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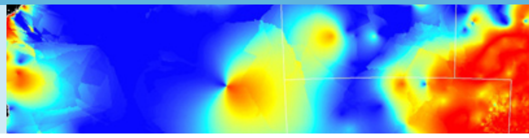
In search of the next hotspot



Project to boost exploration for bountiful, renewable energy

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Geoscience Australia's Geothermal Energy Project is part of the Energy Security Initiative announced by the Prime Minister in August 2006.

Geoscience Australia received $58.9 million over five years to implement the Onshore Energy Security Program by acquiring new data to attract investment in exploration for onshore petroleum, geothermal, uranium and thorium energy sources.

The program will acquire national-scale geophysical and geochemical data, including seismic, gravity, heat flow, radiometric, magneto-telluric and airborne electromagnetic data in collaboration with the state and Northern Territory governments under the National Geoscience Agreement.

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Formulating the Geothermal Energy Project

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 radioactive 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 a sedimentary cover that lies above the granite like a blanket.

Where temperatures are high, water circulating through the hot rocks can be used to generate electricity. At lower temperatures, the heat can be used for direct-use applications, such as space and water heating.

By raising awareness of Australia's geothermal potential among decision-makers and the general public, Geoscience Australia aims to provide background information to support policy formulation regarding a potential new geothermal industry.

Extensive consultation with state and Northern Territory geological surveys and geothermal exploration companies has identified a list of key impediments faced by geothermal explorers. The project aims to reduce those impediments through geoscience input.

The greatest identified geoscience need is for a better understanding of the distribution of temperature in the continent's upper crust. Two existing datasets—the Austherm05 map of temperature at five kilometres depth, and a database of heat flow measurements—suffer from having too few data points, compounded by poor distribution. Geoscience Australia aims to provide additional information for both datasets.

A third way to predict heat distribution is to use geological modelling of high heat-producing granite locations and overlying low thermal-conductivity sediments.

Other geoscience inputs to be developed to improve discovery rates and reduce risk for explorers include:

- a comprehensive and accessible geothermal geoscience information system
- an improved understanding of the stress state of the Australian crust
- increased access to seismic monitors during reservoir stimulation
- a reserve and resource definition scheme.

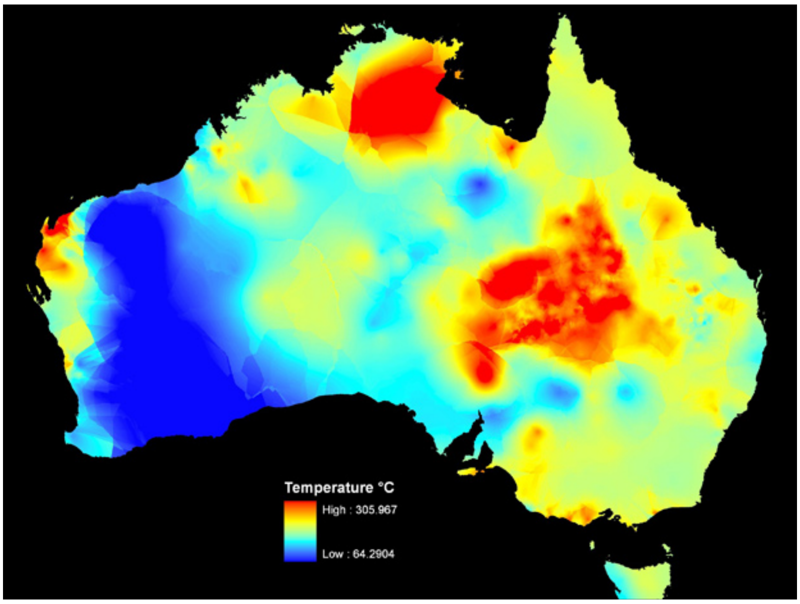

Figure 1. Modelled crustal temperature at five kilometres depth, using Austherm07 data, OZ SEEBASE™ depth to basement and basement temperature gradient defined by heat flow provinces. Temperature data in this image have been derived from proprietary information owned by Earth Energy Pty Ltd (ABN 078 964 735).

"The greatest identified geoscience need is for a better understanding of the distribution of temperature in the continent's upper crust."

Mapping heat in the crust

Temperature increases with depth in the crust, but current drilling technologies limit economic development of geothermal systems to about five kilometres maximum depth. Temperatures greater than 200°C are required at such depths for commercial electricity generation; however, 200°C at five kilometres is anomalous in Australia. It is necessary to find 'hot spots'—areas with above average crustal temperature.

Three methodologies will be applied, and the datasets will be integrated to map the continent's heat flow provinces and define geothermal potential in each province.

Temperature at five kilometres depth

Temperature measurements are often taken at intervals in boreholes. This is particularly true for petroleum, as temperature provides important information for understanding the maturity and therefore the type of hydrocarbon that may be expected. Temperature measurements, combined with other information such as thermal gradient, allow the temperature expected at five kilometres depth to be extrapolated vertically. This extrapolated temperature can be interpolated horizontally between drillholes, and contoured to produce a continuous map of temperature at five kilometres depth across the entire continent.

