How deep does ground EM see?

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SUMMARY

Nickel exploration routinely utilises electromagnetic techniques as a direct detection tool. In the Australian context, conductive regolith dominated terrains reduces the depth of penetration of electromagnetic techniques. Modelling is typically performed to determine the depth of investigation for basement conductors. These can be modelled as plates of various geometries, size, dip and conductance, leading to an infinite number of scenarios. IGO Limited has been exploring for nickel deposits in the Albany Fraser Orogeny in Western Australia at belt scale. This has generated a large number of ground electromagnetic targets to form a significant database. This paper presents an empirical approach of depth of investigation using this comprehensive EM plate database, in conjunction with a conductance grid derived from a belt-scale AEM survey. The results provide a more practical tool for depth of investigation approach that can assist geologists determine effectiveness of EM in their given project area.
Key words: moving-loop EM, depth of investigation

INTRODUCTION

Magmatic nickel deposits are a favourable deposit type for mineral explorers, due to their polymetallic character (typically Cu, Co and/or PGE's), high grade, and most notably their high value. These deposits are predominantly massive, making them excellent targets for direct detection through electromagnetic techniques due to their high conductivity. Ground time domain EM surveys are the preferred technique to provide maximum depth of investigation and to accurately characterise the conductor target depth, conductance and geometry to aid in drill targeting.

In Australian settings, conductive regolith reduces the effectiveness of electromagnetic techniques, as its response dominates the EM data, and diminishes the response of basement conductors (Stolz, 2000; Trench and Williams, 1994). Mineral explorers are interested in understanding how effective their electromagnetic surveys are in these environments. Forward modelling is commonly used to assess (Wolfgram and Holden, 2001, King, 2007) EM's effectiveness. Although forward modelling can be generated for an infinite number of target geometries, conductance and depth, practically it is typically limited to a single expected response, or various end-member scenarios.

IGO has been exploring for magmatic Nickel sulphides throughout the Albany Fraser Orogen (AFO), with tenements covering ~350km of strike. As a consequence, a large number of ground EM surveys have been collected in conjunction with airborne EM. This has allowed an alternative approach to assess depth of investigation using an empirical methodology. This approach is described in this paper using the extensive geophysical data collected and interpreted over the Albany Fraser Orogeny.

GEOLOGY

The Albany-Fraser Orogen is composed of Mesoproterozoic rocks that outcrop along the south and southeast of Western Australia. The AFO is tectonically juxtaposed against the Archean Yilgarn Craton to the northwest and extends eastwards under the Eucla Basin (Spaggiari et al., 2014). It is interpreted as a collisional zone between the Mawson Craton and Yilgarn Craton. The AFO has been divided into four lithotectonic domains, which are defined by differences in structural style from geophysical datasets and confirmed by field and isotopic studies (Beeson et al., 1988; Myers, 1990; Fitzsimons, 2003; Spaggiari et al., 2011).

Of most interest is the Fraser Zone rocks which are a complex succession of mafic granulites and felsic gneisses that have been intruded by ultramafic to mafic sills and dykes. These ultramafic to mafic intrusives host nickel-copper-cobalt mineralisation at the nearby Nova Operation, which has a mineral resource of 13.1Mt at 2.0% nickel, 0.8% copper and 0.07% cobalt for 270kt of nickel, 107t of copper and 9kt of cobalt (IGO, 2019).

METHOD AND RESULTS

A large airborne electromagnetic survey covering an area of 11,709 km^2 was flown over the Albany Fraser Orogeny (Fitzpatrick and Whitford, 2019) using the Spectrem Plus system. The data was inverted using the GALEI 1D inversion code (Brodie, 2015) to a model depth of 500m. A conductance image was generated from the resultant conductivity model (Figure 1.)

