Geological and cover thickness mapping using airborne electromagnetic data in an UNCOVER application

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SUMMARY

Airborne electromagnetic (AEM) data are an immensely useful tool for mapping cover thickness and under cover geology in Australia. The regional AEM surveys conducted by Geoscience Australia (GA) and other agencies are an ideal starting point for integrating legacy AEM datasets across a range of scales with other information, e.g. borehole stratigraphy and shallow seismic data, as part of a national cover thickness map. Geoscience Australia is working towards this end as part of the UNCOVER Initiative.

Key words: airborne electromagnetics, cover thickness mapping, UNCOVER.

INTRODUCTION

The 2012 document *Searching the Deep Earth: A vision for exploration geoscience* (Australian Academy of Science, 2012), summarises the Australian Academy of Science's 2010 Theo Murphy Think Tank discussion on the future of the Australian minerals industry and lays a path for future mineral discovery. The UNCOVER Initiative as it is now known is accepted as part of the National Mineral Exploration Strategy of the Council of Australian Governments (COAG, 2012). The UNCOVER Initiative recognises that it is increasingly difficult to discover near-surface mineral resources in Australia, and our continuing prosperity requires effective exploration that leads to new discoveries to provide an ongoing 'pipeline' of resource development. One of the major factors in the decline of exploration success is the difficulty in exploring beneath the weathered bedrock (the *regolith*) and sedimentary basins that cover approximately 80 per cent of Australia's landmass.

Airborne electromagnetic (AEM) data are ideally suited to provide answers to the UNCOVER Initiative Theme 1 (Characterising Australia's cover) and Theme 4 (Characterising and detecting distal footprints of mineralization). Applied research at Geoscience Australia (GA) using AEM datasets collected by GA, Commonwealth, State and Territory governments, and industry, is directed at mapping the thickness and characterising the electrical architecture of cover, as well as mapping the electrical architecture of covered basement geology. This paper describes some of the interpretations from GA's AEM datasets and discusses the future uses of AEM data in Australia as a tool for uncovering new mineral resources for Australia's continued prosperity.

AEM SURVEY DATA IN AUSTRALIA

In Australia AEM data have been collected by the minerals industry since the 1950s using a variety of platforms to obtain generally small-area, close-line-spacing data; Australia was one of the first countries to adopt the method (Fountain, 1998). Geoscience Australia and its predecessor, the Australian Geological Survey Organisation (AGSO), commenced acquiring AEM data for groundwater related issues, and has a long history of cooperation with Commonwealth, State and Territory governments. Figure 1 illustrates the coverage of major AEM surveys in Australia. It was not until the advent of the Onshore Energy Security Program (OESP; McKay *et al.*, 2011) between 2006 and 2011 that large area, wide line-spacing, regional AEM surveys were flown by Government in Australia for minerals purposes using modern, calibrated, repeatable AEM systems. In the OESP AEM surveys, flight line spacings of up to 6 km were used to rapidly map the electrical architecture of the near-surface primarily for detecting the key components of energy mineral systems in the Paterson, Western Australia (Roach, 2010), Pine Creek, Northern Territory (Craig, 2011) and Frome, South Australia (Roach, 2012b) AEM surveys (Figure 1). The success of the Paterson AEM Survey in mapping the key components of uranium mineral systems and under-cover basement geology influenced the State Government of Western Australia to continue the wide line spacing regional AEM survey format, initially in a test area over the Bryah Basin (Munday *et al.*, 2013), and then in the Capricorn Orogen region (Costelloe, 2014). Geoscience Australia has most recently flown a small regional AEM survey in the southern Thomson Orogen region of northwestern New South Wales and southwestern Queensland as part of the Southern Thomson Project (Roach, 2015), which is a joint project between GA, the Geological Survey of New South Wales and the Geological Survey of Queensland established under the banner of the UNCOVER Initiative. Geoscience Australia has also had involvement in the acquisition, processing and interpretation of AEM surveys in the Kimberley and coastal plains of Western Australia for State groundwater agencies there.

Numerous quality AEM datasets are now available for free download from GA, and quality AEM data are now becoming available from State and Territory geological survey archives as they come out of their embargo periods in each jurisdiction. All of these datasets are instrumental for mapping electrical architecture and interpreting cover thickness, hydrogeology and basement geology, and form one of the cornerstones of work towards a national cover thickness map.

