NEW DATA AND IDEAS FOR ENERGY EXPLORATION IN AUSTRALIA

Ned Stolz
Geoscience Australia, ned.stolz@ga.gov.au

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INTRODUCTION

Pre-competitive geoscience is a strategic asset for assessing and reducing risk in energy exploration in Australia. Exploration differs from other business processes because the outcomes are highly uncertain. Investment in exploration carries a high degree of risk which is often exacerbated by a lack of information and knowledge pertaining to areas being considered for targeting. Perceived prospectivity is usually the main factor influencing the decision to explore a certain country or region, and this can only be assessed by a robust scientific understanding of the geological processes that may have been active in the area (Powell, 2007). Such understanding is generally based upon thorough analysis and interpretation of good quality data-sets.

Mining and energy companies cannot capture the value of this type of geoscientific analysis until they have taken up exploration permits or tenements. Thus companies will not usually commit large amounts of exploration dollars and geologist's time to regional-scale data acquisition and interpretation for area selection (Powell, 2007). This is especially true for under-explored 'frontier areas' which have sparse data and are often poorly constrained geologically. Exploration is now an international business with companies taking a global perspective when deciding where they will obtain best return for their exploration dollars. Provision of high-quality pre-competitive geoscience data by Australian Governments allows these companies to assess the risk in regional prospectivity without committing to expensive data acquisition themselves. It also promotes Australia as a sound exploration destination in a highly competitive global market.

In addition, exploration is a cyclical business which is often driven by commodity prices, and is iterative in nature. It is rarely the first company that takes up tenements over an area that discovers and develops a profitable resource. New data and results can radically change the assessment of an area, while new technologies and geological ideas may provide new pathways to exploration success. Governments must maintain pre-competitive data-sets throughout these cycles and develop them over the long term (20 years plus). Data need to be updated and improved as scientific and technological advances are made, and they must be readily accessible and vigorously promoted to the global exploration industry (Powell, 2007). By attracting exploration investment, governments ensure effective exploration and development of energy resources for the benefit of all Australians.

ONSHORE ENERGY SECURITY PROGRAM

In 2006 the Commonwealth Government announced the Onshore Energy Security Program (OESP) which will spend $59 million over five years on providing pre-competitive geoscience data for energy exploration. Geoscience Australia is using these funds to implement a scientific program designed to enhance the prospectivity for hydrocarbons, uranium, thorium and geothermal energy on the Australian continent.

The pre-competitive geoscience model that Geoscience Australia has adopted for the OESP and other programs is presented in schematic form in Figure 1. Pre-existing data-sets and scientific publications were reviewed for their relevance and impact on energy prospectivity in Australia at a continental, regional, and province scale. On the basis of this examination,

new surveys to extend or improve existing data coverage, acquisition of new data-types such as seismic or magneto-tellurics (MT), and new scientific research into energy systems were proposed to further enhance energy exploration potential.

The new combined data were processed, analysed, modelled and interpreted with reference to the latest scientific concepts and knowledge. The outputs are high quality basic data, maps, 3D models and other predictive products that can be considered by companies during area selection for energy commodity exploration. All products will be delivered exclusively through the Geoscience Australia website, or via FTP download for larger sets of digital data.

