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Geoscience Australia: Building Australia's resource wealth

Geoscience Australia (GA) exists to meet the geoscience information needs of the Australian Government. GA's strategic priorities are focussed on six key areas:

(i) Building Australia's Resource Wealth;
(ii) Ensuring Australia's Community Safety;
(iii) Securing Australia's Water Resources;
(iv) Managing Australia's Marine Jurisdictions;
(v) Providing Fundamental Geographic Information, and
(vi) Maintaining Geoscience Knowledge and Capability.

For more than six decades GA has been collecting geophysical datasets over the Australian region with the provision to the public of pre-competitive geophysical data a fundamental activity of the agency. GA, its predecessor organisations – the Bureau of Mineral Resources and the Australian Geological Survey Organisation – and the State and Northern Territory (NT) geological surveys continue to acquire geophysical data covering all jurisdictions (see reports from the other surveys in this section). Geophysical surveys have collected magnetic, radiometric, gravity, airborne electromagnetic, seismic (passive and active), and magneto-telluric datasets at various resolutions depending on the aims of the respective surveys. Through collaboration with governments at all levels, GA is the custodian of the largest publicly available geophysical databases in Australia. These geophysical databases can then be combined with other geoscientific datasets (e.g. geology, geochemistry and geochronology) to enable GA to build and map the national geological framework of the continent in order to inform resource exploration and development. This knowledge is publicly available to enable the development of new methods and tools, and new data interpretations to accurately assess the resource prospectivity of the Australian continent. This information enables industry to explore and invest in Australia with confidence.

Onshore geophysical activity

GA is currently addressing the challenge of delivering geoscience solutions to reduce exploration risks where a relatively thin veneer of regolith covers the prospective basement rocks. GA is collaborating with stakeholders from government, industry and research institutions on what is known as the UNCOVER initiative (http://www.uncoverminerals.org.au), which has four main themes:

(i) Characterising the cover – lifting the veil on mineral deposits;
(ii) Lithospheric structure – understanding the architecture of mineral systems;
(iii) 4D geodynamic evolution and metallogenesis – understanding the processes that control mineral deposit formation, and
(iv) Distal mineral footprints – improving our ability to detect the presence of mineral deposits across a range of scales

The first theme aims to define the nature and character of the cover and the depth to prospective basement rocks. The use of geophysics is essential to capture baseline data to provide information on the geological context of an area for mineral systems.

The current flagship geophysical activity at GA is the AusLAMP (Australian Lithospheric Architecture Magneto-telluric Project), which is collecting long-period broad-band data on a 0.5° grid (55 km) across the continent

The current flagship geophysical activity at GA is the AusLAMP (Australian Lithospheric Architecture Magneto-telluric Project), which is collecting long-period broad-band data on a 0.5° grid (55 km) across the continent. The aim is to produce a national conductivity dataset of Australia to complement the other national datasets previously released by GA – geology, gravity, magnetic, radiometric and geochemistry. This project started in 2013–14 in Victoria and is continuing into South Australia, Tasmania and New South Wales in 2016. The AusLAMP project was 16% complete as at 1 July 2016.

The national datasets mentioned above are made possible by GA's continued acquisition of geophysical survey data over the past six decades. All these data (Commonwealth, State and NT) are contained in national geophysical databases of which GA is the custodian. The data from these databases can be discovered and delivered free-of-charge through the Australian Geoscience Information Network (AusGIN – http://www.geoscience.gov.au), which brings together geological and geophysical information for mineral exploration in Australia.

To enable interpretation of the geophysical datasets GA has built the National Rock Properties Database (http://www.ga.gov.au/explorer-web/rock-properties.html) to provide access to petrophysical data (e.g. mass density and magnetic susceptibility) that links the observed geophysical data and interpreted geology.

With improvements in instrumentation and data processing methods these geoscientific datasets are being produced at finer resolutions. This makes utilising these datasets as an end-user increasingly challenging. To meet this challenge GA and its partners (CSIRO and the State/NT geological surveys) are developing the Australian National Virtual Geophysical Laboratory that will provide the exploration industry with easy online access to existing and new, pre-competitive datasets and geophysical analysis tools at both State and Commonwealth levels.

The 3rd edition of the National Gravity Bouguer Anomaly Grid is being released at the 25th ASEG Conference

The data and tools will be of use to the government agencies, research sector and private companies for analytical and research purposes.

The 3rd edition of the National Gravity Bouguer Anomaly Grid is being released

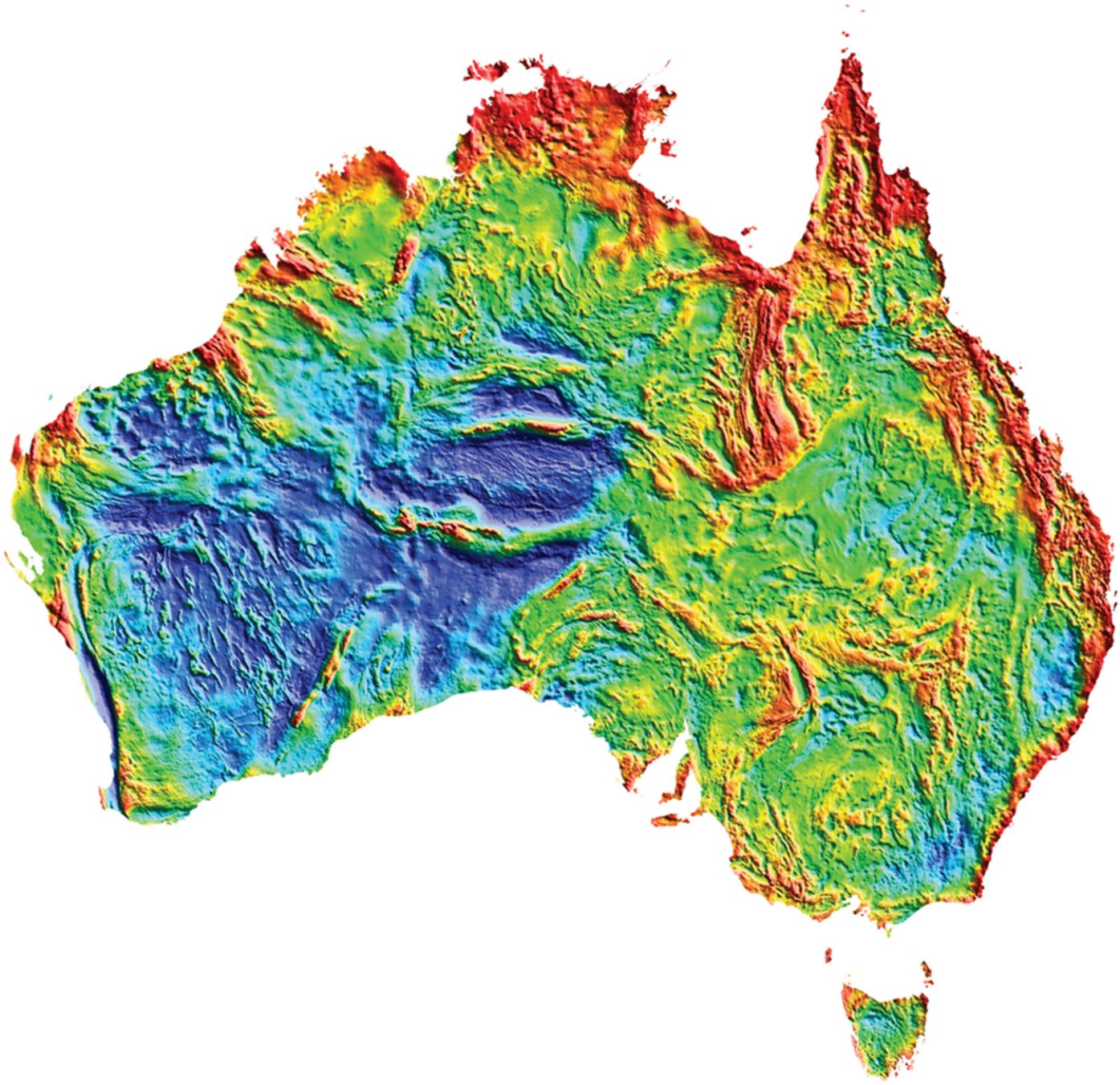

Figure 1. *Bouguer Gravity Grid of Australia 2016 (anomaly values are coloured from blue (low) to red (high).*

at the 25th ASEG Conference (Figure 1). This is the latest edition, replacing the 2nd edition released in 2009, and contains an additional 100 000 gravity stations from surveys collected by GA, states and the NT.

Offshore geophysical activity

GA continues to acquire pre-competitive geophysical data on Australia's continental margin. The most recent data acquisition has taken place in the frontier northern Houtman Sub-basin off Western Australia (http://www.ga.gov.au/about/projects/energy/northern-houtman-sub-basin-project), and as part of a collaboration with the Japan Agency for Marine-Earth Science and Technology (JAMSTEC) that aims to drill a deep stratigraphic well through a rift basin on the Lord Howe Rise off eastern Australia (http://www.ga.gov.au/about/projects/energy/lord-howe-rise).

Northern Houtman Sub-basin

Between November 2014 and January 2015, GA acquired 3 455 km of new 2D seismic data in the northern Houtman Sub-basin (Figure 2), a large offshore frontier basin. The data on 25 lines with a 12 second record length and a sample rate of 2 milliseconds were processed using anisotropic PreSTM and PreSDM, including the application of a deghosting algorithm. The data from GA survey 349

were publicly released at APPEA in June 2016 and are available by contacting AusGeoData@ga.gov.au.

Geoscience Australia is using these new data as part of a study to better understand the potential hydrocarbon prospectivity of the Houtman Sub-basin. This study includes seismic interpretation tied to petroleum exploration wells in the southern Houtman and Abrolhos sub-basins, mapping of potential source rocks and petroleum systems modelling. The study will also contribute to a better understanding of the tectonic evolution of the Western Australian margin. The results of the prospectivity study and interpretation of the new seismic data will be completed in 2017.

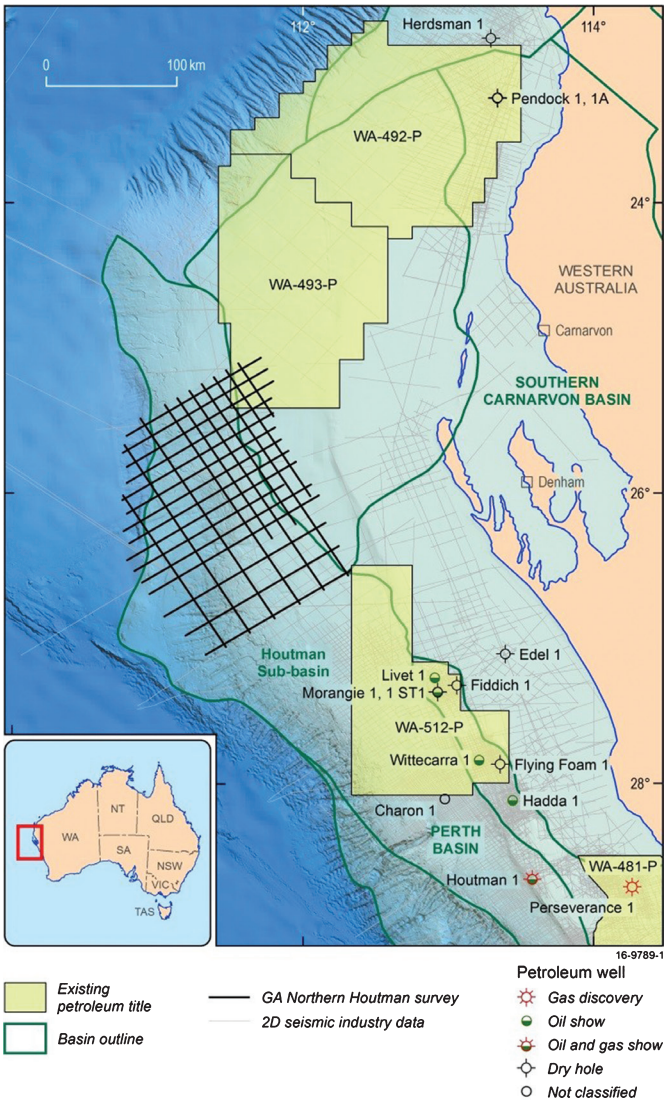

Figure 2. *Location of the northern Houtman Sub-basin 2D seismic survey lines (GA349) acquired between November 2014 and January 2015.*

Lord Howe Rise

A proposal for drilling up to 3500 m below the seafloor through a Lord Howe Rise (LHR) rift basin using the JAMSTEC drilling vessel CHIKYU is currently under review with the International Ocean Discovery Programme (IODP). The objectives of the IODP deep stratigraphic drilling are to:

1. define the role and importance of continental crustal ribbons, like the Lord Howe Rise, in plate tectonic cycles and continental evolution;
2. recover new high-latitude data in the southwest Pacific to better constrain Cretaceous paleoclimate and linked changes in ocean biogeochemistry; and
3. test fundamental evolutionary concepts for sub-seafloor microbial life over a 100-million-year timeframe.

The IODP deep stratigraphic drilling is supported by a programme of geophysical data acquisition to define the geological framework of the proposed drill sites and the crust and upper mantle structure of the Lord Howe Rise extended continental ribbon. JAMSTEC and GA, together with participants from the University of Sydney and GNS Science (New Zealand), successfully completed the first of two pre-drilling site surveys in May 2016 (Figure 3). This survey acquired 2D seismic reflection data and seismic refraction data, recorded by 100 ocean-bottom seismometers, on a long, east-west transect across the LHR to map regional crustal structure. Additional data acquired during the survey included ~600 line km of high-resolution multi-channel seismic data over the proposed drill sites, as well as multibeam bathymetry, sub-bottom profiler, gravity and magnetic data. All data collected during this survey will be made publicly available.

More information about GA's geophysical programmes can be obtained from:

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Please visit us at ASEG-PESA-AIG booths 66 and 69.

