GEOPHYSICAL SIGNATURE OF THE SOUTHERN GURUBANG BASE METAL OCCURRENCE IN SOUTH EASTERN NSW

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SUMMARY

Ground-based, time-domain electromagnetic, magnetic and gravity datasets were obtained for the southern-section of the Gurubang VHMS deposit located approximately 15 km east of Cooma, NSW. The Gurubang deposit is hosted in a mid-late Silurian sequence of rock composed of shallow marine sediments and felsic volcanic rocks. The aim of this research was to ascertain the usefulness of high-resolution geophysical techniques in targeting and evaluating a small-scale polymetallic massive sulphide deposit, and to investigate how the detailed geophysics relates to the overall geological framework of the prospect area. The acquired data was analysed using a forward modelling approach. Due to the deposits high concentration of conductive minerals, a coincident loop time-domain electromagnetic 2D survey effectively delineated the sulphide mineralisation, and was useful in interpreting and adapting deposit parameters such as the azimuth, dip and strike length. Based on the physical nature of the target deposit, it was determined that high-resolution magnetic and gravity surveys would not be effective methods in directly delineating these smaller-scaled (10's of m's) mineral deposits. However, magnetics and gravity did prove effective in depicting the surrounding geology, including potential volcanic intrusions and basement lithologies and structures.

Key words: Ground-based, time-domain electromagnetic, magnetic, gravity, polymetallic massive sulphide, Gurubang.

INTRODUCTION

Palaeozoic polymetallic volcanic-hosted massive sulphide (VHMS) deposits of south eastern New South Wales, have been a major source of Cu ± Au (e.g. Mt Morgan and Captains Flat) and a significant source of Pb – Zn – Ag (e.g. Woodlawn and Thalanga) over the last one hundred years of mining. Prior to the 1960s, all VHMS discoveries in Australia were based on outcropping gossans and mineralisation. However, more modern exploration commonly incorporates a multidisciplinary approach, using a combination of geological mapping to define volcanic facies, accompanied by geophysics and geochemistry to define drill targets (Gemmell, Large and Zaw, 1998).

In more recent times, geophysics has become an important tool in base metal exploration as companies turn their efforts towards buried and hidden deposits. Magnetic, gravity and electromagnetic methods are useful tools in VHMS detection. However, they are typically applied at a prospecting or regional-scale and may miss smaller, potentially profitable, deposits. In this context, it is important to know the limitations of the method and data when targeting such small-scale deposits, and therefore a greater understanding of the optimum data resolution is needed for the range of geophysical methods.

This study was aimed at utilising newly acquired ground-based geophysical data to ascertain the usefulness of high-resolution geophysics in the search and delineation of small-scale base metal deposits, and to investigate how the detailed geophysics relates to the overall geological framework of the prospect area.

Since the initial discovery of placer gold along the Numeralla River in 1858, the Cooma region (Figure 1) and surrounding districts have undergone extensive exploration in the hopes of locating profitable mineral occurrences. A recent geological report by Smith Engineering (2015), suggests that the mineralisation in the district is minor but still significant enough to warrant further exploration. There are numerous small-scale base metal deposits (Figure 2 a) located within the Cooma region. Such deposits include, the Glenfergus Prospect, Woodend Prospect, Skidmore (North and East) Prospect, and the Square Range Prospect. These deposits vary in scale and contain base metal commodities such as Cu, Zn and Pb.

The Cooma region is located within the east province of the Lachlan Fold Belt, NSW. Major stratigraphic sequences in the Cooma region range from early Ordovician to late Devonian age (Figure 1). The geology is dominated by an early Ordovician to late Silurian contact sequence, which is composed of groups such as the Bendoc, Yalmy and Bredbo Group. As described by Lewis and Glen (1994), these Groups encompass mainly shallow water sedimentary rocks and I-type volcanic fill of the Ngunawal Basin.

