A regional scale Fixed-Wing TDEM survey of the Palaeo-Proterozoic Bryah Basin, Western Australia: Providing insights into a setting highly prospective for VMS Cu-Au and mesothermal Au Systems

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SUMMARY

The Bryah Basin is part of the Capricorn Orogen, a collision zone between the Archaean Pilbara and Yilgarn Cratons in western Australia. The Basin is host to significant mineralisation, including mesothermal orogenic gold, copper–gold volcanogenic massive sulphides. Among the challenges in the exploration for these mineral systems is the paucity of outcrop and the extent and variability of a complex regolith cover. To better understand this regolith, a reconnaissance, regional-scale, fixed-wing time domain AEM survey was undertaken over the Bryah Basin in 2012. The resulting data were inverted using a smooth model layered earth inversion. In this paper we compare results on mapping regolith variability obtained from the full inversion of the AEM data against that defined from the fast approximate transform of the same data set. The inverted data show the most dominant regolith features are associated with sediment filled palaeovalleys. The regional regolith framework determined from this study provides a basis for better understanding and interpreting an extensive regolith geochemical data set with respect to metalloid anomalies linked to buried Cu-Au mineral systems

Key words: Bryah Basin, Fixed-Wing AEM Systems, inversion, Regolith Cover

INTRODUCTION

The Bryah Basin, part of the Capricorn Orogen located between the Archaean Pilbara and Yilgarn Cratons in Western Australia is characterised by a thick and variably complex regolith (Figure 1), which has developed over a succession of mafic and ultramafic rocks, and clastic and chemical sedimentary rocks. The Basin is host to significant mineralisation, including mesothermal orogenic gold, copper–gold volcanogenic massive sulphides. The Basin is relatively under-explored, although host to significant mineralisation, including mesothermal orogenic gold, and copper–gold volcanogenic massive sulphides (Pirajno et al. 2004). The Cu-Au VMS deposits include DeGrussa and Horseshoe Lights, hosted by a sequence of weathered sediments, mafic volcaniclastics, dolerites and gabbros in a structurally complex setting, are examples. DeGrussa has an identified resource of ~ 14.33Mt @ 4.6% Cu and 1.6g/t Au. One of the principal challenges for exploration through the Bryah Basin is the paucity of outcrop and the extent of regolith cover. In the Bryah, Yerrida and Earaheedy basins, for example, outcrop constitutes less than 15% of the surface area Pirajno (2004). This problem requires the use of geophysical (aeromagnetic, electromagnetic and gravity) and geochemical techniques as aids in the mapping of lithostratigraphic units that are covered by regolith materials, but also in providing an understanding of the regional geological factors that control the mineralisation (Pirajno 2004).

In recognition of such challenges, a regional fixed-wing AEM survey was undertaken across the Bryah Basin with the primary aim of mapping regolith character and thickness at a regional scale, and mapping subsurface geological units. Similar surveys have been undertaken elsewhere in WA, South Australia and the NT (e.g. Roach, 2010 and Craig, 2011). In addition to reducing exploration risk and enhancing prospectivity, within a region having potential for Cu-Au and Au mineralisation, this survey was also undertaken to assess the SPECTREM fixed-wing time domain EM system (Leggatt et al 2000) as a regional regolith mapping technology. In this paper we describe an approach to interpreting the resulting data with a view to accurately determining regolith characteristics. For comparative purposes, we also examine results derived from the SPECTREM system against those obtained from another fixed-wing time domain EM system – the TEMPEST^{TM} EM system (Lane et al. 2000).

