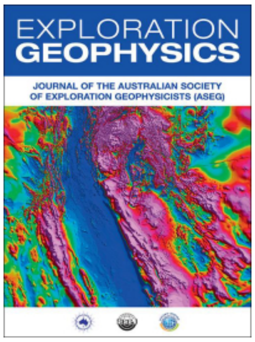

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A brief description of the Andromeda Zn-Cu prospect in the Albany-Fraser Orogenic belt: A geophysical discovery using HT SQUID

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A brief description of the Andromeda Zn-Cu prospect in the Albany-Fraser Orogenic belt: A geophysical discovery using HT SQUID

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SUMMARY

The Andromeda Zn-Cu-Au-Ag prospect is a geophysical discovery that represents the first VMS prospect of significance in the Albany-Fraser Orogenic belt, Western Australia. The prospect was first identified following a ground Transient Moving Loop Electromagnetic survey over a structural ellipse that is recognised in aeromagnetic data and has similarities to the Nova "eye". A conductive plate, 450 m from surface was drilled, but it was the subsequent Down Hole Transient Electromagnetic survey that ultimately led to the intersection of 29.9 m @ 2.5% Zn, 1.4% Cu from 548 m and confirmed the discovery.

Andromeda is classified as a strongly deformed Besshi-style, VMS deposit that has been metamorphosed at low granulite grade conditions. Ore lenses reach ~20 m true width and comprise coarse-grained pyrrhotite, pyrite, sphalerite and chalcopyrite. This paper outlines the geophysical methods used to identify and discover Andromeda and describes our current understanding of the geology, mineralogy and representative geochemistry.

Key words: Andromeda, moving loop electromagnetics, copper, zinc

INTRODUCTION

The Andromeda Zn-Cu prospect is located in the Albany-Fraser Orogenic belt (AFO) of Western Australia, 200 km northeast of Norseman and 75 km to the north of the Nova Ni-Cu-Co mine.

Andromeda was a geophysical target that represents the first VMS discovery of significance in the AFO. A narrow, structural ellipse apparent in aeromagnetic data was originally interpreted as the top of an "eye feature" similar to that at the Nova-Bollinger Ni-Cu sulphide deposit and was targeted for follow-up (Figure 1; Parker et al., 2017). A ground Transient Moving Loop Electromagnetic (MLEM) survey over the ellipse identified a strong conductive anomaly 450 m below the surface. The first drill hole to test the conductor intersected 4.5m of pyrrhotite-dominated Zn-Cu sulphides from 510 m. A Down Hole Transient Electromagnetic (DHTEM) survey identified an off-hole conductor which was the target of a second drill hole, and which is now recognised as the discovery hole. Two additional drill holes confirmed the discovery and established that Andromeda comprises multiple lenses of Zn-Cu mineralisation, is approximately 400 m long x 150 m wide, and is open in most directions. This paper outlines the MLEM survey parameters, the drilling results to date and some high-level geological and geochemical observations.

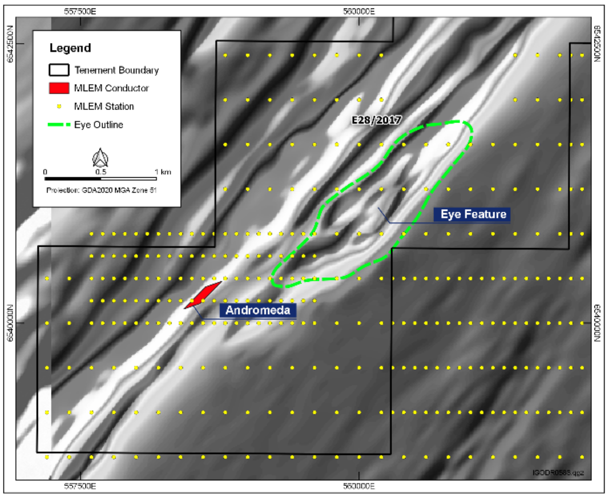

Figure 1. The position of the Andromeda conductor relative to the structural ellipse and the MLEM survey stations.

REGIONAL GEOLOGY

The AFO comprises Mesoproterozoic rocks that are tectonically juxtaposed against the Archean Yilgarn Craton to the west and extends eastwards under the Eucla Basin (Spaggiari et al., 2014). The AFO has been divided into four lithotectonic domains that include the Northern Foreland, the Kepa Kurl Booya Province, the Recherche Supersuite intrusives, and the Esperance Supersuite intrusives (Spaggiari et al., 2009). The Kepa Kurl Booya Province has been further sub-divided into the Biranup, Fraser and Nornalup Zones. The Andromeda prospect occurs within a strongly deformed and sheared section of the western Fraser Zone.