The Gurubang VHMS deposit (Figure 1 and 2) is located 15 km east of Cooma. The small-scale deposit lies within the Cappanana Formation of the Bredbo Group, which is composed predominately of quartzose sandstone, siltstone, shale, black shale, fossiliferous limestone and minor tuffaceous sediments. The deposit was first discovered by Aquitaine Australia Minerals during the mid-1970's. Numerous drillings were carried out across the prospect area, targeting two EM anomalies that were previously identified using a

CRONE EM system (Argaud, 1976). Previous performed diamond drilling intersected significant VHMS mineralisation hosted in an alternating sequence of limestone and shale (Castle, 1976; Argaud, 1976; and Cooke, 1977). However, the yielded sulphide values were considered too low and no further investigation was undertaken (Wilson, 1994). Previous geological reports describe the sulphide mineralisation as disseminated with moderate concentrations of pyrite and pyrrhotite, and minor sphalerite and other secondary sulphides (Elliot, 1983; Horsburgh, 1983).

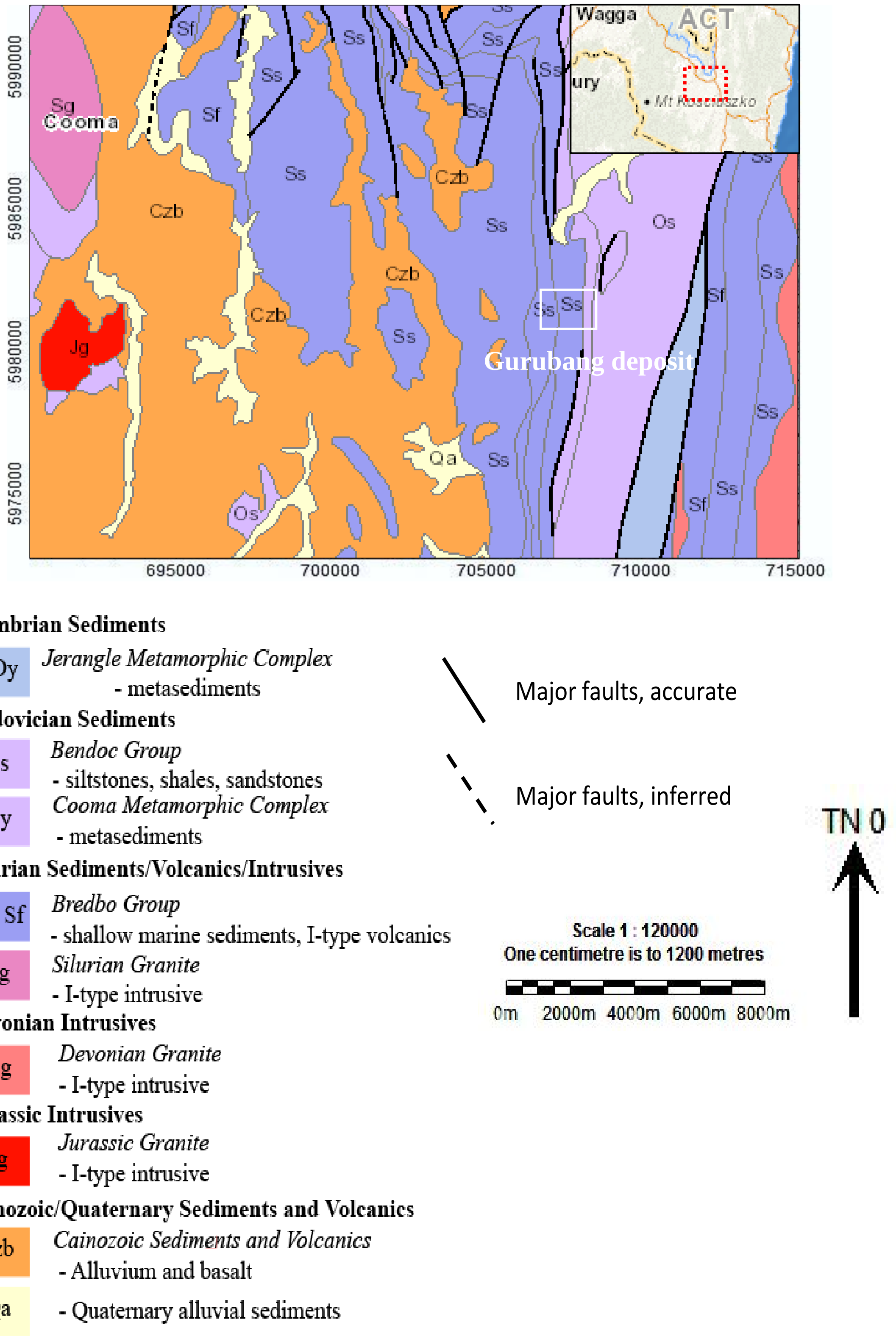


Figure 1. Regional geological interpretation map of the Cooma region. Image sourced from (http://www.ga.gov.au/interactive-maps/#/theme/minerals/map/geophysics). Grid reference in GDA 94.

