Is it hot enough down there? Assessing geothermal potential in the Sydney-Gunnedah-Bowen Basin.

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SUMMARY

The Earth's upper crust hosts many important economic resources, from minerals to groundwater to energy, but the subsurface structure and associated thermal structure is poorly understood. Internal heat is the driving force behind many of the Earth's processes and is now being considered as a new form of clean renewable energy. High resolution 3D thermal models, incorporating detailed geological structure and real world data, are effective in assessing thermal structure and provide improved temperature estimates for geothermal exploration. Unlike historical 1D models and extrapolated temperature at depth maps, 3D thermal models are appealing to the geothermal exploration industry as they are not limited by the sparse nature of down-hole temperature measurements or heat flow and the uncertainties of such models can be calculated.

In the Sydney-Gunnedah-Bowen Basin (SGBB) system, Australia's energy rich sedimentary basin, the thermal structure is poorly understood resulting in its geothermal potential largely being ignored. Thermal modelling using optimised parameters shows estimated temperatures at 5km below the surface, the economic limit of drilling, to range from 120°C to 240°C, with highest temperatures under thick sediments with multiple insulating coal layers. Using the 150°C temperature contour as in indicator for potential geothermal prospectivity, the most potential basins are in the Bowen and Sydney.

Key words: geothermal potential, Sydney-Gunnedah-Bowen Basin, thermal structure.

INTRODUCTION

Multidimensional, scalable geodynamic models are required to combine the knowledge of heat flow and thermal characteristics, with detailed geological structure and real world measurements, to better understand the thermal structure of the Earth's upper crust. Historical approaches, using 1D models (i.e. Chopra and Holgate, 2006) and extrapolated temperature at depth maps (i.e. Gerner and Holgate, 2010) have inherent limitations and are inappropriate for complex systems. Around the world, the resources of the upper crust are experience rapid rates of development as demand increases. In Australia the development of multiple resources, i.e. minerals, energy (coal, coal seam gas, natural gas, geothermal), groundwater, in the energy rich sedimentary basin of the Sydney-Gunnedah-Bowen Basin (Figure 1) has highlighted the lack of subsurface information that exists, particularly thermal structure.

The advancement of geothermal energy exploration in the SGBB has been limited by scarce and inaccurate thermal datasets, oversimplified interpretations and under-constrained thermal models (Mussons et al., 2009). Geothermal exploration requires accurate assessments of the temperature at depth. High resolution 3D thermal models provide a new method of accurately assessing the thermal structure of the SGBB with representative estimates of temperature at depth. 3D thermal models in systems such as *Underworld* are advantages as they approach the problem of assessing thermal structure from the upper crustal scale (>500km x 500km), as opposed to the small scale (<25km x 25km) reservoir models used for resource modelling, allowing 3D elements, like heat flow, to fully interact with detailed geological structures and physical rock properties. The big advantage of this model is the uncertainty of parameters used have characterised, optimised for best-fit to match real world observables.

The 3D thermal model of the SGBB shows the importance of subsurface architecture and geology on heat flow, with high temperatures observed in the Bowen and Sydney Basin, under thick sediments with multiple insulating coal layers. The depth of the 150°C temperature contour provides a primary indicator of geothermal potential. Assessing temperatures, at 5km below the surface, shows parts of the Sydney and Bowen basins generally exceed 170°C with some areas in the Bowen Basin reach over 200°C

METHOD

High resolution 3D model of the SGBB is created in the *Underworld* platform, with the detailed geological model used previously in Danis et al. (2010, 2011) (Figure 2), and run using the *Underworld-GT* toolbox. This model covers the area between Latitude -36 to -19 and Longitude 147 to 154 at a resolution 3000m by 17m by 3000m. The four major material volumes; basement, basal volcanics, sediment and coal measures, are imported in as ten surfaces, in stratigraphic order, and smooth particle hydrodynamics is used to interpolate between the surface points to create the surface geometry of the chosen resolution.

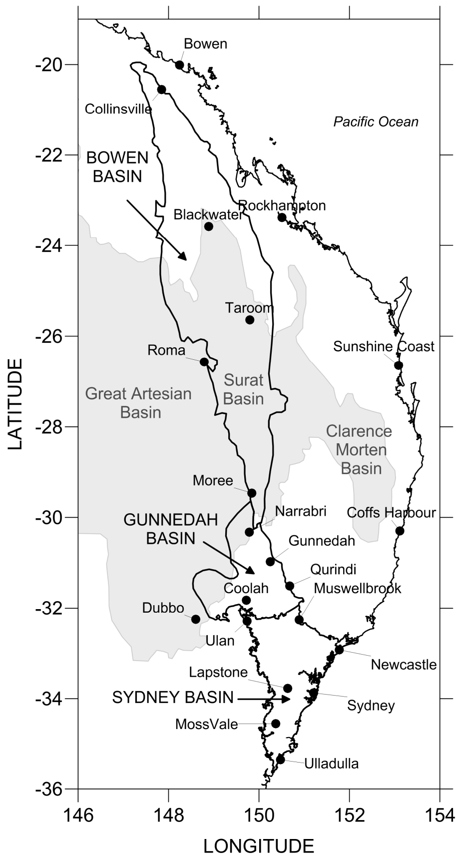

Figure 1. The Sydney-Gunnedah-Bowen Basin system, east coast of Australia.

