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Cooper Basin region now in 3D

New 3D map assists geothermal exploration

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The new 3D Cooper Basin map will aid explorers in a region identified as highly prospective for geothermal energy. The newly produced map incorporates the two fundamental components which define a hot rock geothermal play: the potential heat source (high-heat producing granites) and the thermal insulation (overlying sediments).

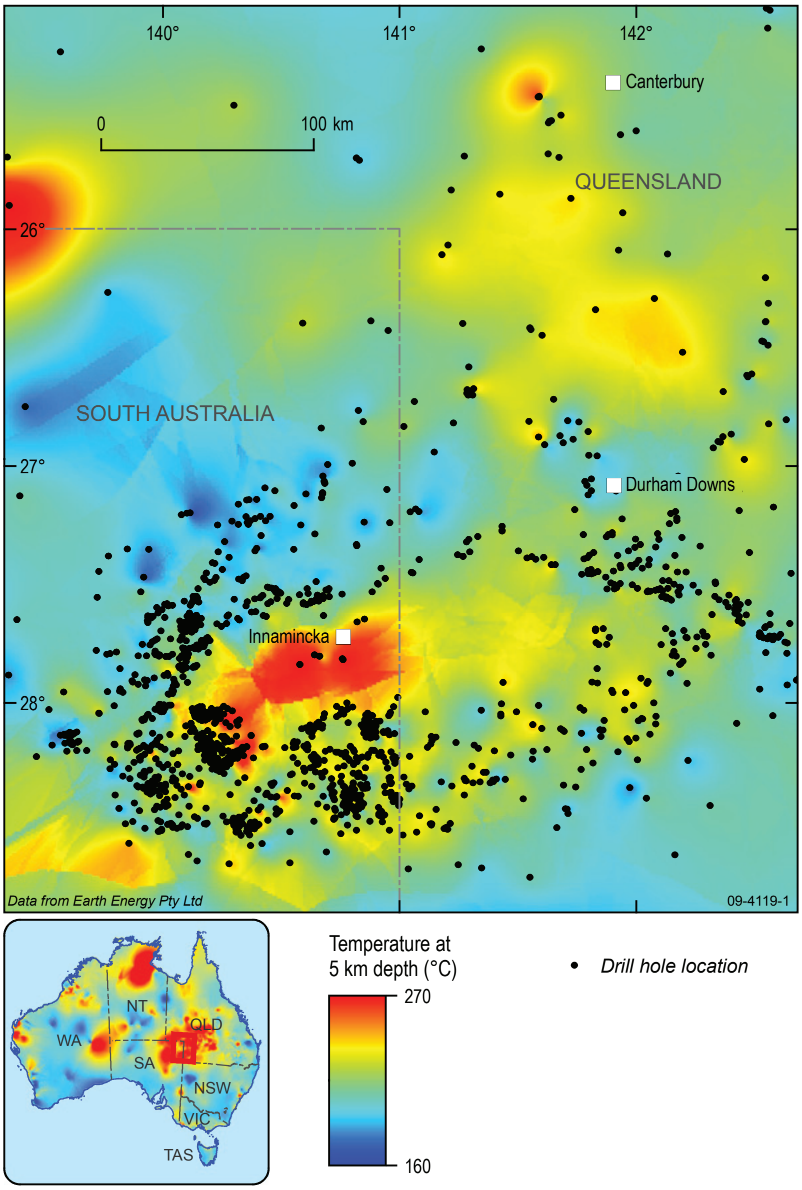

Figure 1. Predicted temperature at five kilometres depth (Chopra & Holgate 2005) including well locations.

By delineating the 3D geometries of both the known high-heat producing granites and inferred granitic bodies that may be high heat producing, and the overlying sedimentary basins, potential hot rock geothermal plays are identified.

This study was carried out by Geoscience Australia's Geothermal Project as part of its Onshore Energy Security Program which provides pre-competitive information to support mineral and energy resource exploration.

