Lithospheric Electrical Resistivity Heterogeneity: A Vector to Mineralization

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World-class mineral systems are characterized by fluid processes that have originated in the deep crust and mantle. However, the processes that entrain and focus fluids through the lithosphere from a deep source that may be tens-of-kilometres in scale to a deposit-scale of less than 1 km are unclear, and the practice of locating world-class deposits is still empirical. In this study, we demonstrate a whole-of-lithosphere magnetotelluric (MT) program across the Gawler craton, South Australia, that provides a potential vector to identifying major mineral systems.

From an array of ~250 long-period MT sites spaced between 50 and 10 km apart, we present new 3D crustal and upper mantle resistivity models of the Gawler Craton and Stuart Shelf to a depth of up to 200 km. Such resistivity models image an extensive conductive cover sequence, but also show large variations at lower crustal and upper mantle depths. The depleted Achaean lithosphere of the Gawler Craton is electrically resistive (>1000 Ohm.m), while Proterozoic basement beneath the Stuart Shelf is two to three orders of magnitude more conducting. Major mineral systems, including Olympic Dam and Carapateena, are coincident with the maximum gradients in mid- and lower crustal resistivity, which may delineate significant deep crust and mantle fluid pathways. However, other significant gradients in resistivity are also imaged, suggesting that these 3D models may provide a new approach to defining regional prospectivity.

We also present a detailed 200 km transect across Olympic Dam, and other prospective areas including Wirrda Well and Vulcan. An 80-site broadband MT survey was conducted along an 80 km profile with a NE-SW orientation along the eastern margin of the Stuart Shelf, centered over Olympic Dam. These MT responses provide much higher resolution of upper and midcrustal resistivity than have been seen before, and have been integrated with existing 5 km spaced long-period MT data over 200 km.

Our modelling shows a significant electrical resistivity anomaly of less than 10 Ω.m in the upper most mantle and lower crust over a scale length of 100 km wide, and perhaps hundreds of km in strike along the edge of an Archean craton. The anomalous region is terminated at a depth of about 10 to 15 km, above which narrow electrical pathways branch to the surface, linking the lower crust with all major mineral systems. We suggest that this whole-of-lithosphere approach images the fluid source region in the crust and upper mantle, and that detailed imaging of the upper crust provides a direct vector to economic mineralization.