The discovery of the Artemis polymetallic deposit

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SUMMARY

The Artemis Cu-Au-Zn-Ag deposit is located approximately 43 km southeast of Cloncurry and 19 km west of Eloise in northwest Queensland. The deposit, hosted within the Paleoproterozoic Mount Norna Quartzite unit which is part of the Lower Soldiers Cap Group, is a steeply-dipping massive sulphide body. The Artemis deposit was discovered by Minotaur in July 2014, only 9 months after taking possession of the project. The deposit is a new type of mineralisation that has previously not been identified in the Cloncurry district. The discovery was made by meticulously piecing together the historical geophysical and geological data, complimented by new geophysical data sets including airborne EM and ground EM to improve the understanding of prospective targets throughout the area. The dominant sulphide within the deposit is pyrrhotite, hence the deposit is highly conductive. Airborne and ground EM techniques were therefore the main tools in resolving the mineralisation. The pyrrhotite is non-magnetic and therefore the deposit has no discernible magnetic signature and magnetics played no part in the discovery process. The deposit had no associated surface geochemical anomalism and very little alteration, making this deposit geologically difficult to find and essentially reliant on EM techniques in making the discovery.

Key words: Discovery, polymetallic, mineralisation, Airborne EM, Ground EM, magnetics, Mt Isa Inlier

INTRODUCTION

This paper outlines the discovery of the Artemis polymetallic deposit located in northwest Queensland within the Eastern Succession of the Mount Isa Inlier and 30 km west of the Eloise Copper Gold Mine (Figure 1). IOCG-style mineralisation at the Eloise deposit was discovered by BHP in 1987 using ground EM techniques and it is estimated that 10 MT of ore have been mined from the deposit (Breccianini et al., 1992). Despite extensive exploration for the next 6 years, no similar deposits were discovered and the deposit was then divested to Amalg Resources in 1994 with mine development commencing in 1995 (mine now managed by FMR Investments). In the following years, Amalg Resources (Breakaway Resources) had limited success in outlining copper + gold mineralisation at Sandy Creek and established an Inferred Resource comprising 2 Mt grading 1.32 % Cu and 0.3 g/t Au. Minotaur Exploration obtained the project (but not the Eloise Mine) after a merger with Breakaway in 2013 and immediately undertook extensive exploration commencing with a large airborne EM survey over exposed basement and regions where cover thickness was less than ~50 m. The airborne EM survey identified a number of new anomalies, enabling Minotaur to quickly focus on key geophysical features with additional ground EM surveying indicating that a very prospective EM target just west of Sandy Creek had not been effectively tested. This paper discusses the process leading to discovery and goes on to describe the mineralisation and its physical properties.

GEOLOGICAL SETTING

The Eastern Succession of the Mount Isa Inlier in the Eloise Mine area consists predominantly of the ~1700-1650 Ma Lower and Upper Soldiers Cap Groups, regionally characterised by low degrees of magnetisation. The Lower Soldiers Cap Group (LIewellyn Creek Formation and Mount Norma Quartzite) consists predominantly of psammitic and pelitic rocks along with dolerite sills whereas the Upper Soldiers Group contains abundant basalt (Toole Creek Volcanics). Deformation during early (~1600–1550 Ma) and late (1540-1500 Ma) stages of the Isan Orogeny have resulted in broad N-trending anticlinal domes, tight synclines and major shear zones. Major IOCG-style mineralisation was spatially and contemporarily associated with late-stage granite plutonism (Williams Naraku Batholith) and brittle tectonism along pre-existing shear zones (Blake *et al*, 1990; Betts and Giles, 2006; Geological Survey of Queensland, 2011).

HISTORICAL EXPLORATION

Historic ground EM surveys were conducted by BHP in 1988 and 1989 over gossanous exposures in the Sandy Creek area (Sandy Creek Deposit) and also over another prospect ~400 m to the west. The survey was a single component dB/dT Sirotem survey which recorded data out to 81 ms. A weak conductor was resolved in the vicinity of the Sandy Creek Deposit, but a stronger response was observed at the western prospect (Figure 2). Holes SCD05 and SCD06 targeted the southern and northern ends of this EM feature, and intersected up to 4 m of massive pyrrhotite which recorded 11.5 g/t Au and accompanied by minor chalcopyrite, and was thought to have adequately explained the source of the surface EM response. However, DHEM surveys within holes SCD05 and SCD06 revealed strong off-hole responses, especially at the bottom of drill hole SCD05 (Figure 3). BHP annual technical reports indicate that the source of this response was thought to be barren pyrrhotite as nearby surface exposures of iron formation lack any geochemical anomalism. In 1996 Amalg drilled holes SCD07 and SCD08, targeting extensions to the thin mineralisation intersected in holes SCD05 and SCD06. SCD07 intersected further thin zones of sulphide and SCD8 was drilled at an angle too steep to intersect the mineralisation.