The Cooper Basin region

The Cooper Basin region straddles the Queensland/South Australia border, and is coincident with a prominent anomaly on a map of predicted temperature at five kilometres depth (figure 1). The region forms part of a broad area of anomalously high heat flow attributed to Proterozoic basement rocks enriched in naturally occurring radioactive elements. High-heat producing granites, including granodiorite of the Early to Mid-Carboniferous Big Lake Suite, intrude the basement beneath the Cooper and Eromanga basin sequences.

These high-heat producing granites form a significant geothermal play being targeted by Australia's first hot rock development by Geodynamics Limited at Habanero, near Innamincka in South Australia.

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The relationship between high heat flow, high temperature gradient and anomalous heat production in the Big Lake Suite is well recognised. The thick sedimentary sequences of the overlying Cooper and Eromanga basins provide a thermal blanketing effect resulting in temperatures as high as 270° C at depths of less than five kilometres. There is a high probability that corresponding geothermal plays exist in association with other granitic bodies lying beneath the Cooper and Eromanga basins. For the most part, the location and characteristics of these bodies are poorly understood and accurately identifying them is an important first step towards any future geothermal exploration in this region.

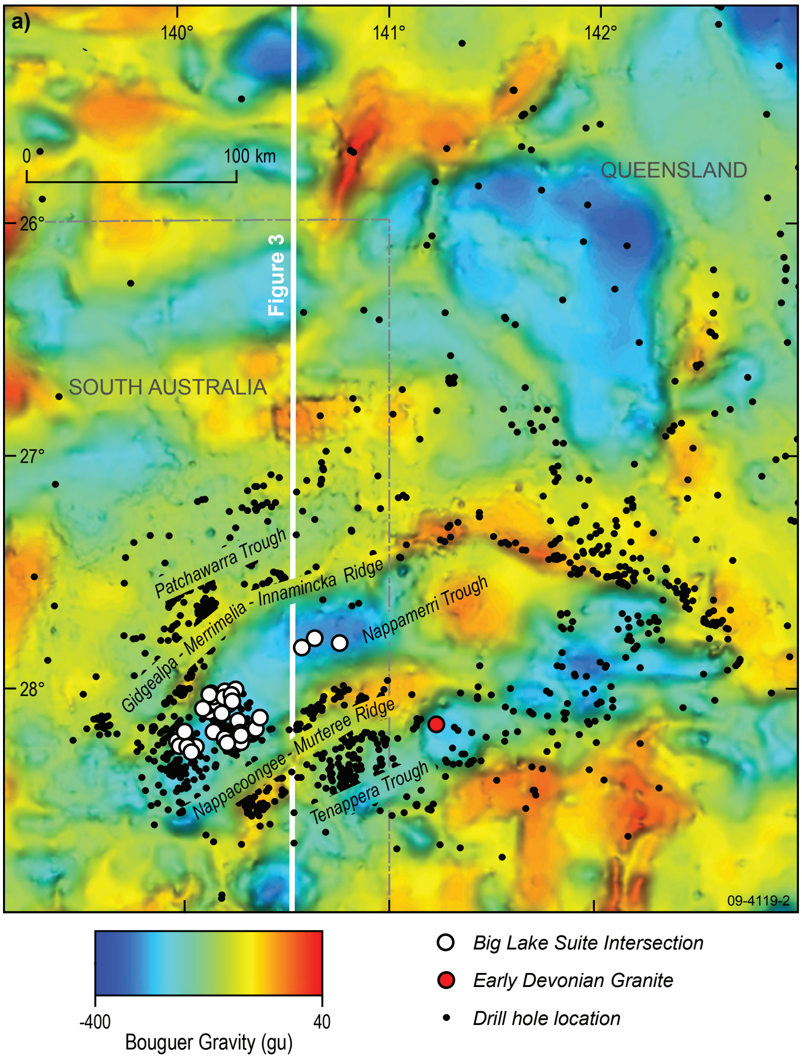

Figure 2a. Gravity image showing drill-hole locations (Big Lake Suite intersections in white; early Devonian granite in red). The major structural elements of the Cooper Basin and the location of the north-south section in figure 4 (white) are also shown.

