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The Southern Thomson Orogen AEM Survey

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SUMMARY

The Southern Thomson Orogen airborne electromagnetic (AEM) Survey was flown in 2014 using the Geotech $VTEM_{plus}$® AEM system. The AEM survey was designed by Geoscience Australia, and its partners the geological surveys of New South Wales and Queensland, to help solve geological problems in the Southern Thomson Orogen as part of the UNCOVER Initiative of the National Mineral Exploration Strategy.

Survey results indicate variable depth of penetration governed by conductive cover, primarily the Cretaceous Rolling Downs Group, and saline groundwater in broad ephemeral drainage systems including salt lakes and channel country around the Paroo River. The unconformity between the Paleozoic rocks of the Eulo Ridge (a partially-exposed palaeotopographic high) and the overlying Mesozoic and Cenozoic cover is well mapped in the central part of the survey area. The survey data reduce risk to explorers in the area by decreasing uncertainty regarding depth of cover for drilling activities and advising where ground and airborne electromagnetic methods can be expected to produce reliable results.

Key words: airborne electromagnetics, depth to basement, cover thickness, UNCOVER.

INTRODUCTION

The Southern Thomson Orogen AEM Survey is Geoscience Australia's first geophysical dataset collected and published under the auspices of the UNCOVER Initiative (Australian Academy of Science 2012) that has been adopted by Geoscience Australia as part of the National Mineral Exploration Strategy (COAG 2012). The UNCOVER Initiative is designed to encourage new mineral exploration investment in cover-dominated areas by testing innovative geological, geophysical and geochemical techniques and by providing new assessments and pre-competitive datasets.

The Thomson Orogen stretches from northwestern NSW through to northeast Queensland and is largely covered by younger Mesozoic and Cenozoic sedimentary basins (Fergusson and Henderson 2013). The southern portion of this poorly-understood Cambrian-Ordovician (Lower Paleozoic) orogen is now the focus of a collaborative research program between Geoscience Australia, the Geological Survey of NSW and the Geological Survey of Queensland. This program will assess the mineral potential of the southern portion of the Thomson Orogen, concentrating around the border of New South Wales and Queensland, and attempt to add clarity to the boundary between the Thomson Orogen and the Lachlan Orogen.

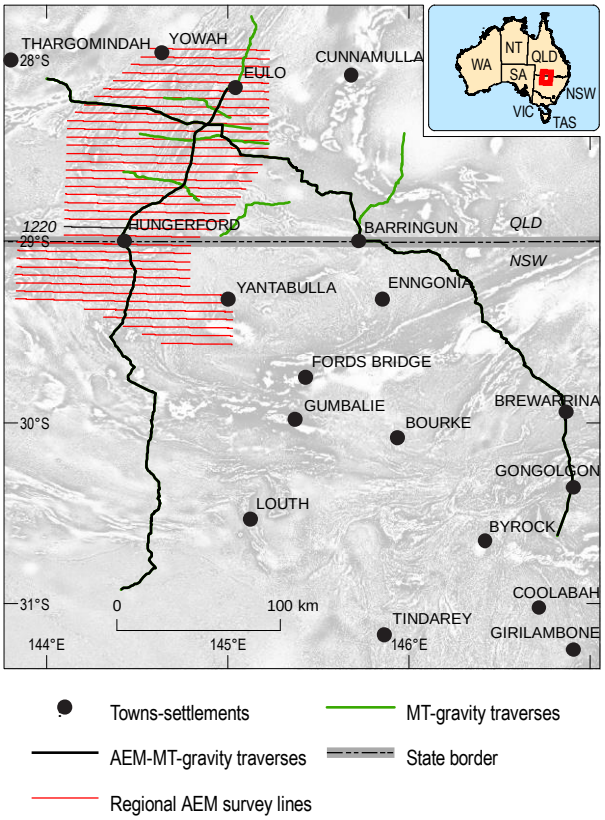

Figure 1. Acquired AEM and planned MT and gravity acquisition in the southern Thomson Orogen. Flight line 1220 (see Figure 2) is indicated in black.

The research program includes regional-scale geophysical data acquisition in the form of a regional AEM survey and two traverses of AEM and complementary gravity and magnetotelluric (MT) data acquisition, as well as additional MT

and gravity data acquisition along smaller targeted traverses in Queensland (Figure 1).

This abstract describes the AEM acquisition, processing and interpretation program and discusses some of the geological highlights. You can learn more about the Geoscience Australia AEM program and the Southern Thomson AEM Survey dataset at http://www.ga.gov.au/about/what-we-do/projects/minerals/current/continental-geophysics/airborne-electromagnetics.