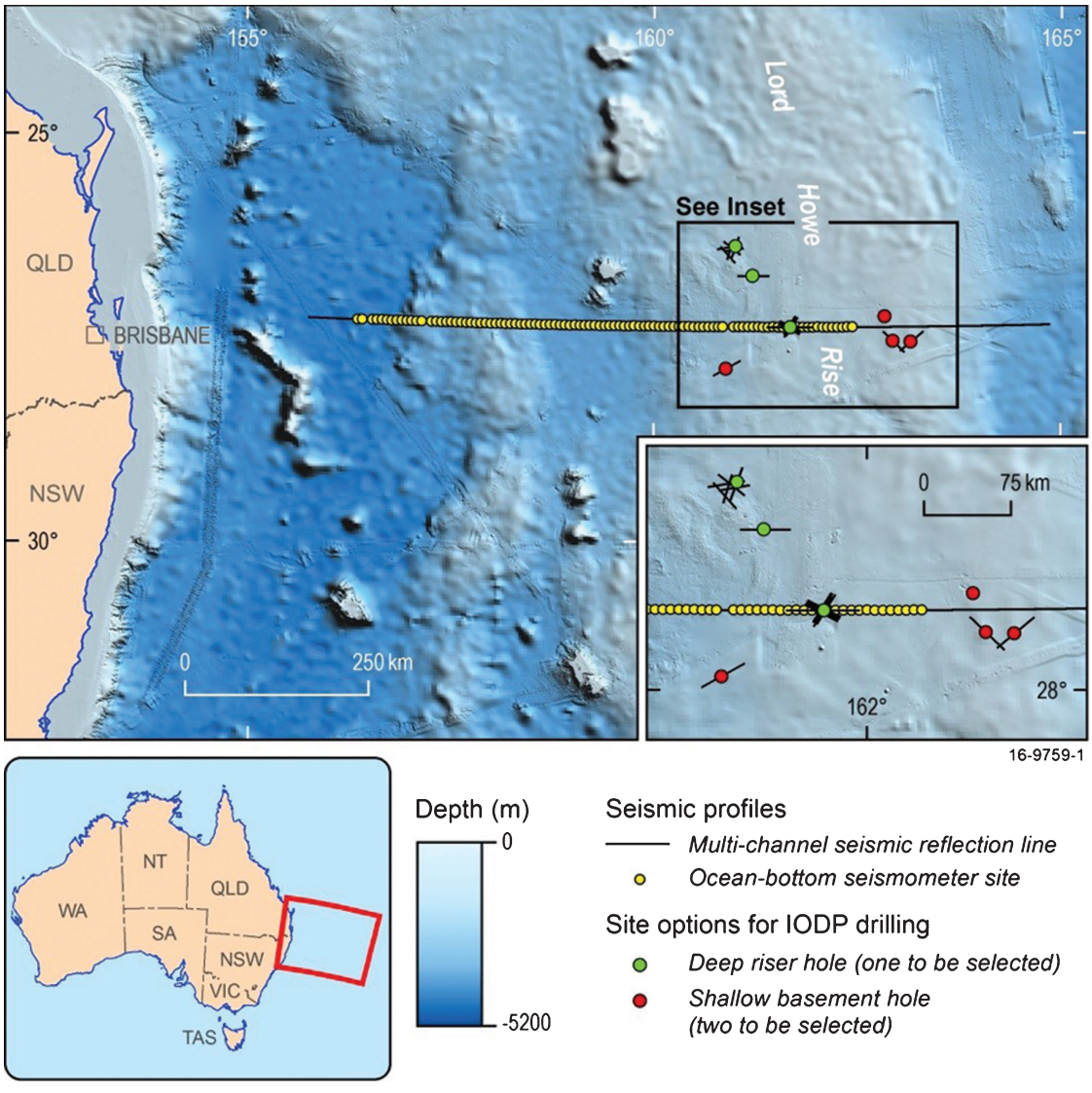

Figure 3. *Lord Howe Rise Project study area, showing seismic lines acquired during the 2016 geophysical survey and the locations being considered for deep stratigraphic riser drilling and shallow basement drilling.*

The Geological Survey of South Australia: Geoscience for the benefit of South Australians

The Geological Survey of South Australia (GSSA) has an active Geophysics and Prospectivity Team, dealing with all things geophysical and GIS related. This article provides an overview of recent activities the team has been involved in. For more information please visit the GSSA in the Exhibition Hall at ASEG-PESA-AIG 2016.

Gravity

The most recent in-house gravity survey was conducted in late 2015 to tie in gravity stations in the Carrieton area, and to investigate options for a new Australian Fundamental Gravity Network station at Horrock's Pass south of Port Augusta. In collaboration with Geoscience Australia (GA) several new AFGN sites have been installed in the Adelaide region, as well as at numerous regional locations. The SA Government is also funding a major gravity survey in the far west of the state to cover the Coompana Anomaly.

Airborne surveys

The latest magnetics and radiometric survey was the Coompana survey completed in late 2015. The magnetics data are available for download via SARIG and at the time of writing we are still waiting on the final radiometric data. The next magnetic and radiometric survey will cover much of the Gawler Province at 200 m line spacing and a constant 60 m flying height. This will standardise the coverage over the Gawler and the higher resolution will allow greater understanding of the subsurface geology.

The GSSA is custodian of four radiometric calibration pads. Until recently these were stored at our Thebarton depot in suburban Adelaide. We're relocating these pads to Rollos Airfield, near Monarto and Murray Bridge. This will allow aircraft-mounted spectrometers to be calibrated. To organise a time to use these pads please contact the geophysicists at the GSSA. There is no charge to use them.

There are now 88 Airborne EM surveys available for download through SARIG, with more to come. Visit the SA Government booth at the trade exhibition for a demo of how to download these data for free.

Magnetotelluric surveys

There has been increased activity in the western part of the state with two magnetotelluric (MT) surveys, the 50 km spaced AusLAMP long-period MT grid across the Maralinga Tjarutja Lands and the Nullarbor Reserve, as well as the 5 km spaced broadband MT profile along the railway line (see Figure 1). After the completion of the Maralinga Tjarutja AusLAMP MT acquisition in December, the data have been processed and MT responses of 52 long-period MT stations are being prepared for 3D inverse modelling. The joint project between the GSSA, GA and the University of Adelaide extends the AusLAMP MT coverage westward from the Central Gawler Craton, the Flinders Ranges and the Coompana Province and will provide crucial constraints on the crustal and mantle lithospheric architecture of the largely unexplored western margin of the Gawler Craton as well as the Coompana Province.

There are now 88 Airborne EM surveys available for download through SARIG, with more to come

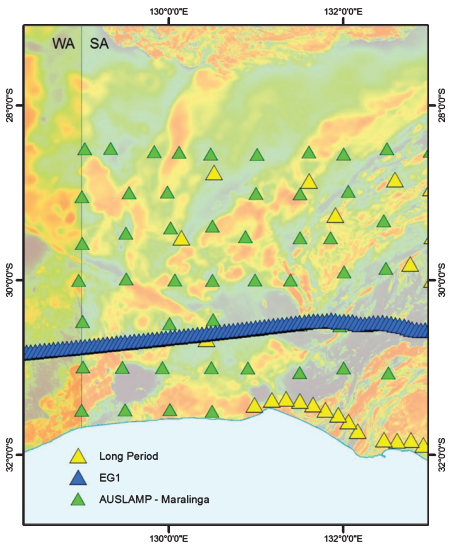

Figure 1. *MT station locations of the AusLAMP MT grid, the EG1 MT profile along the railway line and legacy long-period data collected by the University of Adelaide across the western part of South Australia.*

The broadband EG1 MT line, co-located with the seismic reflection line, crosses the AusLAMP grid in the far west of the state. Modelling of the broadband MT data is underway and was presented in a dedicated session at the AESC conference (June 2016, Adelaide) for the entire 1200 km long section from Tarcoola to the western side of the Albany Fraser Orogen in WA. This profile, with over 200 MT sites, will illuminate the basement of the entire Nullarbor Region from east to west and further our understanding of the tectonic evolution of this underexplored area.

State images

A new 2016 edition of the State TMI aeromagnetic grid is nearing completion. There remain a small number of surveys which require further reprocessing and correcting. This grid has been compiled from a total of 342 airborne surveys flown within the South Australia and includes the Marree/Warrina and the new 2015 Coompana survey. The final processed grid resolution is 35 m.

The compilation and production of a new suite of State Radiometric grids has also been commenced. It is anticipated that final Dose, Total Count and Potassium grids will be available before the end of this calendar year.

As we reported in the last edition of *Preview,* there are now approximately 680 000 gravity stations available for download through SARIG (compared with approximately 495 000 prior to May this year). These new data are feeding into new state gravity images. Laz Katona has been working on a supervised variable density algorithm to better grid gravity datasets. Figure 2 shows some preliminary results.

3D modelling

The South Australian Depth to Crystalline Basement Data Package is a collection of GIS datasets (in ArcGIS and MapInfo formats) that portray actual or inferred depth to crystalline basement in South Australia, and have been assembled on a province-by-province basis. Crystalline basement for the purposes of this dataset

is generally taken to be the shallowest rocks affected by a pervasive orogenic event in any given area. This dataset includes: basement intersecting drillholes, seismic and AEM points, outcropping basement geology polygons, a data reliability map, basement elevation grid, cover thickness grid and a basement elevation TIN file. The Depth to Crystalline Basement Data Package (GDP00003) can be downloaded via the following URL: http://tinyurl.com/zppulko.

The GSSA also has an active programme producing a variety of 3D models within key regions of South Australia. The Fleurieu Peninsula Earthquake Hypocentres model (http://tinyurl.com/htmgy68) highlights 100 earthquakes between 2007 to mid-2015 in a region with dense seismograph coverage. The model consists of an earthquake magnitude map, ranging from near 0.0 to 3.8 near Mount Barker and a 'quake reliability' map showing the error ellipses (2σ) of the hypocentres.

The Eastern Gawler/Woomera Prohibited Area 3D map, a collaboration between Department of State Development (DSD), the University of Adelaide and the Deep Exploration Technologies Cooperative Research Centre (DETCRC), integrates one hundred years of publicly available datasets. This model provides background data to help interpret the IOCG mineral prospectivity in the Eastern Gawler Craton. The Eastern Gawler/Woomera Prohibited Area data package (GDP00010) can be downloaded via the following URL: http://tinyurl.com/zu6udoa.

there are now approximately 680 000 gravity stations available for download through SARIG

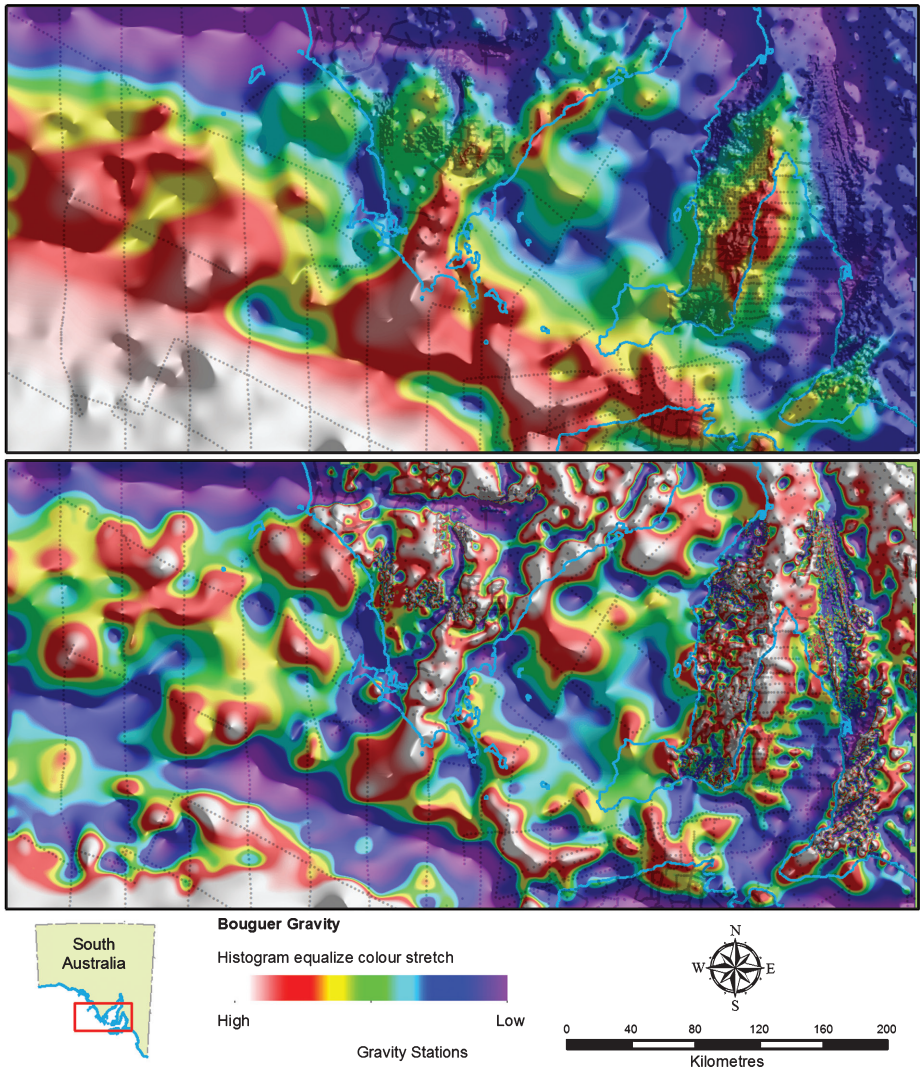

Figure 2. *The figure at the top has been gridded using a supervised variable density methodology, resulting in a smooth grid and minimising gridding artefacts. The figure at bottom is a vertical gravity gradient (1VD) of the top image.*

GIS and map releases

Working alongside the geological survey's Mineral Systems Drilling Programme (MSDP), geological mapping of the Cariewerloo, Peltabinna and Mt Double areas has been completed. This mapping will soon be released as 3 special edition 1:75 000 maps with accompanying reports describing the stratigraphy and geological history.

The MSDP geological mapping programme also comprises a detailed regolith map. Regolith maps of the Southern Gawler Ranges Margin (YARDEA and PORT AUGUSTA 1:250 000 map sheets), all 1st editions, will be available later this year.

A forthcoming release from the Mapping the Musgrave Programme is the new compilation of the ALCURRA 1:100 000 map sheet, which now contains more lithological subdivisions, increased geochemical, isotopic and geochronological control, and greater structural understanding of the area.

Geological and geophysical interpretation

Following the release of the 2015 Coompana Airborne Survey, the largest of its kind in South Australia, the GSSA has been working on deciphering the geology of the Coompana Province in the west of South Australia (Figure 3). This work has been detailed in a short article on geological interpretation of the aeromagnetic imagery of this region (https://sarigbasis.pir.sa.gov.au/WebtopEw/ws/samref/sarig1/image/DDD/MESAJ079.pdf).

The increased resolution (200–400 m line spacing compared to 1600–3000 m previously) of the 2015 survey has enabled contact relationships and relative age constraints to be placed on the body causing the enigmatic Coompana magnetic anomaly.

In conjunction with interpretation of the aeromagnetics, the GSSA has been working collaboratively with GA, the Geological Survey of Western Australia and the Australian National University to interpret the Coompana section of the Eucla-Gawler seismic line (13GA-EG1).

