the thicknesses and thermal conductivity of the overlying sedimentary strata, the heat production of the buried granites and estimation of heat flow upwards from the mantle, local temperature profiles of the crust in that location may be estimated.

Initial stages of this work have been undertaken with the compilation of information about outcropping granites and their chemistry. The heat production of the granites has been calculated, and combined in a GIS with maps of basin thickness (Figure 3). This provides a first-pass map of prospective areas, but also highlights where more granite geochemical data is needed.

OTHER ACTIVITIES

Geoscience Australia is currently involved in five of the Technical Interest Groups of the Australian Geothermal Energy Group (AGEG). The AGEG comprises the majority of government, industry and academic workers with an active interest in geothermal in Australia, and has grown from the early involvement of the IEA GIA signatories.

Land Access Protocols

Several aspects of Hot Rock developments have possible environmental impacts that will need to be assessed on a case-by-case basis. These include the potential mobilisation of radioactive elements, induced seismicity, and impacts on surface or groundwater. It must be stressed that experience to date suggests that none of these environmental impacts will provide insurmountable impediments to development. Geoscience Australia aims to have input into each of these areas from both a geoscience research and information perspective. In addition, Geoscience Australia may take an active role in seismic monitoring during reservoir stimulation, as the information gained may be useful for neotectonic hazard studies.

Direct-Use Applications of Geothermal Energy

The majority of current geothermal exploration activity in Australia is focused on electricity production, yet most of the existing developments use low-temperature geothermal resources in direct-use applications, e.g. for spas and space heating. Direct-use applications of geothermal energy have two key advantages, firstly they are generally very energy efficient, and secondly low-temperature geothermal resources are likely to be more widespread than the high-grade resources necessary for electricity generation. In a sub-project called “Geothermal for Cities” Geoscience Australia will compile detailed information on possible geothermal resources near major energy markets (i.e. cities and industrial centres) with the aim of targeting new drilling for infill heat flow measurements.

Geothermal Database

Geoscience Australia has developed an Information Management Plan for the capture, storage, manipulation and delivery of geothermal-related geoscience data. The first stage of the plan is to develop a heat flow database. This database will be populated with new data acquired by this project, as well as legacy data compiled during an extensive literature search, contributions from geothermal companies, State and Territory geological surveys, and universities. As well as complete heat flow measurements, this database will store temperature-only and thermal conductivity-only records. Other data layers that will be captured in either a relational database system or GIS include:

- Extrapolated and interpolated temperature at 5 km grid
- Geochemistry
- Drill hole locations and attributes
- Bouger gravity (and stations), magnetics, and radiometrics coverages
- Topographic information (population centres, infrastructure)
- Gamma logs
- Geology layers (outcrop, solid, faults etc)
- Seismic lines
- Digital Elevation Model
- Mean Average Surface Temperature
- Thermal IR
- Hydrogeology

Reserves & Resources Scheme

Geothermal explorers in Australia have been increasingly successful in raising money through the Australian Securities Exchange. However, as some companies move toward the project development stage, a formally defined reporting system is desirable for the purposes of ongoing capital raising. Individual developments require very large investment, with costs anticipated to be in excess of AUD$100 million. Work has commenced on a draft public reporting scheme and guidelines for geothermal resource and reserve definitions. This will be directly analogous to the Joint Ore Reserves Committee (JORC) Code for Mineral Resources and the SPE/WPC/AAPG Petroleum Resources Classification and Definitions. The geothermal scheme is being developed in collaboration with both local and international stakeholders.

Outreach

The function of this Technical Interest Group is to communicate the potential of geothermal energy to decision makers, investors and the general population. As well as describing the well-known positive aspects of geothermal developments (a cost effective low-emission renewable energy source), this TIG aims to provide information on potential areas of concern, including possible mobilisation of radioactive elements, induced seismicity during reservoir stimulation, and effects on groundwater. These are issues that will need to be addressed at each prospective development. Providing information about these concerns at an early stage will ensure informed and even debate regarding the true risks involved rather than misinformed reactions based on incorrect assumptions. Geoscience Australia is writing factsheets and other materials that aim to educate about these and other geothermal issues. The education unit of Geoscience Australia will assist in this goal, by providing information to school children, their teachers and parents. Other outreach opportunities will be taken as they arise. The Geothermal Energy Project has recently set up its own web page at http://www.ga.gov.au/minerals/research/national/geothermal/index.jsp.

Provision of Advice

Geoscience Australia provides advice to policy makers within government. This includes the formulation of the Geothermal Drilling Program, a AUD$50 million dollar-for-dollar grant scheme to progress proof-of-concept drilling and reservoir development projects in Australia, and the Geothermal Industry Development Framework and Geothermal Technology Roadmap. Both of these programs are delivered by the Australian Government Department of Resources, Energy and Tourism. Geoscience Australia also provides impartial advice to groups including the Clinton Foundation's Climate Change Initiative.

SUMMARY

New data acquisition by the Geoscience Australia Geothermal Energy Project will be conducted as part of the Onshore Energy Security Program and will include heat flow measurements across the continent. Other activities undertaken by the project will focus on compiling and interpreting relevant geoscience datasets, developing and implementing a geothermal geoscience information system, participating in the development of a Reserves and Resources reporting schema and guidelines, and helping to educate the Australian community about the Nation's geothermal potential.

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