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Identification of massive sulphide targets using the Galvanic Source EM (GSEM) signal from a Sub-Audio Magnetic (SAM) survey at the Far South Project, Western Australia

Yvonne Wallace
Southern Geoscience Consultants
Belmont, WA
Yvonne@sgc.com.au

Daniel Card
Southern Geoscience Consultants
Belmont, WA
Daniel@sgc.com.au

Keith Gates
Saracen Mineral Holdings Ltd
Perth, WA
KGates@saracen.com.au

Mal Cattach
Gap Geophysics Australia
Brisbane, WA
mcattach@gapgeo.com

SUMMARY

The Far South project is located five kilometres along strike from the Deep South mine, where gold mineralisation is commonly associated with semi-massive pyrrhotite and pyrite. Data from a Sub-Audio Magnetic (SAM) survey set up in galvanic configuration were acquired over the project principally to map stratigraphy and structure using the on-time Magnetometric Conductivity (MMC) and Total Magnetic Intensity (TMI) responses. The off-time Galvanic Source EM (GSEM) data were subsequently extracted from the raw data and examined. Four late time anomalous responses were identified. Two of these responses are strong late-time (>45ms) anomalies up to 350m in strike length, and the remaining two are weaker mid-time, more subtle and less diagnostic responses. Follow-up Moving Loop Transient Electromagnetics (MLEM) and Fixed Loop Transient Electromagnetics (FLEM) surveys confirmed well defined conductive responses over all four follow-up areas. Modelling of the GSEM data over the two strongest anomalies is in good agreement with modelling of the MLEM/ FLEM data, confirming the ability to identify and model conductive targets from SAM GSEM data. The two weaker GSEM responses could not be reliably modelled and use of the MLEM/ FLEM data was necessary to produce robust models. The identified conductors were all interpreted as having good exploration potential, and a subsequent drill program intersected the source of all four as sulphide zones of varying widths and types.

Key words: SAM, GSEM, massive sulphide

INTRODUCTION

The SAM method was developed for simultaneously mapping the magnetic and electrical characteristics of the Earth (Cattach et al, 1993). The method has been used in both mineral exploration, and for unexploded ordnance detection (eg Meyers et al., 2005). Recent developments over the last five years in instrumentation and processing software have now allowed the practical extraction of the EM component from the measured signal.

Late time EM conductors have the potential to map zones of well-connected sulphide, or graphitic shales in the bedrock. Gold deposits such as the Banded Iron Formation (BIF) - hosted Hill 50 (Vella, 1995), and the sheared basalt-hosted Bellevue (Liu et al, 2002) deposits in Western Australia have previously demonstrated the ability of EM to detect gold-related sulphides such as pyrrhotite, pyrite and chalcopyrite.

The SAM method was applied to the Far South project, located within the Linden domain of the Archaean Yilgarn Craton. The geology of the survey area consists of a narrow zone of high-grade metamorphic rocks including felsic volcaniclastic rocks, meta-sediments, BIF and ultramafic units, and extending to the east over a basalt-granite contact. Along strike 5 km to the north is the Deep South Gold Mine where gold mineralisation is hosted in a hydrothermally altered carbonate-rich chemical sediment and a parallel BIF unit. Downhole Electromagnetics (DHEM) has been demonstrated to be effective here in detecting the key mineralised lodes associated with sulphides.

The principle aim of the SAM survey was to use the TMI and MMC data to map stratigraphy and structure. The GSEM data were additionally extracted to identify potentially mineralised conductive shear zones, and/ or zones of gold-bearing sulphide. Four such targets were identified from the GSEM data, and these were followed up with conventional MLEM and FLEM surveys. Two of the targets were high amplitude conductance EM anomalies, which were well-defined and modelled using the GSEM data, then further refined by modelling using the MLEM data. The remaining two targets were identified by a more subtle and less conductive response in the GSEM data which was not sufficiently defined to permit modelling. These two targets were modelled and targeted based on follow-up FLEM and MLEM survey data. All the targets were drilled, successfully intersecting the source of the EM anomaly in each case.