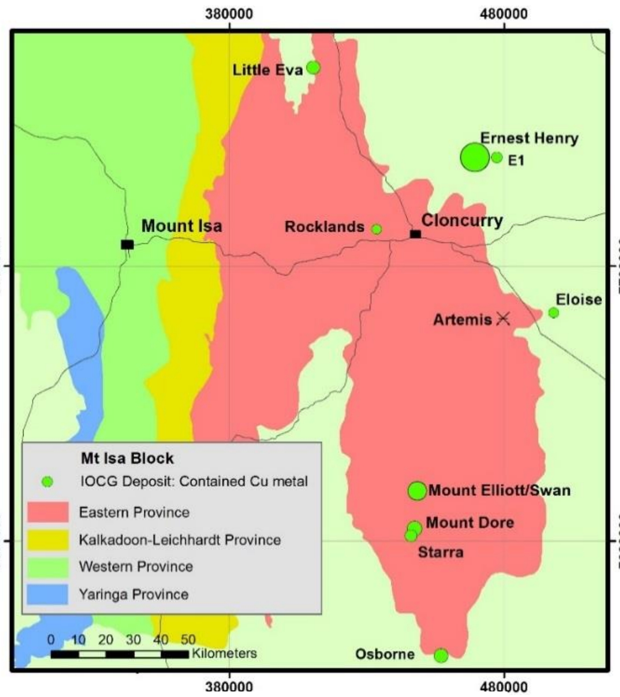

Figure 1: Location of the Artemis Prospect with respect to major IOCG mines in the eastern Mt Isa block

A detailed airborne magnetic survey was flown in March 2005 at 50 m line spacing and 30 m flight height. The survey clearly delineated the barren ironstone in the vicinity of the ground EM response west of Sandy Creek (Figure 4).

In 2011, Breakaway drilled several holes beneath the ironstone, but only intersected minor mineralisation. In 2013, Breakaway surveyed four lines of moving-loop EM at 400 m intervals and 100 m station spacing over the Sandy Creek area. The survey was conducted using a transmitting loop of 200 m, a fluxgate B-Field sensor and a transmitting frequency of 1 Hz. A strong Z-component EM response with a Tau of 85 ms was identified west of Sandy Creek, however, it was thought to have been explained by current drilling intercepts.

Modelling by Minotaur of the historical ground EM data strongly suggested that intersected mineralisation in SCD5 and SCD6 was insufficient to adequately explain the ground EM response. As ~2 Mt of IOCG-style mineralisation grading 1.32% Cu and 0.3 g/t Au had been defined only ~400 m to the east, then further exploration was warranted.

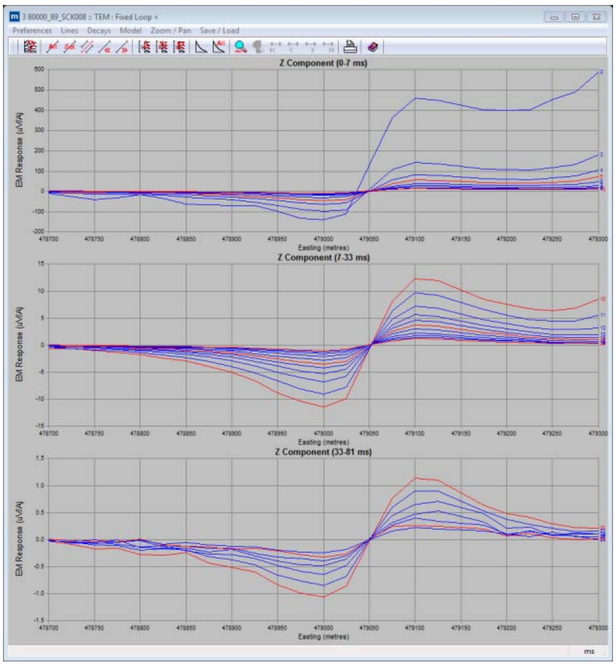

Figure 2: Historic dB/dT Z-component fixed-loop EM profiles over the prospect 400m west of Sandy Creek