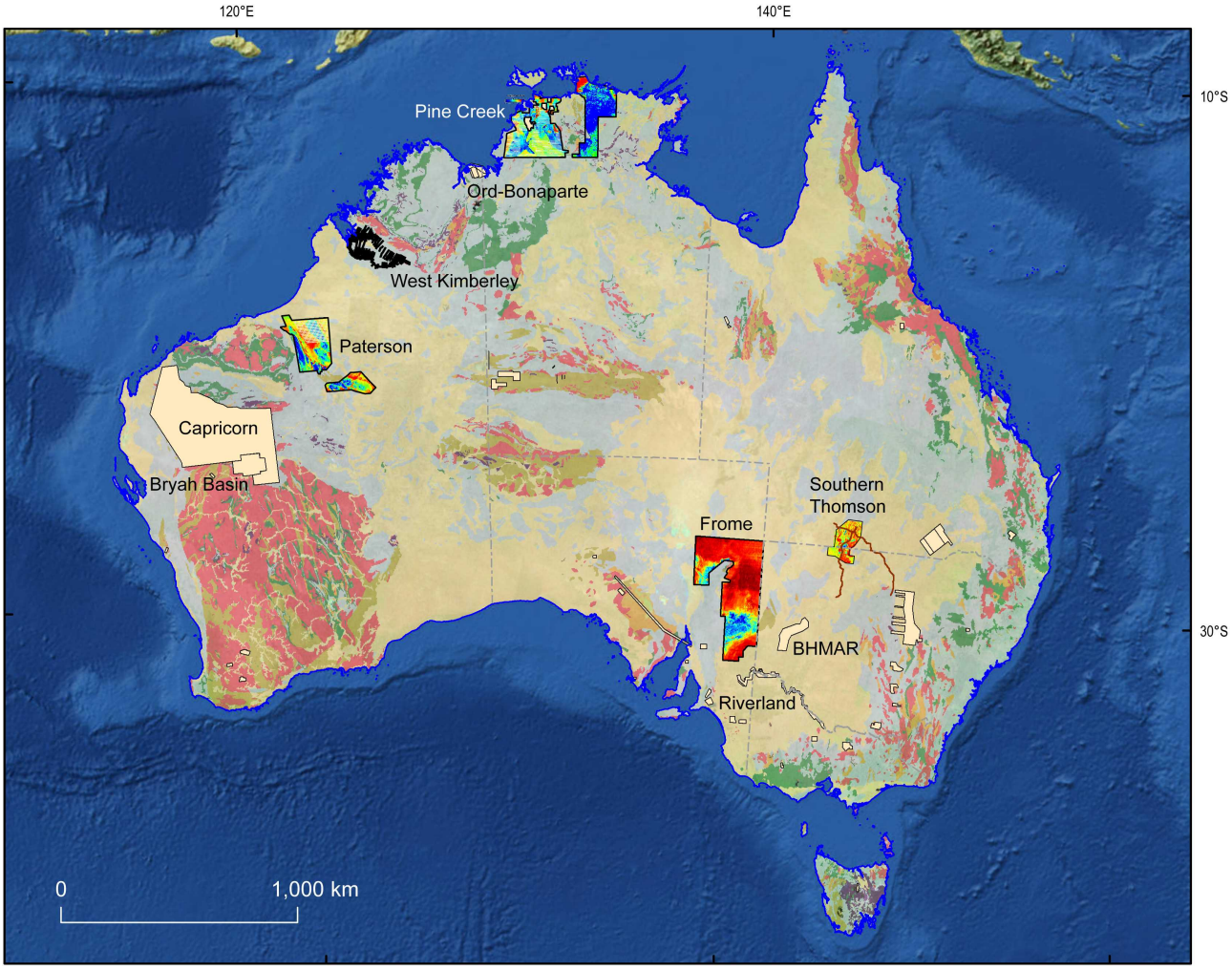

Figure 1: Geoscience Australia's involvement in AEM surveys in Australia. Background: 1:2.5 million scale Geology of Australia Map highlighting the prevalence of cover (yellow and light blue areas on the map).