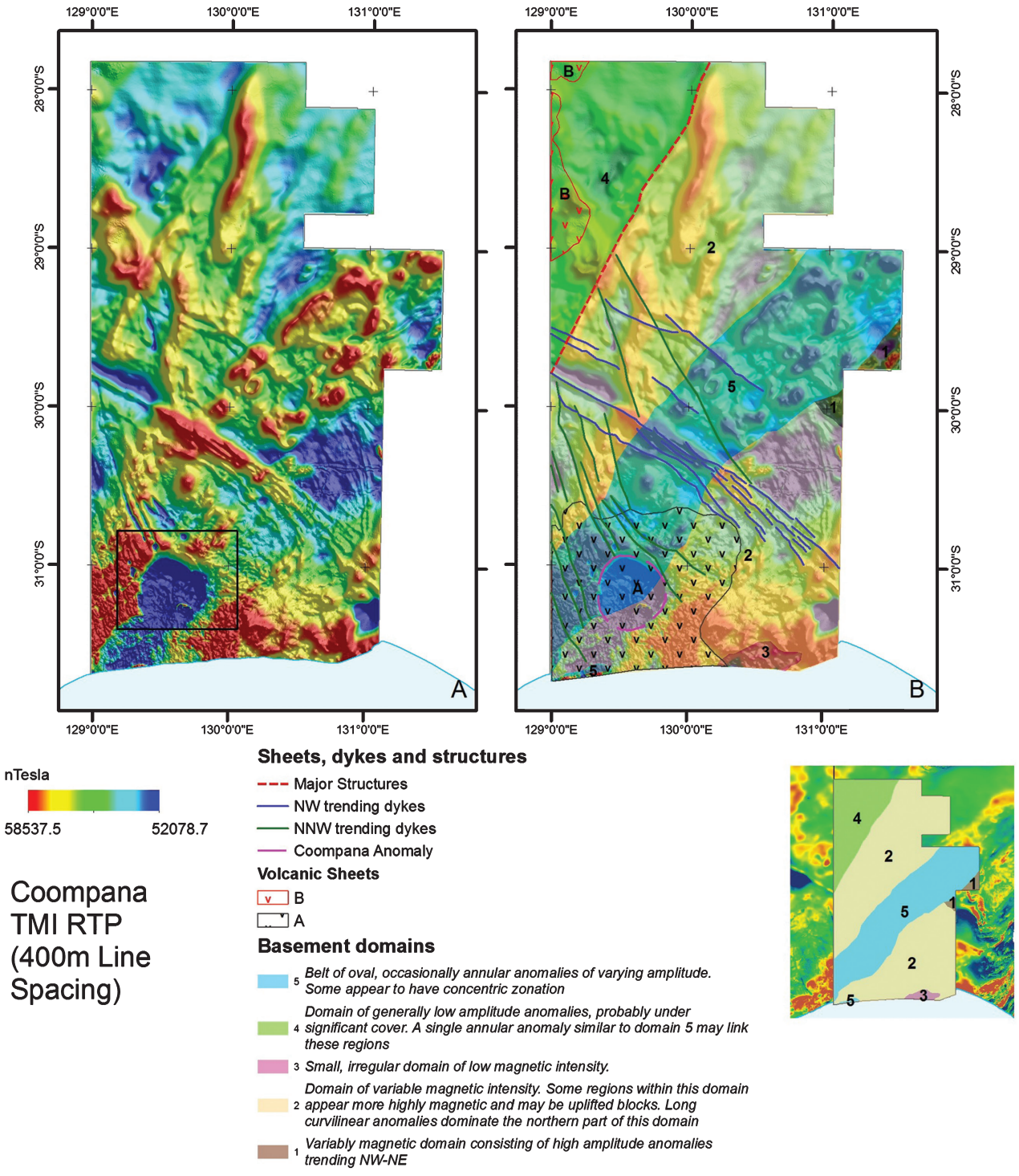

Figure 3. *Basement domains, sheets, dykes and structures of the Coompana Province based on interpretation of the 2015 Coompana Airborne Survey.*

The results of this work were presented in a dedicated session at the Australian Earth Sciences Convention (June 2016, Adelaide).

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Northern Territory Geological Survey: Creating opportunities for resource exploration

CORE (Creating Opportunities for Resource Exploration) is a four year, $23.8 million exploration initiative launched by the Northern Territory Government in 2014. The initiative builds on the original CORE launched in 2013 and is designed to maximise opportunities for exploration, discovery and development of new mineral and petroleum resources.

The Northern Territory Geological Survey (NTGS) is currently undertaking a range of regional geoscience programmes funded by CORE and focussing on the Arunta Region, Arnhem Province Amadeus and greater McArthur basins. Geophysical acquisition programmes aimed at improving ground gravity resolution across the Amadeus and greater McArthur basins to 4 km or better, and airborne magnetic and radiometric coverage to 500 m line-spaced or better, are largely complete. Since the original CORE initiative six gravity surveys covering over 30% of the NT mainland have been completed and data released (Figure 1). The NTGS Daly Basin Gravity Survey is currently underway and the NTGS South Nicholson Gravity Survey is planned for mid-2017 completing regional ground gravity coverage across the Amadeus and greater McArthur basins. Two magnetic and radiometric surveys have been acquired (Figure 2), completing the magnetic and radiometric acquisition programme.

In 2015 PGN Geoscience was contracted to produce a potential field structural interpretation of the greater McArthur Basin (NTGS, 2015). This project was aimed at understanding the structural evolution of the basin and has provided key information on fault timing and kinematics. This has then been integrated with other datasets including outcropping geology and cross sections, seismic and drill-hole data to build a 3D model of the greater McArthur Basin (Bruna and Dhu, 2016). Two 3D models of the Mesoproterozoic Wilton package are currently available: one incorporates the extent of the Mesoproterozoic stratigraphy across the greater McArthur Basin; the second focusses on the thickest stratigraphic section, the Beetaloo Sub-basin (Figure 3), highly prospective for shale gas. Both these models are revised on a regular basis as new data becomes available and understanding of the basin's structure and evolution evolves.

The PGN Geoscience structural interpretation of potential field data was completed prior to the North McArthur Basin, North Wiso Basin and Victoria Basin gravity surveys and both magnetic and radiometric surveys being acquired. This work is currently being revisited in collaboration with CSIRO through a CSIRO postdoctoral researcher embedded with NTGS working on potential field modelling and interpretation of the newly acquired data. To assist this work rock properties (primarily bulk density and magnetic susceptibility) are being both acquired by NTGS in conjunction with the NTGS HyLogger programme and compiled from archival data such as industry exploration reporting (Hallett, 2016).

The newly acquired geophysical surveys are available both on request to the Department of Mines Infocentre (geoscience.info@nt.gov.au) or downloadable via GADDS (www.geoscience.gov.au/gadds). Images of the individual surveys are available on the NTGS Geophysical Image Web Server (www.geoscience.nt.gov.au/giws) along with Territory wide images incorporating the new data; these Territory wide images are also available on the Spatial Territory Resource Information Kit for Exploration (www.strike.nt.gov.au). Please visit the NTGS booth for further information on these and the many other geoscientific resources available.

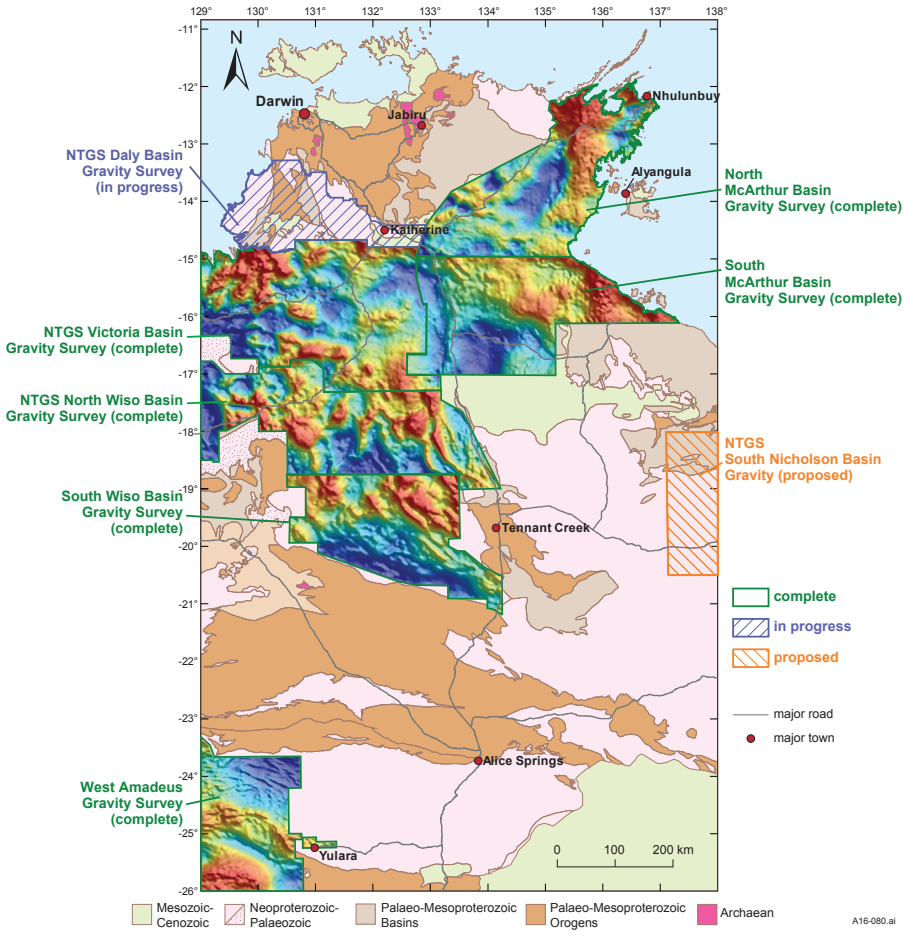

Figure 1. *Location of ground gravity surveys: completed, planned or proposed under the CORE initiative. Bouguer anomaly images for completed surveys (outlined in green) are shown on the map. Discontinuities at the boundary between adjacent images are the result of colour stretches being applied to individual surveys rather than continuously.*

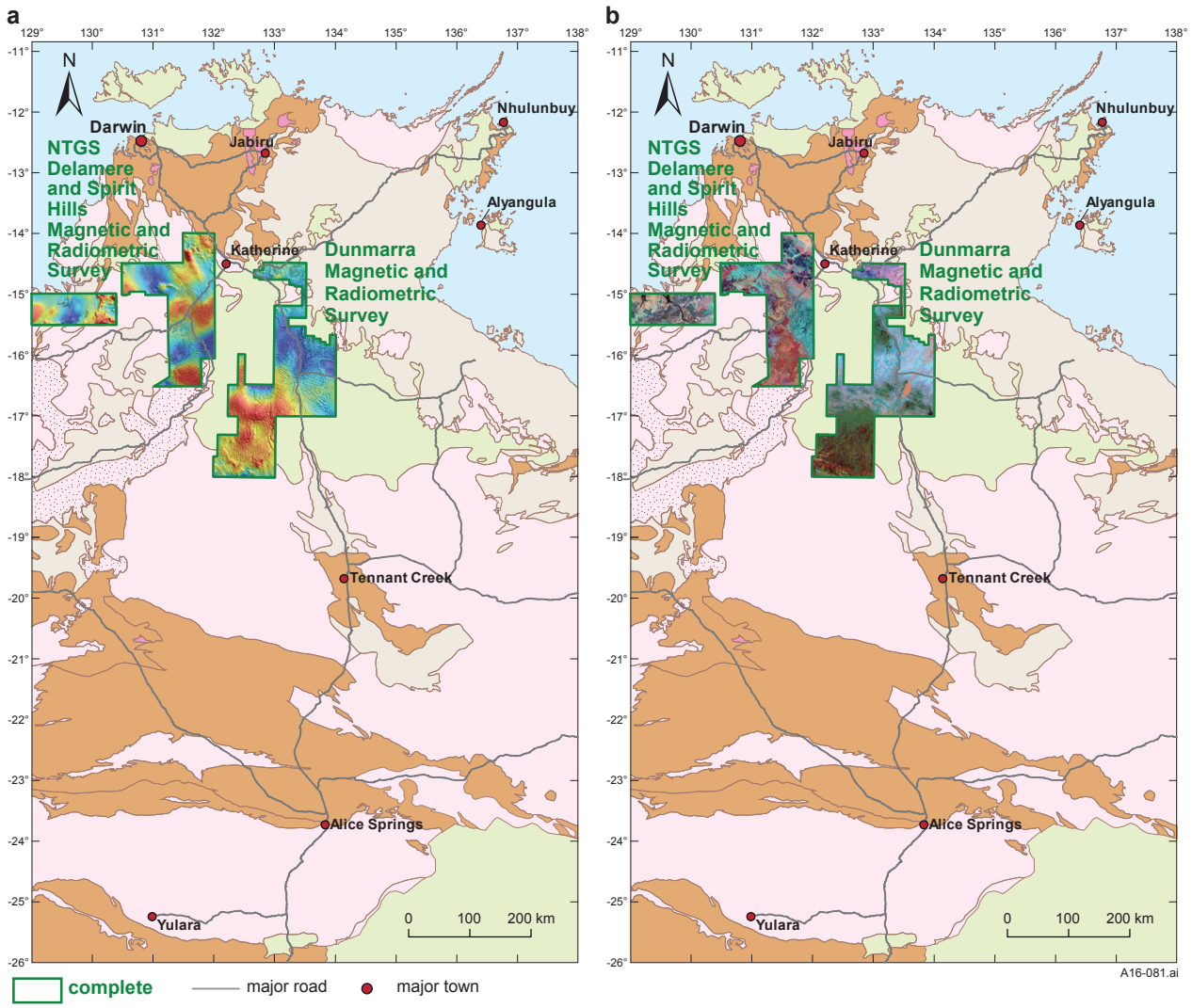

Figure 2. *Location of magnetic/radiometric surveys completed under the CORE initiative (a) Magnetic: reduced to pole, total magnetic intensity is plotted for each survey. (b) Radiometric: ternary radiometric image (red is potassium, green is thorium and blue is uranium) is plotted for each survey.*

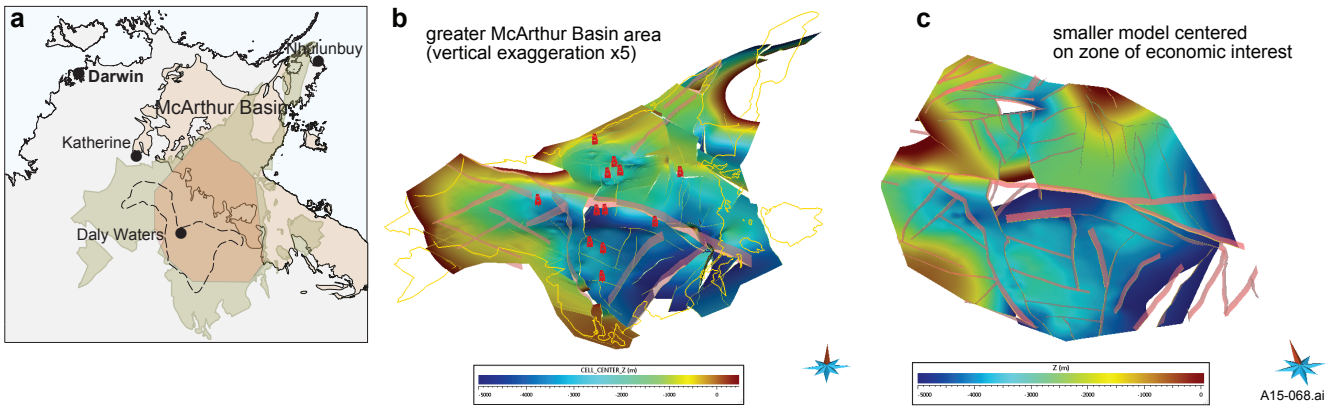

Figure 3. *3D architecture of the base Wilton package: (a) location of modelled area (greater McArthur Basin model extent is shown in green, Beetaloo Sub-basin model extent is shown in red, Beetaloo Sub-basin outlined by dashed line), (b) surface showing depth to the base of the Wilton package in the greater McArthur Basin and (c) surface showing depth to the base of the Wilton package in the Beetaloo Sub-basin.*

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Hallett, L, 2016, Rock property dataset of the Northern Territory (March 2016). Northern Territory Geological Survey, Digital Information Package DIP 013.