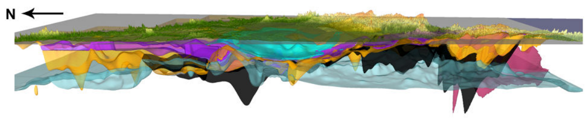

Figure 2. Image of the SGBB 3D Geological model from the gLucifer viewer associated with *Underworld*.

Four each of the four material types thermal properties area assigned (Table 1) which have been derived from material and subsurface parameter optimisation work using measured down-hole temperature data. These 'best-fit' parameters satisfy the thermal constraints imposed by over 300 temperatures at depth points across the Sydney Basin.

The work of Clauser and Huenges (1995) demonstrate there is a significant decrease in thermal conductivity of rocks when temperature is increased; therefore this model contains temperature dependent conductivity parameters for each material. In Table 1, K_0 represents the conductivity of the material at the surface at T_0, which is 15°C. Thermal conductivity decreases linearly between the surface to a point where it remains at a constant value Kcrit, at Tcrit which is 300°C.

In the model the temperature boundary condition is 15°C at the surface, the basal temperature at 12km is 345°C and the side boundary conditions are reflective. The model is run from low resolution to high resolution and the temperatures at 5km below the ground surface extracted and contoured, as shown in Figure 3.

Table 1. Thermal properties of materials

Material	Density (t/m^3)	K_0 (W/m-K)	K crit (W/m-K)	Heat Production ($\mu W/m^3$)
Sediment	2.46	2.00	1.50	1.25
Coal Measures (Greta / Maules / Reid Dome / Jurassic)	1.90	3.00	0.20	1.25
Coal Measures (PCM)	1.90	1.20	0.20	1.25
Basal Volcanics	2.95	3.00	2.25	0.50
Basement (under fault)	2.70	3.00	2.25	2.00
Basement	2.70	3.00	1.50	2.00

RESULTS

The geothermal potential of the SGBB is dependent on many interplaying factors but exploration programs are developed based on estimated subsurface temperatures. Figure 3 presents a temperature contour map for the SGBB at 5km below the surface, which is deemed the current limit of economic drilling and development (i.e. Budd et al. 2008).

In the Sydney Basin, temperatures range from approximately 140°C to 185°C. The offshore part of the Sydney Basin is not considered practical for exploration and is not well constrained in this model. The highest temperature area in the Sydney Basin is south of Cessnock, at 170°C to 180°C, and between Singleton and Newcastle temperatures are above average. This reflects the presence of multiple coal measures; the Permian Coal (PCM) and the lower Greta Coal, and thick sediments (3-4km).

In the Gunnedah Basin, temperatures range from 140°C to just above 150°C. Despite the presence of Permian Coal measures over much of the Gunnedah Basin the overall thickness of sediments (1-3km) is much less than in the Sydney or Bowen basins. Only in the Maules Creek sub-basin, west of Boggabri, does the temperature reach just over 150°C, helped by the addition of the Maules Creek Coal measures and the Permian Coal measures.

In the Bowen Basin, temperatures range from 140°C to 240°C, with higher temperatures concentrated between Meandarra and Baralaba. In the Denison Trough temperatures range from 190°C to 240°C, a result of thick overlying sediment (~4km) and the Permian and Reid Dome Beds Coal measures. In the southern part of the Basin, between Roma, Taroom and south of Meandarra the addition of Jurassic Coal measures, with the sediments and Permian Coal measures, influences the lateral distribution of the 150°C contour.

The 15°C temperature contour (Figure 3, dashed line) shows the parts of the SGBB where, to reach temperatures of value for geothermal exploration, exploration companies would need to drill to 5km. Higher temperatures in Figure 3 indicate the depth of drilling required to reach 150°C will be less than 5km and in some places, like the Denison Trough and Taroom Trough, considerably less.