Three examples are presented here to illustrate the provision of cutting-edge pre-competitive geoscience at the national, regional and local scales. These data, predictive products, and scientific publications will highlight Australia as a data-rich destination for energy explorers, and by reducing risk, will increase the probability of a significant energy discovery in Australia.
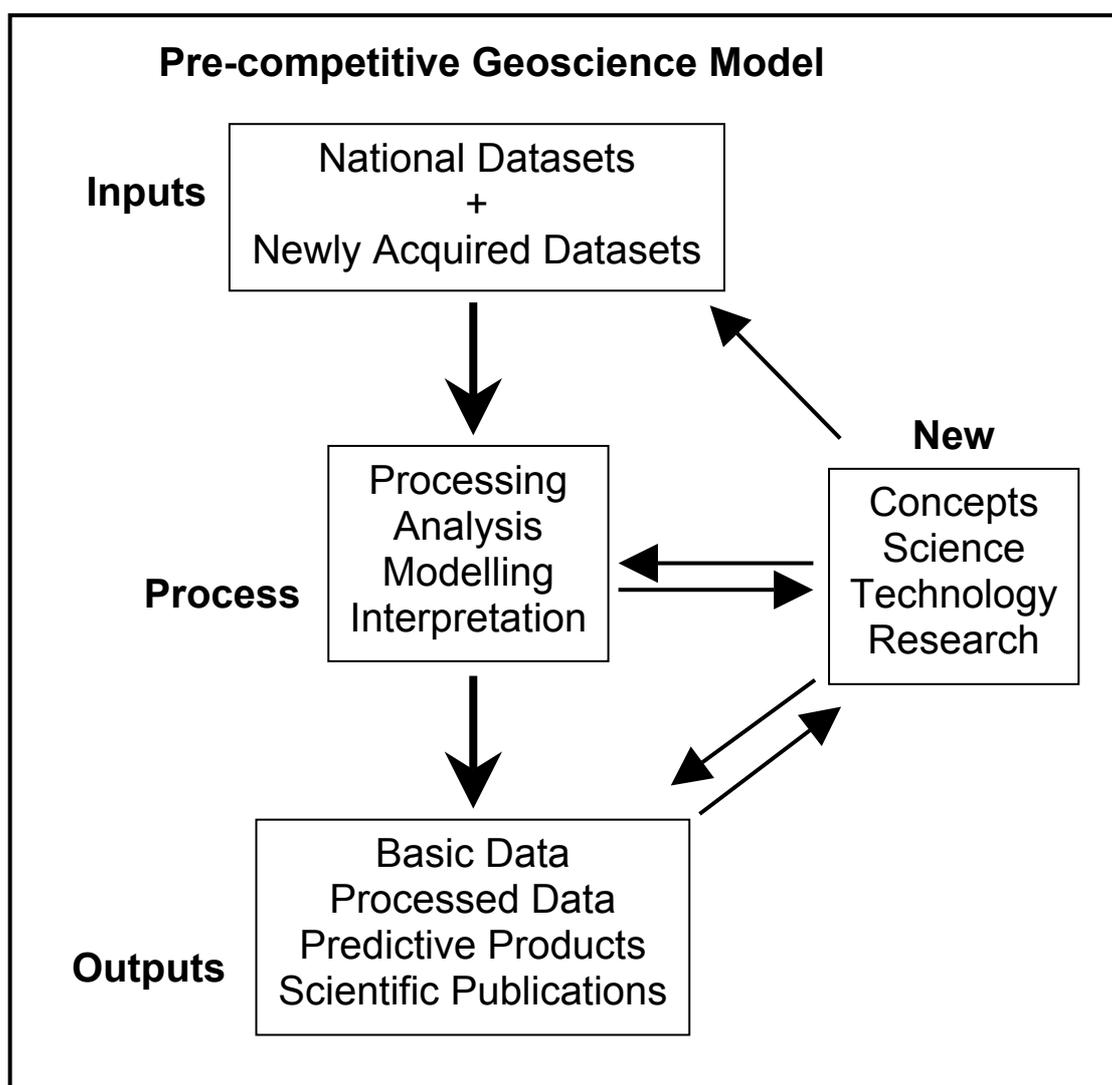

Pre-competitive Geoscience Model

Inputs — National Datasets + Newly Acquired Datasets

Process — Processing Analysis Modelling Interpretation

New — Concepts Science Technology Research

Outputs — Basic Data Processed Data Predictive Products Scientific Publications

Figure 1: Diagram illustrating the application of pre-competitive geoscience data within the OESP.