AEM DATA ACQUISITION AND PROCESSING

Geoscience Australia is a key agent for regional airborne electromagnetic (AEM) data acquisition, processing and interpretation. New data are acquired by a panel of commercial AEM contractors who can meet the standards required under GA's Deed of Standing Offer. Geoscience Australia manages many AEM surveys for State, Territory and Australian Government clients in the minerals exploration and groundwater mapping areas. Geoscience Australia supervises the AEM data acquisition in a quality assurance and quality control (QA/QC) process and inverts the AEM data using its own algorithms on the National Computational Infrastructure (NCI) supercomputer (http://nci.org.au) at the Australian National University. Contractors supplying data to GA under the Deed of Standing Offer also supply noise estimates and waveform parameters that are used to constrain the inversions. These parameters are not usually supplied by the commercial AEM operators when flying for the minerals or groundwater industries, therefore GA keeps a library of the noise estimates and waveform parameters for a number of the popular AEM systems, allowing us to invert legacy datasets of a similar era when no other information is available. Once inverted, conductivity estimates are converted into a number of different interpretation products including geolocated raster conductivity sections and grids for 2D interpretation, and GOCAD objects for 3D interpretation. Once these quality regional AEM datasets are available, older industry datasets may be inverted and reinterpreted through a standardisation process (e.g. Sorensen *et al.*, 2015), allowing higher-resolution infill of the information from the regional AEM datasets.

EXAMPLES OF 3D MAPPING

The Paterson AEM Survey

The first of the OESP AEM surveys, the Paterson AEM Survey (Roach, 2010) was flown using the Fugro (now CGG) TEMPEST® AEM system at line spacings of between 200 m and 6 km totalling 28 200 line km. The Survey data yielded a basement elevation model and derived cover thickness map based on recognising the conductivity contrast at the base of the Paleozoic cover over Proterozoic basement using stratigraphic borehole validation. In this example a basement elevation model was created, which was then subtracted from the Shuttle Radar Topographic Mission (SRTM) digital elevation model (DEM) to create a depth to basement

model. Figure 2 illustrates the interpreted palaeosurface of the top of the Proterozoic, regarded as the basement for economic minerals deposits at Telfer, Nifty and Kintyre, derived from picking the conductivity contrast using drill hole stratigraphy validation.

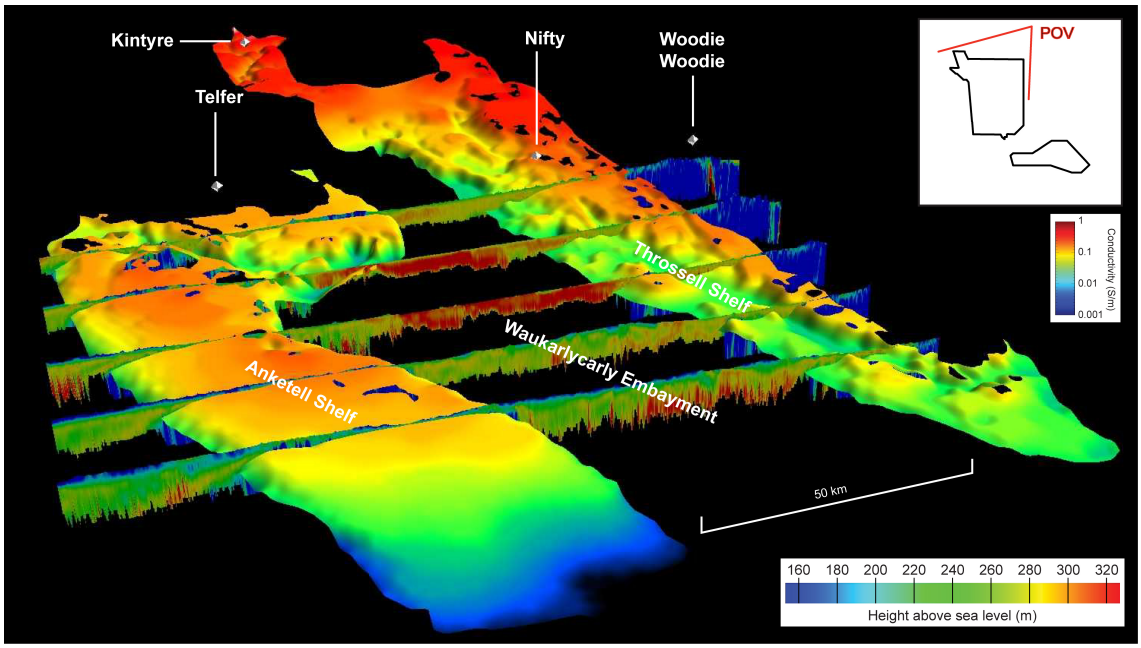

Figure 2: Perspective view of the Paterson basement elevation GOCAD® model showing the interpreted Proterozoic palaeotopography in the Paterson AEM Survey area, Western Australia, looking southwest, from Roach (2010). Hydrostratigraphic units of the Canning Basin can be seen lapping onto the palaeosurface in the selected flight lines intersecting the model.

