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Strategic electromagnetic geophysical prospecting across a belt - an example over the Albany Fraser Orogen

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SUMMARY

Nickel exploration routinely utilises electromagnetic (EM) techniques as a direct detection tool. Independence Group is currently exploring a large tenement holding in the Albany Fraser Orogen in Western Australia that contains its flagship Nova magmatic nickel-copper-cobalt deposit. As a first-pass exploration stage, large-scale high-resolution airborne EM is being flown over the project using the Spectrem system. Interpreted discrete basement conductors are then followed up with ground EM surveys. In areas of conductive regolith cover identified from the airborne EM surveys, other datasets are used to determine if subsequent EM is warranted. Such methods include regional aircore geochemistry and/or through favourable lithostructural settings interpreted from high resolution potential field datasets. This program of regional data collection is nearly complete, and a follow-up drilling program is starting in earnest this year. This paper includes a couple of examples of the geophysical targets drill tested to date.

Key words: electromagnetics, nickel, exploration

INTRODUCTION

Electromagnetic (EM) techniques are commonly used for nickel exploration due to their ability to directly detect conductive sulphides. Airborne EM (AEM) systems are a cost-effective method for rapid data collection, however they are limited in depth penetration compared to ground EM surveys. The detection of basement conductors (particularly) with AEM are typically not fully resolved, as their secondary decay still has signal in the latest time channels. Therefore, airborne EM anomalies are often validated with ground EM, to fully resolve target depth, conductance and geometry to aid in drill targeting.

Exploration over an entire mineral belt is a challenging undertaking, particularly in the case of the Albany Fraser Orogen (AFO) where previous exploration is limited, the area is largely under cover and the tenure portfolio (~14,500 km^2) covers a very large area. To effectively explore at such a scale, a systematic regional exploration program was designed, which included an aircore (AC) drilling program to test for mafic/ultramafic rocks with base, precious and PGE metal anomalism, large ground gravity surveys, existing aeromagnetic and radiometric surveys to generate lithostructural basement interpretations, and a high-resolution AEM survey at an unprecedented scale. Anomalies generated from the AC and AEM programs lead to additional verification and drill targeting using ground EM.

This paper discusses the application of airborne and ground EM techniques across the AFO.

GEOLOGY

The Albany-Fraser Orogen (AFO) 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 north and 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 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).

AIRBORNE EM METHODS

Several airborne EM systems were evaluated using desktop forward modelling to determine which was best suited for targeting the expected target size, geometry and conductance based upon the known response of the Nova Ni-Cu-Co deposit. The Nova deposit itself is blind to airborne EM due to thick conductive overburden masking any response from the mineralisation. The following systems were evaluated; VTEM, Helitem (25 Hz), SkyTEM, Xcite, Spectrem and TEMPEST. Several models were examined, but those best suited for detecting a 2,600S dipping plate of 600 m x 225m under moderately conductive 35m-thick overburden was the CGG TEMPEST 12.5 Hz system and the SpectremAir Spectrem system. The Spectrem was selected for the belt-wide survey, as the 12.5 Hz TEMPEST has not commercially flown at this stage.

Approximately 45,000 line km were planned over the AFO. The flight line spacing was typically 300 m and this was decreased to 200 m closer to the Nova deposit. At the time of writing, 80% of the survey had been completed.

Data products delivered by the contractor included conductivity-depth images, basement conductor anomaly picks and interpreted regolith thickness products. A Late Tau Z component of the survey as completed in December 2018 is shown in Figure 1. The image clearly shows a combination of conductive palaoechannels that dominate a third of the survey area, clear conductive stratigraphic units composed of graphite and/or sulphide material, and discrete bedrock conductors. The basement conductors are then followed up with ground EM for detailed characterisation, to either upgrade or downgrade the target for subsequent drill testing.

GROUND EM METHODS

We typically conduct time domain EM surveys using the moving loop (MLEM) technique in slingram configuration. The slingram configuration reduces the effect of IP effects (Descloitres et al., 2000) compared to in-loop geometries. Typically, transmitter loop configurations range between 200 x 200 to 400 x 400 m in size. Currently a range of sensors have been deployed, from 3-component fluxgates to high and low temperature (LT) SQUIDS (Super-conducting Quantum Interfering Devices). Initially fluxgates were used in areas of little to no conductive cover, and SQUIDS were dedicated to areas of conductive cover. The low temperature SQUID is used solely within a 30 km radius of the Nova deposit. Recently we have moved to the use of SQUID sensors exclusively in the AFO including our own in-house survey crews and equipment.