AEM SYSTEM SELECTION AND DATA ACQUISITION

The southern Thomson Orogen is known to have variable thickness conductive cover consisting of Mesozoic and Cenozoic sedimentary basin rocks, and fresh to highly saline groundwater. Assessments on likely geoelectrical conditions were made on government and industry AEM surveys from the wider area including the Lower Macquarie AEM Survey (Macaulay and Kellett 2009), the Lower Balonne AEM Survey (Lane, et al. 2004) and the Louth AEM Survey (Burtt 2009). Groundwater data from the National Groundwater Information System database (BOM 2014) were also considered to build up regional detail of the geoelectrical conditions. These assessments were then used to inform the choice of system available on the Geoscience Australia AEM Deed of Standing Offer. The highly conductive cover and complex flight lines meant that a high-powered helicopter borne AEM system was preferable for this survey.

The Southern Thomson Orogen AEM Survey was flown between March 25 and May 5, 2014, using the Geotech Airborne Ltd VTEMplus® AEM system (Geotech 2014). This helicopter-borne system was used to fly a survey in two parts across the area of interest (Figure 1) including:

1. A regional AEM survey with east-west flight lines at 5000 m line spacing totalling 3352 line km covering 16,261 km^2
2. Two single AEM traverses roughly between Gongolgon and Thargomindah, and Louth and Eulo, totalling 915 line km, to complement later MT and gravity acquisition.

The system was configured to use a trapezoidal transmitter waveform with 25 Hz base frequency, 7.3 ms pulse width, and a 1.3 ms turn-off ramp time. Z-component and X-component data were recorded in streamed fashion at 192 kHz.

Before and during the survey the AEM system collected data across repeat lines to assess repeatability and system drift, and high altitude tests were flown to assess system noise.

PROCESSING AND INVERSION

The data processing was carried out in Canada by Geotech using their FullWaveform® processing methodology. The electromagnetic processing steps described in the survey report (Geotech 2014) can be summarised as:

1. Parallax correction
2. Sferic rejection
3. Sensor response calibration to a common impulse response
4. Stacking into 15 half-cycles per stack
5. Binning of 192 kHz samples into 45 off-time windows with centre times from 0.021 to 10.667 ms
6. Compensation for bucking loop variations
7. Non-linear 0.4 s and low-pass 1.0 s filters
8. Subtraction of high altitude measured zero-level bias
9. Derivation of B-field from streamed dB/dt data.

The transmitter-receiver loop height above ground and position were not directly measured. Instead they were estimated via data from the helicopter radar altimeter and laser altimeter, inclinometer and GPS units located on the magnetic gradiometer loop. Geotech also produced EM Flow® conductivity depth imaging (CDI) products. Final processed data and the report are available from http://www.ga.gov.au/metadata-gateway/metadata/record/81852.

At the time of writing, we have generated two 1D layered earth inversions from the preliminary data and waveforms. The first a regularized (vertically smooth) deterministic inversion using the Geoscience Australia sample-by-sample layered earth inversion algorithm *GA-LEI SBS* (see Appendix 3.2 of Roach 2010). The second, using the Geoscience Australia stochastic reversible jump Markov chain Monte Carlo algorithm *rj-McMC* (Brodie and Sambridge 2012).

GEOLOGICAL INTERPRETATIONS

Survey data were combined with available drill hole lithology or stratigraphy data, groundwater chemistry data, regional geophysical data (magnetics, gravity, radiometrics) and interpreted basement geology (Purdy, et al. in prep). These were used to help interpret the depth to basement (here regarded as the top of the southern Thomson Orogen), the location of potential discrete conductors in the basement and the architecture of cover sedimentary sequences within the regional survey area, and partially along the AEM traverses.

The resistive basement—in this case granites, volcanics and metamorphosed sedimentary rocks of the southern Thomson Orogen—is readily recognisable across the Eulo Ridge. This is a palaeotopographic high extending north-northeast from Hungerford to Eulo across the New South Wales-Queensland state border. Rocks of the southern Thomson Orogen are generally resistive, however a number of discrete conductors within the basement appear to be related to fracture zones and interpreted black shale, hornfels or volcanic units within the basement.

The Eulo Ridge exhibits dramatically higher palaeorelief (hundreds of metres) compared to present-day topography (tens of metres). A number of palaeovalleys are visible at the base of the Mesozoic cover of the Eromanga Basin, as well as cut-and-fill features that may extend into the Cenozoic cover of the Lake Eyre Basin. These are up to 100-150 m deep and in some places appear to take advantage of differential erosion between more easily-erodible igneous or regionally metamorphosed rocks and less easily-erodible contact-metamorphic aureoles around granite intrusions. A number of basement highs are also mapped, surrounded by onlapping Mesozoic sedimentary rocks. These features support the conceptual Mesozoic environment of deposition as one of the Eulo Ridge forming a chain of islands surrounding by a cool to cold shallow sea (Alley and Frakes 2003, Frakes, et al. 1995) with sedimentation being generally mud-dominated, except

where local erosion scoured more quartzose sand-rich sediments from the exposed islands (Exon and Senior 1976).

The different inversion products (Figure 2) are used to interpret depth to basement. Initial interpretations using the EM Flow® CDI product are cross-checked against the GA-LEI SBS deterministic product and the rj-McMC product. The rj-McMC product provides more surety to interpretations of the other inversion products, by providing sharper conductivity boundaries and uncertainty estimates to interpret, and may allow the interpretation of the lower surfaces of conductive stratigraphic units in some circumstances.