AWAGS – NEW RADIOMETRIC MAP OF AUSTRALIA

Geoscience Australia and State Government Geological Surveys have been collecting airborne radiometric data over Australia for the past 40 years. These data are normally acquired simultaneously with aeromagnetics, and the surveys have employed a wide variety

of flying heights, sensor types and calibration datum. The variations between surveys present major difficulties to geophysicists attempting to merge data into consistent regional scale images. National and regional scale aeromagnetic images have been available to industry for many years and are a major input into area selection activities (Minty et al, 2003).

Radiometric data are a major consideration when targeting for uranium and also map hot granites for geothermal energy. The data are widely used for mapping bedrock geology, regolith, and soil formations, as well as for assessing radiation hazards and other social impacts. Improving the quality of Australia's pre-competitive airborne radiometric data will have significant impact on energy exploration and increase geo-scientific understanding of the continent.

As part of the OESP, Geoscience Australia commissioned the Australia Wide Airborne Geophysical Survey (AWAGS) which acquired 145,000 line km of airborne radiometric and magnetic data on 75km spaced north-south lines and 400km spaced tie lines across the Australian continent and Tasmania (Minty et al, 2009). Flying was completed in December 2007. In terms of area, this is the largest single airborne geophysical survey ever flown, and the first time an entire continent has been covered by a single survey.

AWAGS provides a set of tie lines for levelling of all existing and future airborne radiometric surveys to the International Atomic Energy Association (IAEA) datum. Worlds best practice calibration procedures were implemented for the AWAGS survey and new grid levelling and merging algorithms were developed for combining hundreds of existing datasets into single nation-wide grids at 100m resolution of potassium, uranium, and thorium concentrations, and also the IAEA dose rate (Minty et al, 2009). The new radiometric Map of Australia was released in December 2008, and a preliminary RGB image is presented in Figure 2. Grid data can be downloaded via the GADDS facility on the GA website, and more products and refinements are currently under development for later release.

Geoscience Australia scientists have applied expertise in surface regolith processes developed during the CRC into Landform Evolution and Minerals Exploration (CRCLEME) to extract key geological signatures from the new products. These interpretations will be available in publications and reports, while some aspect will be included on the published map. The science of interpreting airborne radiometric data has not been widely adopted by industry in Australia because of the lull in uranium exploration in the previous twenty years. With the re-emergence of uranium as an important energy commodity it is important that interpretation and processing skills in government and research institutions are quickly transferred to explorers.
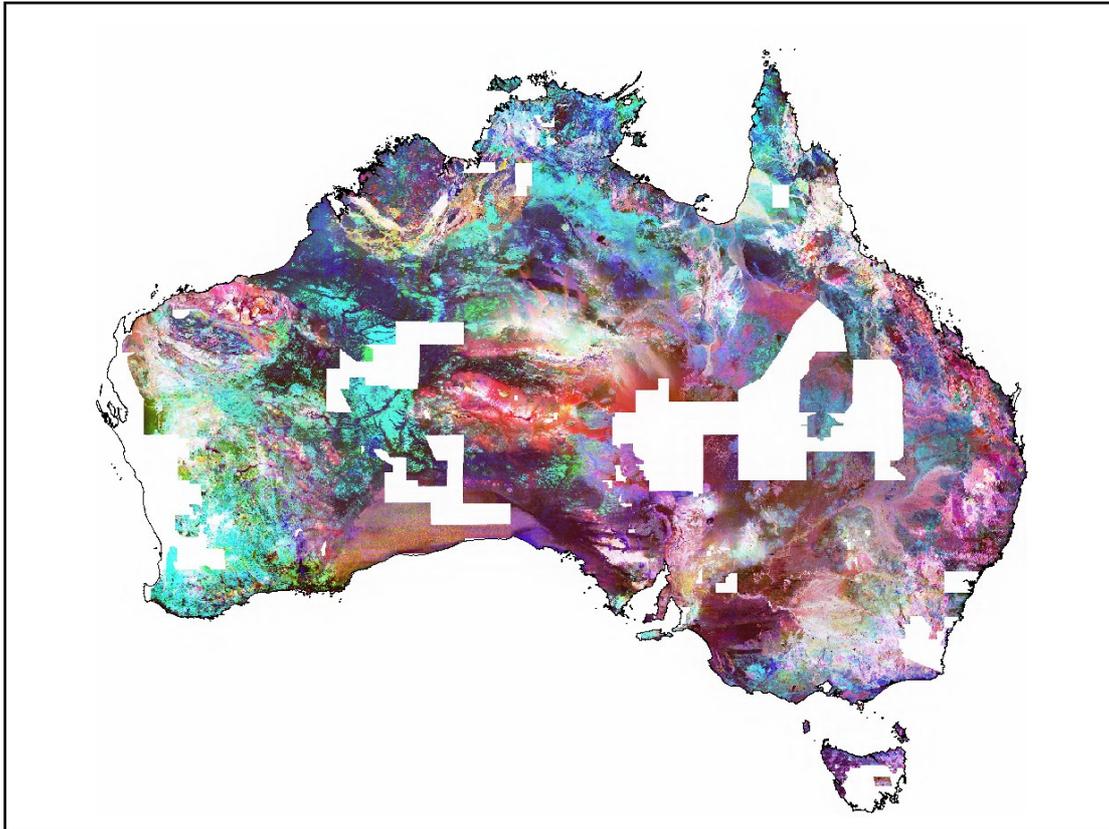
Figure 2: Ternary image of uranium (blue), thorium (green) and potassium (red) radioelement concentrations for Australia derived using the AWAGS survey results (after Minty et al, 2009).