The Fraser Zone is a fault-bounded unit up to 50 km wide that is dominated by high-grade metamorphic rocks that include the 1305–1290 Ma Fraser Range Metamorphics (Spaggiari et al., 2009). These comprise thin to voluminous sheets of metagabbroic rocks interlayered with sheets of metamonzogranitic to metasyenogranitic gneisses and pyroxene-bearing granitic gneiss. All are interlayered at various scales with amphibolite to granulite facies, pelitic, semipelitic, and psammitic gneiss, and locally calc-silicate and iron-rich metasedimentary rocks of the Mesoproterozoic Arid Basin (Spaggiari et al., 2014). Much of the western side of the Fraser

Zone is dominated by tightly to isoclinally folded, strongly foliated to mylonitic rocks. A comprehensive structural interpretation, based primarily on aeromagnetic image interpretation, can be found in Brisbout (2015).

METHODS

The Andromeda survey area is proximal to the Lake Harris saline playa. Gypsum sand dunes and saline ground water occur in the general area. To minimise the impact of these features on any EM survey, a High Temperature Superconducting Quantum Interference Device (HT SQUID) sensor was chosen for its low noise and ability to record clean data at late times. The first pass survey was designed to cover large areas of ground quickly. Therefore, large 400 m loops, 400 m line spacings and 200 m station spacings were routinely employed (Figure 1). The receiver set up adopted a slingram configuration to minimise IP and superparamagnetic effects. The initial Andromeda anomaly was followed-up using both a HT SQUID and a fluxgate sensor. Infill survey specifications were 100 m station spacings, 200 m line spacings and 400 m loops, with the addition of a fluxgate sensor at 200 m station spacing for comparison. The survey parameters for the EM acquisition are shown below. Data received for the HT SQUID was of excellent quality, showing repeatability down to less than 0.02 pT/A for the Z component. For comparison the fluxgate data showed good repeatability down to levels of ~ 0.1 pT/A in the Z component.

Configuration	Slingram
Loop Size	400 m (200 m infill)
Line Spacing	400 m (200 m infill)
Station Spacing	200 m (100 m infill)
Receiver system	Smartem24
Jessie Deeps HTS	Bz (up), Bx (east), By (north)
Fluxgate	Bz(up), Bx (east), By (north)
Sensor Location	400 m east of loop centre
Transmitter	Transmitter Technologies TTX
Effective Current	~80A
Frequency	0.5Hz

Downhole transient electromagnetic (DHTEM) surveys are completed on all drill holes. DHTEM uses a DigiAtlantis B-field EM probe, coupled with a transmitter with an output of 50A. Noise levels are ~0.3 pT/A.

RESULTS

The Andromeda conductor is seen as a late time anomaly with good responses in all three components of the HT SQUID readings (Figure 2). The response was characterised by an exponential decay with a time constant of approximately 80 ms and interpreted to indicate massive sulphide mineralisation. Model parameters were best fit by a plate 400 m long, 100 m wide, 450 m deep, dipping 80 degrees to the west and with a conductivity thickness of 4,200 Siemen. Finding this plate in proximity to the structural "eye" feature seen in the aeromagnetic data made Andromeda a high priority drill target.

A fluxgate sensor MLEM survey also detected Andromeda. The modelled parameters were indistinguishable from those best fitting the HT SQUID data, however the fluxgate signal was noisier (Figure 2). This finding provides confidence that fluxgate MLEM surveys over parts of the Fraser Range devoid of thick cover do test prospective geology to depths greater than thought.

Drill hole 18AFRD002 (Figure 3; Table 1) was designed to intersect the centre of the modelled plate. However, owing to unexpected lift of the drill bit the hole intersected the EM target almost 80 m from the planned pierce-point. Nevertheless, 4.5 m of pyrrhotite-dominated sulphides were drilled from 510.5 m downhole.

A DHTEM survey identified two in-hole conductors associated with the observed sulphides, and one off-hole conductor exhibiting exponential decays in the latest time channels. Time-constants were in the order of ~200 ms. A 400 m x 100 m, 24,000S off-hole plate was modelled to the north-east of 18AFRD002.