METHODS

The SAM method requires a time-varying electric current to be artificially applied to the ground. This is achieved with a high power transmitter producing a broadband (low frequency square wave) signal that is introduced into the ground either through distant electrodes as for conventional gradient array electrical resistivity or magnetometric resistivity surveys, or induced into the ground through a loop as for conventional electromagnetic surveys. The induced electromagnetic signal is then measured simultaneously with the Earth's spatially varying magnetic field using a rapid sampling total field magnetometer. The resulting current channelling produces the high resolution MMC response, which complements the TMI data. The GSEM data can then be extracted from the off-time part of the signal as induced electromagnetic responses are decaying.

The SAM survey at Far South was acquired in two grids, in galvanic configuration with a transmitter frequency of 3.125Hz. A wire electrode pair surrounds each grid, passing a current from the transmitter in a direction approximately parallel to geological strike (Figure 1). A line spacing of 50m was used and the data were typically acquired at 0.5m (TMI) and 2m (MMC, GSEM) along-line spacing.

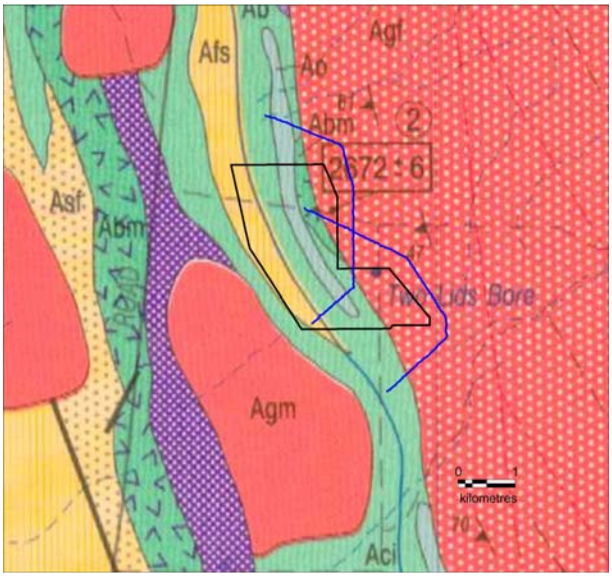

Figure 1. Layout of SAM survey with 1:250,000 scale GSWA solid geology map). The grid locations (black) and wire layout (blue) are indicated.

The resulting TMI and MMC data were used to produce a geological interpretation of the area, including the extension of the mineralised stratigraphy at Deep South. The GSEM data were reviewed for conductive anomalies with target potential, in particular stationary anomalies often weaker at early times but persisting and getting more prominent through to late time. Four such targets were identified (Figure 2).

The Northern 1000 and Southern 2125 targets were identified in the GSEM data as strong late time (75ms) dipole responses. In addition, they are both proximal to subtle stratigraphy-parallel magnetic units, interpreted as possible zones of pyrrhotite and indicative of potential zones of gold-bearing sulphide.

The Western and South 3600 targets were also identified from the GSEM data as more subtle lower amplitude responses, both stratigraphically along strike from Deep South.

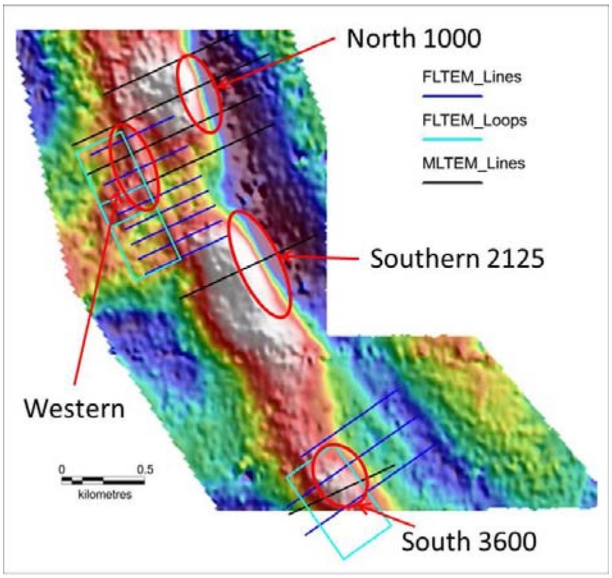

Figure 2. Off-time channel 6 (12.5ms) GSEM grid showing the conductors identified from the GSEM data, with MLEM and FLEM line locations