URANIUM SYSTEMS PROJECT AND GEOTHERMAL ENERGY PROJECT

Australia hosts considerable defined uranium and geothermal resources, and has extensive scope for more discoveries. Uranium, and to lesser extent geothermal exploration has traditionally centred upon a search for particular geological features (i.e. a Proterozoic unconformity) which are deemed a necessary condition for a certain style of deposit. As part of the OESP, Geoscience Australia undertook a new holistic assessment of all geological processes that may be active in forming a significant uranium or geothermal deposit.

The CRC for Predictive Mineral Discovery (pmd*CRC) referred to mineral deposits as small parts of much larger geological phenomena called mineral systems. Similarly, geothermal resources can be considered as small elements of geothermal systems. The CRC proposed that mineral systems could be described by answering five questions about the geological processes that had been active:

1. What is the geodynamic setting?
2. What is the structural architecture?
3. What are the fluid sources?
4. What are the fluid drivers and pathways?
5. What are the deposition processes (traps)?

Geothermal systems can be described using the same questions but substituting 'heat' for 'fluid'. The Uranium Systems Project and Geothermal Project were established under the OESP to develop the mineral systems approach for energy resources. The projects provide a new geological framework for energy exploration and for interpreting pre-competitive geoscience information.

MT ISA – GEORGETOWN REGIONAL PROJECT

Analysis by Geoscience Australia suggested that although the Mt Isa province was well studied in terms of copper and base-metal deposits, the region had significant under-explored potential for uranium resources. This Proterozoic inlier hosts the historic Mary-Kathleen uranium mine as well as numerous other small uranium occurrences. Likewise, the Georgetown Province has had some exploration effort for copper and gold deposits, but also has unrealised potential for Phanerozoic basin-related uranium deposits. In addition, both the Mt Isa and Georgetown provinces are known to contain high heat producing granites as well as thick layers of sediments in younger overlying basins and, as such, should also be considered prospective for geothermal energy resources.

The Mt Isa – Georgetown provinces were examined with reference to the mineral systems framework described above. A program was designed to enhance the energy prospectivity of the area by:
1. Establishing the geodynamic framework for northern Queensland and the regional scale architecture of the provinces, and
2. Investigating the regional and local controls on mineral systems, in particular, possible fluid (heat) sources and fluid (heat) pathways.