BRYAH BASIN AEM SURVEY

The Bryah AEM survey was flown with the SPECTREM$_{2000}$ fixed wing AEM system (see Leggatt et al. 2000), with ~5.2km line spacing orientated N-S. The SPECTREM$_{2000}$ is a fixed wing, time domain AEM system employing a bipolar, 100% duty cycle, and a square-wave current pulse which operates at variable base frequencies of 25 Hz and higher. It has a peak moment of 400,000Am^2. These specific characteristics imply that the transmitted current pulse is coupled with ground response so further processing is needed in order to separate the secondary field response. Both X- and Z-component data are recorded and at each station the EM decay is as a step response, averaged and then sampled into 10 time windows (window times: 0.026 – 16.65ms). In this processing scheme, the last window of the decay is subtracted from all the earlier windows in an attempt to remove the transmitted primary present in the recorded response. This compares with the TEMPEST^{TM} which is also a fixed-wing, time-domain electromagnetic system (Lane et al 2000). However, it employs an approximate square-wave, 50% duty cycle current waveform with a base frequency of 25 Hz or

higher, and has a much lower peak moment – 61880 Am^2. As with the SPECTREM system, the current is transmitted through a single turn transmitter (TX) loop draped around the nose, wings and tail of the aircraft, and X- and Z- component data are recorded by receiver (RX) coils are housed in a 'bird' towed behind and below the aircraft.. For the TEMPEST system, survey data are deconvolved to a ground response, then transformed to B-field response for a perfect 100% duty cycle square wave, and finally binned into 15 time windows (window times: 0.013-16.2ms). The lower moment and measurement at earlier times, suggests that TEMPEST would be more sensitive to variations in the regolith compared with the SPECTREM system.

. INTERPRETATION METHOD

In order to fit the SPECTREM data through inversion, we first restored the removed primary field and converted the data from ppm to Teslas. We then inverted the total field (primary + secondary) data using a modified version of the Geoscience Australia-Layered Earth Inversion (GA-LEI) algorithm. The algorithm, initially conceptualised by Lane et al. (2004), was developed and implemented by Brodie (2012). The GA-LEI LEI algorithm inverts for layer conductivity and some geometric parameters. At each station the recorded X- and Z-component total field data, and additional measured or assumed elements of geometry are employed. The primary field is calculated using dipole equations derived by Wait (1982) using the high-altitude receiver position estimates. More detail on the procedure is given in Ley-Cooper et al. (2013). The forward AEM response is calculated given a set of unknown parameters of conductivity, layer thicknesses and some elements of geometry. Parameters such as transmitter height, system waveform and window positions are also used in calculating the forward response. We inverted to solve the electrical conductivity of each layer on a sample-by-sample basis for a fixed-thickness smooth (30-layer) model. For comparative purposes we also inverted a coincident line of data from the TEMPEST fixed-wing TDEM system acquired over part of the Bryah Basin. The comparison was facilitated by using the same model parameterization and a common inversion kernel, specifically the GA-LEI. The inversion approach for TEMPEST data is described in Brodie (2012).

RESULTS

A comparison between conductivity-depth sections obtained through the GA-LEI versus results obtained from a fast approximate transform of one line of SPECTREM data are shown in Figure 2. Close examination show marked differences in the detail obtained in the upper 100m, detail that relates to variations in a conductive regolith cover. The GA-LEI shows a variable structure and vertical conductivity variation not apparent in either the SPECTREM supplied CDI, or that obtained with EMFlow. A forward modeling study for a 3 layer model, indicative of a regolith setting, indicated that failure to take account of system geometry (Dz and Dx in Figure 2) could result in significant errors in the definition of regolith thickness and character (Ley-Cooper et al 2013). For that reason, we believe a more accurate definition of the conductive regolith in Australian settings such as encountered in the Bryah Basin, requires a considered approach to SPECTREM data interpretation which can only be achieved through an inversion approach that attempts to determine, and account for Tx-Rx variations. The fixed-wing TDEM system comparison (Figure 3) indicates that both EM systems appear to resolve similar conductivity structure, although the detail in the conductive regolith differs slightly. Further work is required to determine how each of the systems performs in mapping detail within the regolith. Both systems define a deeper, unmapped palaeovalley to the north, suggesting that the gravity data used to delimit the regolith-basement boundary cannot resolve a density contrast between the palaeovalley sediments and the underlying metasediments. A gridded map of regolith thickness derived from the fully inverted data for the Bryah survey is shown in Figure 4. The most dominant, and thickest, regolith features are associated with sediment filled palaeovalleys, valleys that underlie the current track of the Murchison and Gascoyne Rivers and their tributaries. In places regolith thickness exceeds 150m, with the orientation of the palaeovalleys indicating a strong lithostructural control (Figure 4).

