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Scale reduction using magnetotellurics – a mineral exploration example from the Olympic Domain, South Australia

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SUMMARY

We present results of 334 ultra-wide band MT stations across an area of 100 km x 100 km in the prospective eastern Gawler Craton. The survey area is situated ~100 km south of the supergiant Olympic Dam IOCG deposit, across an area of several IOCG deposits and prospects, including Carrapateena, Oak Dam, and Khamsin. Station spacing varies between 5 km and reduces to 1.5 km around areas of known IOCG prospects. The 3D resistivity models show a north-south oriented conductor in the upper crust. Known IOCG prospects are situated along its margins. These results expand the previously only 2D defined signatures of IOCG deposits, such as Olympic Dam to the full 3D domain. Together with the wider-spaced AusLAMP deployment and a 1.5km to 3 km spaced AEM survey, the survey is unique for imaging the whole-of-lithosphere footprint of IOCG deposits under cover.

Key words: magnetotellurics, Olympic Domain, mineral exploration, electrical resistivity

INTRODUCTION

Mineral exploration in covered terranes poses a significant geoscientific challenge due to lack of outcrop and sparsity of geochemical expressions in the overlying cover sequences. Recent results of the Australian Lithosphere Architecture Magnetotelluric Project (AusLAMP) across the Gawler Craton, South Australia, have revealed zones of enhanced crustal conductivity along the eastern margin of the craton coinciding with a highly prospective iron-oxide copper gold (IOCG) belt and connected to a mantle plumbing system (Thiel et al., 2013; Thiel et al., 2016; Heinson et al., 2018). The results show that the eastern margin of the Gawler Craton has a significant geophysical footprint associated with fluid and magmatic processes leading to the mineral enrichment of the crust.

To date only one example exists of an in-fill MT survey spanning the eastern Gawler Craton margin, which showed fossil fluid and magmatic pathways imaged by zones of low resistivity extending from the lower crust to the upper crust beneath known IOCG deposits and prospects (Heinson et al., 2018). This current study introduces a grid of over 334 ultra-wide band MT sites about 100 km south of Olympic Dam across an area of several IOCG prospects including Carrapateena, Freemantle Doctor, Khamsin, and Oak Dam.

METHOD AND RESULTS

Magnetotellurics is a passive electromagnetic technique measuring natural variations of the Earth's magnetic and electric at the surface of the Earth (Cagniard, 1953). Interactions between the solar plasma with the Earth's ionosphere and magnetosphere (Frequency f<10 Hz or its inverse period T>10 s) or global lightning activity (f>10 Hz) cause magnetic field variations, which act as a source for the induction of electric eddy currents in the Earth.

In the field, the MT systems sample time series of the horizontal electric field $\{E_x, E_y\}$ and the three-component magnetic field $\{B_x, B_y, B_z\}$, with $\{x, y, z\}$ denoting geographic north, east, and vertically down, respectively. The time series convert into the frequency domain using robust remote referencing processing schemes. The frequency of the signal as well as the bulk resistivity of the subsurface determines the penetration depth δ of the signal via the skin-depth relationship (in m):

$$\delta = 503\sqrt{\rho \cdot T}$$

The complex ratio of the horizontal electric to magnetic field, as a function of period T, yields the impedance tensor Z via:

$$[E_x \quad E_y] = \begin{bmatrix} Z_{xx} & Z_{xy} \\ Z_{yx} & Z_{yy} \end{bmatrix} \cdot \begin{bmatrix} B_x \\ B_y \end{bmatrix}$$

Each component of $Z = X + iY$ can be expressed as a magnitude ρ_a and phase ϕ as follows:

$$\rho_a = \frac{1}{\omega\mu_0}\left|Z_{ij}\right|^2$$

Where ω denotes the angular frequency, and μ_0 the magnetic permeability.

$$\phi = \tan^{-1}\frac{\Im Z_{ij}}{\Re Z_{ij}}$$

Where I and R denote the imaginary and real part of Z_{ij}, respectively. Figure 2 shows an example of a MT response for a station within the survey. The bandwidth extends to the AMT band with shortest periods around 10^{-4}s and extends to just over 1000 s at the longest periods.

Strike analysis of the data reveals a predominantly 1D nature for periods <0.1 s reflecting the sediment cover across the survey area, which extends several hundred metres below the surface. At a period of 10 s, the general strike of the basement turns to north-west reflecting a structural grain in the upper crust. At periods of 1000 s, representative of the lower crust, the strike direction turns to NNE, aligning itself with the orientation of the Gawler Craton margin, and imaged in the AusLAMP model for this part of South Australia (Figure 1).