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Geological Survey of Western Australia: Update on progress of 'Generation 2' gravity coverage

The Geological Survey of Western Australia (GSWA) completed 'second generation' airborne magnetic and radiometric coverage of Western Australia at a line spacing of 500 m or less with an accelerated programme of surveys between 2009 and 2012 that was undertaken under the State Government's Exploration Incentive Scheme (EIS). GSWA then turned its attention to completing the upgrade of Western Australia's regional gravity coverage to 'Generation 2' standard. 'First generation' data is defined as the continental coverage by the then Bureau of Mineral Resources of aeromagnetic and radiometric surveys at line spacing of 800 m – 3200 m and ground gravity surveys at 11 km station spacing.

In May 2013, GSWA and Geoscience Australia (GA) entered into a seven-year National Collaboration Framework Project Agreement titled 'WA Reconnaissance Gravity Surveys 2013–20 (WARGRAV2)' with the objective of completing gravity coverage of Western Australia at a spatial wavelength resolution of 5 km or less (equivalent to ground station spacing of 2.5 km).

When the WARGRAV2 Project commenced in July 2013, approximately 60% of the area of Western Australia – about 1.5 million square kilometres – remained to be covered to the required standard (accepting that it may not be practical to upgrade areas that had been surveyed at 4 km spacing between 1995 and 2005).

300 000 km^2 have been completed

Since then, with continuing funding from the EIS and under project management by GA, five stages covering about 300 000 km^2 have been completed with helicopter-assisted ground surveys in more remote areas or by road traverses in the south and southwest of the State. A sixth stage of helicopter-assisted ground measurements over an area of some 100 000 km^2 is currently in progress in the Wiluna area in central Western Australia with final coverage dependent on the outcome of land access negotiations (see Table 1 and Figure 1).

100 000 km^2 is currently in progress

As land access issues become more time consuming, GSWA and GA have been investigating the viability of airborne gravity surveys. With current airborne survey technology able to provide along-line wavelength resolution of 4–6 km — about the same as that from ground gravity station spacing of 2.5 km — it is considered that despite their still substantially lower precision, airborne gravity surveys can provide 'regional interpretability equivalence' with ground measurements at 2.5 to 4 km station spacing.

A request for tender for an airborne gravity survey over an area of 80 000 km^2 in the East Kimberley was issued by GA in June 2016. Responses are being reviewed with the intention of awarding a contract for a survey of up to 38 000 line km with a line spacing of 2.5 km as the seventh stage of the WARGRAV2 Project.

The WARGRAV2 Project is in addition to GSWA's other geophysical data acquisition programmes including:

- 100 m aeromagnetic and radiometric surveys over selected areas
- passive seismic surveys in the Capricorn and Albany–Fraser areas
- deep seismic and magneto-telluric traverses
- regional airborne electromagnetic survey plans.

For further information, please contact GSWA on geophysics@dmp.wa.gov.au.

Table 1. WARGRAV2 project stages

Stage: FY	Survey name	Stations	Survey configuration
1: 2013–14	Esperance 2013	7891	2.5 km grid (helicopter); 1 km road traverses
2: 2013–14	Goldfields 2013	8119	2.5 km grid
3: 2013–14	Sir Samuel – Throssell 2014	11 662	2.5 km grid
4: 2014–15	Ngururrpa 2015	4964	2.5 km grid
5: 2015–16	Southwest Yilgarn 2015	23 736	2 km road traverses
6: 2016–17	Wiluna 2016 (in progress)	Up to 15 000	2.5 km grid (coverage extent dependent on land access negotiations)
7: 2016–17	East Kimberley 2016 (request for tender)	38 000 km	Airborne gravity, 2.5 km line-spacing

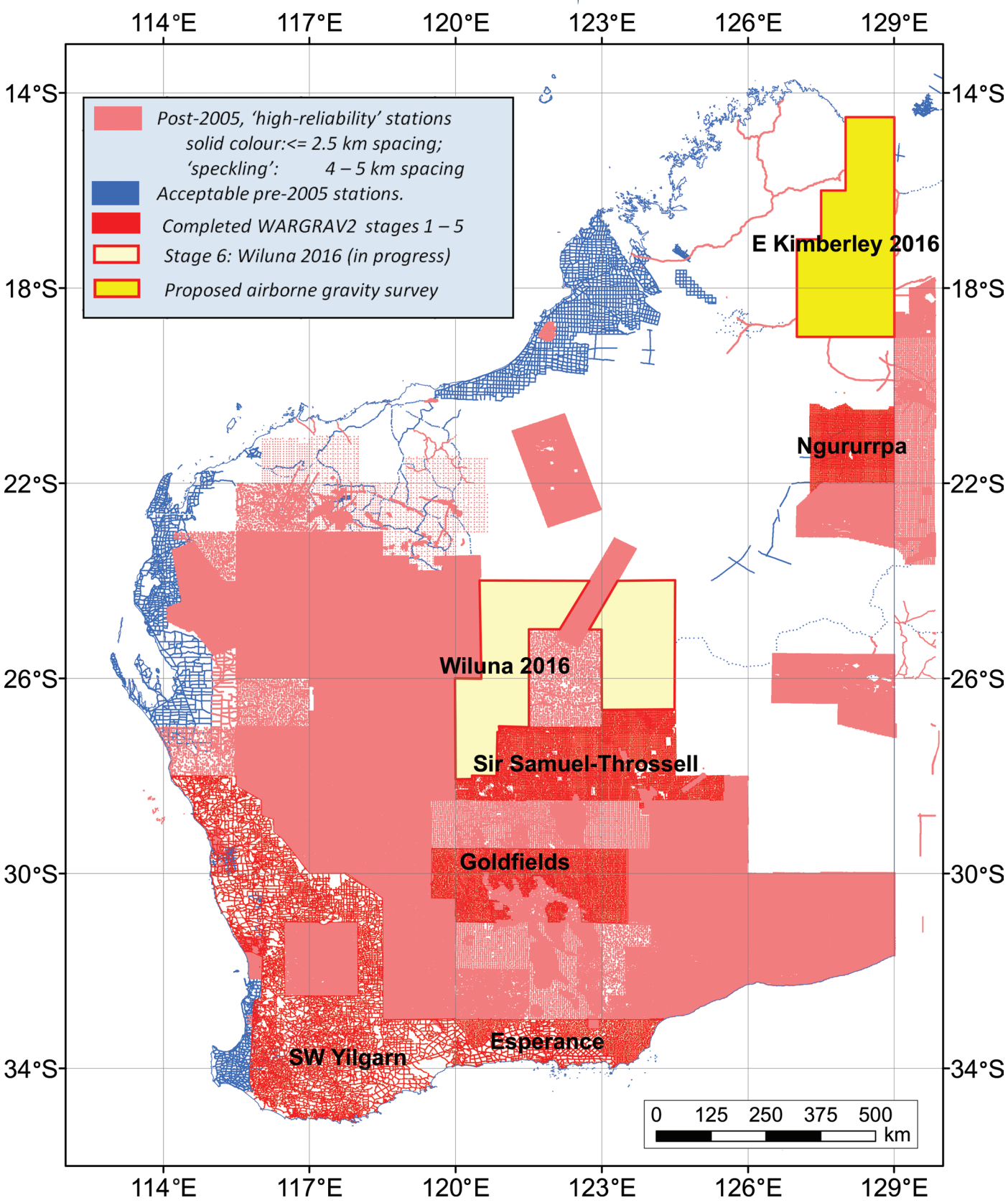


Figure 1. *Distribution of 'Generation 2' ground gravity stations in National Gravity Database (stations with a GA 'reliability rating' of five or more).*

Geological Survey of Queensland: Latest happenings

Now in its final year of funding, the Queensland Government's Future Resources Programme is keeping the geophysics team at the Geological Survey of Queensland (GSQ) busy as we enter the final stages of collecting new precompetitive data and begin releasing and publishing new products for explorers in Queensland.

Magnetotelluric surveys

Adding to our already extensive collection of high resolution magnetotelluric (MT) surveys, GSQ is collecting further MT stations at 2 km grid spacing in the Cloncurry area (Figure 1). There are approximately 490 planned sites to be collected over more than 2000 km^2. Acquisition of the data commenced in July and is expected to be completed by October with release of data expected before the end of the year.

Work is progressing well on the Boulia MT survey inversions. For a detailed update on the progress so far be sure to catch Janelle Simpson's presentation on Tuesday at the ASEG-PESA-AIG Conference. The processed EDI files have been made available on GSQ's data hosting web application QDEX Data (http://qdexdata.dnrm.qld.gov.au).

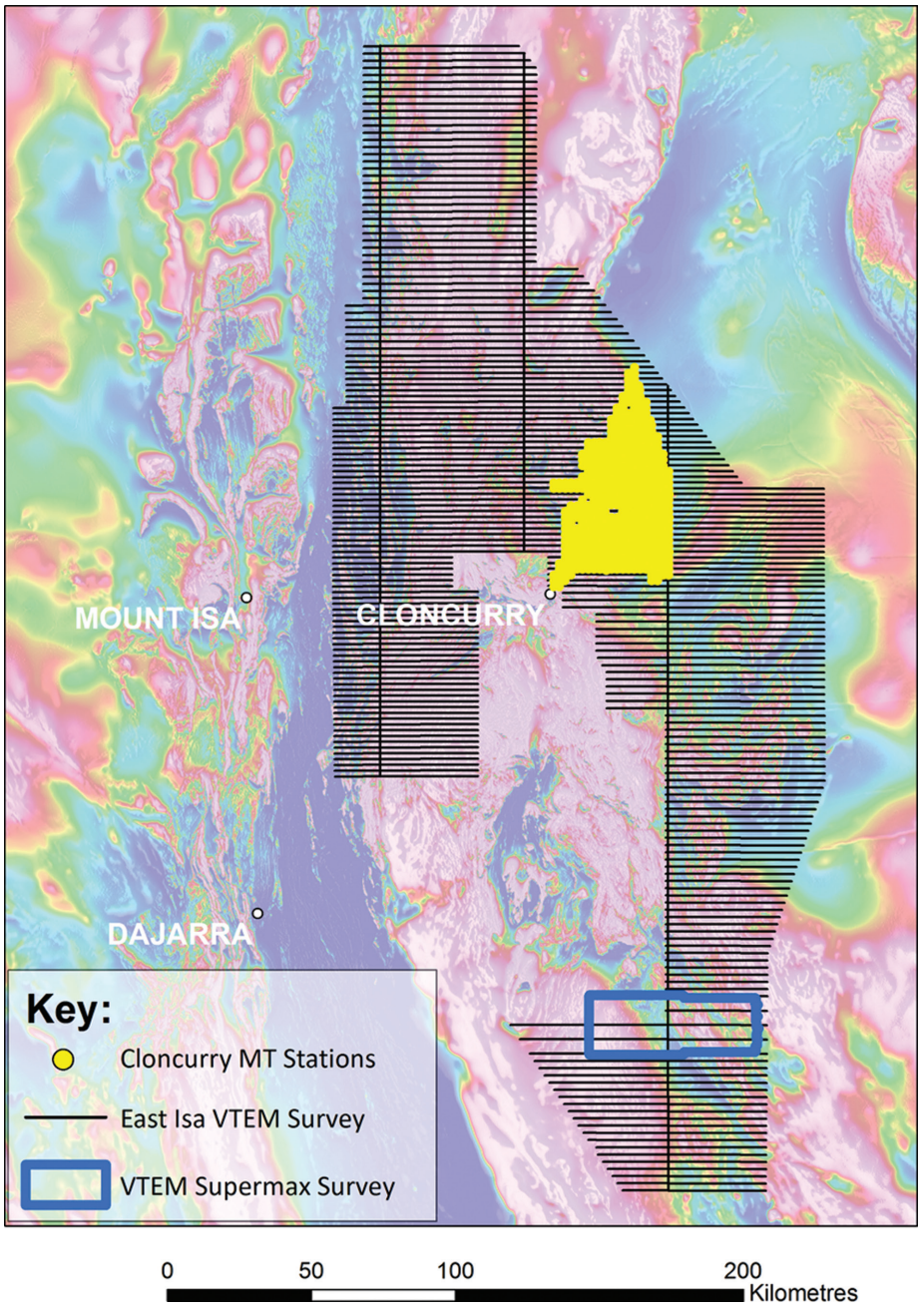


Figure 1. *Current Geophysical data collection around Cloncurry region.*

Airborne electromagnetic surveys

After positive responses from explorers to the recent AEM survey flown in the Osborne region, another AEM survey is being flown in the Cloncurry area. Geotech's VTEM Plus system will be collecting data at a nominal spacing of 2.5 km, with some areas of a central area of interest being flown at 2 km (Figure 1). This style regional reconnaissance AEM has proven successful in mapping regional variations in bedrock conductivity and thickness of cover. A total of 17 600 line kilometres are to be collected over 34 000 km^2. Flying is currently underway so expect the data to be available towards the end of the year.

The new survey overlaps part of the new Cloncurry MT survey as well as last year's VTEM Supermax survey and we are eagerly looking forward to seeing comparisons of the datasets.

Seismic surveys

Processing on lines 14GA-CF2 and 14GA-CF3 is complete. Over the past 10 years, there has been 3 800 km of deep crustal reflection seismic acquired in North West Queensland (Figure 2), forming a continuous backbone of seismic data all the way from Birdsville to Cairns!

As of August, all of the final migrated and stacked sections of the deep seismic lines are available to download from QDEX Data. An interpretation process in collaboration with Geoscience Australia and other interested parties will follow

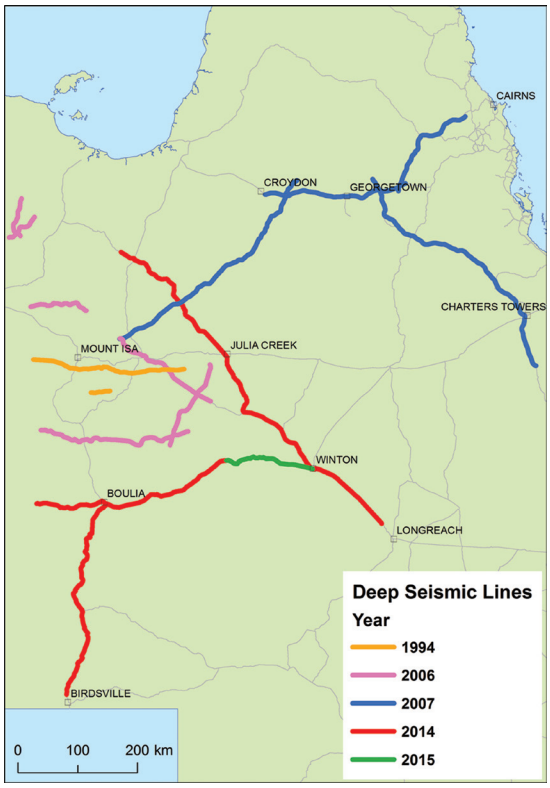


Figure 2. *Deep crustal seismic reflection surveys in North West Queensland.*

the data release and will yield further products.

In other seismic news, our seismic header update programme (SHUP) is nearing completion and the entire open file dataset will be available by the end of the year. We are looking forward to seeing the entirety of Queensland's seismic sections loaded in 3D space.

Conclusions

We look forward to seeing you all at the conference in Adelaide! If you can't make it to our booth, please drop us an email with any queries you may have about geophysics in Queensland.