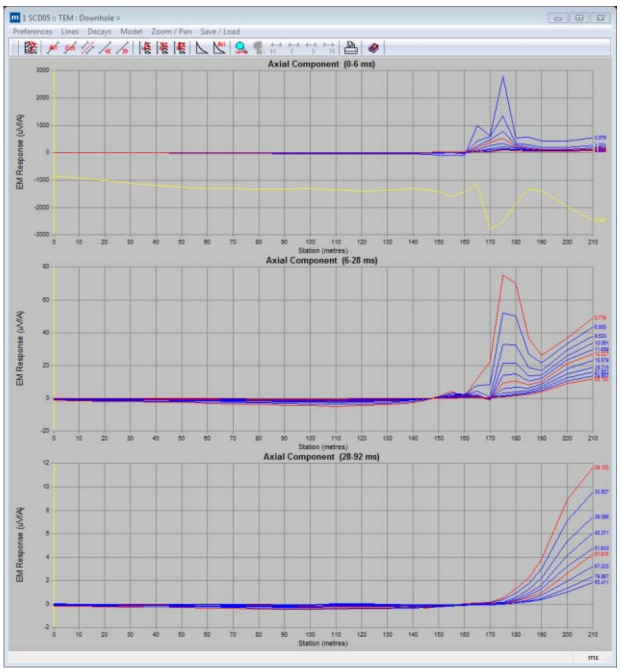

Figure 3: SCD05 Axial-component DHEM profiles showing offhole conductor toward bottom of hole.

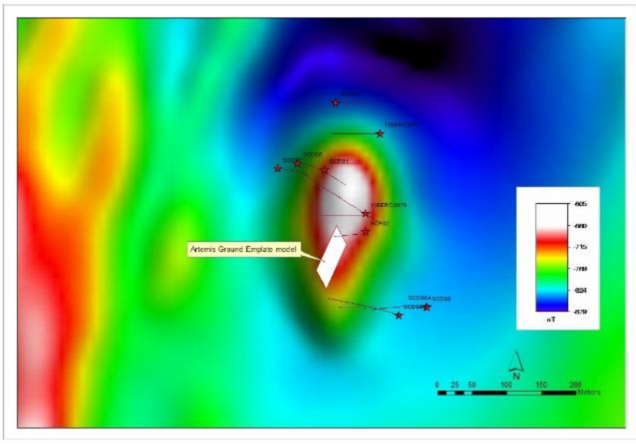

Figure 4: Historic drill holes over airborne RTPTMI image.

GEOPHYSICAL METHODS AND RESULTS

Minotaur's exploration methodology included a regional airborne EM survey over a large area west of the Eloise Mine, where the thickness of Mesozoic sediments was <50 m, followed by ground EM over prospective targets prior to drill testing.

Airborne EM

A 1,000 line km VTEM Max survey in 2013 was flown by Geotech Airborne along E–W flight lines, line spacing of 200 m line and typical flight height of 30 m. VTEM Max is a helicopter AEM system with an in-loop configuration and peak dipole moment of 881,192 NIA. The VTEM data clearly showed a number of late-time bedrock responses including two closely-spaced responses in the Sandy Creek area with the eastern response corresponding to then known Sandy Creek mineralisation (Figure 5). The feature to the west of Sandy Creek (target EVT54) is only present on a single line as a late-time M-shaped response and 1D inversion modelling, using EmaxAir software, indicated a steeply-dipping conductor at a depth to top of ~50 m. The response over Artemis was anomalous but similar in character to that of the response over Sandy Creek and a number of other targets. Ground EM was required to further resolve the AEM targets prior to target selection and drill testing.