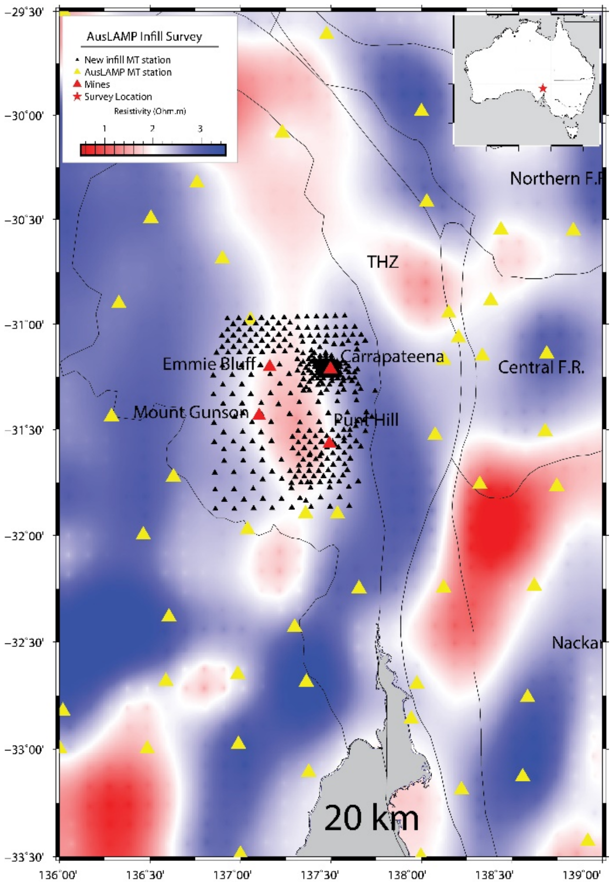

Figure 1. Outline of the broadband and audio-magnetotelluric stations (black triangles) of the new Olympic Domain in-fill survey on top of a 20 km depth slice of the 3D AusLAMP MT model across the Gawler Craton. Yellow triangles denote locations of the AusLAMP MT sites. The survey area is placed atop an elongated crustal conductor of the eastern Gawler Craton IOCG terrane. This survey is designed to provide an enhanced 3D resolution of this mineral system.

Preliminary results of the 3D inversion of all MT stations using a smooth non-linear conjugate gradient algorithm (Egbert and Kelbert, 2012; Kelbert et al., 2014) across the survey area reveals the varying sediment thickness beneath the survey area. The shallowest sediments appear in a north-south direction in the eastern half of the survey area increasing to around 800 m in the western part of the 100 km x 100 km grid. Beneath the sediments, a north-south orientation of the main conductivity variations is apparent, with higher resistivities beneath the shallower part of the sediments.

The majority of the significant IOCG prospects appear to lie at the margins of the resistor in the eastern part of the survey area that spans the entire upper crust.

CONCLUSIONS

AMT and BBMT data were collected at 334 sites across the Olympic Domain, 100 km south of Olympic Dam. The 100 km x 100 km grid of sites spaced between 1.5 km and 5 km represent a scale reduction from the long-period AusLAMP deployment across South Australia, focussing on one of the elongated lower crustal pathways coinciding with the eastern margin of the Gawler Craton. The survey has been able to a) image the varying sediment thickness across the survey area; b) reveal a north-south oriented conductivity gradient between a resistive upper crust in the eastern part of the survey area and a more conductive crust to the west; and c) show that some of the prospective IOCG targets lie along the margins of the upper crustal conductor.

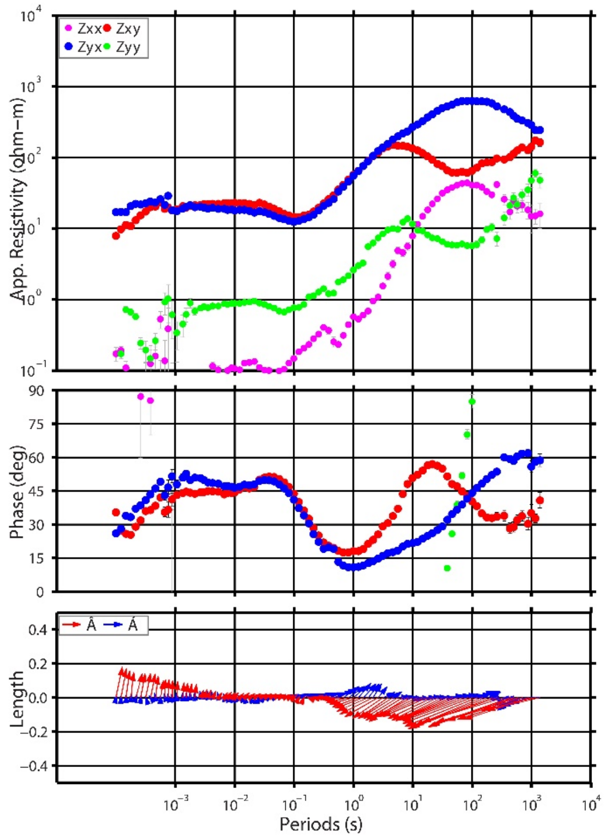

Figure 2. Apparent resistivity (top), phase (middle) and induction arrow (bottom) plots of site 109 showing an example of the data quality.

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