Roger Cant, Matthew Greenwood and Janelle Simpson, Geological Survey of Queensland
geophysics@dnrm.qld.gov.au

For a detailed update on the progress of MT surveys in Queensland be sure to catch Janelle Simpson's presentation on Tuesday at the ASEG-PESA-AIG Conference

Geological Survey of New South Wales: Exploring new frontiers

The Geological Survey of New South Wales (GSNSW) collects and manages geological, geophysical and geospatial data to inform the government, exploration and mining industries and the community about the state's geology, mineral, coal and petroleum resources. Important regional projects are supported by the New Frontiers Exploration Initiative, which is funded by industry through mineral and petroleum annual rental fees. The initiative aims to stimulate investment in under-explored areas within NSW and includes acquisition of precompetitive geophysical data to provide essential support for geoscience mapping and mineral exploration.

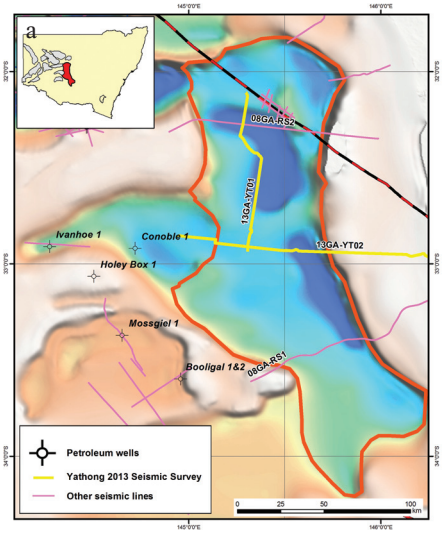
AusLAMP long-period MT acquisition for NSW announced

GSNSW and Geoscience Australia (GA) signed a National Collaborative Framework (NCF) agreement in June 2016 to fund and support this new acquisition programme. The Australian Lithospheric Architecture Magnetotelluric Project (AusLAMP) aims to establish baseline deep crustal conductivity between 11 km and 100 km depth and the acquisition of continental-scale coverage is an UNCOVER priority. The new data will add to adjacent coverage and modelling already completed for Victoria and South Australia.

At half-degree grid spacing, approximately 300 of the total 2800 AusLAMP sites lie within NSW (Figure 1). Full coverage of NSW will be undertaken over the next three years, with MT measurements being acquired as campaigns. Acquisition has started in the southeast of the State where GA is testing new equipment already. The Southern Thomson region will be a top priority, so that new data and models can complement 2014 broadband MT results undertaken at 5 km spacing along regional traverses.

Yathong Trough deep seismic reflection survey released

Early to Late Devonian sedimentary sequences of the Yathong Trough cover approximately 15 000 km^2 in central NSW. The trough is one of 10 sub-basins within the Darling Basin. Two survey lines of deep (20 and 22 second) seismic reflection data were acquired as part of the New Frontiers Initiative of GSNSW (Figure 2). The north–south line GA130-YT01 is aligned through the long axis of the trough and intersects the earlier Rankins Springs seismic line. The east–west line GA13-YT02 was extended approximately 50 km eastward into the Lachlan Orogen to provide data for mineral systems studies in the broader Cobar Basin region.



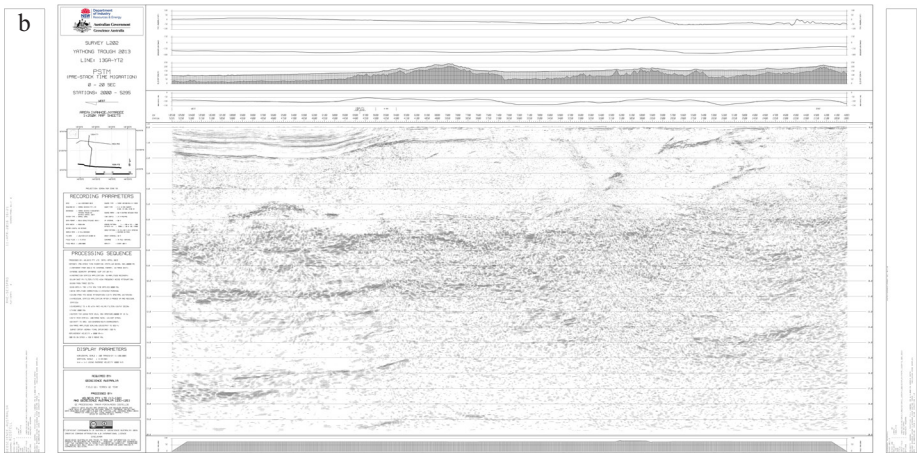


Figure 2. *(a) Location map of the Yathong 2D Seismic Survey in central NSW, shown over interpreted SEEBASE™ basement surface. (b) Seismic Line 13GA-YT02 data to 22 seconds, pre-stack time migrated.*

Southern Thomson Collaborative Project geophysical surveys

The Southern Thomson Project is a cross-border collaborative study between the GSNSW, GA and the Geological Survey of Queensland that commenced in 2014. It is investigating poorly-known basement geology and mineral prospectivity below thick sedimentary rock sequences in the Eulo–Wanaaring–Hungerford–Bourke region of northern New South Wales and southern Queensland.

Ground geophysical surveys including shallow seismic refraction, passive seismic and AMT were completed in October 2015 in order to test the application of these methods to determining the cover/basement interface depth. The results will guide a stratigraphic drilling programme that will commence in NSW around Wanaaring and Bourke during the second half of 2016. About eight drill holes within NSW will investigate key geological sites selected on the basis of regional geophysical survey data and geological synthesis work (Figure 3).

An airborne electromagnetic survey was undertaken between Tilpa, Louth and Enngonia during June 2016. This survey was funded by GA and had access support from the GSNSW. The technique had been used with success in the

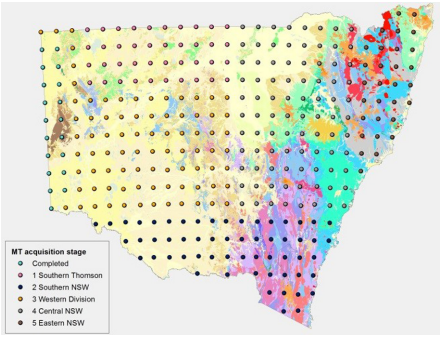


Figure 1. *GSNSW and GA long-period MT acquisition sites in NSW.*

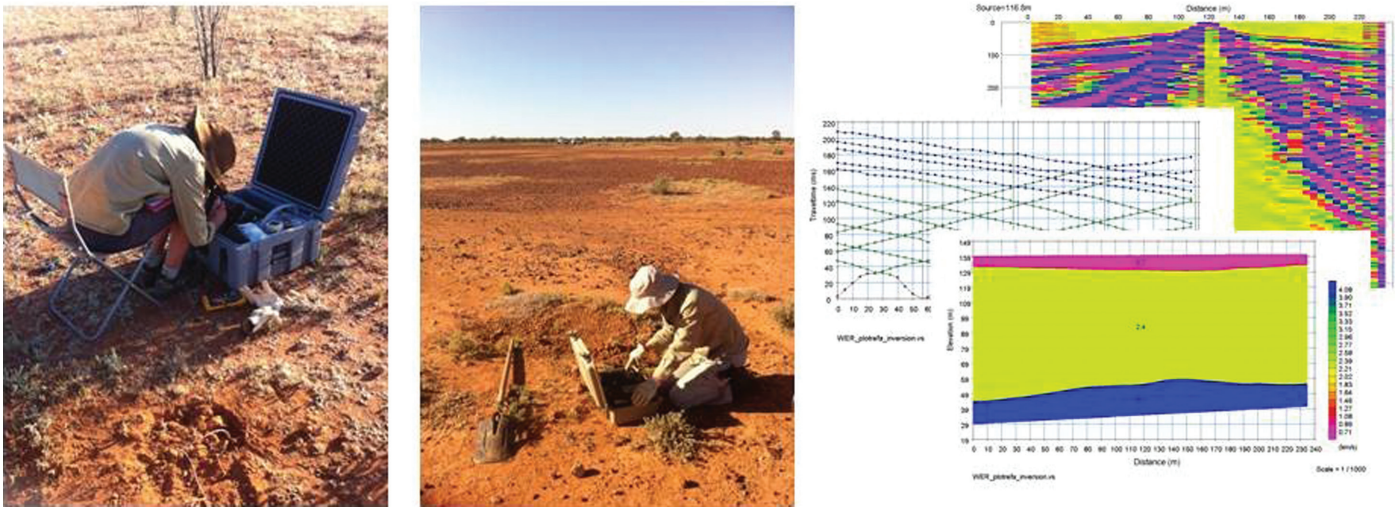


Figure 3. *Basement depth estimates from 2015 ground geophysical survey results will be tested by drilling. An 'explorer's toolbox' is being developed for the Southern Thomson region.*

Hungerford to Wanaaring area in 2014, penetrating to depths of approximately 100 to 300 m below ground surface to indicate areas where the sedimentary sequences thinned over shallow basement ridges.

Ongoing management and delivery of geophysical data

GSNSW strives to continually improve the management and delivery of geophysical data, both government surveys and archived private open-file data. Recent workshops were held in Sydney and Orange to highlight geoscience datasets (in particular, geophysics) and how to access them:

- Open file company geophysical surveys held by the GSNSW can be located via the Minview portal through Minerals View (http://www.resourcesandenergy.nsw.gov.au/miners-and-explorers/geoscience-information/services/online-services/minview) and can be requested by email geophysics.products@industry.nsw.gov.au.
- NSW statewide magnetic, radiometric and gravity datasets are available as grids and imagery on DVD, with located government survey data available on request or through GADDS.
- Over 7300 geophysical images are now available for online delivery as image suites prepared for each of the 1:250 000 map sheets within NSW. These are useful for geological reconnaissance projects, survey planning and regional studies. They can be downloaded through the new spatial DIGS report and publication portal as both geographic coordinates and MGA projection and as .ecw, .jpeg and .tiff formats (https://search.geoscience.nsw.gov.au/ – search publications tab for 'geophysical imagery').

The new data will add to adjacent coverage and modelling already completed for Victoria and South Australia

Integration of regional geophysical data in 3D modelling

New methodology has been documented for interpretation and integration of potential field and seismic data to construct and edit cross sections used in the development of crustal-scale 3D geological models (Figure 4). Importing cross-sections from the NSW statewide 3D model into geophysical modelling software enables forward modelling of joint gravity and magnetic data and validation testing and refinement of key interpretations for the 3D models. Completed 3D models can be downloaded from the Department's website (http://www.resourcesandenergy.nsw.gov.au/miners-and-explorers/geoscience-information/projects/3D-mapping-of-NSW).

Contacts in the GSNSW are: Rosemary Hegarty and Astrid Carlton (geophysicists), Dr Robert Musgrave (research scientist), Jamie Robinson and Felipe Oliveira (senior 3D modelling geoscientists), and John Davidson (geoscientist – seismic).

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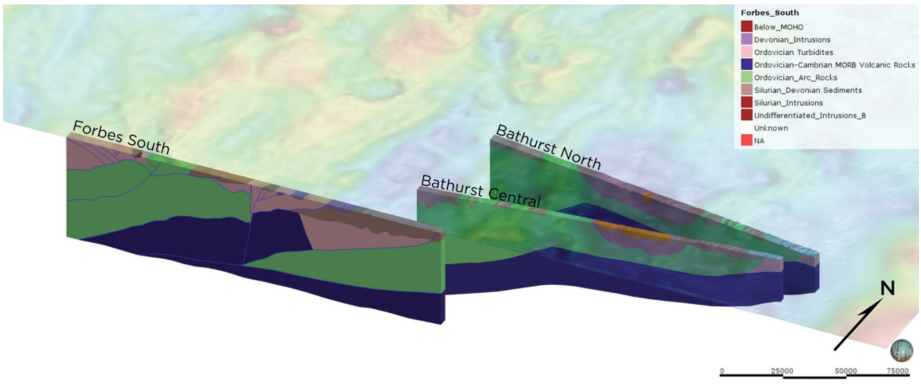

Figure 4. *Test sections from a 3D model hung from a gravity image across the Lachlan Orogen.*

Geological Survey of Victoria: New geological and geophysical data for the Stavely Project

The Geological Survey of Victoria (GSV) has recently collaborated with Geoscience Australia (GA) and the University of Adelaide to acquire new geological and geophysical data in Victoria. These data have been integrated with existing data to inform new regional and local-scale geological and structural interpretations in Western Victoria and South Gippsland.

The Stavely Project, an area of 20 000 km^2 in western Victoria (Figure 1, http:// www.energyandresources.vic.gov.au/earth-resources/geology-of-victoria/gsv-projects/the-stavely-project), is a collaboration between the GSV and GA, and a contribution to the broader UNCOVER Initiative. The UNCOVER Initiative seeks to address the challenges of 'greenfield' exploration in under-cover areas in Australia through the acquisition

Insights from the Stavely Project have resulted in an updated interpretation of the Cambrian Stavely Arc

and delivery of pre-competitive fundamental geoscience data and concepts.

Insights from the Stavely Project have resulted in an updated interpretation of the Cambrian Stavely Arc, including the identification of numerous previously unknown structures that have deformed the basement and cover rocks. This new interpretation along with geophysical modelling of potential field data has enabled the palinspastic retro-deformation of regional-scale aeromagnetic data. Given that a number of known historical mineral prospects of porphyry and VHMS affinity are associated with the poorly exposed Cambrian basement, several of which are currently being actively explored for copper and associated metals, opportunity exists for new mineral discoveries under cover.