Ground EM

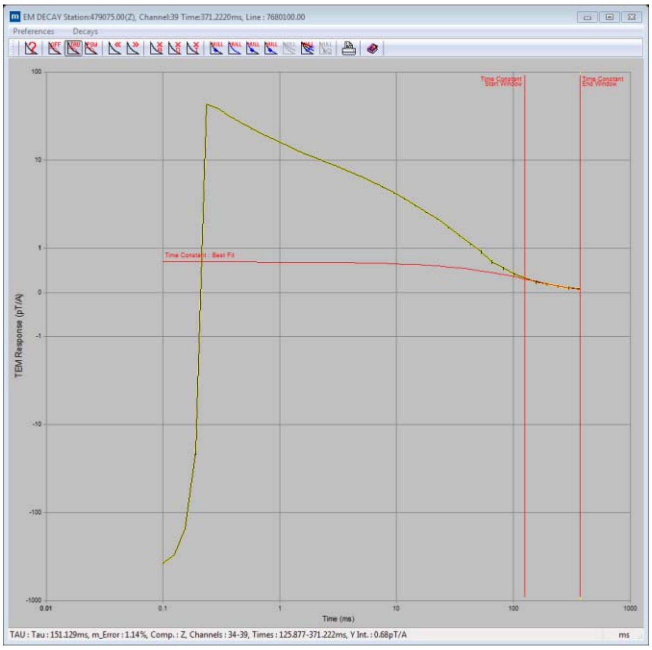

Figure 7: Z-component B-Field decay from fixed-loop EM survey showing calculated time constant.

A fixed-loop ground EM survey was surveyed for Minotaur Exploration by Gem Geophysics using a Zonge ZT-30 transmitter along with a Jessy Deep 3-component SQUID B-Field Sensor connected to a SmartEM24 receiver. Data were collected at 25 m intervals along lines 50 m apart using a single 500 m by 300 m transmitting loop located to the west of the target. The initial survey was conducted at a frequency of 0.5 Hz and a current of 23 Amps within the transmitting loop.

Modelling of the late-time data indicated a steeply east-dipping conductor of limited strike length at a depth to top of 75 m (Figure 6). The modelled conductance of the plate was 16,000 Siemens and the measured time constant was 151 ms (Figure 7). The ground EM data clearly identified the EVT54 target (later known as Artemis) as the most conductive target in the survey area and was subsequently upgraded to the highest potential for IOCG-style mineralisation. A number of other targets were also selected for drill testing.

DEPOSIT GEOLOGY

Artemis occurs within an area of well exposed quartz +muscovite +staurolite schist, quartzite and psammite (Mt Norna Quartzite) and a discontinuous banded iron formation consistent with being an exhalative sediment. Historical geological mapping and rock chip sampling revealed no significant geochemical anomalism proximal to and immediately above the interpreted high-conductance plate, despite it being modelled at only ~75 m below the surface.

The initial drill hole (EL14D09) intersected massive and marginal stringer sulphide zones between 148-182m (Figures 8-10). In particular, a broad mineralised interval very rich in pyrrhotite, chalcopyrite, sphalerite and calcite, contained:

- 22m @ 3.02% Cu, 3.81 g/t Au, 111.6 g/t Ag, 6.64% Zn, 1.35%Pb and 0.11% Co (157-179 m down-hole depths).

A higher-grade subzone (167-176m) contained:

- 9m @ 5.16% Cu, 7.94 g/t Au, 181.6 g/t Ag, 10.23% Zn, 1.97% Pb and 0.12% Co (167-176 m down-hole depths).

Mineralisation is massive, coarse-grained and occasionally compositionally layered due to hydrothermal fluid flow, but lacks any deformational fabrics. There is minimal alteration and veining within adjacent rocks and hydrothermal fluid was apparently emplaced into an open fracture during a phase of local brittle extension.