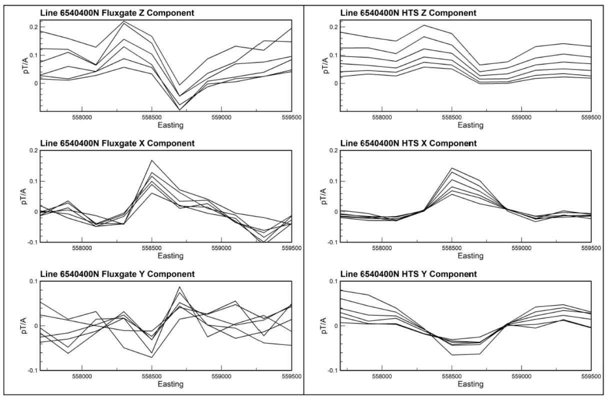

Figure 2. MLEM profiles across Andromeda showing Fluxgate (left) and HT SQUID (right) results.

The second drill hole, 18AFRD004, targeted the centre of the DHEM plate and intersected 29.9 m @ 2.5% Zn, 1.4% Cu, 0.4 g/t Au and 20 g/t Ag from 548 m downhole. This is now recognised as the discovery hole. Drill holes 18AFRD007 and 18AFRD008 confirmed that Andromeda comprises multiple lenses of mineralisation, is approximately 400 m long x 150 m wide, and is open in most directions (Figure 3; Table 1).

ORE AND HOST ROCK GEOLOGY

Massive sulfides from the multiple ore lenses are remarkably similar texturally and mineralogically. The main ore lens reaches ~20 m true width and comprises coarse-grained anhedral, streaky and patchy pyrrhotite and more crystalline pyrite, with variable amounts (to ~10%) of deep red Fe-rich sphalerite, chalcopyrite and subhedral to euhedral magnetite (to ~10%) (Figure 4). Tiny grains of galena were observed in only one sample.

Andromeda ore shows pervasive durchbewegung textures characterized by mainly sub-2 cm, angular to rounded and milled lithic fragments that are often disaggregated to discrete grains of (i) amphibolite derived from mafic host rocks and (ii) polycrystalline, quartzose rocks and quartz grains considered to be recrystallized cherty, siliceous metasediments, also from the host package (Figure 4). These are very evenly distributed through the ore suggesting significant mechanical mixing and the destruction of primary textures. This, together with the absence of any preserved metal zonation across the mineralisation, indicates that the orebody became plastic during deformation, probably syn- or pre-peak metamorphism, and 'moved' extensively as a stratabound mass within its original host rock package. A very narrow stockwork – stringer zone underlies the deposit, but otherwise alteration is not readily observed. On the other hand, the upper contact of the main mineralised zone is a 1m wide foliation-parallel mylonite that separates the upper contact of the mineralisation from the hangingwall. It is unclear how much movement has occurred along this structure. However, the host rocks in the footwall and the hanging wall are the same making it improbable that there was significant (i.e. km-scale) decoupling.

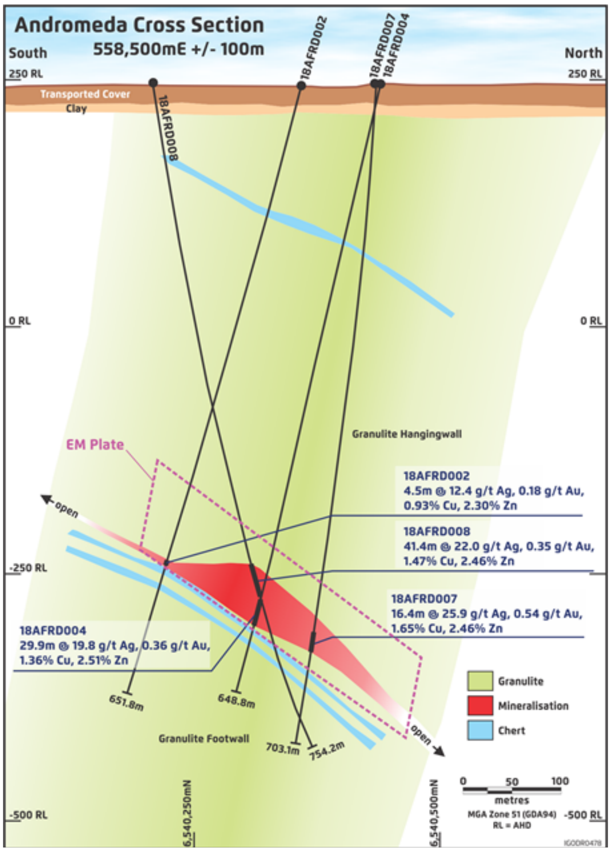

Figure 3. Schematic cross section through the Andromeda prospect looking west (Independence Group, 2019).