New geophysical data from the Stavely project has resulted from the completion of 14 stratigraphic drill holes totalling 2708 m of sonic and diamond drilling. Pre-drilling geophysical surveys conducted by GA were used to predict depth to basement. Drill core rock

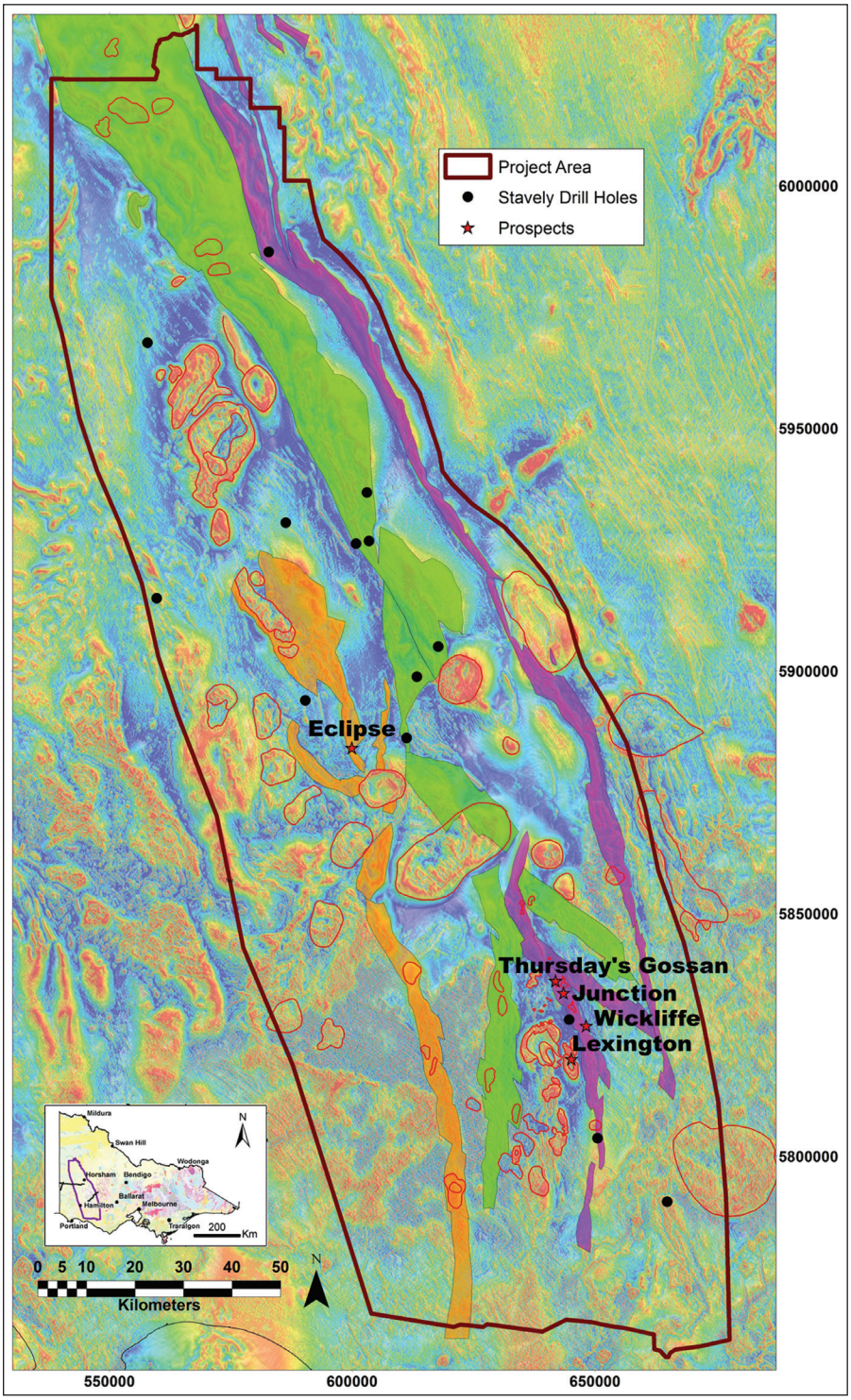

Figure 1. *Stavely Project area showing Stavely Arc volcanic belts as coloured screens, Cambrian and Devonian intrusions with red outlines, stratigraphic drill hole collar locations and mineral prospects on a tilt-filtered TMI image.*

property measurements acquired at the AuScope Australian Geophysical Observing System facility at the University of Melbourne and hyperspectral scanning using the HyLogger™ system combined with

downhole wireline logs, geology, geochemistry and geochronology provide an extensive suite of new pre-competitive data. Results from each study are being released progressively and will be followed by a new solid geology and 3D model, a regional synthesis of the geology and mineral systems, historical exploration compilation and an explorers' guide.

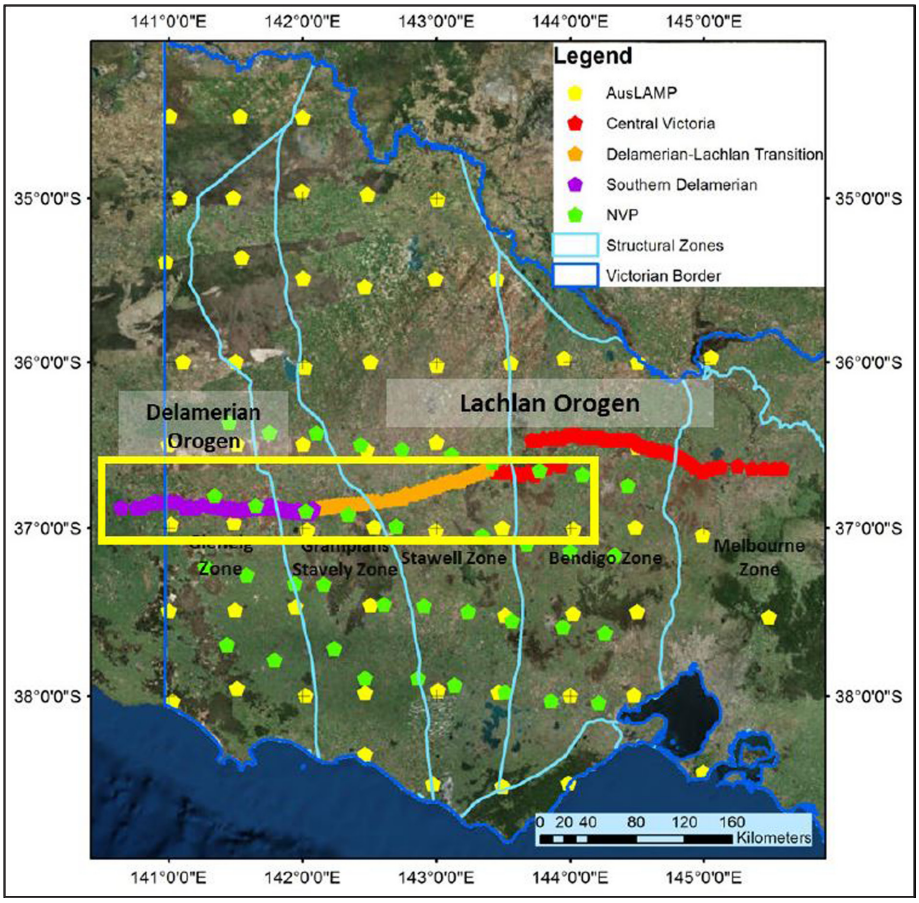

Figure 2. *Location of the MT sites in western Victoria. Yellow sites are part of the Australia-wide AusLAMP project. Close spaced sites included in the yellow box are displayed in Figure 3.*

Development of the 3D geology model for the Stavely Project area has been complemented by the completion of a 450 km east-west traverse of magnetotelluric (MT) data (Figure 2) along the path of deep crustal seismic reflection lines collected from 2006 to 2011. The GSV has collaborated with the University of Adelaide to collect close-spaced broad-band MT data that join to the MT data previously collected along the seismic lines. The broad-band MT lines provide a detailed 2D transect inside the broader 50 km-spaced 3D grid of AusLAMP long-period MT data that has been collected by GA (www.ga.gov.au/about/projects/minerals/current/auslamp). The 2D transect has resulted in a detailed image of the mantle beneath the transition from the Delamerian to Lachlan Fold Belts (Figure 3) by crossing the Stavely and Stawell geological zones.

In the South Gippsland region of Victoria, 203 km of 2D seismic vibroseis reflection data were acquired between June and July in 2015 (Figure 4). The project is a collaboration between GSV and GA. The purpose of the survey is to gain a greater understanding of the geometry and internal structure of the Cretaceous Strzelecki Group that includes up to 100 m of Older Volcanics, and the underlying Palaeozoic basement of the

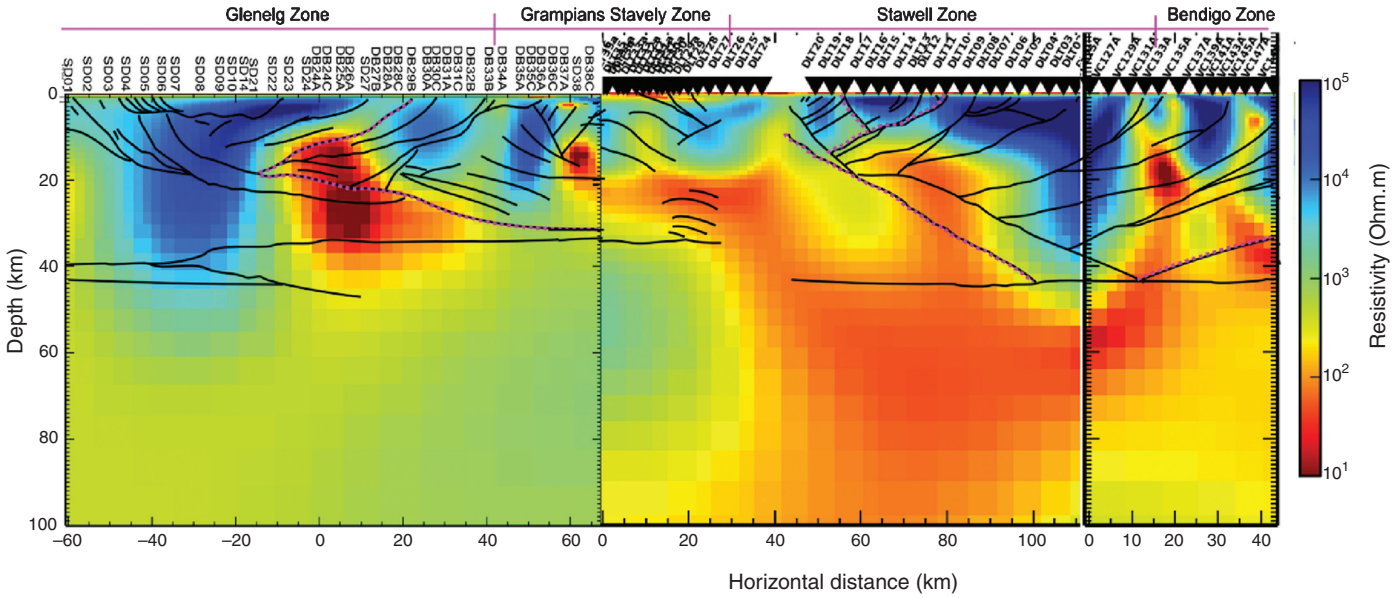

Figure 3. *Electrical resistivity slice from the surface to 100 km depth along the profile of sites shown in the yellow box in Figure 2. Black lines are faults interpreted from deep reflection seismic surveys. Red regions are conductive, blue are resistive. An anomalous zone of mantle conductivity might be a relic of Cambrian subduction associated with the Stavely Arc, or could be the 2D intersection of some other regional scale conductive features currently being analysed in the 3D AusLAMP data.*

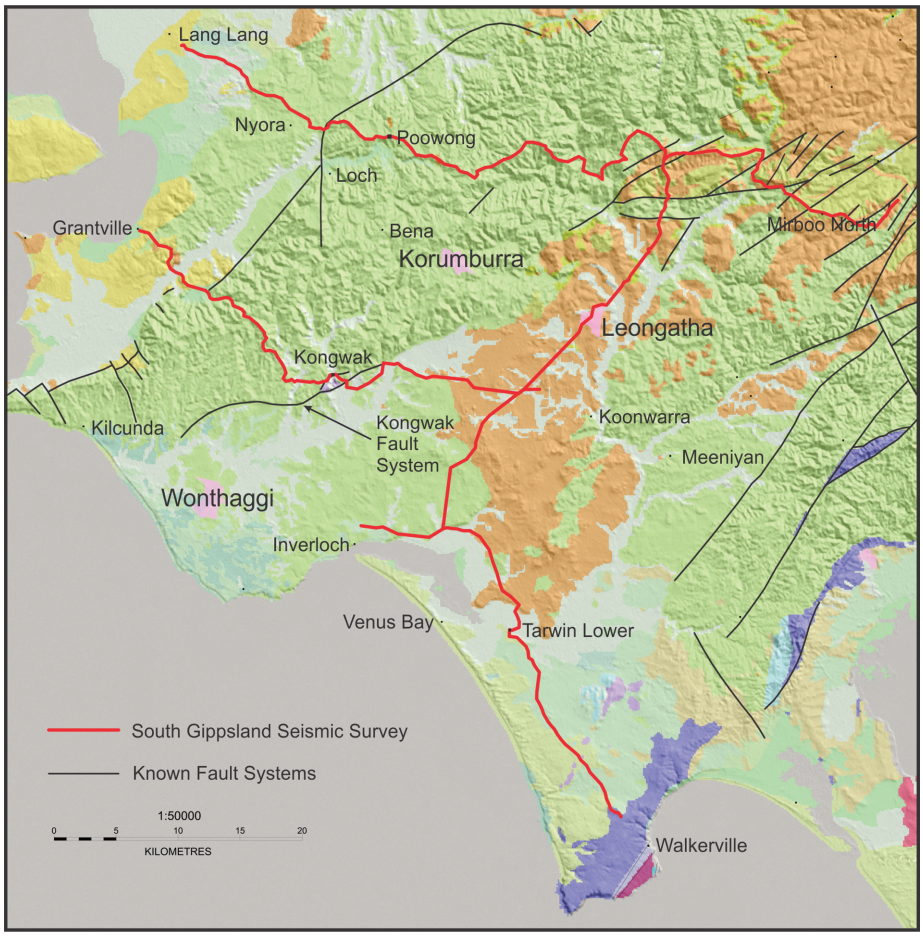

Figure 4. *Location of South Gippsland reflection seismic survey lines in red.*

Melbourne Zone. Interpretation is currently underway on the processed dataset.

In addition to the acquisition of new data, the GSV is continuing to digitise and compile historical exploration data and reports, and make them available online. The Earth Resources Search Assistant (www.energyandresources.vic.gov.au/earth-resources/maps-reports-and-data/search-tool) is an online search engine that assists users to access specific information and open file reports relating to the earth resources sector in Victoria. The GSV also provides a free web mapping application – GeoVic, which allows users to search geospatial databases and to display the results as maps or tables (www.energyandresources.vic.gov.au/earth-resources/maps-reports-and-data/geovic).

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Mineral Resources Tasmania: A new model of the Rosebery-Lyell mineral province

Mineral Resources Tasmania (MRT) has developed a high resolution regional 3D model of Tasmania's most important mineral province. The Rosebery-Lyell 3D geological model is an extension and refinement of previous MRT 3D models in the region. It expresses a new structural synthesis based on mapping and multiple cross sections produced by numerous geologists over several decades. The model is constrained by 3D geophysical modelling using MRT's gravity and magnetic survey data coupled with drilling and rock physical property databases. For the first time, statistically generated sensitivity characterisation is being incorporated in the model products, as a step towards estimating the spatial variability of confidence in the model elements.

Geological setting

The Rosebery-Lyell study area (Figure 1) encompasses some of the most highly and diversely mineralised crust on the planet; the Rosebery and Mount Lyell polymetallic ore mineral systems being foremost among many others. A large number occur within the Mount Read Volcanics, a predominantly submarine succession of rhyolitic to basaltic volcanic and hypabyssal intrusives with variable proportions of intercalated volcano-sedimentary rocks. These are interpreted to be products of volcanism following collision of a proto-Tasmanian micro-continent (represented by Crimson Creek Formation and older units) with an oceanic island arc around 520 Ma. In the late Devonian the region was intruded by granites. This led to additional metallogenic activity including the world's largest underground tin deposit (Renison).