The geodynamic framework question was addressed by acquisition of province-scale, deep crustal seismic and magneto-telluric (MT) surveys. A network of five traverses had been collected over the Mt Isa block in 2006 as part of a pmd*CRC project. The OESP and Geological Survey of Queensland co-funded a new program of three lines linking the Mt Isa and Georgetown Provinces (IG1, 440km long), spanning the Georgetown Province (IG2, 243km long), and linking the Georgetown and Charters Towers Provinces (GC1, 493km long). In addition, The AuScope program (part of NCRIS) funded a 205km line running north-east from Georgetown. The total coverage of seismic lines in north Queensland is presented in Figure 3.
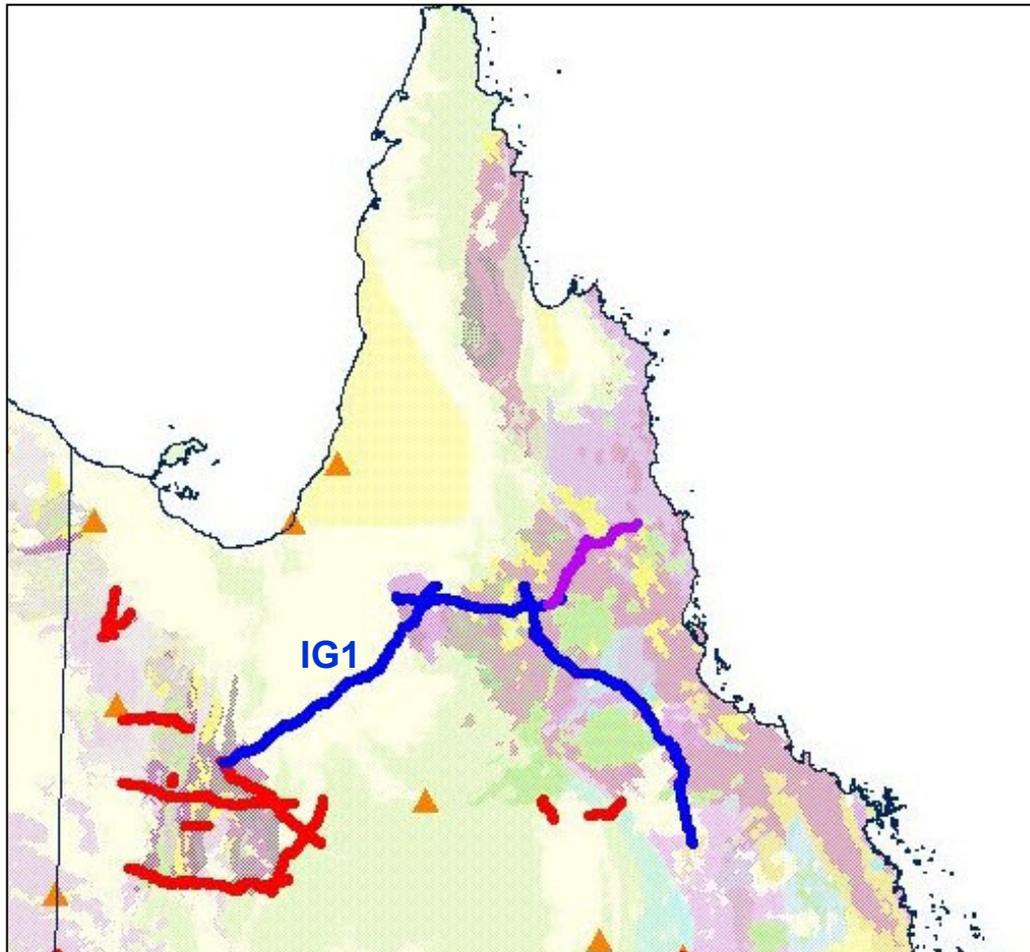
Figure 3: Location of deep reflection seismic traverses in north Queensland over schematic geology map. Surveys shown are Mt Isa 2006 (red lines), Mt Isa – Georgetown 2007(blue lines), and AuScope FNQ (purple line). The IG1 traverse linking the Mt Isa and Georgetown Provinces is labelled. Orange triangles denote passive-seismic stations. Pink and grey geology polygons indicate crystalline basement regions.