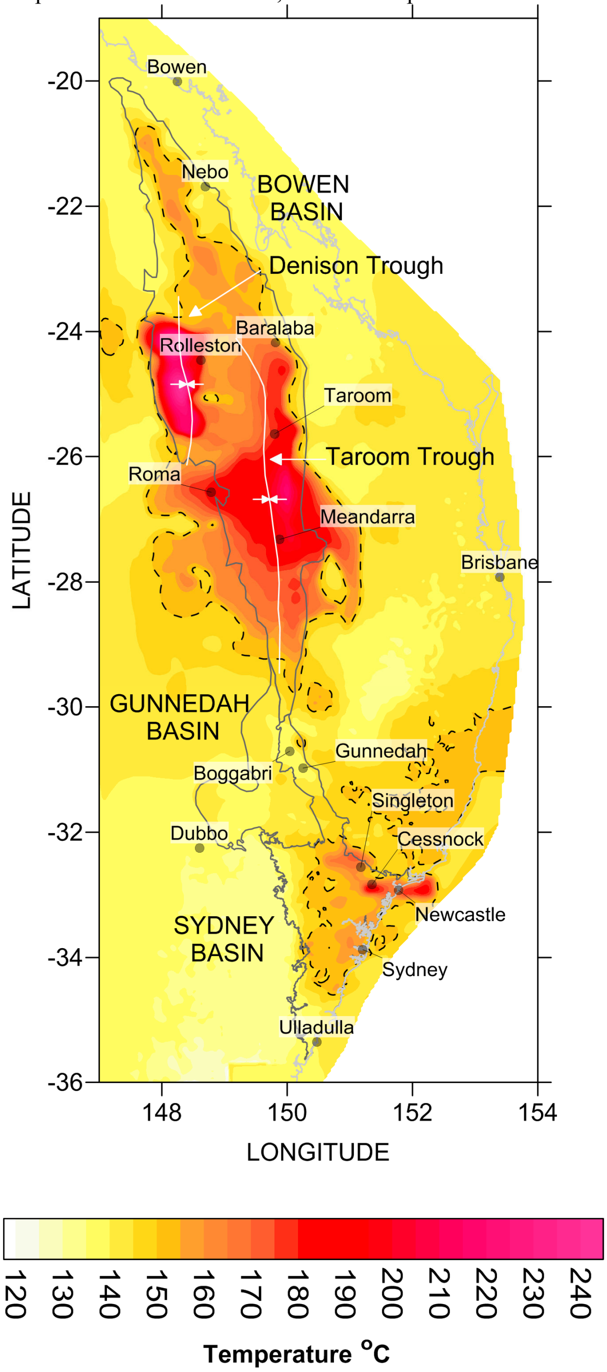

Figure 3. Temperature contour map of the SGBB at 5km below the surface. Dash black line is 150°C contour. Place names, SGBB (grey) and coastline.

CONCLUSIONS

The geothermal potential of the SGBB system has largely remained unexplored, due to a limited understanding of the thermal structure of the system. High resolution 3D thermal modelling, using a detailed geological model and optimised 'best-fit' thermal properties and subsurface parameters, allows for a comprehensive assessment of the thermal structure of the SGBB as well as providing representative estimates of temperature at depth. For a vast part of the Bowen Basin temperatures at 5km exceed 180°C making it a good place to begin detailed geothermal exploration. The temperature estimates at 5km below the surface show that large parts of both the Sydney and Bowen basins have significant potential for geothermal resources.

REFERENCES

Budd, A., Holgate, F., Gerner, E., and Ayling, B., 2008, Pre-competative geoscience for geothermal exploration and developmen in Australia: Geoscience Australia's Onshore Energy Sercurity Program and the Geothermal Energy Project: GRC Transactions 32, 347-350.

Chopra, P., and Holgate, F., 2006, A GIS analysis of temperature in the Australian crust: Proceedings of the World Geothermal Congress, Turkey, Abstracts.

Clauser, C., and Huenges, E., 1995, Thermal conductivity of rocks and minerals – Rock Physics and Phase Relations, A handbook of physical constraints: Americal Geophysical Union.

Danis, C., O'Neill, C., and Lackie, M., 2010, Gunnedah Basin 3D architecture and upper crustal temperatures: Australian Journal of Earth Sciences 57, 483-505.

Danis, C., O'Neill, C., Lackie, M., Twigg, L., and Danis, A., 2011, Deep 3D structure of the Sydney Basin using gravity modelling: Australian Journal of Earth Sciences 58, 517-542.

Gerner, E., and Holgate, F., 2010, OzTemp – Interpreted temperature at 5km depth image: Geoscience Australia.

Mussons, A., Harrison, B., Gordon, K., Wright, S., Sandiford, M., 2009, Thermal thinking: optimal targeting for Australian geothermal explorers: Proceedings Australian Geothermal Energy Conference, Brisbane, Record 2009/35.