Across the top of the Eulo Ridge the AEM data allow us to confidently interpret and map the depth to basement, and derive a cover thickness map, along flight lines. These interpretations are then extrapolated between flight lines with the aid of bore hole lithological data provided by water bores scattered within the regional survey area. A more difficult task is to interpret depth to basement away from the Eulo Ridge, where the Mesozoic cover thickens. It is here that other interpretations need to be combined with the AEM and drill hole data including depth to magnetic basement determinations such as tilt depth and Euler methods; this task is on-going.

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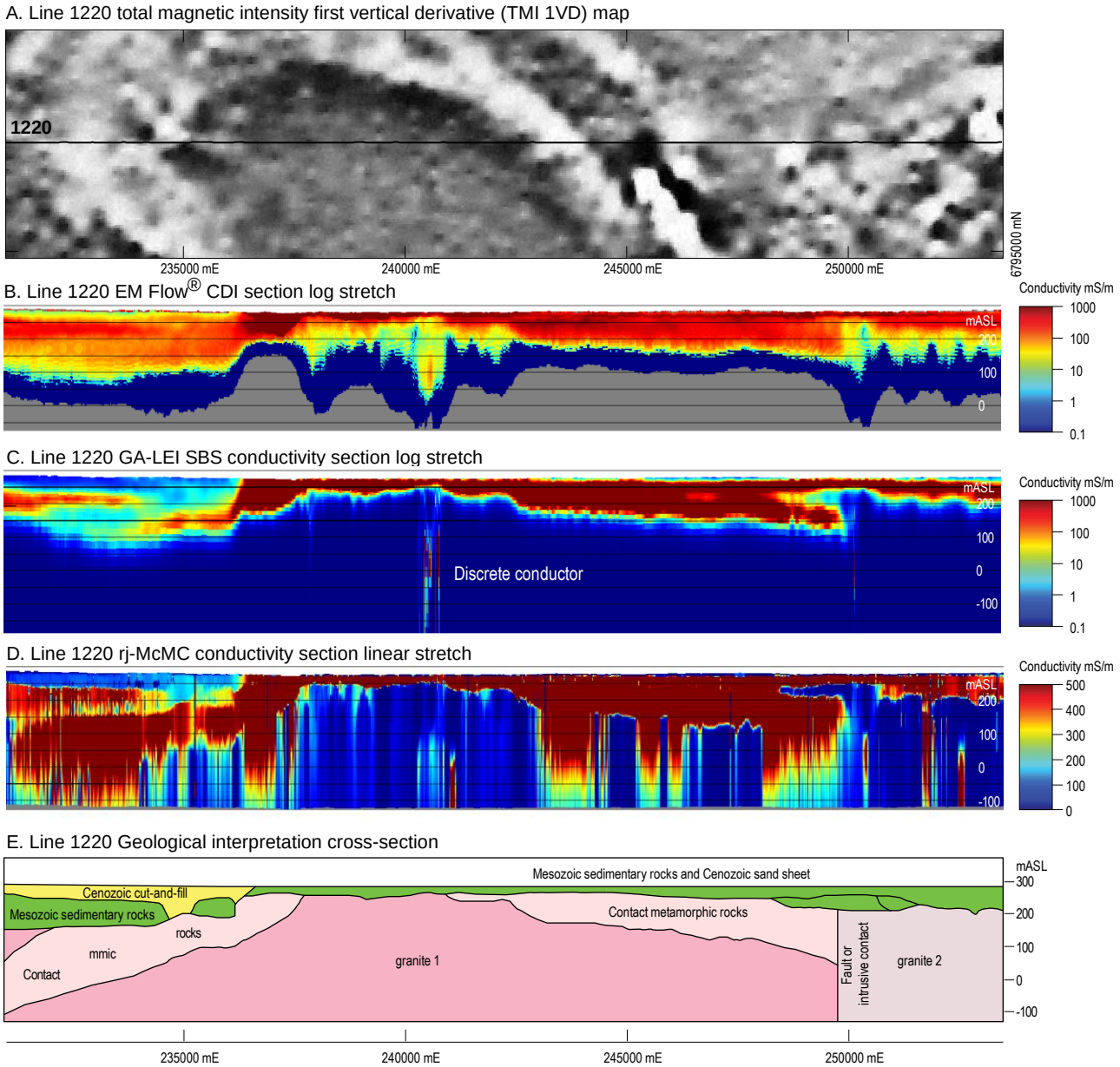

Figure 2. Comparison of conductivity sections from a part of flight line 1220. A: total magnetic intensity first vertical derivative (TMI 1VD) map of flight line 1220; B: EM Flow® CDI section; C: GA-LEI SBS conductivity section; D: rj-McMC conductivity section; E: A preliminary geological interpretation cross-section. 50 m depth interval lines are drawn on each conductivity section.