METHODS

This study uses ground-based time-domain electromagnetic (TEM loop size of 100 – 200 m^2), magnetic and gravity (line spacing of 20 – 50 m and station spacing of 5 – 10 m) surveys conveyed across the southern section of the Gurubang VHMS deposit (traverse lines depicted in Figure 2 b).

High-resolution, ground-based TEM involved using a terraTEM Transient EM System that was connected to a set of grounded wires. Basic TEM field configurations are summarised by Nabighian and Macnae (1991). An in-loop TEM survey, where by the Rx coil is placed in the centre of the Tx loop, was initially proposed for the Gurubang deposit. This setup was aimed at limiting the amount of noise contamination caused by sferics. However, it was found that the in-loop Rx equipment was damaged beyond instant repair, prior to the commencement of the survey. Therefore, the coincident loop was used to collect the TEM data.

(a)

(b)

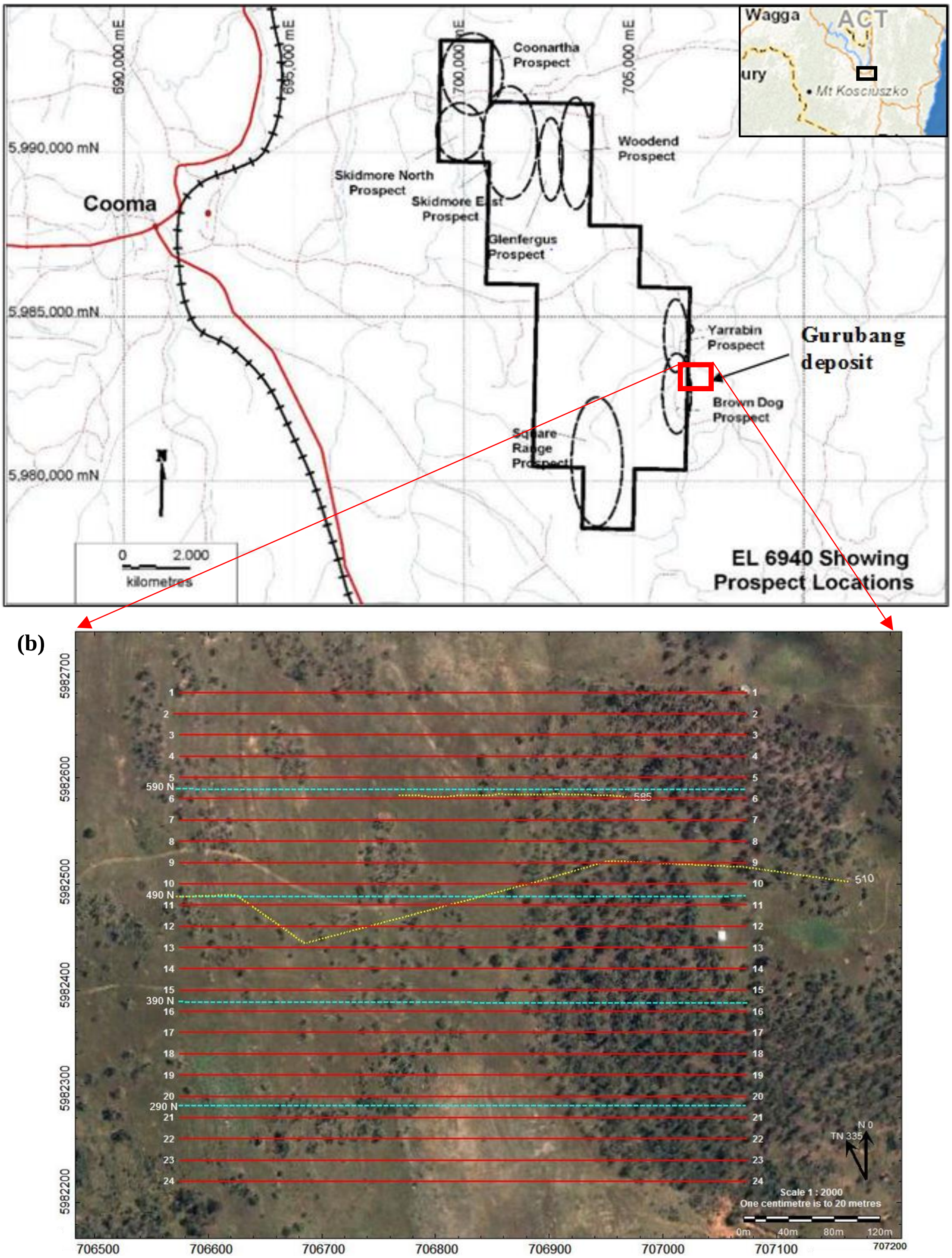


Figure 2. (a) Exploration license 690 showing prospects (Smith Engineering Systems, 2015). (b) Gurubang deposit site with east-west trending survey lines:(Red) Magnetic; (Blue) TEM, and; (Yellow) Gravity. Grid reference in GDA94.

Diurnally corrected magnetic readings were acquired using two G 856 Memory-MAGTM Proton Precession Magnetometers (accuracy of ~1 nT) and a single G 858 MagMapper Caesium Vapour Magnetometer (accuracy of ~0.01 nT). During each survey period, a G 856 magnetometer was used as a base station.