The Pine Creek AEM Survey

The second of the OESP AEM surveys, the Pine Creek AEM Survey (Craig, 2011), overflew the Pine Creek-Woolner area using the Fugro (now CGG) TEMPEST® AEM system and the Kombolgie area using the Geotech Airborne Ltd VTEM® AEM system at line spacings of between 200 m and 6 km totalling 29 900 line km. Uranium systems research in the area recognised the importance of the Paleo-Mesoproterozoic Depot Creek Sandstone at the base of the Daly Basin and the underlying Paleoproterozoic rocks of the Pine Creek Inlier for the generation of unconformity-related uranium mineral systems. Figure 3 illustrates how the Depot Creek Unconformity can be interpreted and mapped across successive AEM conductivity sections using surface geological mapping and stratigraphic drill holes as validation.

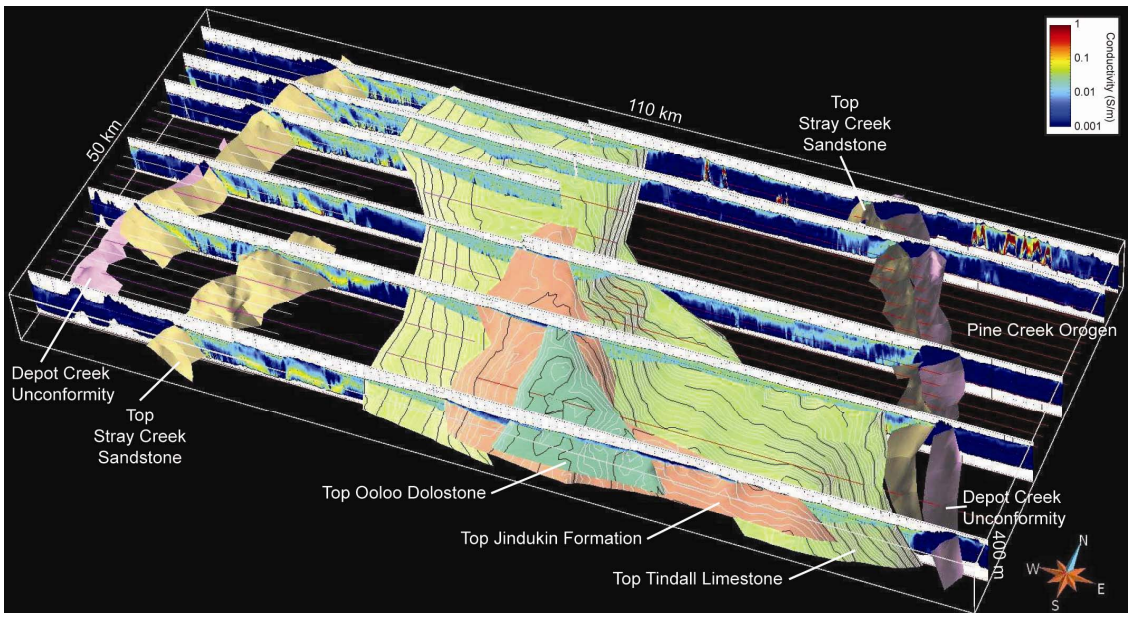

Figure 3: Perspective view of an incomplete Daley Basin, Northern Territory, GOCAD® model, showing selected flight lines. The Depot Creek Unconformity plays a major role in the generation of unconformity-related uranium mineral systems in the overlying sandstones. This model incorporates an earlier model by N.C. Williams, included in Craig (2011).

The Frome AEM Survey

In the last of the OESP AEM surveys, the Frome AEM Survey was flown using the Fugro (now CGG) TEMPEST® AEM system. The Survey was flown mostly at 2.5 km line spacing, opening to 5 km line spacing in the Strzelecki Desert area to the north, totalling 32 317 line km. The regional AEM data can be integrated with older data, including a TEMPEST® multi-client survey flown by Fugro, and various other AEM surveys flown using different systems that are now available for free download from the South Australia Resource Information Geoserver (SARIG; https://sarig.pir.sa.gov.au/Map). The Goulds Dam area was the focus of an intensive study by Sorensen *et al.* (2015) demonstrating how data obtained by different AEM systems could be standardised and integrated using a common inversion algorithm and ground validation. The Frome AEM dataset was used to construct a number of 3D models of the Precambrian basement in this area (Figure 4), as well as mapping the architecture of sandstone-hosted uranium mineral systems with the intention of reducing exploration risk and opening up new areas for uranium exploration (Roach, 2012b; Roach *et al.*, 2014).