Model construction

The Rosebery-Lyell 3D model (Figure 2) was constructed as a synthesis of all previous work using the GOCAD® Mining Suite from Mira Geoscience. The model incorporated significant elements of the 2002 Statewide 3D geological model (Murphy et al., 2002) and also relied heavily on the structural interpretation of Berry (1997) and recent investigations by MRT staff and contractors. After construction, the model

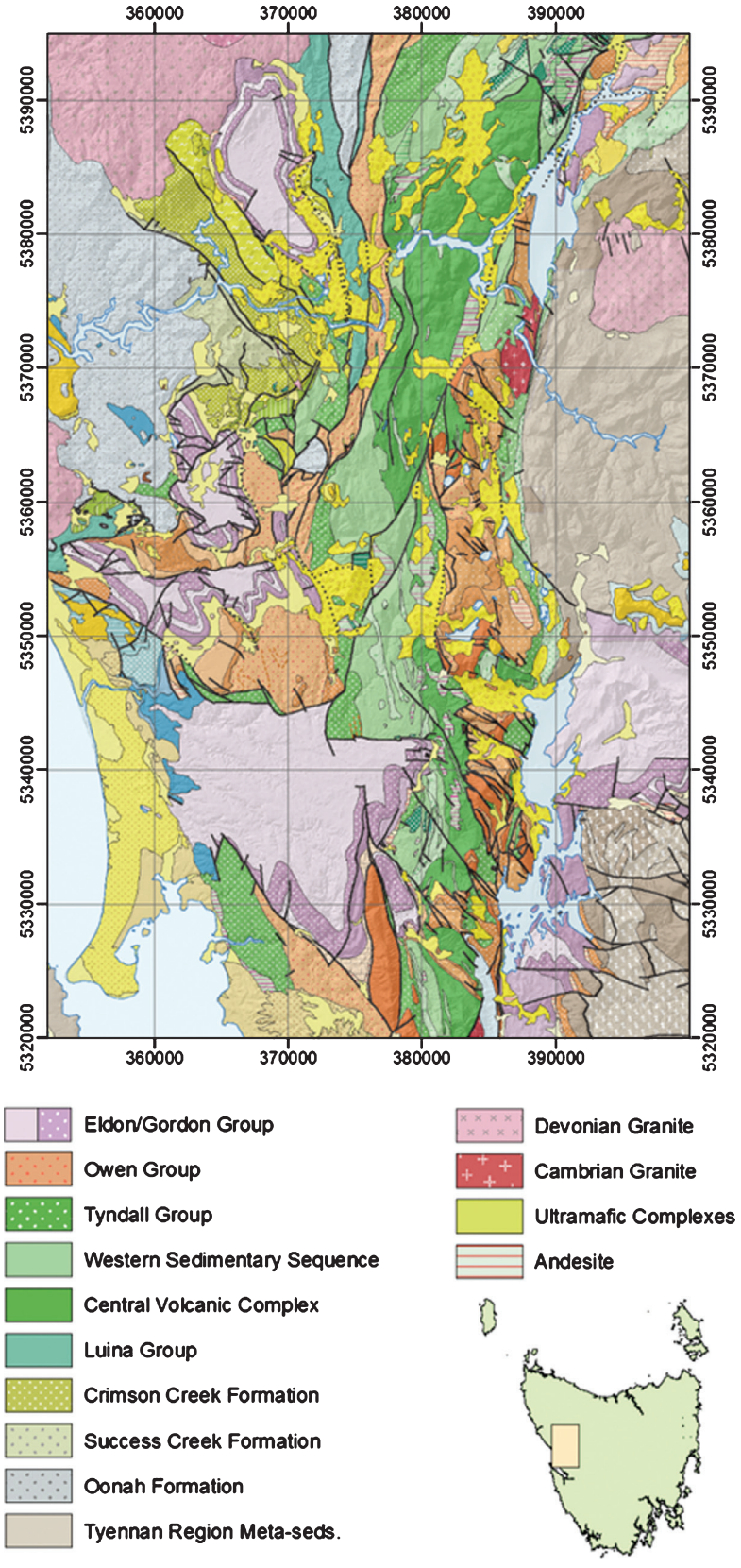

Figure 1. *Rosebery-Lyell geological setting. The Mount Read Volcanics encompass the Tyndall Group, Western Sedimentary Sequence, Central Volcanic Complex and andesite.*

was discretised to 200 × 200 × 100 m cells for forward and inverse gravity and magnetic modelling using the GOCAD® potential field module (VPmg code; Fullagar et al., 2008) and unit property estimates derived from MRT's petrophysical data base and previous work.

Modelling the magnetic response

Magnetic and gravity data were extracted from MRT's public domain databases. The magnetic coverage (Figure 3) is predominantly from surveys of E–W flight lines at 200 m spacing and ~80 m clearance. Upward continuation of 200m and regional separation were applied prior to modelling.

The magnetic response is dominated by allochthonous fault-bounded slices of serpentinised ultramafic material ('ultramafic complexes'). Resolution of the geometry of these units effectively provides a structural framework for the remainder of the model. Unresolved broad scale misfits from the starting forward model were found to be best accounted for by additional ultramafic material at depth in a configuration consistent with the regional structural style (listric thrust detachments).

After geometry modification and fixing, the residual from homogeneous inversion (Figure 4) isolates signal due to magnetic property variations within modelled units. Subsequently this drives inversion for apparent magnetic susceptibility within modelled units (Figure 5). Broad scale features associated with ultramafic complexes suggest substantial compositional variation (as is known to exist from petrophysical data) or inadequate model geometry. In contrast, finer scale features are likely truly anomalous in a geological sense, and thus of potential direct exploration interest.

Gravity modelling – Tributary Creek example

The modelled Bouguer gravity field (Figure 6) is a residual derived from the State crust-mantle-ocean model MANTLE-09 (Leaman 2009). Upward continuation of 200 m was applied prior to modelling.

In 2013 a preliminary 3D modelling study on the northern part of the region highlighted a significant negative gravity residual informally named the Tributary Creek gravity anomaly (TCGA). The

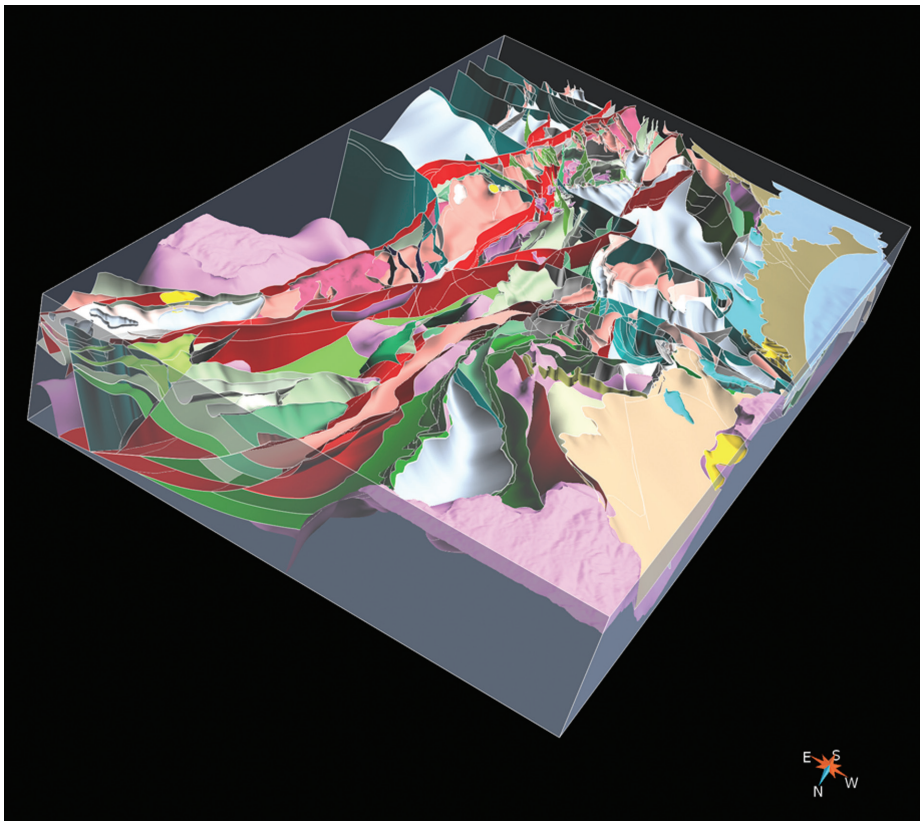

Figure 2. *Rosebery-Lyell 3D geological model surfaces.*

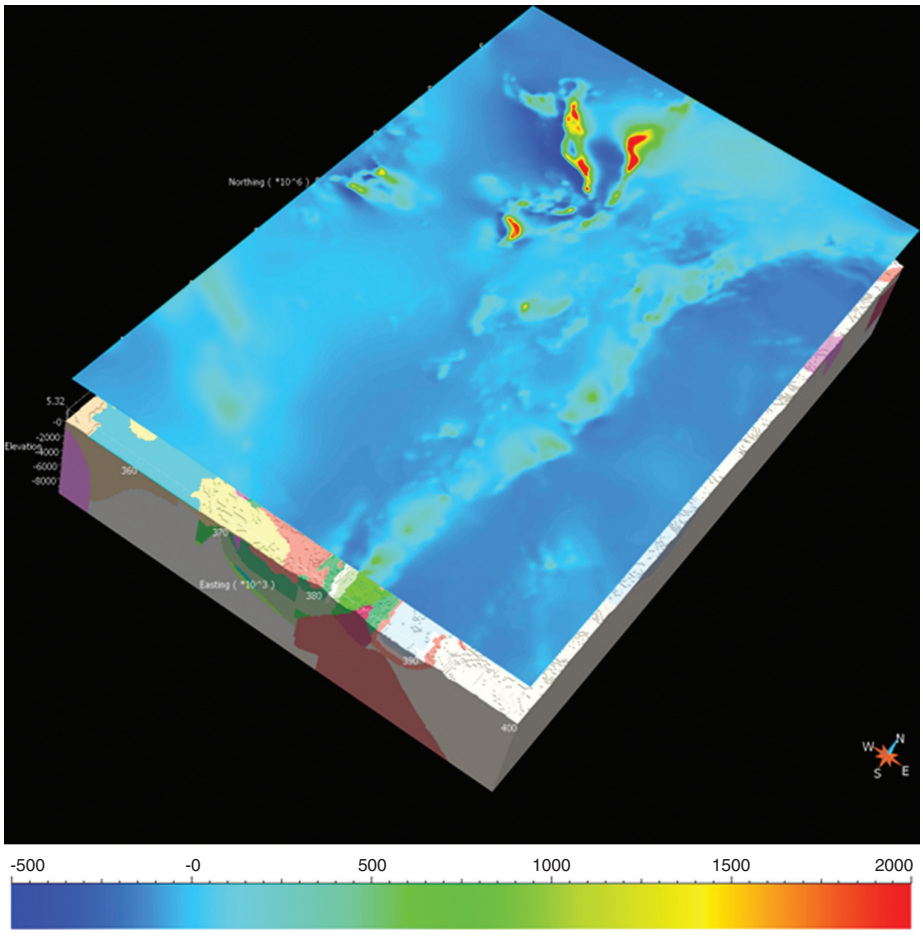

Figure 3. *Observed total magnetic intensity (nT).*

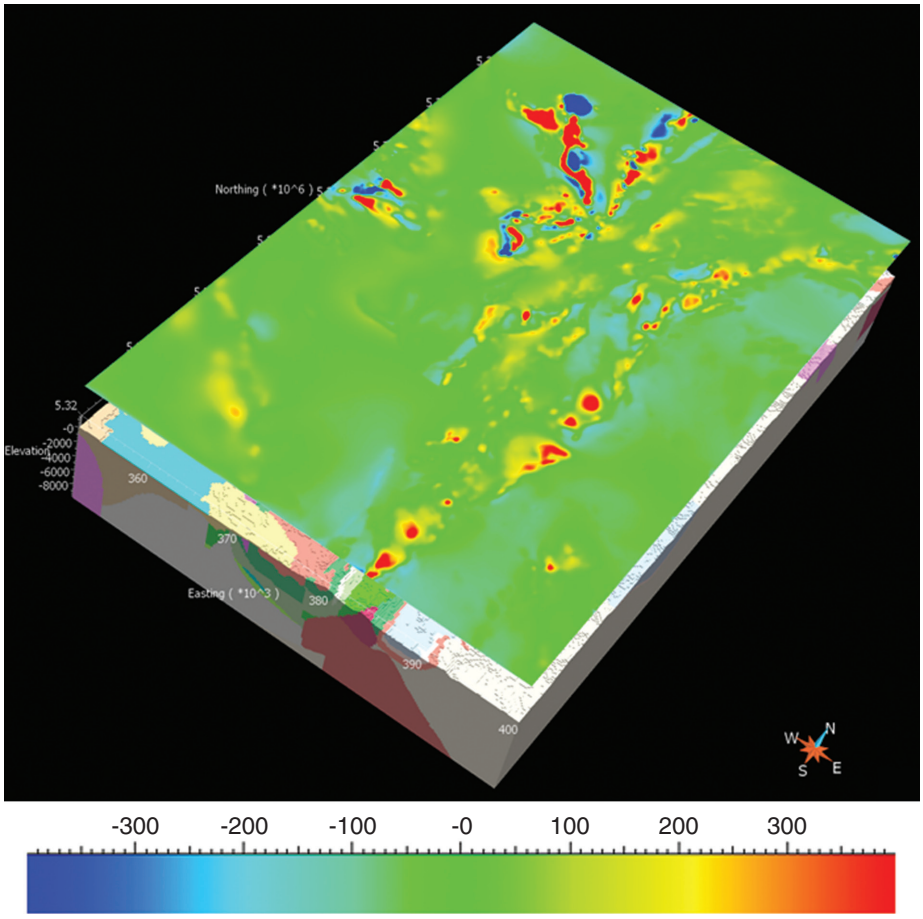

Figure 4. *Residual magnetic intensity (observed – model) following homogeneous inversion (nT).*

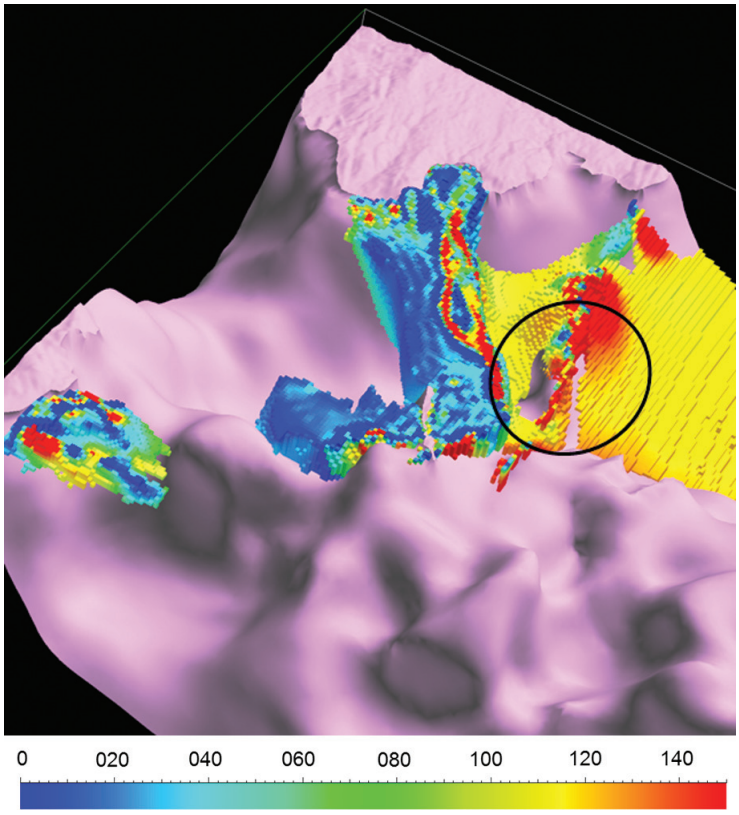

Figure 5. *Apparent magnetic susceptibility (SI x 10-3) within Crimson Creek Formation and ultramafic complexes, resulting from heterogeneous inversion.*

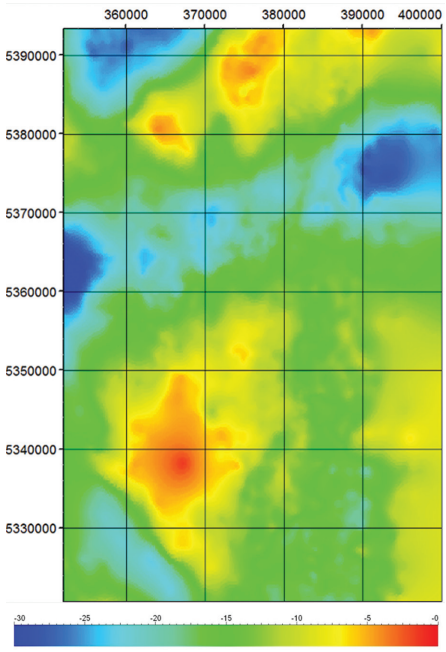

Figure 6. *Bouguer gravity (terrain-corrected, mGal).*

inversion process resulted in a substantial change to the previous granite model in the form of a spine intruding the corresponding area (Figure 7, red ellipse). Depth to this crest at its shallowest is estimated to be ~1000 m.