Ground-based gravity surveys were collected using a Scintrex CG-3 and a Scintrex CG-5 gravimeter. Positioning and elevation of gravity stations were measured using an Ashtech Real Time Kinematic (RTK) satellite navigation, which has an accuracy of ~ 1cm. The relative positions and elevations were later corrected using the positioning from Geoscience Australia's AUSPOS (http://www.ga.gov.au/scientific-topics/positioning-navigation/geodesy/auspos) to accurately locate the GPS base station.

RESULTS AND INTERPRETATION

The high-resolution, ground-based magnetic data highlights areas of contrasting magnetism. The total magnetic response ranges from -323 – 2276 nT. Anomaly A (Figure 3 a), is a broad, weakly-elongate feature, showing a high magnetic response ranging from 158 - 511 nT. The anomaly extends north for approximately 200 m and has a width of about 100 – 150 m. Smaller magnetic anomalies are located just east of the larger anomaly A. Anomaly B is a relatively thin, 10 – 20 m response, that has a magnetic signature ranging from 210 - 616 nT. Its irregular elongate, flexing shape appears to trend north-south and differs from the more elliptical shapes of the surrounding responses. Anomaly C has a broad magnetic response, ranging from 109 - 341 nT, and an elliptical shape extending north-south. In contrast to the strongly magnetic north, the data presents areas to the south with significantly low magnetic intensities. Anomaly D is located at the base of anomaly A and has a magnetic signature ranging from -179 - 323 nT and has a slightly rounded, irregular shape.