The host rock succession is dominated by oxide-poor mafic granulites that have been thoroughly recrystallized during low-grade granulite metamorphism together with a small proportion of felsic rocks and interbedded siliceous, probably chemical, sediments (i.e. cherty rocks). The oxide-poor mafic granulites range from medium- to fine-grained and are massive to mineralogically banded. Mineral assemblages vary from garnet-bearing gabbros (garnet, augite, plagioclase, minor khaki/olive hornblende, FeTi oxides and minor sulfides) through to garnet-bearing gabbronorite (garnet, augite, hypersthene, plagioclase, minor khaki/olive hornblende, FeTi oxides and minor sulfides) and garnet-bearing norite (garnet, plagioclase, hypersthene, minor khaki/olive hornblende, FeTi oxides and minor sulphides). Felsic sweats/leucosomes are common throughout this package of rocks.

A number of thick (to 50 m) FeTi oxide-rich mafic granulites are interpreted to be sills of ferrogabbro that intruded the basalt-dominated volcanic package before peak metamorphism. These "sills" are defined by their high Ti composition and comprise garnet, hypersthene and augite, with abundant FeTi oxides (8% magnetite, 5% ilmenite), 10% quartz and minor apatite and trace amounts of sub-0.2 mm pyrrhotite with occasional flames of chalcopyrite. Less common are olive-coloured hornblende or assemblages of garnet, brown hornblende, augite, hypersthene, plagioclase and minor ilmenite in which the Ti is predominantly in the brown hornblende. These oxide-rich mafic granulites rarely incorporate any felsic leucosomes.

Minor rock types within the oxide-poor mafic granulites include metasediments of either: 1) banded quartz, K-feldspar, albite, biotite, graphite, with trace garnet and pyrrhotite, or 2) highly siliceous, probably chemical, sediments that may be metacherts. Felsic sweats/leucosomes with pegmatitic textures dominated by quartz-K-feldspar-plagioclase are common throughout the rock package, although individual units range from <0.5 cm to 30 cm wide and they are volumetrically minor.

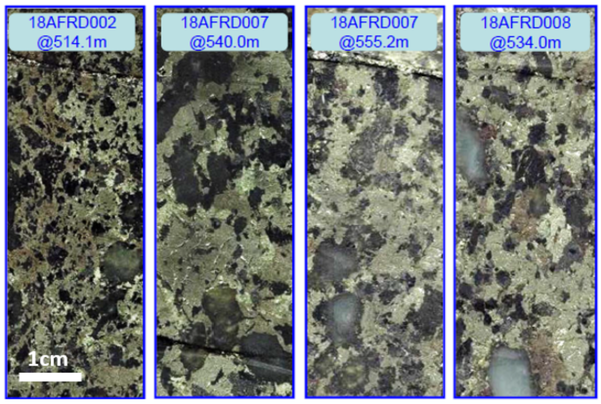

Figure 4. Typical durchbewegung textures in massive sulfides showing 'xeno'lithic fragments of dark amphibolite and amphiboles, and pale quartzose aggregates in coarse-grained, pyrrhotite-dominated sulfide.

GEOCHEMISTRY

The oxide-poor mafic granulites typically contain 3-6% MgO and 38-53% SiO_2. These mafic granulites are characterised by LREE-depleted chondrite normalised profiles. High field strength (and immobile) element ratios such as Zr/Ti and Nb/Y (<0.1) are consistent with the oxide-poor granulite protolith being a sequence of rift tholeiites. Other oxide-poor mafic granulites with lower MgO contents but up to 68% SiO_2 have identical high field strength element ratios despite including thin leucosomes. These granulites were likely derived from the same tholeiite sequence but incorporate variable amounts of felsic sweats, the latter possibly derived from the protolith during the granulite grade metamorphism.