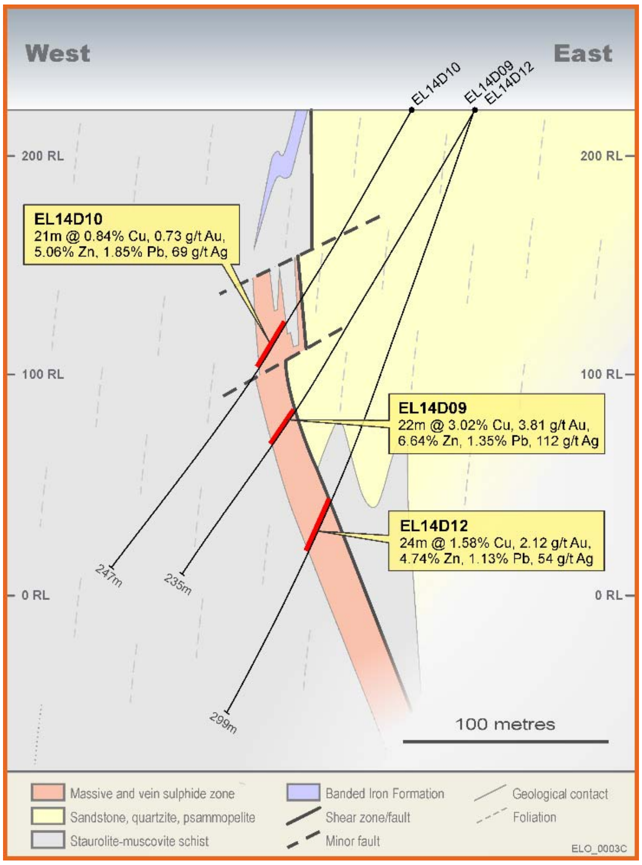

Figure 8: Geological cross section at Artemis Deposit based upon initial three drill holes

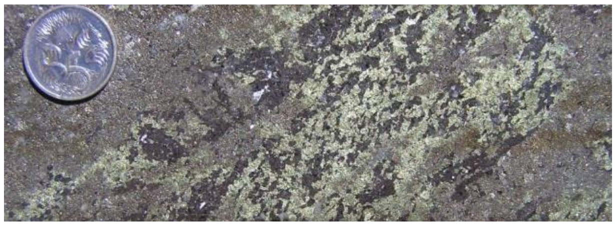

Figure 9: Compositionally-layered pyrrhotite, chalcopyrite and sphalerite at 174.15m in hole EL14D09

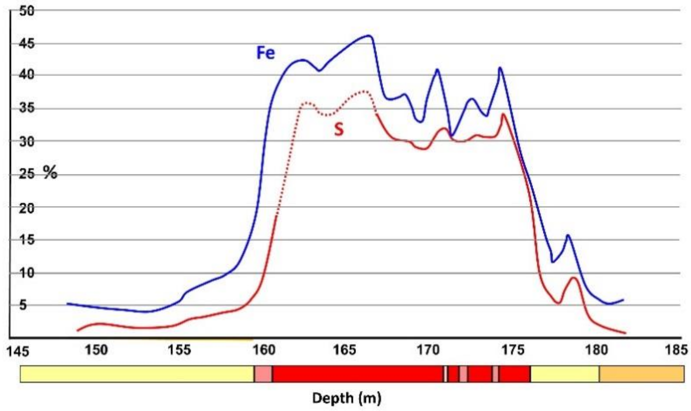

Figure 10: Fe and S distribution across mineralised interval in hole EL14D09 (see Figure 11 for lithologies)

PETROPHYSICAL MEASUREMENTS

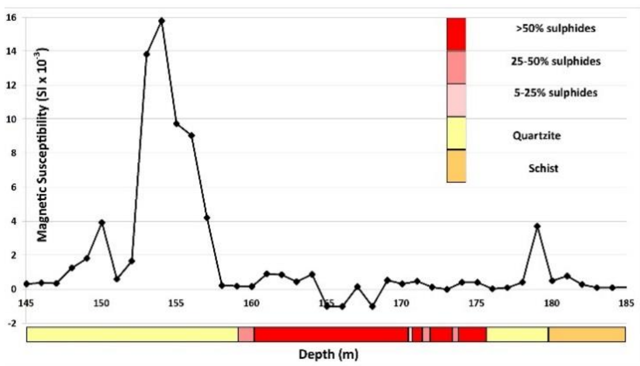

Figure 11: Magnetic susceptibility plot for mineralised interval within discovery hole EL14D09

Down-hole magnetic susceptibility readings and specific gravity measurements were recorded every 1 m across the mineralised interval in hole EL14D09 (Figure 11). The main sulphide-rich interval is devoid of magnetite and magnetic susceptibility values are very low, predominantly <1 x 10^{-3} SI and even several negative values were recorded. Pyrrhotite present is non-magnetic. Higher recorded magnetic susceptibilities within adjoining psammite and quartzite are due to detrital magnetite. Specific gravity measurements for the mineralised interval yield consistently high values and average ~4.15 g/cc.