In-house testing of the various sensors has found that the noise levels of each system is about one order of magnitude lower from fluxgate, to high temperature (HT) SQUID to low temperature SQUID. Although in an ideal world, the low temperature SQUID would be used exclusively, the expense of the consumable liquid helium cryogen becomes a budgetary consideration and is logistically more challenging.

Several forward models have been constructed for the detectability of a conductive plate at various depths using different overburden conductances. A few models can be constructed for various sized plates and dips. One example shown in Figure 2 is for a 400 m x 400 m 2,000 S flat lying conductive plate. The four plots are for various overburden conductances (0, 2, 5 and 10 S). The vertical axis has been normalised in to signal/noise. The graph demonstrates under 10S of overburden the plate would only be detected shallower than 400 m. Using the airborne EM data, we can calculate conductance grids of the overburden across the belt, and therefore determine how deep we can detect targets. Conductivity models were derived from the Spectrem data using the GALEI (Brodie, 2016) inversion code. The data was subsequently clipped to above the interpreted bedrock-regolith interface, and conductance was calculated using the average conductivity of the overburden multiplied by its thickness.

An example of a conductance image is shown in Figure 3 over the Nova lease. This demonstrates that for the majority of the southern half of the lease, overburden conductance is on average about 4S and can be as high as 10 S, and therefore the selection of an appropriately low noise sensor is important when planning EM programs in order to achieve a maximum depth of effective exploration.

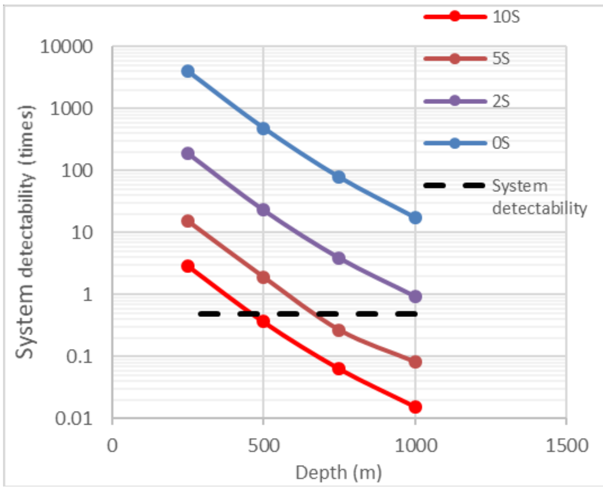

Figure 2. System detectability of a 400 x 400 m 2,000 S flat lying conductive plate using a Low Temperature SQUID sensor in a slingram configuration with 400 x 400 m transmitter loop for various conductance overburden.

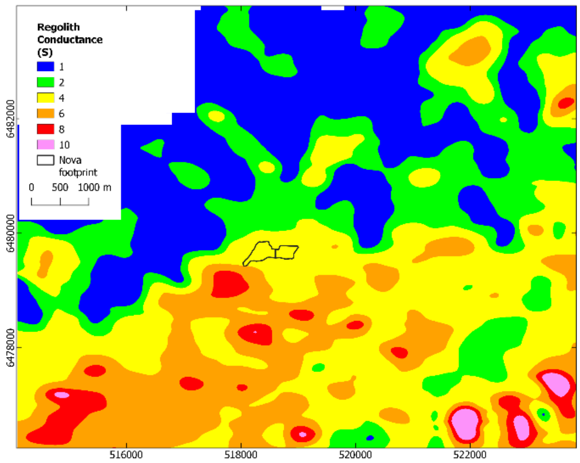

Figure 3. Regolith conductance map derived from Spectrem AEM survey over the Nova mine lease. The projected footprint of Nova is shown in the black outline.

RESULTS

Two examples of drill-tested targets (Wooly and Andromeda) are discussed in detail below.

The Wooly target was characterised by MLEM using a HT SQUID sensor (Figure 4) and was also detected by the Spectrem system.

Plate modelling using Maxwell produced a 500 x 380 m sized plate of 3,600 S. The plate was sub-vertical with a 60 degree dip and the depth to the middle of the plate was 290 m.

Drilling at Wooly confirmed the cause of the conductivity anomaly was 30 m of massive pyrrhotite, barren of economic sulphides. Although not economic it did provide a practical demonstration that in the absence of thick conductive cover Spectrem could detect a target at ~300 m depth.

The Andromeda target (discussed in these conference proceedings by Polito et al., 2019) was not detected by the Spectrem system. A MLEM survey completed using an HT SQUID sensor identified a late-time anomaly. Subsequently the MLEM survey was extended to better characterise the target using a HT SQUID and fluxgate sensor. The HT SQUID data clearly outlined the extents of the anomaly while the fluxgate sensor indicated the target was detectable, though with much noisier data.