As the TCGA was defined by only a few stations, UTas Honours student Jie Yu was sponsored by MRT and Venture Minerals in 2014 to conduct a gravity survey clarifying this and other sparsely covered areas (see *Preview* 173). Results of this study confirmed the likelihood of a volume of low density material at this location, interpreted as granite intruding ultramafics and/or Gordon Group carbonates. These insights have led to increased exploration in this area.

Uncertainty characterisation

The 3D model derived to this point is a 'best estimate' synthesis that is also consistent with observed gravity and magnetic data. However, as is well known with potential fields, this solution is not unique. GeoModeller^{TM} is being employed to explore the range of similarly plausible possible models.

The stochastic exploration algorithm takes a Monte Carlo approach, generating a sequence of linked models starting with the initial model making small 'random' changes to the lithological boundaries and physical properties. After each change is made, the likelihood of this combination is assessed by comparing the model magnetic or gravity response to the

observation data. The proposal is then accepted or rejected, depending on whether the misfit is improved or maintained below an acceptable threshold. Upon completion of the inversion run GeoModeller™ carries out an analysis of the ensemble of models that reproduced the observations to an acceptable degree.

Geological constraints are retained by application of various parameters that act to restrict the extent to which the model can be modified from the initial version, in addition to hard constraints such as surface outcrop. Physical properties of modelled units are constrained by enforcement of a distribution defined using a petrophysical database mainly obtained from core.

Preliminary evaluations of this method were run using a coarser version of the model, with gravity responses only (Figure 7), for speed. In this instance, 7 million acceptable model variants resulted, which were used to characterise the solution space statistically.

The probability threshold

The probability threshold is one of several statistical measures to indicate model sensitivity. For each voxel location the most probable threshold records the lithology assigned to that voxel in at least 90% of the ~7 million models satisfying the observed gravity data. Black voxels are those that failed to meet this threshold for any one unit, thus indicating uncertainty in the model at these locations (Figure 8). Other measures of sensitivity at particular points in the model can also be generated. Note no black pixels on top granite surface, indicating high confidence, largely due to high density contrast.

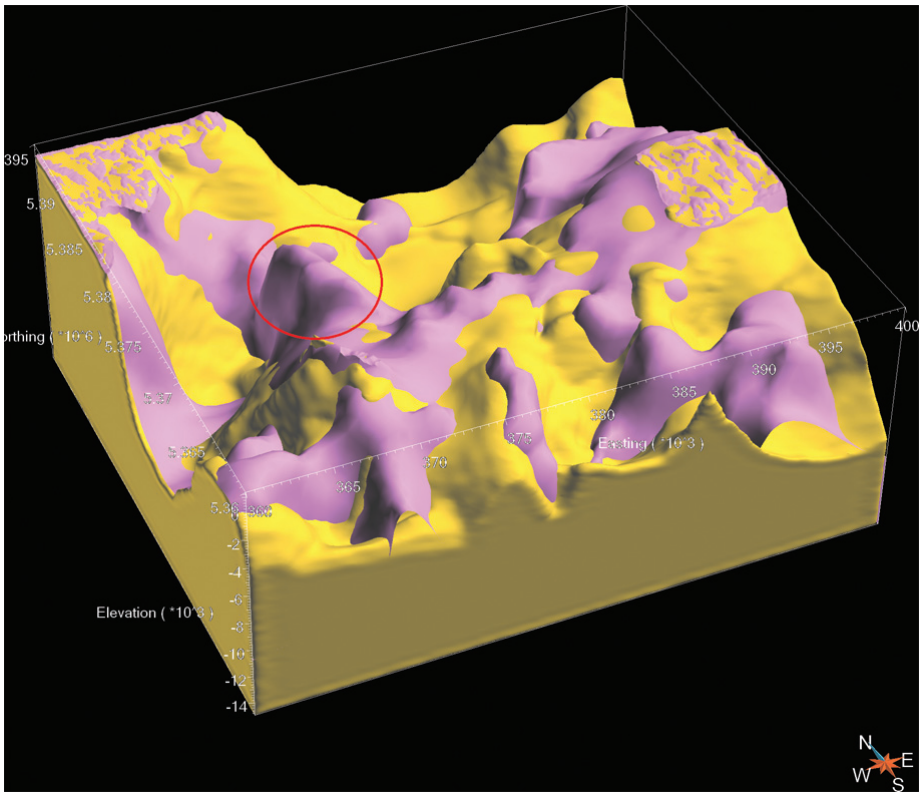

Figure 7. *Granite surfaces in the northern part of the model before (yellow) and after (pink) the 3D gravity geometry inversion phase.*

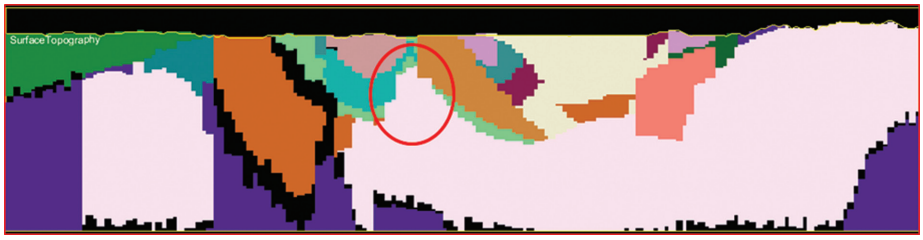

Figure 8. *East-west 'probability threshold' section through TCGA (red ellipse), showing presence of units in >90% of acceptable solutions.*

Summary

MRT has developed a new methodology for constructing multiply constrained regional 3D models. The method involves constructing a model using the GOCAD® Mining Suite from Mira Geoscience followed by deterministic geophysical validation using the VPmg code. This model is then used as an initial model in GeoModeller™ for uncertainty characterisation. It is hoped that the resulting fusion of geological and geophysical information with measures of model sensitivity will be a significant addition to the suite of public precompetitive geoscience products reducing exploration risk.

The Rosebery-Lyell 3D model files are available for download from the MRT website.

Acknowledgements

Thanks to Tim Chalke and Glenn Pears (Mira Geoscience) and Rod Paterson (Intrepid Geophysics) for their assistance with Gocad® and GeoModeller™ respectively.

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GA: Update on geophysical survey progress from the Geological Surveys of Western Australia, South Australia, Northern Territory, Queensland and Victoria (information current on 12 July 2016)

Further information on these surveys is available from Murray Richardson at GA via email at Murray.Richardson@ga.gov.au or telephone on (02) 6249 9229.

Table 1. Airborne magnetic and radiometric surveys

Survey name	Client	Project management	Contractor	Start flying	Line km	Spacing AGL Dir	Area (km^2)	End flying	Final data to GA	Locality diagram (*Preview*)	GADDS release
Coompana	GSSA	GA	GPX Surveys	7 Feb 2015	255 265	400 m 80 m E–W	85 910	8 Nov 2015	Dec 2015 for magnetic and elevation data	173: Dec 2014 p. 24	The radiometric data are expected to be released in Jul 2016
Menindee	GA	GA	Thomson Aviation	10 Jun	8300	100 m 50 m NE–SW	660	29 Jun 2016	Aug 2016	182: Jun 2016 p. 22	The survey covers parts of the Menindee, Nartooka and Lake Tandou Standard 1:100k map sheets
Gawler - PACE area	GSSA	GA	TBA	TBA	1 800 000	200 m 60 m NS or EW	324 000	TBA	TBA	This issue (Figure 1)	TBA

TBA, to be advised.

Table 2. Gravity surveys

Survey name	Client	Project management	Contractor	Start survey	No. of stations	Station spacing (km)	Area (km^2)	End survey	Final data to GA	Locality diagram (*Preview*)	GADDS release
Stavely	GSV	GA	TBA	Survey Quotation Request in preparation	Approx. 8000 in 9 separate areas	500 m regular grid in 8 areas and 500 m station interval along one traverse	TBA	TBA	TBA	The proposed survey covers parts of the Horsham, Hamilton, Ballarat and Colac Standard 1:250 000 map sheets	TBA
Wiluna	GSWA	GA	Atlas Geophysics	Aug 2016	Approx 17 000 in 2 separate areas	2500 m regular grid	103 000	TBA	TBA	The survey covers parts of the Bullen, Trainor, Nabberu, Wiluna, Sir Samuel, Madley, Herbert, Robert Standard 1:250 000 map sheets. The Contract was formally executed on 8 Jul 2016	TBA
Daly Basin	NTGS	GA	Atlas Geophysics	13 Jul 2016	2537	Regular grid of 4, 2 and 1 km	35 730	TBA	TBA	182: Jun 2016 p. 22	The proposed survey covers parts of the Cape Scott, Pine Creek, Port Keats, Fergusson River and Katherine Standard 1:250k map sheet areas. The Quotation Request was released on 13 May and closed on 27 May
Coompana - PACE area	GSSA	GA	TBA	TBA	15 362	Regular grid of 2, 1 and 0.5 km	100 000	TBA	TBA	This issue (Figure 2)	TBA

TBA, to be advised.

Table 3. AEM surveys

Survey name	Client	Project management	Contractor	Start flying	Line km	Spacing AGL Dir	Area (km²)	End flying	Final data to GA	Locality diagram (*Preview*)	GADDS release
Musgraves – PACE Area	GSSA	GA	CGG Aviation	15 Aug 2016	8489	2 km; E–W lines	16 371	TBA	TBA	179: Dec 2015 p. 23	The proposed survey covers parts of the Mann, Woodroffe, Birksgate and Lindsay Standard 1:250 000 map sheets
Musgraves – CSIRO Area	GSSA	GA	SkyTEM Australia	End Aug 2016	7182	2 km; E–W lines	14 320	TBA	TBA	179: Dec 2015 p. 23	The proposed survey covers parts of the Woodroffe, Alberga, Lindsay and Everard Standard 1:250 000 map sheets
West Kimberley and Ord-Bonaparte	WA Government: Departments of Water, Agriculture and Food	GA	SkyTEM Australia	26 Sep 2015	7837	Various + traverses	TBA	3 Nov 2015	TBA	178: Oct 2015 pp. 30–31	The release date for the survey data is to be decided by the WA Government Department of Water
Isa Region	GSQ	GA	Geotech Airborne	Jul 2016	15 692	2 km; E–W	33 200	TBA	TBA	182: Jun 2016 p. 23	The survey covers the Dobbyn, Cloncurry, Julia Creek, Duchess, McKinlay, Boulia and Mackunda Standard 1:250 000 map sheets
Thomson Extension	GA	GA	Geotech Airborne	28 May 2016	2415	5 km, E-W lines	TBA	15 Jun 2016	Jul 2016	182: Jun 2016 p. 23	The survey covers the Toompine, Eulo, Yantabulla, Enngonia, White Cliffs and Louth Standard 1:250 000 map sheets

TBA, to be advised.

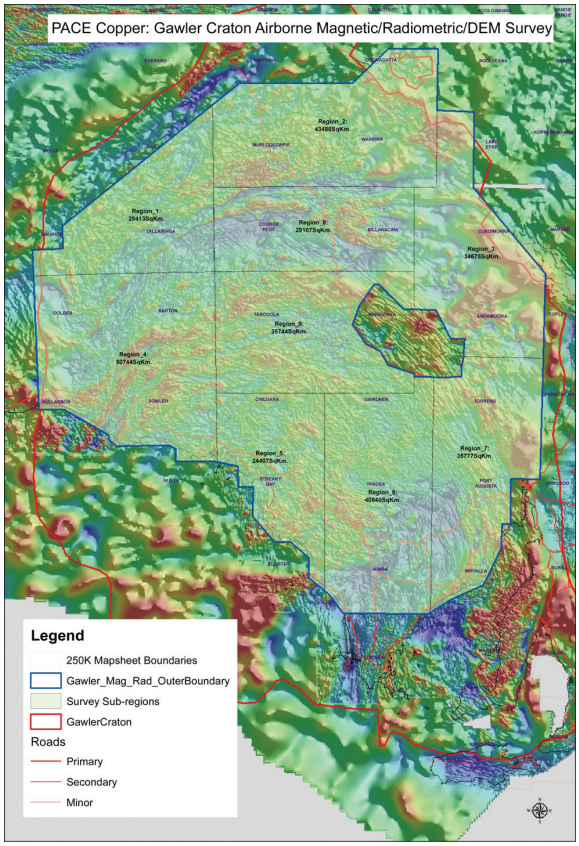

Figure 1. *Area of the Gawler – PACE Area magnetic and radiometric survey.*

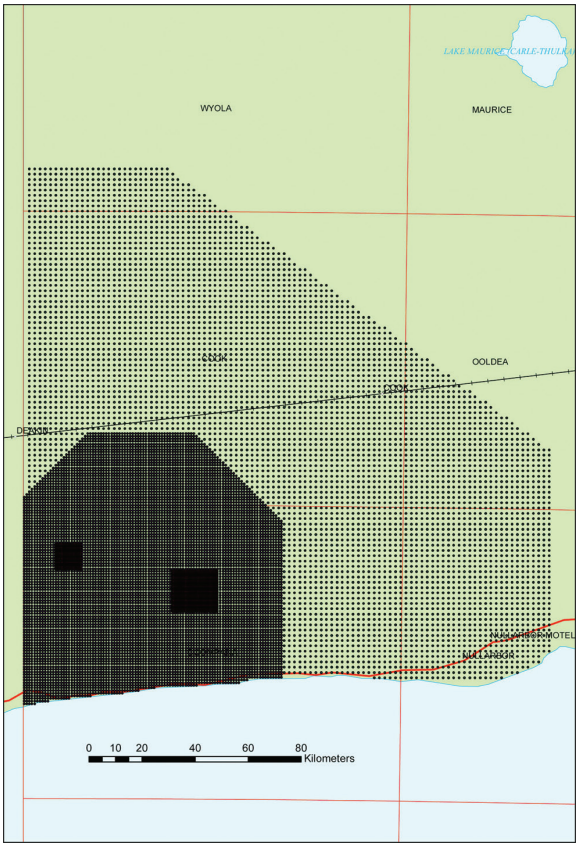

Figure 2. *Area of the Coompana – PACE Area gravity survey.*