The GSEM targets were followed up with conventional surface EM surveys, in order to confirm the existence of the GSEM anomalies, and define them sufficiently for drill testing. The MLEM method was used at all of the target areas with 200 x 200m single turn in-loop configuration, 80-130A current, and 50m station spacing. At the Northern 1000 and Southern 2125 targets, this was sufficient to define the conductive body for drill testing.

At the less conductive Western and South 3600 targets however, further definition was required. The FLEM method was additionally used with a fixed single turn transmitter loop (80A) of 500 x 300m and 350 x 600m (respectively), and 25-50m station spacing.

Forward and inverse modelling was carried out using Maxwell (Ribbon-based plate modelling program produced by ElectroMagnetic Imaging Technology Pty Ltd) to create plate models of the conductors for drill testing.

RESULTS

The parameters of each conductor, and optimum drill hole positions for each target were estimated by modelling the MLEM and FLEM data. The GSEM data from the SAM survey was also modelled to provide a comparison with the conventional EM data, by using an assumed loop location.

At Northern 1000, the data fit well with the calculated response from a single plate model of 650m strike, and 105m depth from surface (Figure 3).

The SAM GSEM data (Figure 4) had a broad peak, initially indicating the possible presence of a second conductive unit; however the MLEM data provided clarification of a single conductor only. Despite the broader peak, the MLEM plate still gives a reasonable fit with the GSEM data although a wide range in possible dip and dimensions was possible illustrating that the MLEM data was needed in order to provide a reliable plate model for drill testing.

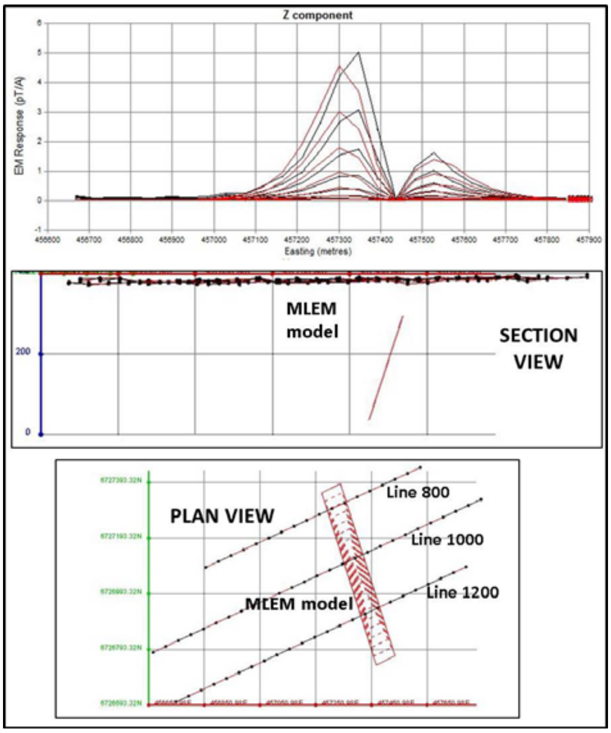

Figure 3. Northern 1000 target: Top panel – Channel 30-36 (45-220ms) in-loop MLEM response profiles (black) with MLEM model response (red). Middle & bottom panels – Section & plan views of the MLEM plate model.