Seismic and MT data were collected along these lines in 2007 and are currently being interpreted by GA scientists in conjunction with the 2006 Mt Isa data. In all surveys, seismic data is recorded out to twenty seconds which is roughly equivalent to 60km depth, which allows interpretation of the full lithosphere above the Moho. Seismic and MT data from IG1 are presented in Figure 4. Many large-scale features are evident from both images including a previously un-detected basin underlying the shallow Carpentaria Basin, low-angle faults that penetrate to the Moho and possibly tap deep mantle fluids, and major step-discontinuities in the Moho that may represent geodynamic boundaries.

Specialist processing techniques will be applied to the deep crustal seismic to enhance the structural information. The resulting images will be interpreted with reference to expert understanding of the regional geology in order to establish the most probable geodynamic context for north Queensland. This includes the boundary between the Proterozoic North Australia Craton and the Phanerozoic of Eastern Australia.

The seismic and MT images will also be integrated with gravity inversion results, solid geology interpretations, stratigraphic studies and other information to construct a 3D GoCad model of north Queensland. Analysis of satellite spectral data, airborne radiometrics and geochemistry will map zones of mineral alteration and interpreted high fluid flux. Combination of mineralogical and structural information will highlight the active faults, fertile intrusions and other fluid (heat) sources and pathways that may constrain mineral and geothermal systems at the regional and local scales.
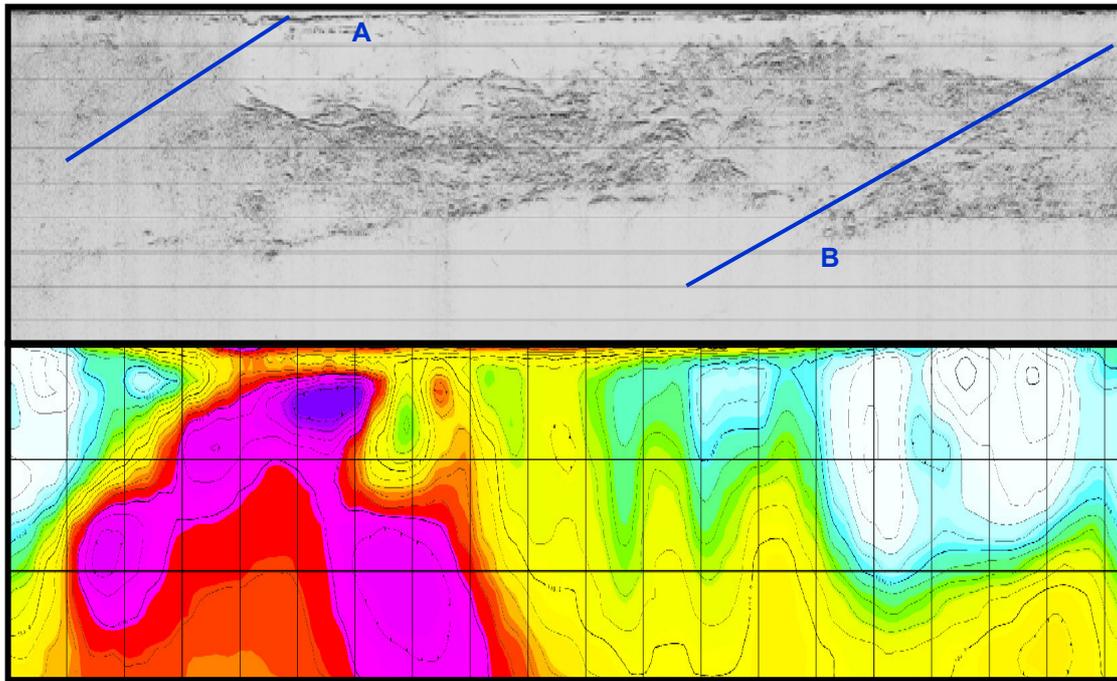
Figure 4: Field stack of seismic reflection data (top) and MT conductivity image (bottom for seismic traverse IG1. Both images are 440km long by 60km deep, warm colours denote high conductivities. Blue lines indicate interpreted low angle faults, which also separate zones of distinct seismic and MT character. A newly detected basin is shown at (A,) and a major break in the Moho at the base of the reflective lithosphere is evident at (B).