The Cooper region Bouguer gravity field is shown in figure 2a and the Z-horizon (top of basement) is shown in figure 2b. Two northeast-trending gravity lows broadly coincide with the Nappamerri and Tenappera troughs. These are bounded by northeast-trending gravity highs which are similarly associated with two structural ridges. In the northeast of the study area, two prominent structural lows coincide with low gravity anomalies. Thus, there is a broad regional correlation between known basin structure and the gravity field, suggesting that the distribution of low-density basin sediments is of significance.

There is, however, evidence that density variations in the basement are contributing to the gravity field. Gravity lows that are coincident with the Nappamerri and Tenappera troughs extend beyond the trough boundaries (figure 2b). A number of intense, discrete gravity lows lie within

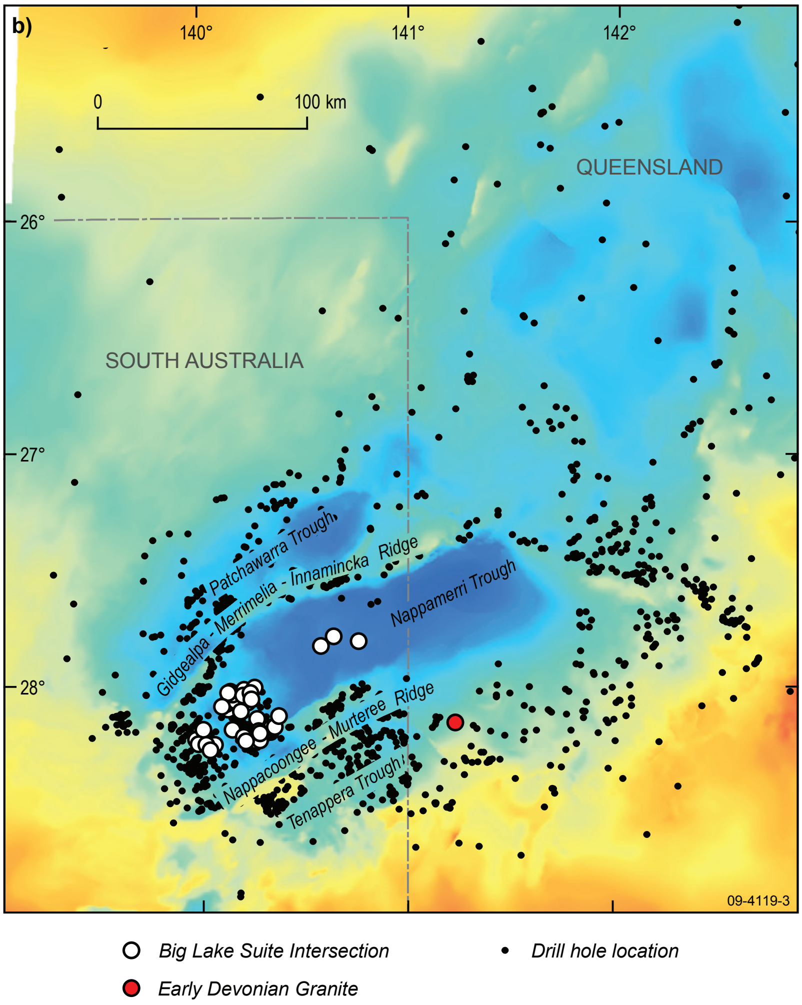

Figure 2b. Z-horizon image compiled from existing open file seismic sections, industry interpretations and 1300 well intersections (PIRSA 2008). This surface represents the base of the stacked Cooper and Eromanga basins. The Z-horizon ranges from 815 to 4496 metres below the topography.

the broader northeast trends, in some cases coinciding with granite intersections in the Nappamerri and Tenappera troughs. In the northwest of the study area where the Eromanga Basin lies directly on basement, there are a number of prominent gravity lows that are not associated with any known basin structure.

The gravity field is therefore influenced by both the thickness of basin sediments and by density variations in the basement. For this study, the gravity lows are interpreted as being sourced primarily from relatively low density granitic bodies that have intruded the basement. This assumption is supported by two lines of evidence. Firstly, all granite well intersections coincide with gravity lows and secondly, the nature of the basement which consists of Cambro-Ordovician Warburton Basin and Early Palaeozoic and Proterozoic elements. These basement units have been deformed and metamorphosed to such an extent that the densities of the constituent units will be generally higher than granites that intrude these units.