DISCUSSION

The Artemis deposit was difficult to find due to a number of factors. Despite the lack of Mesozoic sediments in the area and the presence of plenty of outcrop, the deposit is blind as there is no surface geochemical anomalism above the mineralised zone. Additionally, there is very little alteration associated with the mineralisation and that present is restricted to <5 m. hence the mineralisation has a very small geochemical footprint. Secondly, despite the main sulphide zone containing large amounts of pyrrhotite, the mineralisation is non-magnetic and has no discernible magnetic signature. Lastly, the significant number of drill holes in the area, some of which were targeted at the EM conductor, created the illusion that there was not enough room for a potential orebody to exist and that the source of the EM response had largely been tested.

The historical data gave a number of hints that there was significant mineralisation hidden in the area. The ground EM data indicated a high-conductance source that existing drill holes could not explain. More importantly, the historical ground EM indicated that the source to the west of Sandy Creek was more conductive than the response at Sandy Creek itself. The downhole EM data in the historic drill holes confirmed the presence of the high-conductance source beneath and between existing drill holes west of Sandy Creek.

The geographical position of historical ground EM survey data could not be adequately confirmed, necessitating the area be resurveyed using airborne and ground EM techniques which not only confirmed the location of the target but also provided more information on its exact location and conductivity. The new airborne EM data effectively mapped the aerial extent and position of the conductors and the ground EM data was able to provide further information on the conductivity of the target relative to other targets in the region. Bringing all the geophysical and drill hole information into a 3D GIS enabled visualisation of the target with respect to the historical drill holes and the realisation that the target had not been tested.

The next step was not to be put off by the lack of geochemical anomalism and alteration above and in the vicinity of the target as well as the lack of any magnetic response that would be expected from a typical mineralised zone containing large amounts of pyrrhotite. In contrast, the EM body was extremely conductive and great faith was bestowed on the EM interpretation. The positive for this area was that EM techniques worked extremely well due to the total lack of any Mesozoic sediments. The first drill hole into the Artemis target successfully intersected high-grade Cu-Au-Zn-Ag massive sulphide mineralisation and was the best intercept in the region since the Eloise discovery.

CONCLUSIONS

The Artemis discovery was the result of a combination of rigorous assessment of historical data coupled with the use of the latest geophysical technology and software. Previous geophysical interpretations were not simply accepted on face value, instead historical raw geophysical data were rigorously re-interpreted and re-assessed with respect to previous drill holes. This was complimented by acquisition of new ground EM data using the latest B-Field technology. Lastly, despite the lack of any surface geochemistry or alteration in the target area, the technical focus was on the massive sulphide model and drill testing of the best EM conductors.

The result of this sound technical approach was a new discovery of significant Cu-Au-Zn-Ag massive sulphide mineralisation in an area with a 30 year history of extensive exploration and drilling.

Exploration of the Artemis deposit is ongoing in order to establish a resource size and grade.

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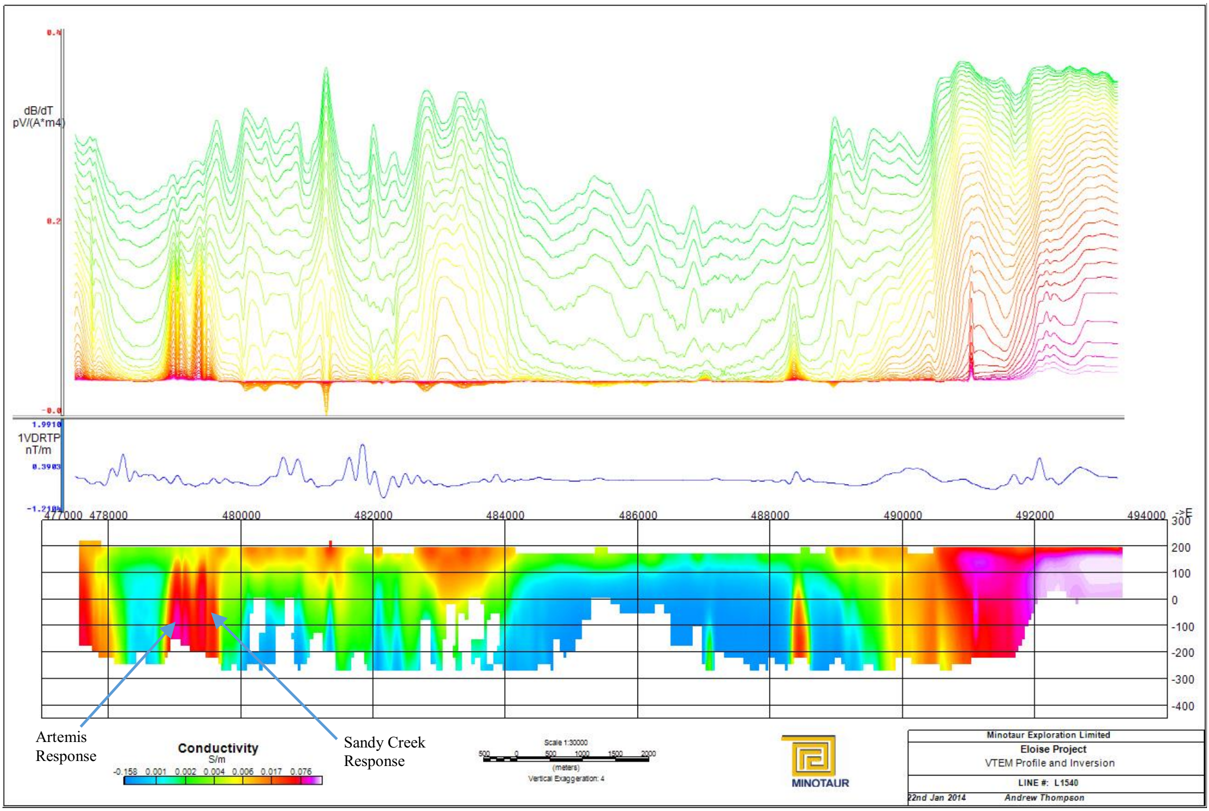