This technique was pioneered by Somerville et al (1994: Geotherm94 database) at the former Bureau of Mineral 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).

Geoscience Australia has since purchased the Austherm07 database and has started making further improvements. These

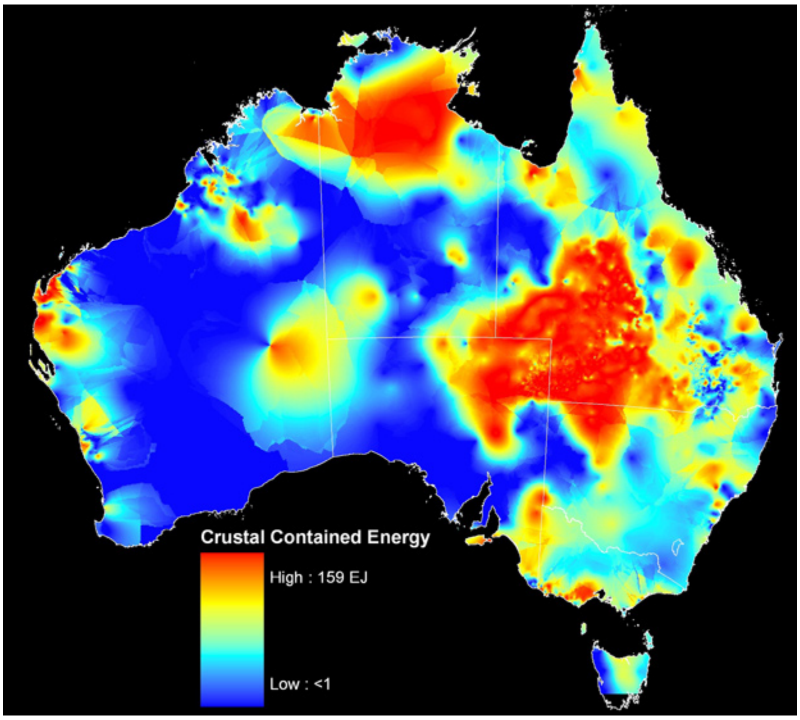

Figure 2. Distribution of contained crustal energy (see text for calculation method). The total resource is 1.9 x 10^{25} J, equivalent to 2.6 million times the gross energy consumption in Australia during 2004–05. Temperature data used in this image have been derived from proprietary information owned by Earth Energy Pty Ltd (ABN 078 964 735).

include utilising the OZ SEEBASE™ (FrogTech 2006) sediment thickness data to better constrain the depth at which geothermal gradients change from those typical of sedimentary basins to lower gradients typical of crystalline basement rocks, and mapping the continent's temperature gradients based on recognised heat flow provinces (figure 1).

The Austherm07 database has also been used in a new way to estimate the geothermal energy contained within the Australian crust. Two grids with 5 kilometre x 5 kilometre cells were made: a lower grid of temperature at five kilometre depth; and an upper grid produced by interrogating the database to predict the depth at which 150°C would be be reached. This temperature is the minimum temperature required for these developments. The average temperature, volume and estimated contained heat were calculated for each cell (figure 2).

This provides an estimate of 1.9 x 10^{25} joules of energy contained in the upper five kilometres of Australia's crust, equivalent to about 2.6 million years total energy supply at the 2004–05 consumption level of 7258.1 petajoules per year (ABARE 2006). Obviously, not all of this energy will be accessible for extraction, but just one per cent could provide 25 000 years of energy supply. Future drilling and extraction technologies will undoubtedly allow extraction of heat at depths greater than five kilometres, increasing this potential resource.

Heat flow measurements

Heat flow is the preferred method of quantifying the amount of thermal energy available at a geographic location. It is the product of thermal gradient and thermal conductivity, and may be measured in the crust via drillholes. Approximately 200 heat flow measurements are available for Australia—far too sparse a coverage to provide a meaningful map of heat flow on a continental scale.

Geoscience Australia is purchasing a thermal conductivity meter and downhole logging equipment to acquire new heat flow measurements and improve the definition of heat flow provinces throughout the continent. Geoscience Australia and the collaborating agencies will measure temperature gradient in selected holes across the continent and take new thermal conductivity measurements of samples from state and territory core libraries.

Granite and sediment map

By mapping out deeply buried granites and with knowledge of their chemistry and the thermal conductivity of the overlying sediment, it will be possible to make predictions about crustal temperature.