Constructing the 3D map

The 3D map, which covers an area of 300 by 450 kilometres by 20 kilometres depth, was constructed in part using 3D inversions of Bouguer gravity described by Li and Oldenburg (1998). Gravity inverse modelling is a process whereby adjustments are made to a density model, in the form of a mesh of rectangular prisms, until there is an acceptable fit between the predicted response of the model and the observed gravity data. Where density observations are available, it is possible to constrain the inversion to match the supplied density values to within a specified upper and lower bound. Where no density observations are available the inversion can be left unconstrained.

The inversion model consisted of a mesh with a cell size of two kilometres lateral and 250 metres vertical lengths. The smaller vertical cell size used in this study was to accommodate the high resolution of the Z-horizon (figure 2b) which represents the base of the stacked Cooper and Eromanga basins. Density values were assigned to the individual cells of the reference model based on whether the centre of the cell falls below the Z-horizon (basement) or between the Z-horizon and the topographic surface (Cooper and Eromanga basin sediments). The inversions were forced to match the basin

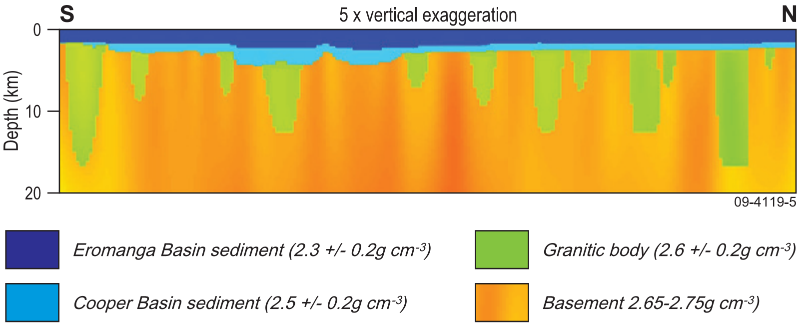

Figure 3. North-south density section through the final gravity inversion model (see Figure 2a for location). The densities of the Eromanga Basin sediments (dark blue: 2.3 +/- 0.2 g cm^{-3}), Cooper Basin sediments (light blue: 2.5 +/- 0.2 g cm^{-3}) and the granitic bodies (green: 2.6 +/- 0.2 g cm-^{3}) were constrained to a narrow density range, while the basement (yellow-red: 2.65–2.75 g cm^{-3}) was left unconstrained.

sediment density, 2.4 grams per cubic centimetre (g cm^{-3}) based on a Bureau of Mineral Resources seismic refraction study, to within ± 0.2 g cm^{-3}. Although a density was assigned to the basement (2.67 g cm^{-3}), the corresponding upper and lower bounds were set such that they encompassed all likely rock densities.

The inversion models of the basement have smooth variations in density. However, discrete boundaries can be constructed by producing 3D contour surfaces of the basement, termed iso-surfaces. A series of iso-surfaces were generated, based on a range of density values, enclosing successively larger regions of low density. The geometry of the regions is lobe-like with the maximum lateral extent at or near the top of the basement and gradually reducing in lateral extent at depth. A gravity edge mapping technique was used to select the optimal iso-surface to constrain the sub-sediment lateral extent of the low density lobes.

A series of separate inversions were generated by assigning three different densities to the enclosed ‘granite’ lobes. The densities selected (2.55, 2.6 and 2.65 g cm^{-3}) cover a range of typical granite densities and were constrained by specifying ± 0.02 g cm^{-3} as an upper and lower bound. A large proportion of the low density lobes had total depths of less than eight kilometres. However, a number of lobes, coincident with the more intense gravity anomalies, were considerably deeper with total depths up to 20 kilometres. Granites with these larger depth extents were considered geologically unrealistic and were restricted by specifying a maximum cut-off depth for the low density lobes. Three additional models were generated for each of the above granite densities by assigning different levels of maximum cut-off depths of 8, 12, and 16 kilometres.