Plate modelling using Maxwell produced a 295 x 440 m sized plate of 4,600 S. The plate was sub-vertical with a 60 degree dip and the depth to the middle of the plate was 535 m. Several drill holes were completed and intersected the plate, with the hole targeting the centre of the plate intersecting 29.9 m @ 2.5% Zn, 1.4% Cu, 0.4 ppm Au and 20 ppm Ag from 548 m hosted within massive pyrrhotite.

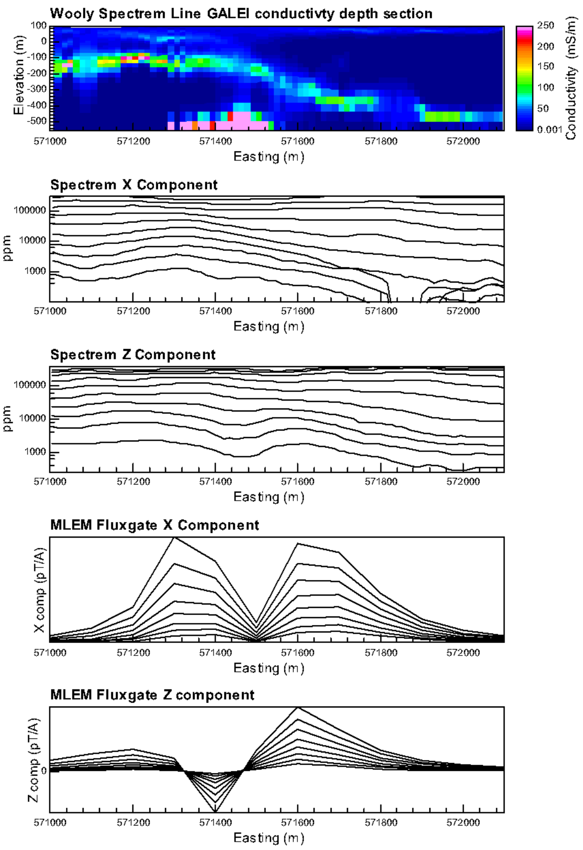

Figure 4. Spectrem GALEI conductivity depth section and line profile data over the Wooly target. The Spectrem data and inversion identifies a basement conductor. The ground MLEM clearly identifies an anomalous basement response.

CONCLUSIONS

Systematic exploration using geophysical methods has been successful in accelerating and prioritising targets across a large belt. The use of airborne EM provides a rapid first pass approach, and in areas of minimal conductive regolith is likely to detect basement conductors to depths of up to 300 m. Although the method is inhibited by conductive cover, which covers ~50% of the project area, it still allows many targets to be identified, particularly in the more resistive areas of the belt.

Ground EM is deployed to verify AEM and test around and beneath AC geochemical anomalism. The ground EM provides additional resolution and depth penetration in order to accurately resolve target conductance and geometry. In areas of deep conductive cover, ground EM methods have been proven to detect targets at 500 m in the AFO. Additionally, recent work has demonstrated the use of more sensitive TEM sensors (i.e. SQUIDS) greatly enhances the depth of exploration, up to and beyond 1,000 m in some cases.

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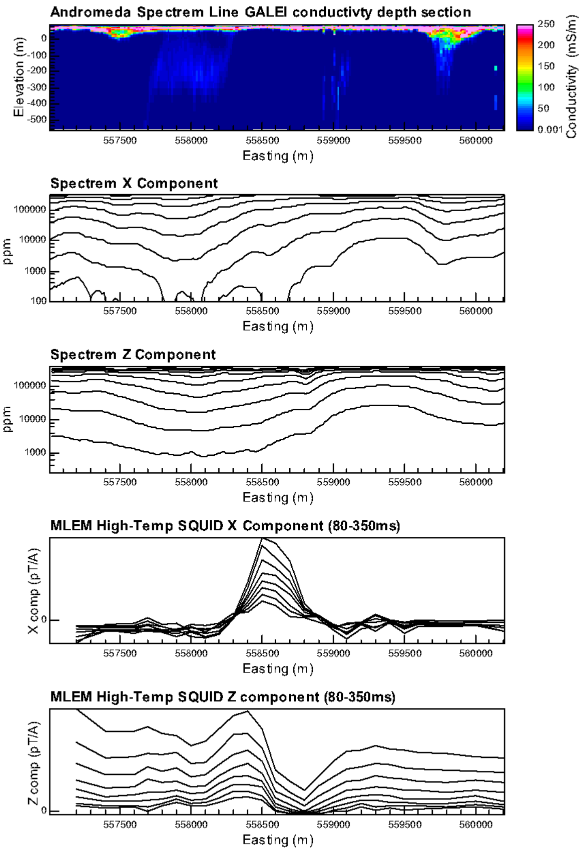

Figure 5. Spectrem GALEI conductivity depth section and line profile data over the Andromeda target. The Spectrem data fails to detect the basement response. The ground MLEM using a HT SQUID clearly identifies an anomalous basement response.