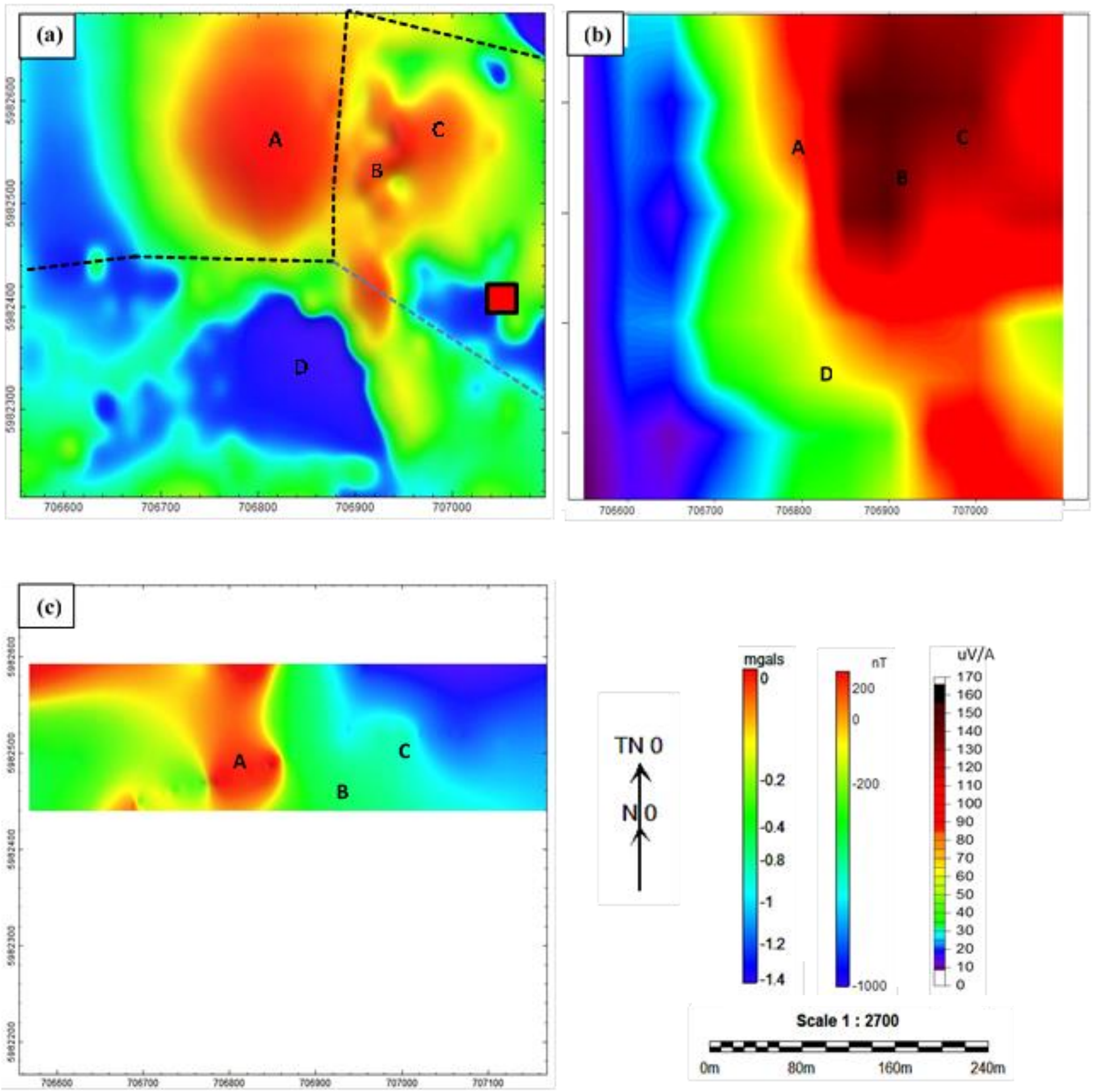


Figure 3. (a) Magnetic, (b) TEM response for channel 95, (c) Gravity maps. Grid reference is GDA94. Boundary fence indicated via dotted line.

The high-resolution, ground-based gravity method outlined areas of contrasting densities associated with the overall geological framework of the target area. The total gravity response over the southern Gurubang deposit ranges from -1.29 – 0.14 mgal (milligal). The imaged data highlights an overall east-trending negative gradient, with the greatest gravity response located between 706750E – 706850E (Figure 3 a, anomaly A). This anomaly corresponds with the magnetics anomaly A seen in Figure 3 a. Forward modelling of the data indicated that the major geological units are the prime contributors to the gravity response. Delineating the response associated with the sulphide deposit from the host geology was challenging, which was most likely due to its relatively small size. It is surmised that a gravity survey conducted using a tighter station spacing (~ 2.5 m) may be more effective in identifying and evaluating the small-scale mineralisation, but is not worth the effort in time and cost.