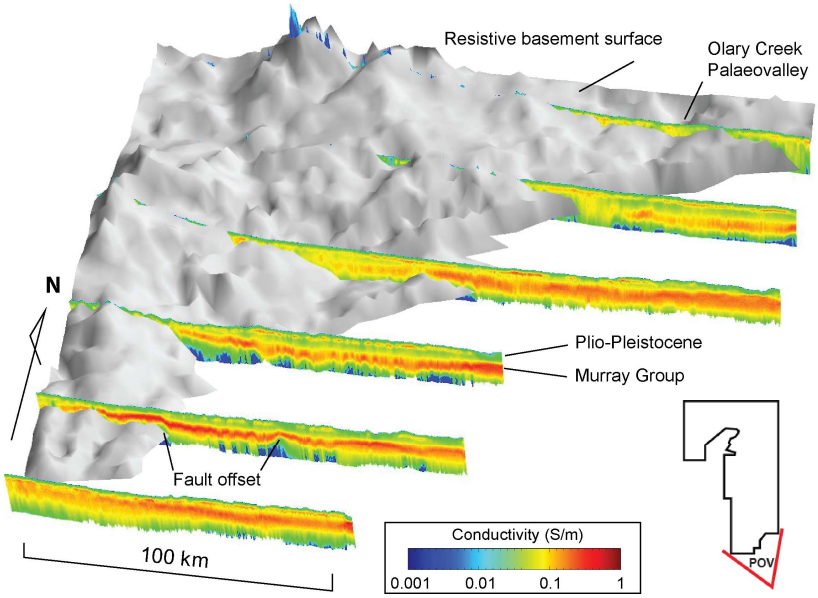

Figure 4: Perspective view of a GOCAD® 3D model of the Nackara Arc, looking northwest. In this model, Cenozoic sedimentary rocks of the Murray-Darling Basin onlap basement consisting of Neoproterozoic rocks of the Nackara Arc and Paleozoic intrusive rocks of the Delamerian Orogen. A number of faults that define the edge of the Nackara Arc influence the geoelectrical stratigraphy of the Murray-Darling Basin indicating post-depositional fault reactivation. Every tenth flight line is shown. From Roach and Costelloe (2012) and Roach (2012a).

The Southern Thomson Project

The southern Thomson Orogen is a poorly understood Paleozoic (Cambrian-Ordovician) crustal element adjacent to the Lachlan Orogen in northwestern New South Wales and Queensland (see Fergusson and Henderson, 2013; Roach, 2015 and references therein). The Project is designed to improve mineral systems understanding and provide new pre-competitive data and geological interpretation over the region. The outcomes of this Project will be to lower mineral exploration risk and encourage new discoveries in the region. The Project includes new geological and geophysical data collection and interpretation, for instance new surface geochemical sampling, new ground gravity and magnetotelluric data acquisition and modelling, and new airborne electromagnetic (AEM) data acquisition and interpretation (Roach, 2015).

The Southern Thomson VTEMplus® AEM Survey was flown between 25 March and 5 May 2014 by Geotech Airborne Ltd, totalling 4268 line km. The Survey was flown in two parts: 1) a regular survey of east-west flight lines over the Eulo Ridge (a paleo-high of Paleozoic basement); and, 2) as two traverses, along which complementary ground gravity and magnetotelluric data were also acquired for modelling of the Thomson-Lachlan orogen boundary and lithospheric architecture (described by Folkes, 2016).

Results from the regular survey were interpreted using available stratigraphic borehole data and surface geological mapping to produce a new depth to basement model of the area (Figure 5) that will be used to interpret cover thickness and target depths for a round of stratigraphic drilling to answer science questions regarding the nature and age of basement rocks in the region, and assess the mineral potential of this under-explored region.

CONCLUSIONS

The volume of AEM data collected in Australia is now at a critical point where quality and availability allow us to invert most of the more recent data, standardise the inversions against more rigorously quality controlled data, and construct models of the electrical architecture of the near-surface over relatively large areas. This process allows us to fulfil two of the key themes of the UNCOVER

Initiative: to characterise the nature and thickness of cover; and, characterise and detect the distal footprints of mineralisation. At GA we are building a national database for AEM data where survey data and the metadata that describe them can be stored and accessed to increase our understanding of the nature and distribution of cover that may be obscuring future mineral deposits.