Numerous ground EM surveys have been collected over the belt, primarily with MLEM and some FLEM configurations. In recent times low temperature and high temperature SQUIDS have been deployed. All ground EM data containing anomalies has been modelled using EMIT's Maxwell plate modelling software to generate a database of ~480 plates. The conductance value from the Spectrem data over each plate has been incorporated into the database.

The plate database was binned into 4 categories based upon the plate model area, which are described in terms of nominal geometries as per Table 1. These binned categories are plotted again in Figure 2 with depth of plate versus conductance from Spectrem. This plot clearly shows an empirical depth of investigation of the entire plate database. For each category we see plate targets less than 250 x 250m can be identified at depths to as deep at 570m under 7.5S cover and as shallow as 100m under 30S cover. Plates between 250 x 250m and 500 x 500m can be identified at 600m under 28S cover, plates between 500 x 500m and 1000 x 1000m are identified at 700m depth at 20S conductive cover, and plates larger than 1000 x 1000m have been identified at a depth of 1300m. These results provide a guidance to geoscientists to the depths of targets that can be obtained with ground EM survey under a range of varying conductance cover for various sizes. This approach also ignores certain factors such as plate dip, and plate conductance, similarly the survey loop size and receiver type are ignored although these criteria are easily queried for every data point.

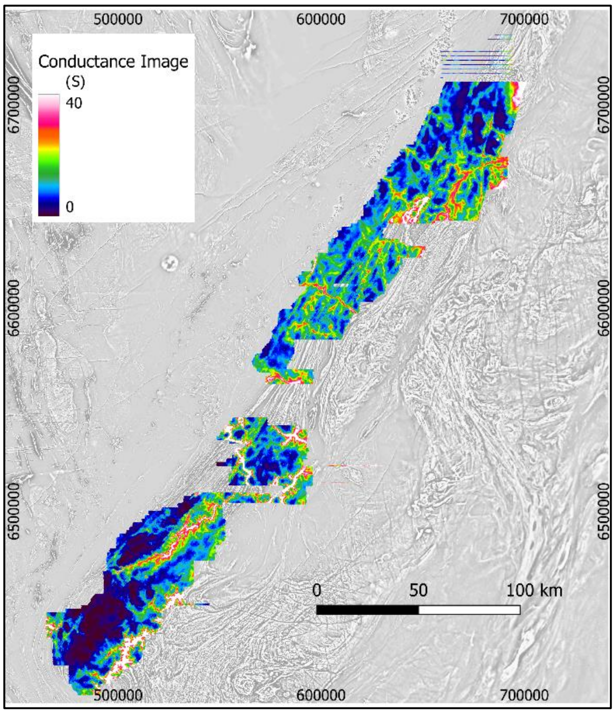

Figure 1. Conductance image of the AFO region generated from Spectrem AEM data, overlying greyscale 1VD aeromagnetics.

Bin	Area (From) m^2	Area (To) m^2	Nominal Size
1	0.00	62,500	up to 250m x 250m
2	625,000	250,000	250m x 250mto 500m x 500m
3	250,000	1,000,000	500m x 500m to 1000m x 1000m
4	1,000,000		1000m x 1000m and greater

Table 1. Binned categories of plates based upon areal size.

This empirical approach is quite practical but does have some limitations. It assumes we have covered a large area of conductive cover to be statistically valid. In order to assess this validity, we plot histograms of number of EM station and number of plates for each of the conductance categories across the belt (Figure 3). This plot does show at high conductances we have less ground EM data, but we still interpret conductors. We may be able to see certain targets deeper than what is depicted in the graphs and this can be confirmed with forward modelling, but the graphs do reveal practically what has been discovered for a range of conductance cover. We believe this is the first time such an approach has been published.