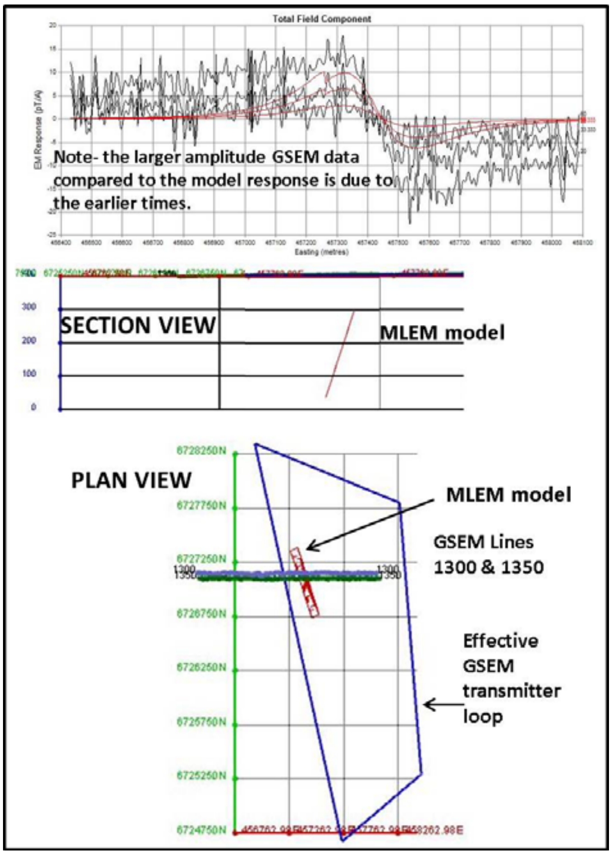

Figure 4. Northern 1000 target: Top panel – Channel 7-9 (15-80ms) GSEM response profiles (black) with MLEM model response profiles (red). Middle & bottom panels – Section & plan views of the MLEM plate model.

Similar results and conclusions were found at Southern 2125, the other strong and well-defined conductor.

At Western, the MLEM data confirmed the presence of the conductor as a small anomaly superimposed on the large amplitude anomaly from the Southern 2125 conductor. The target was not well defined however, both due to ambiguity introduced by the superimposition of the larger anomaly, and due to its short wavelength response in relation to the line and station spacing of the MLEM survey. A higher resolution FLEM survey was therefore acquired to provide a well-refined model sufficient for targeting and drill testing.

The FLEM data confirmed the presence of the Western conductor as a mid-late time anomaly and identified a second similar conductor to the south west (Figure 5). The data fit well with the calculated response of two plates, the northern plate of 145m strike and 75m from surface, and the southern plate of 300m strike and 13m depth from surface.

The SAM GSEM data (Figure 6) again has a broader peak than the higher resolution MLEM and FLEM data. Using the FLEM plates alone, a reasonable fit of the small anomaly, superimposed on the main response from the Southern 2125 conductor was achieved. The addition of the MLEM plate for Southern 2125 completed the model.

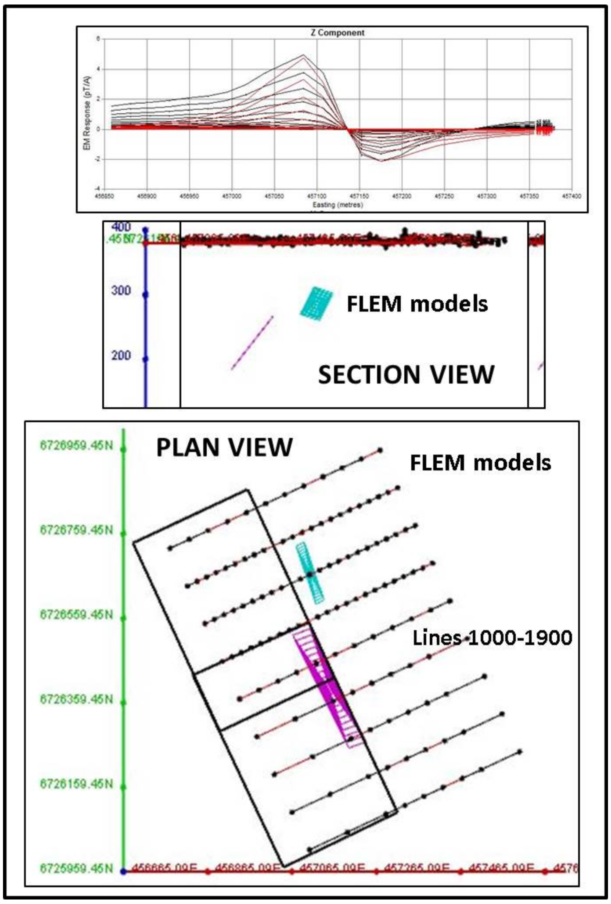

Figure 5. Western target: Top panel – Channel 25-36 (16-220ms) FLEM response profiles (black) with FLEM model response (red). Middle panel – Section view of FLEM plate models. Bottom panel – Plan view of FLEM models.