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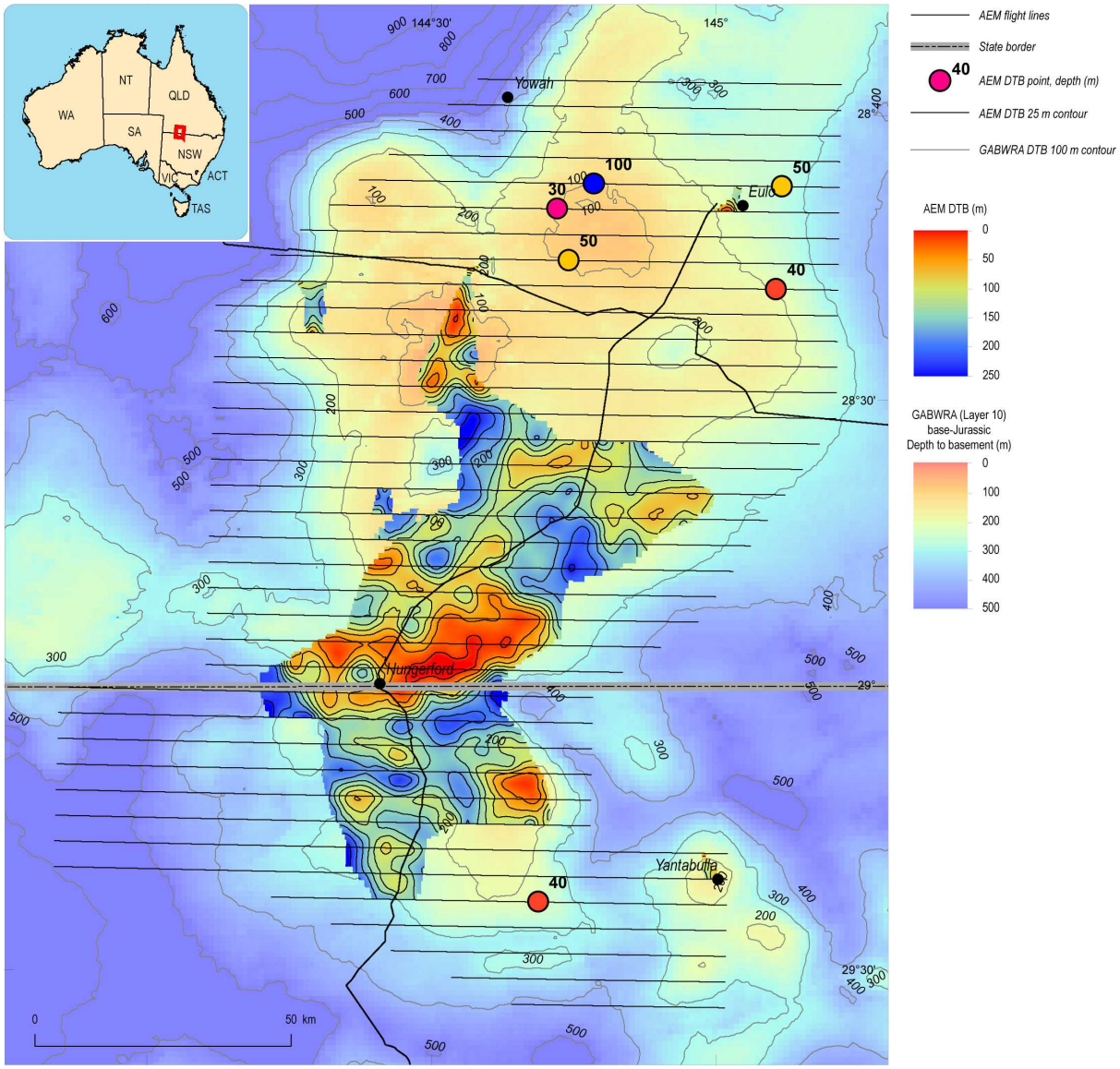

Figure 5: Depth to basement (DTB) model of the Eulo Ridge in the Southern Thomson Project area. The AEM-derived model (bright colours) is overlain on the Great Artesian Basin Water Resource Assessment (GABWRA) base-Jurassic model of Ransley and Smerdon (2012).

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