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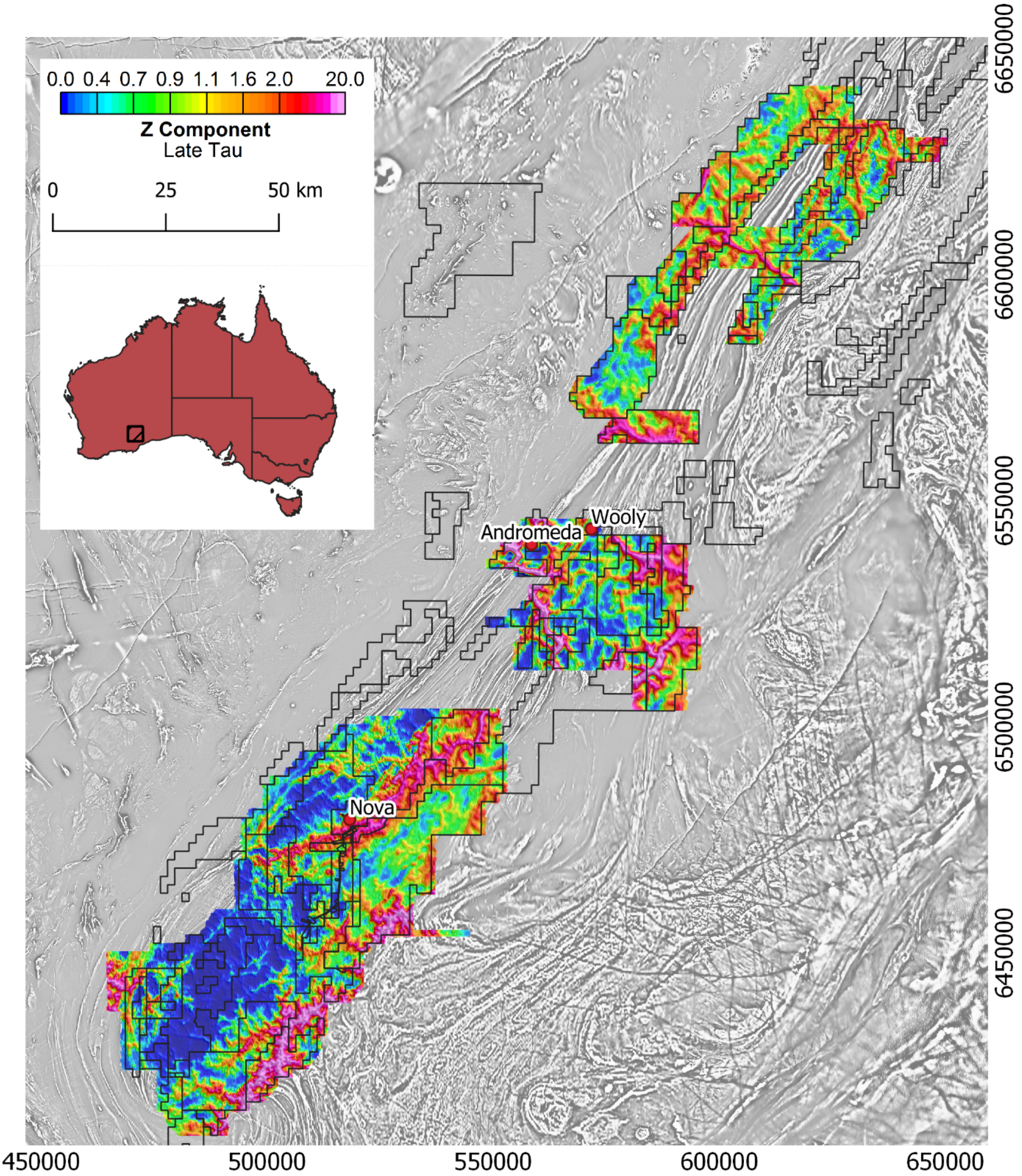

Figure 1. Spectrem airborne EM survey over IGO's tenements in the Albany Fraser Orogen. Late Tau Z component image is shown overlying 1VD magnetic data.