Figure 5: VTEM Max Z Component B Field profiles and 1D inverted section over the Artemis Deposit

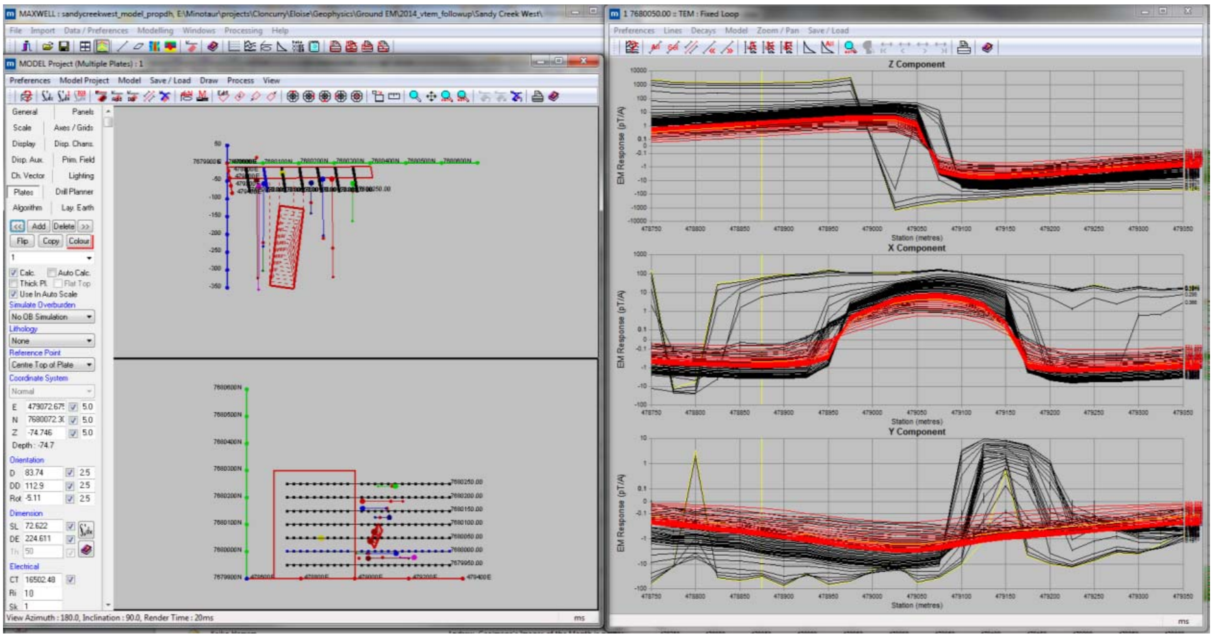

Figure 6: Late-time fixed-loop ground EM model (left) at the Artemis Deposit showing long section (top) and cross section view (bottom) along with observed (black) and model (red) Z-component B-Field ground EM profiles (right).