CONCLUSIONS

We believe the full inversion of fixed-wing TDEM data, taking account of system geometry and the total field, yields a more robust estimate of regolith variability and character. For the Bryah Basin, the inverted regional AEM data show the region to be characterised by a variable regolith that exceeds 150m in depth in places. The most dominant regolith features are associated with sediment filled palaeovalleys. The regional regolith framework defined from the AEM data provides a basis for better understanding and interpreting regolith geochemistry that has been acquired across a region where outcrop is limited, and should assist its exploration for Cu-Au VMS and mesothermal orogenic gold style mineral systems.

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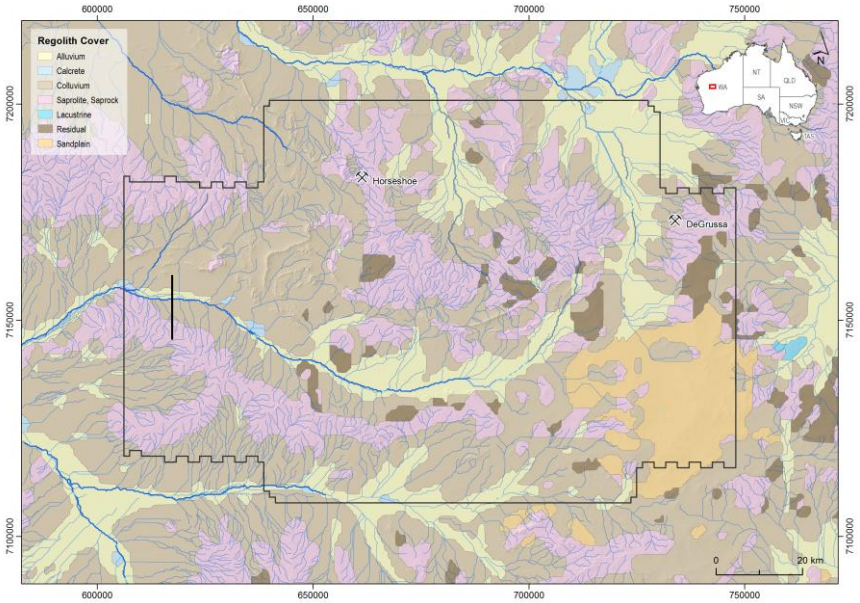

Figure 1. A map of regolith materials across the Bryah Basin. The SPECTREM survey area is outlined by the black polygon. The area is extensively covered by transported cover.

Line of data shown in Figure 2 is shown in the western portion of the area.