Results of the nine inversions were analysed by inspecting the regions of basement immediately below the base of the modelled granitic bodies. If the density of the granite is too high and/or its depth extent is too low, then the inversion result will incorporate an anomalous region of low density in the basement directly beneath the modelled granite. Conversely, if the density of the modelled granite is too low and/or its depth extent is too large, then an anomalous region of high density will be generated at the base of the granite. The inversion model which produced the most ‘neutral’ result had a density of 2.6 g cm^{-3} assigned to the modelled granites and a maximum cut-off of 12 kilometres depth (figure 3). The final 3D map of inferred sub-sediment granitic body distribution is shown in figure 4.

Conclusion

The 3D map indicates that a large volume of granitic material exists within the basement of the Cooper and Eromanga basins. A number of these granite bodies, such as the Big Lake Suite granite shown in figure 4, are coincident with anomalies in the map of predicted temperature at five kilometres depth, indicating that they may have high-heat-producing compositions. A number of interpreted granite bodies do not correspond to temperature anomalies, indicating some granite compositions may have low radioelement concentrations.

The 3D map, which also defines the geometries of the Cooper and Eromanga basins, delineates both potential heat sources and thermally insulating cover. Thus the 3D map can be used as a predictive tool for delineating potential geothermal plays when used in conjunction with the map of predicted temperature at five kilometres depth.

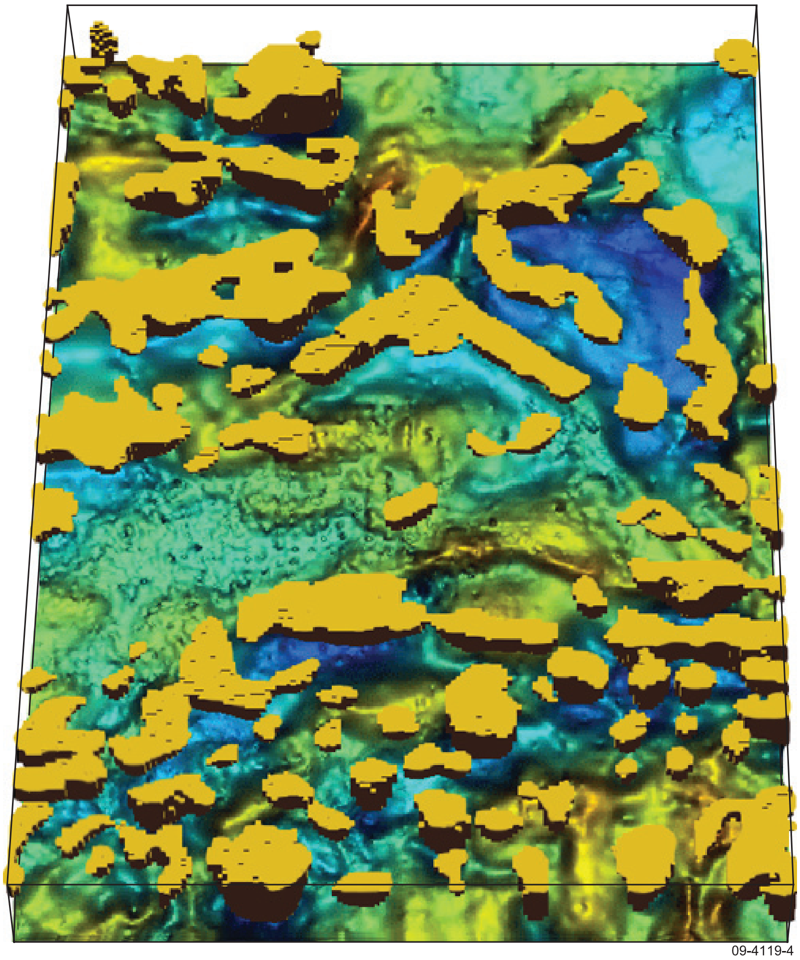

Figure 4. 3D model viewed obliquely from south of inferred sub-sediment granitic bodies overlying an image of gravity data.

For more information

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Cooper Basin region 3D map (Version 1)

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The Cooper Basin region 3D map Version 1: A search for Hot Buried Granites (Geoscience Record 2009/15)

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