Outputs from the Mt Isa – Georgetown regional project will be in the form of basic seismic and MT data, processed and interpreted sections, GoCad model objects, reports and publications, maps of alteration, time – space event charts, and other predictive products. Data and products will be delivered at a series of regional interpretation workshops which will be open to all stakeholders from government, industry and academia. All products will also be accessible via the Geoscience Australia website. Regional projects based around seismic and MT acquisition are also planned for the Gawler and Curnamona Provinces in South Australia, the Pine Creek Province in the Northern Territory, and the Paterson Province in north-west Western Australia.

COOPER BASIN GEOTHERMAL STUDY

The Cooper Basin straddles the border between South Australia and Queensland and is the highest producing onshore petroleum basin in Australia. The area has had considerable exploration effort for hydrocarbons over the past forty years and high thermal gradients have been measured by temperature logging of numerous petroleum wells. Australia's first hot-rock geothermal energy project is being developed at Habanero, near Innaminka in South Australia. Habanero exploits high temperature gradients associated with granodiorite in basement beneath the Cooper and Eromanga Basins. As part of the OESP, Geoscience Australia assessed the potential for other hot granite bodies in the basement by modelling and inverting the gravity response over the region (Meixner and Holgate, 2009).

In 2007 the OESP funded the acquisition of 3548 new gravity stations on a 4km square grid pattern in south-west Queensland. An additional 9170 new stations were collected further north by the Geological Survey of Queensland as part of their QED data acquisition initiative. These data were combined with existing surveys and greatly improved the spatial resolution of gravity images over the Cooper Basin.
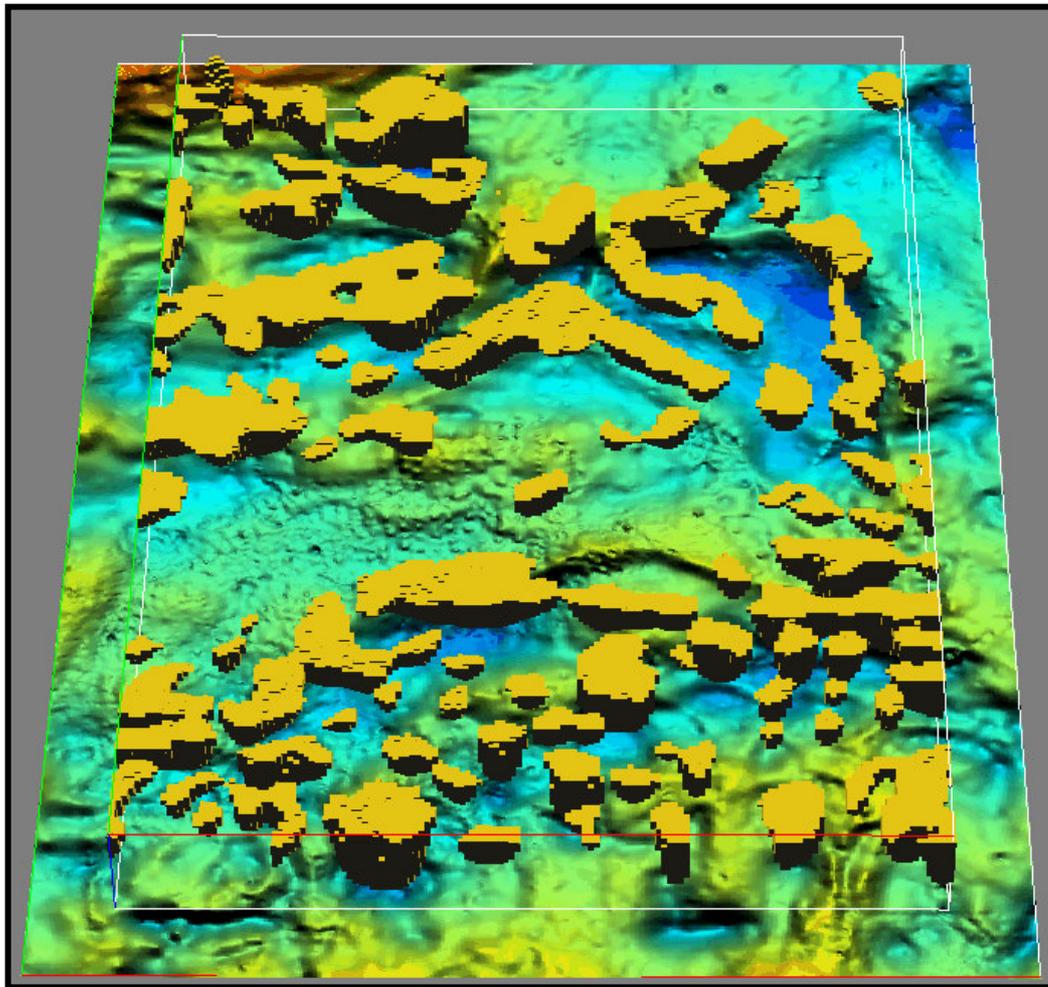
Figure 5: 3D map of the inferred distribution of sub-sediment granite for the Cooper Basin study area displayed over an image of the bouguer gravity anomaly (after Meixner and Holgate, 2009)

