MT conductivity signatures of mineral systems: 3D MT over the Eastern Goldfields Super Terrane, Yilgarn Craton

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SUMMARY

Magnetotellurics (MT) is emerging as a key tool for understanding giant mineral systems. For MT to be effective in mineral exploration we require both an improved understanding of the causes of electrical conductivity anomalies and an increased number of surveys over known mineral deposits.

We present results from a new, lithospheric-scale 3D MT dataset collected in the southern Yilgarn Craton, Western Australia. This 250x250 km survey covers the western Eastern Goldfields Super Terrane and the world-class Kambalda nickel and Kalgoorlie gold deposits. We interpret the electrical conductivity models using experimental electrical conductivity data to link the MT results to a mineral systems analysis.

Key words: magnetotellurics; conductivity; lithosphere; xenolith; Kalgoorlie

INTRODUCTION

Magnetotellurics (MT) is a passive electromagnetic geophysical method that images the electrical conductivity of the Earth to several hundred kilometres depth. In stable lithosphere, the dominant controls on electrical conductivity generally relate to past fluid flow and include high hydrogen contents in nominally anhydrous minerals, the deposition of hydrous minerals and the deposition of graphite. Since giant ore deposits are also often associated with fluid flow events, MT data may be useful for imaging and understanding mineralising systems. This has been perhaps most clearly illustrated by the MT survey over the Olympic Dam IOCG deposit, which imaged a strong conductor at lower crustal depths with conductive 'fingers' extending to the upper crust beneath several mineral deposits (Heinson et al., 2018). Recent results of MT surveys over the Cloncurry Region suggest that the Ernest Henry and Mt Margaret deposits are also associated with conductive anomalies (Wang et al., 2018)

If MT is to become an integrated and useful component of minerals systems analysis, the causes and genesis of conductors associated with mineral deposits must be constrained. We take a two-pronged approach to this problem. First, we 'calibrate' MT interpretations by focussing on areas with good xenolith constraints. This allows us to reduce and constrain some of the uncertainties in using experimental mineral physics data to interpret MT models in terms of lithospheric composition and temperature. Second, we focus on MT data that image giant ore systems at a lithospheric-scale. By investigating how our improved MT interpretations can help us understand these known deposits, our goal is that MT will become a useful exploration tool in greenfields regions.

METHOD AND RESULTS

Improved MT interpretations

Many factors contribute to rock conductivity, including temperature, modal mineralogy, hydrogen content of the composite minerals, and interconnectedness of the different mineral phases. Experimental uncertainties regarding several factors including mineral conductivity and hydrogen partitioning can complicate efforts to interpret MT models in terms of lithospheric composition and temperature.

To reduce uncertainty in MT interpretations we have developed software that allows the user to create a forward model of predicted electrical conductivity with depth for different lithospheric compositions and geotherms. The user is able to choose between different experimental datasets to produce these forward models, enabling clear analysis of how the different experimental constraints affect predicted conductivities. Using this software, we have focussed our analysis on regions with good MT data and abundant xenoliths so that the composition and geotherm of the lithosphere is well known. By comparing MT models with forward models of conductivity in these regions we can calibrate MT interpretations, improving our understanding of which compositional factors control electrical conductivity and which experimental datasets are most reliable.

Eastern Goldfields MT

Several pre-existing MT datasets from the southern Yilgarn Craton have shown that the region is electrically complex. Most notably, a 300 km long broadband MT survey extending from the Southern Cross Terrane to the Kalgoorlie Terrane showed several strong crustal conductors possibly associated with mineralisation (Figure. 1; Dentith et al., 2012). However, this survey also showed that the region is electrically three-dimensional and requires data collection in a grid and inversion in a 3D scheme to be properly characterised (Dentith et al., 2012; van Tilburg, 2018).

From late 2018 to early 2019, new long-period data have been collected at more than 30 stations in the southern Yilgarn Craton (Figure. 1). Stations were deployed in a grid with station spacing ~50 km (within accessibility restrictions) with a total extent of more than 250x250 km. The survey area covers mineralisation including the Norseman gold deposit, the Kalgoorlie Gold Field and the Kambalda nickel deposit. The long-period survey has imaged the 3D, lithospheric-scale electrical conductivity structures associated with these deposits. It was designed to also link with more detailed, camp- and deposit-scale broadband MT surveys that have a better resolution of upper crustal features.

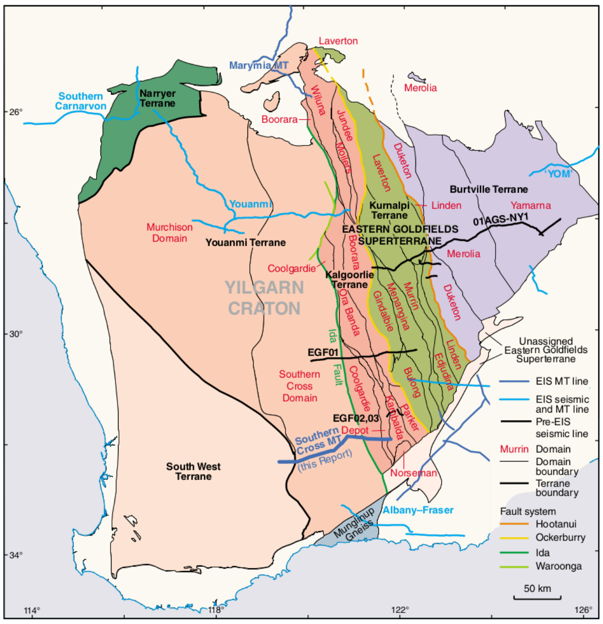

Figure 1. Yilgarn Craton showing the Eastern Goldfields Superterrane and previous geophysical surveys, adapted from Dentith et al. (2012). Blue box shows the approximate extent of the new long-period MT survey.

CONCLUSIONS

The MT method can be developed as a mineral exploration tool by reducing ambiguities in MT interpretations and integrating MT data into the mineral systems analysis of known mineral deposits. In this submission, we advance this goal by using xenolith datasets and experimental mineral physics constraints to improve interpretations of MT models and applying these interpretations to a new, lithospheric-scale 3D model of the Eastern Goldfields region in the Yilgarn Craton, Western Australia.

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