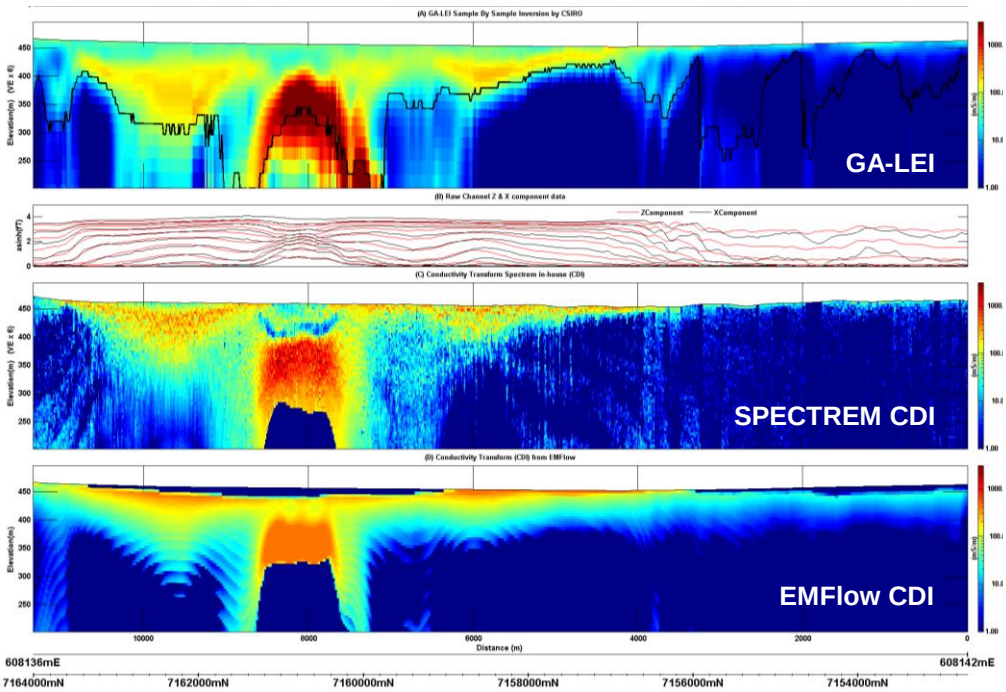

Figure 2. Comparison of conductivity-depth section returned for the same line of SPECTREM data that covers a palaeovalley near Mt Padbury Station in the Bryah Basin survey area. The deep conductor is associated with bedrock. The regolith also appears as a conductive near surface layer with variable thickness and character.