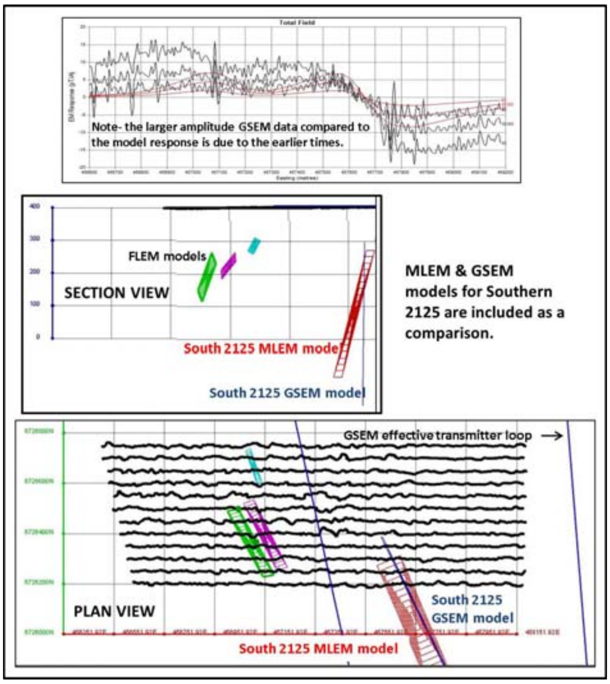

Figure 6. Western target: Top panel – Channel 7-9 (15-80ms) GSEM response profiles (black) with FLEM model response profiles (red). Middle and bottom panels – Section and plan views of the FLEM plate models.

Similar results and conclusions were found for South 3160, the other weaker and more subtle conductor.

DRILL TESTING

The four modelled targets were subsequently drilled using reverse circulation for a total of 2035m. The aim of the program was to intersect the source of the conductors as potential economic gold-bearing intervals. None of the selected targets or the wider area in general has been previously drilled. Overall the results were positive and several significant intersections were returned.

At the strongly conductive Northern 1000 and Southern 2125 targets, 40-50m wide zones of disseminated (1-3%) sulphide were intersected. This zone is predominantly comprised of pyrite and pyrrhotite. Gold intersections included 1m @ 0.5g/t and 1m @ 3.06g/t.

At the Western targets narrow (1-2m) wide zones of massive sulphide, and wider (4-7m) zones of semi-massive (40-50%) sulphide dominated by pyrite-pyrrhotite were intersected (Figure 7). The sulphide units were intersected less than 5m from the modelled positions.. The plates were found to be concordant with steeply (75°) west dipping stratigraphy confirmed by the drilling. Gold intersections included 2m @ 7.995g/t and 2m @ 7.52g/t within or directly adjacent to the sulphide zones.

At the South 3600 target, a discrete (1m wide) weakly sulphidic zone of pyrrhotite–pyrite was intersected, with anomalous gold returned proximal to this zone. Overall, the drill testing successfully intersected the source of the EM anomalies and significant Au-bearing zones within or proximal to these sulphidic targets.

Figure 7. Example of RC chips from the Western target area.

CONCLUSIONS

The SAM GSEM data were used to identify four conductors which, by using follow-up conventional EM surveys, successfully delineated drill targets. Strong, uncomplicated and well-defined conductors were reasonably well defined by the GSEM plate modelling, requiring a minimum of MLEM data to complete the modelling. The MLEM zones with subtle, weak and complicated responses required higher resolution FLEM data to provide sufficient information to define the drill targets. Of additional note is that the (assumed) loop location can have an impact on the level of response of the conductors, as this will control whether optimal or sub-optimal coupling is achieved.

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