The gravity response was modelled for an area 300km east-west by 450km north-south and to a depth of 20km. Geometries in the model were constrained using seismic interpretations of the base of the Carboniferous Cooper Basin sediments and the base of younger Cretaceous Eromanga Basin. Model densities were estimated from seismic velocities derived from a seismic refraction study completed by the BMR (Collins and Lock, 1990).

The basin and basement model was inverted using programs developed by the University of British Columbia – Geophysical Inversion Facility (Li and Oldenberg, 1998). The resulting density iso-surfaces were compared with worm analysis of gravity images (Archibald et al, 1999) to determine which models were geologically reasonable. The selected iso-surface geometries were then inverted for basement densities which yielded the final 3D map of inferred basement granite distribution (Figure 5). The 3D map shows that considerable potential exists for significant geothermal exploration plays within the Cooper basin. The geometries of model will form the basis for future 3D thermal modelling of this highly prospective geothermal province

CONCLUSION

Under the OESP, Geoscience Australia is applying a range of geophysical methods across all states and the Northern Territory to assist industry by delivering pre-competitive data for hydrocarbons, uranium, thorium, and geothermal exploration. The data and information being

collected is also relevant for a host of other challenges facing Australia, including metals exploration, salinity mapping, defining ground water resources, and mapping natural hazards.

The Onshore Energy Security Program is providing data and scientific knowledge to enhance prospectivity and reduce risk in energy exploration at the national, regional, and geological province scale. The OESP will continue until June 2011, and is the latest embodiment of Geoscience Australia's ongoing mission to provide the highest quality pre-competitive exploration data for the Australian Continent. This body of science and information is a strategic asset which ensures that over the longer term, industry has the strongest opportunity to discover and develop the nation's mineral and energy resources for the benefit of all Australians.

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