In contrast to the oxide-poor mafic-granulites, the oxide-rich mafic granulites are distinguished by having <48% SiO_2, Nb/Y >0.1, significantly higher TiO_2 and Nb contents and LREE-enriched chondrite normalised patterns. These characteristics confirm the two mafic lithologies were not comagmatic.

The Andromeda ores feature Zn-Cu-Ag-Au mineralisation. Values of 100Cu/(Cu+Zn) average 35 (a range of ~20-50 for those assays reporting >20%S) and the "Zn ratio" (100Zn/(Zn+Pb)) is >95, resulting in classification as a Zn-Cu VMS deposit in the scheme of Large (1992). Downhole variations of Cu and Zn through the main ore lens show no obvious metal zoning, nor does the Cu/Zn ratio vary systematically with values being limited to between 0.2 and 1. There is also a very limited range of 20-30% SiO_2 through the massive sulphides. The ores are characteristically Co-poor (<0.04%, often around 0.01% Co). Alteration in the hanging wall is not geochemically obvious, but a thin zone of Na depletion and Mn enrichment defines alteration in the footwall.

DISCUSSION AND CONCLUSIONS

The Andromeda VMS mineralisation is characterised by a sulphide mineral assemblage dominated by pyrrhotite> pyrite>>sphalerite and chalcopyrite. This makes it an excellent conductor that can be detected using both fluxgate and HT SQUID EM sensors. The mineralisation and the host rocks are strongly deformed, having been metamorphosed to lower granulite facies conditions. This metamorphism obliterated primary ore textures, homogenised the Cu/Zn ratio and blended the ores with their cherty metasedimentary and mafic host rocks.

The host rock succession is dominated by oxide-poor mafic granulites with rift tholeiite compositions. These closely match those of basalts erupted during the advanced stages of rifting of continental crust just before breakup. This rock package is interbedded with minor metasedimentary units and features abundant, though volumetrically insignificant, felsic sweats. Oxide-poor granulites with intermediate compositions (up to 68% SiO2) represent tholeiites contaminated by the sweats. The sweats themselves reflect incomplete felsic melt extraction from the mafic protoliths during peak metamorphism. Other felsic 'sweats' may represent partial melting of cherty, siliceous metasedimentary rocks. In contrast, the oxide-rich mafic granulites are interpreted as ferrogabbro sills that were intruded into the volcanic package. The relative absence of sweats/leucosomes in the oxide-rich granulites indicates that they are younger than the oxide-poor granulites, and may also reflect their less hydrous nature (and thus less susceptibility to alteration or partial melting).

The Andromeda mineralisation, ore grade and host rock package closely resembles that of Besshi-type deposits. These typically occur within rock packages dominated by mafic lavas and sills interlayered with deep water sedimentary rocks, usually argillites and shales (Galley et al., 2007). Of note are the Besshi-style deposits of Japan that lack significant stockwork development and have only narrow hydrothermal alteration zones beneath the ore lenses, often on the scale of several meters. These traits are shared by Andromeda. Nevertheless, it is recognised that more work is required to characterise the sedimentary units enclosing the mafic rock packages at Andromeda and it is acknowledged that typical Besshi-style deposits are relatively Co-rich (av. ~0.1% Co), whereas Andromeda is Co-poor.

The discovery of Andromeda has opened a new search space in the AFO for Zn-Cu mineralisation along with the orthomagmatic Ni-Cu-Co mineralisation already known to exist. Independence Group are working towards developing a better understanding of their host rocks, their geochemical signature and their geophysical response with the clear aim of finding additional mineralisation to support mine development.

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Table 1. Drilling results from the first four drill holes at Andromeda (Independence Group, 2019).

Hole ID	From (m)	To (m)	Width (m)	Cu %	Zn %	Au g/t	Ag g/t
18AFRD002	510.55	515.00	4.45	0.93	2.30	0.18	12.4
18AFRD004	548.10	578.00	29.90	1.36	2.51	0.36	19.8
18AFRD007 – upper	539.06	542.69	3.63	2.06	2.25	0.67	32.2
18AFRD007 – main	547.61	564.00	16.39	1.65	2.46	0.54	25.9
18AFRD008 #1	435.02	438.54	3.52	2.51	2.32	0.38	31.6
18AFRD008 #2	499.57	504.24	4.67	0.63	1.92	0.38	12.1
18AFRD008 #3	531.18	572.54	41.36	1.47	2.46	0.35	22.0
18AFRD008 #4	576.70	584.55	7.85	0.77	2.11	0.68	13.3