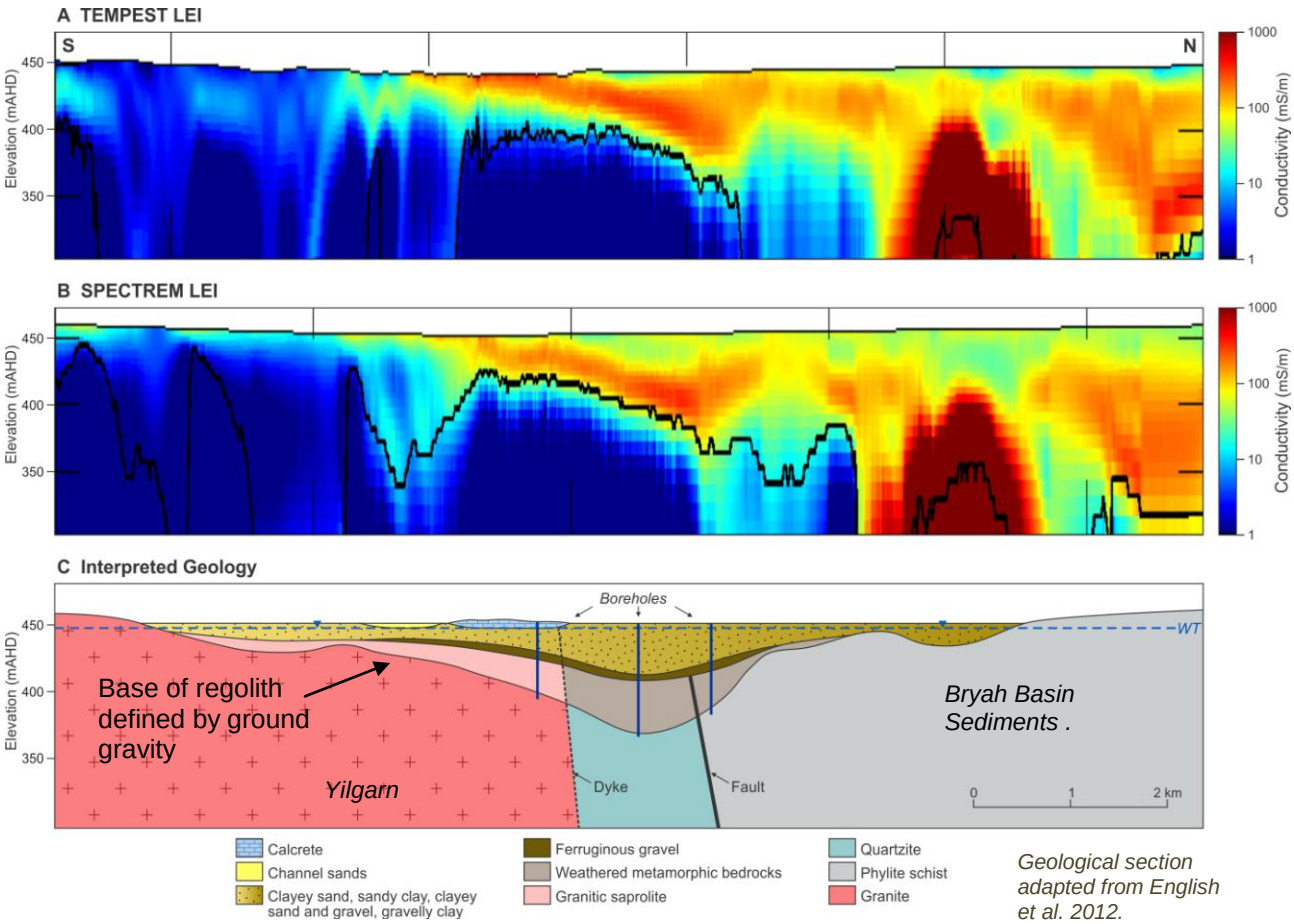

Figure 3. Comparison between inverted (with GA-LEI) TEMPEST and SPECTREM data for a line across the Murchison River. The Geological interpretation has been compiled by English et al 2012, and delimits the regolith – bedrock boundary defined from a ground gravity survey. The Inverted AEM data sets suggest that there may be another palaeovalley system located to the north (right side) of the one determined form the gravity and the existing drilling.

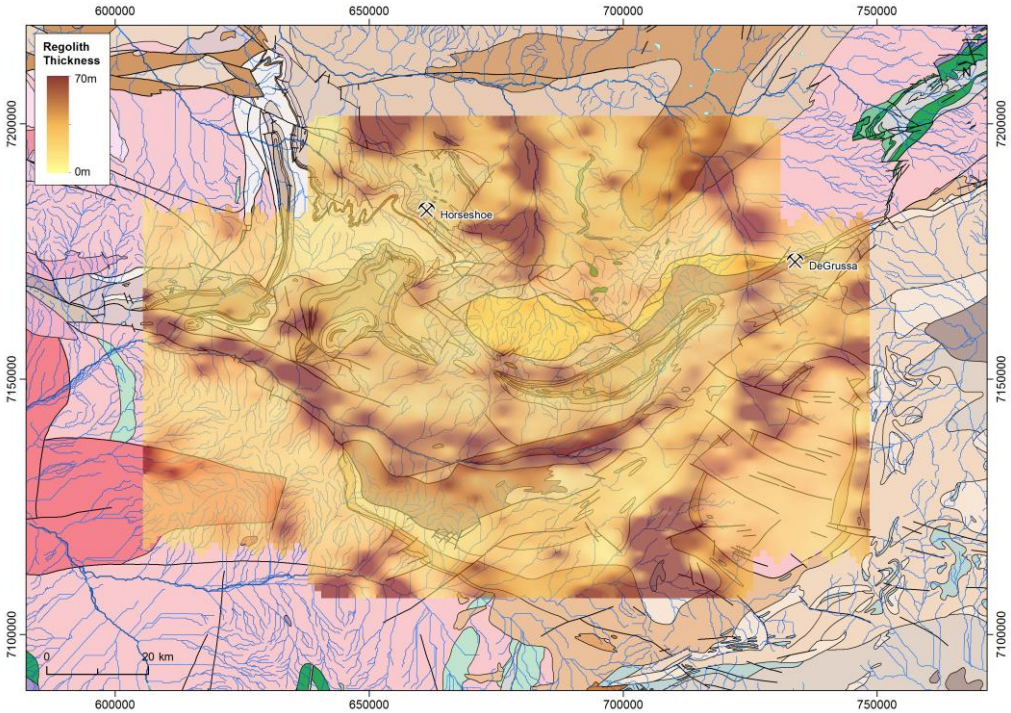

Figure 4. Regolith thickness map for the Bryah Basin derived from the inverted AEM data. The map is overlain on a bedrock geological map and shows how some of the areas defined as thick regolith appear to follow lithological and structural trends.