Unfortunately, most of the available granite chemistry comes from surface samples. However, it is possible to identify buried granites using remote sensing methods, such as gravity and

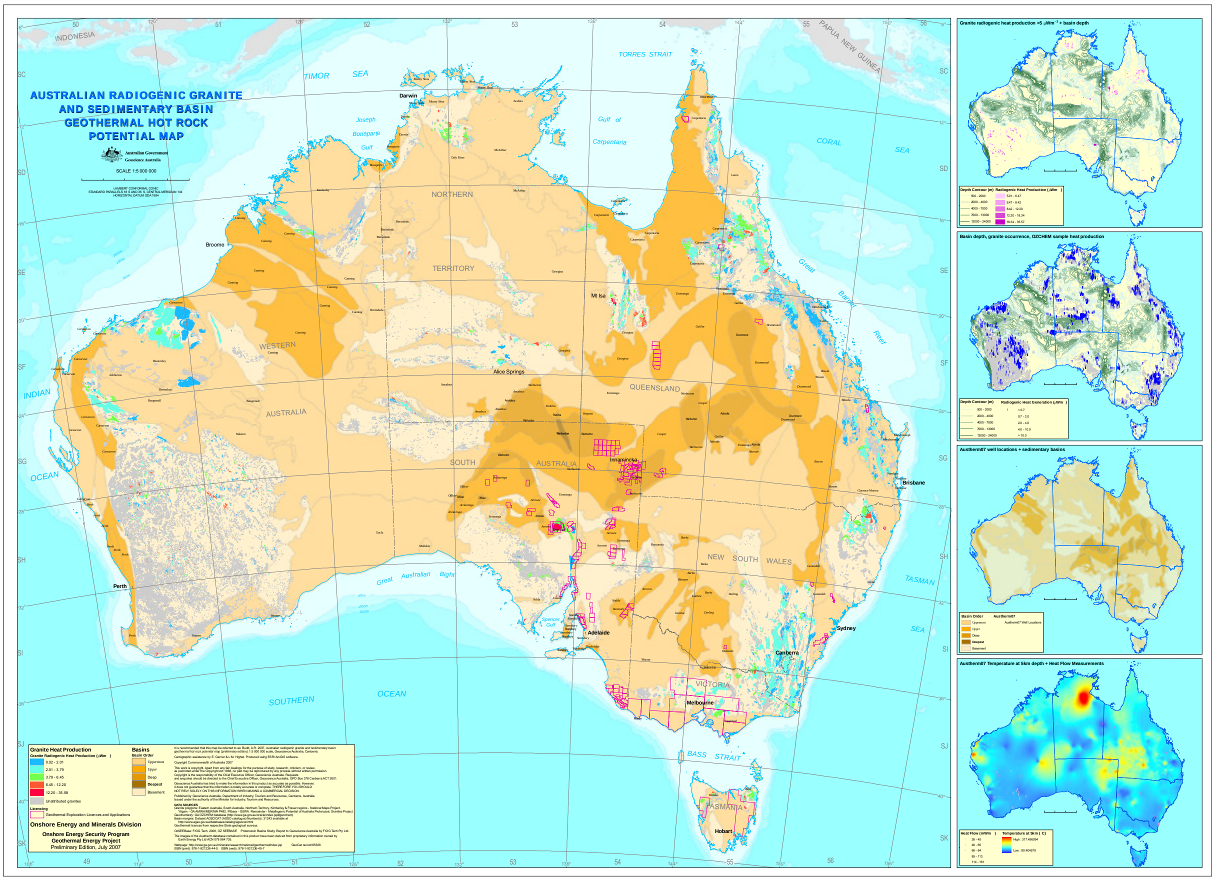

Figure 3. Distribution of granites and their radiogenic heat production, combined with location and depth of sedimentary basins (main panel). Right-hand panels include information on distribution of geochemical samples and their uranium–thorium–potassium contents, distribution of downhole temperature measurements, depth of sedimentary basins, and temperature at five kilometres depth.

magnetics. By mapping granite outcrops, it is also possible to predict 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.

Local temperature profiles of the crust may be estimated using information about the thickness and thermal conductivity of overlying sedimentary strata, heat production by buried granites, and estimates of heat flow upwards from the mantle.

The initial stage of this work was 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 areas where more granite geochemical data are needed.

Other activities

Direct-use applications of geothermal energy

Most current geothermal exploration activity in Australia is focused on electricity production, but most existing applications use low-temperature geothermal resources directly, such as for spas or space heating. Direct-use applications of geothermal energy are generally very efficient and require only low-temperature geothermal resources, which are more widespread than the high-grade resources necessary for electricity generation. Geoscience Australia will compile detailed information on possible geothermal resources near major energy markets, 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 is to develop a heat flow database. This will be populated with new data and legacy data from an extensive literature search, including contributions from geothermal companies, state and Northern Territory geological surveys, and universities.

As well as complete heat flow measurements, the geothermal database will store temperature-only and thermal conductivity-only records. Other data layers to be captured (in either a relational database system or a GIS) include:

- a grid of extrapolated and interpolated temperature at five kilometre depth
- geochemistry
- drillhole locations and attributes
- Bouguer 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.

For more information

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FrogTech. 2006. OZ SEEBASE™ Proterozoic Basins Study. Report to Geoscience Australia by FrogTech Pty Ltd.

Somerville M, Wyborn D, Chopra P, Rahman S, Estrella D & Van der Meulen T. 1994. Hot Dry Rocks Feasibility Study. Report 243, Energy Research and Development Corporation.

Related websites

Onshore Energy Security Program
www.ga.gov.au/minerals/research/oesp/work_program_03.jsp

Geothermal Energy Project, including map showing distribution of granites and their radiogenic heat production.
www.ga.gov.au/minerals/research/national/geothermal/index.jsp