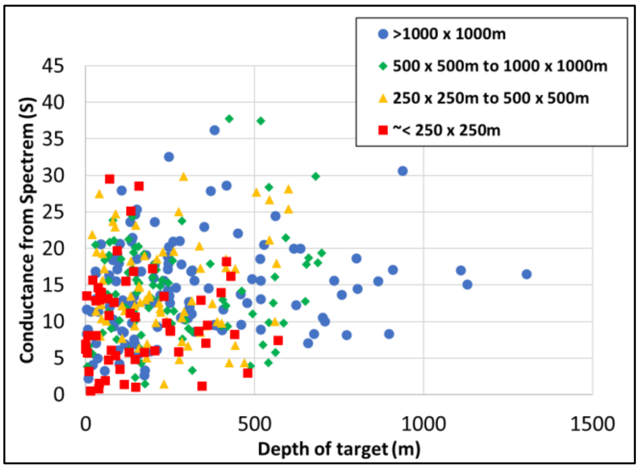

Figure 2. Plot of ground EM plate depths vs conductance for different areal sizes.

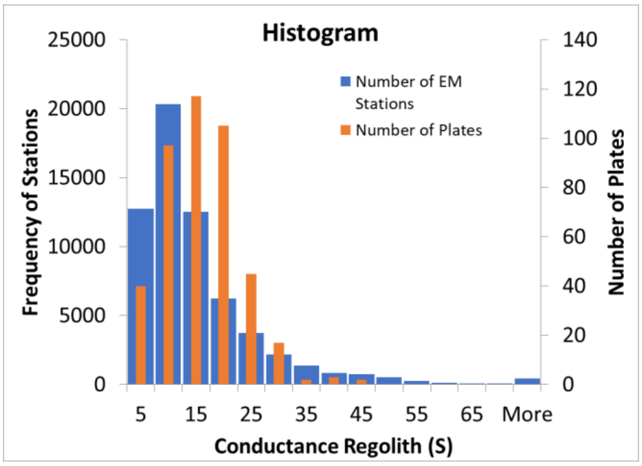

Figure 3. Histogram of ground EM survey points for various conductances and associated plates identified.

CONCLUSIONS

This paper provides an empirical approach to demonstrating how deep our ground EM is seeing over a range of conductive regolith settings. The results can be used by exploration geologists to determine how effective EM will be for particular targets in various settings. Although similar recommendations could be provided through modelling this approach can simply ignore the infinite scenarios that could potentially be generated.

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REFERENCES

Brodie, R.C., 2015, GALEISBSTDEM: A deterministic algorithm for 1D sample by sample inversion of time-domain AEM Data. Australian Government: Geoscience Australia.

Fitzpatrick, A., and Whitford, M., 2019, Strategic electromagnetic geophysical prospecting across a belt- an example over the Albany Fraser Orogeny, AEGC2019 Data to Discovery.

Fitzsimons, ICW; 2003. Proterozoic basement provinces of southern and southwestern Australia and their correlation with Antarctica. Geological Society of London Special Publication 206, 93-130.

IGO, 2019., Annual Mineral resource and ore reserve statement, Indpendence Group NL.

King, A., 2007, Review of Geophysical Technology for Ni-Cu-PGE, Fifth Decennial International Conference on Mineral Exploration, 647-665.

Myers, JS; 1990. Albany-Fraser Orogen, in Geology and Mineral Resources of Western Australia, Geological Survey of Western Australia, Memoir 3, 255-263.

Spaggiari,C.V., Kirkland, C., Smithies, R.H., Occhipinti, S., and Wingate, M., 2014, Geological framework of the Albany-Fraser Orogen. GSWA Record 2014/6 Albany–Fraser Orogen seismic and MT workshop 2014.

Stolz, E.M, 2000, Electromagnetic methods applied to exploration for deep nickel sulphides in the Leinster area, Western Australia: Exploration Geophysics, 31, 222-228

Trench, A., and Williams, P.K., 1994, Nickel: Application of geophysics to nickel sulphide exploration in the Kambalda district, Western Australia, ASEG Extended Abstracts, 169-180.

Wolfgram, P., and Golden, H., 2001, Airborne EM Applied to Sulphide Nickel Examples and Analysis, Exploration Geophysics 32, 136-140.