The data from the TEM survey effectively delineated the sulphide mineralisation from the host rock. The data indicates an overall high TEM response (90 -160 uV/A) in the east and low TEM response (10 – 60 uV/A) in the west (Figure 3 b). The highest TEM response is shown in the northeast and exceeds 160 uV/A. Two discrete mid-late time conductive responses (CC1 and CC2) were identified within the Gurubang deposit locality.

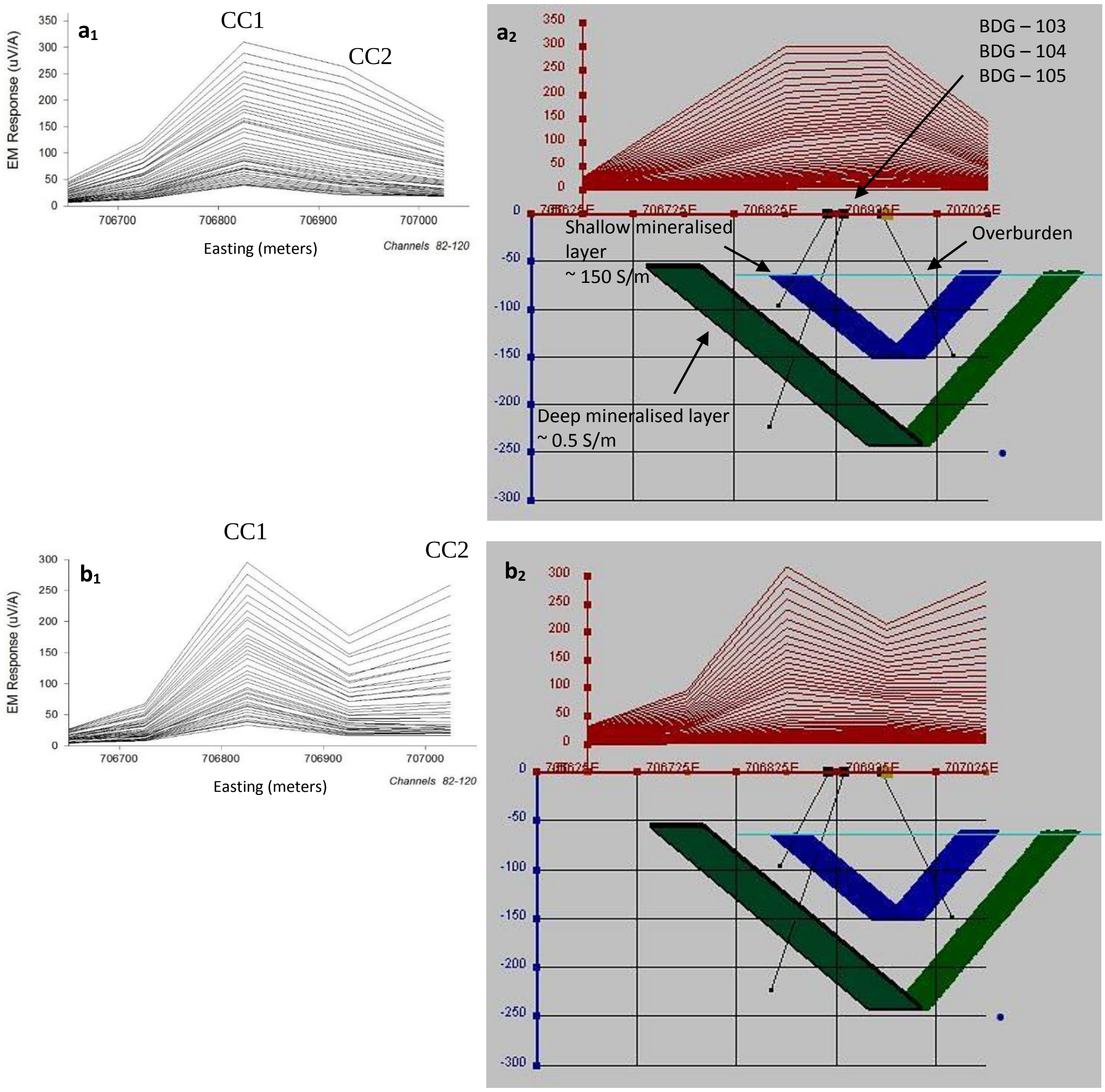
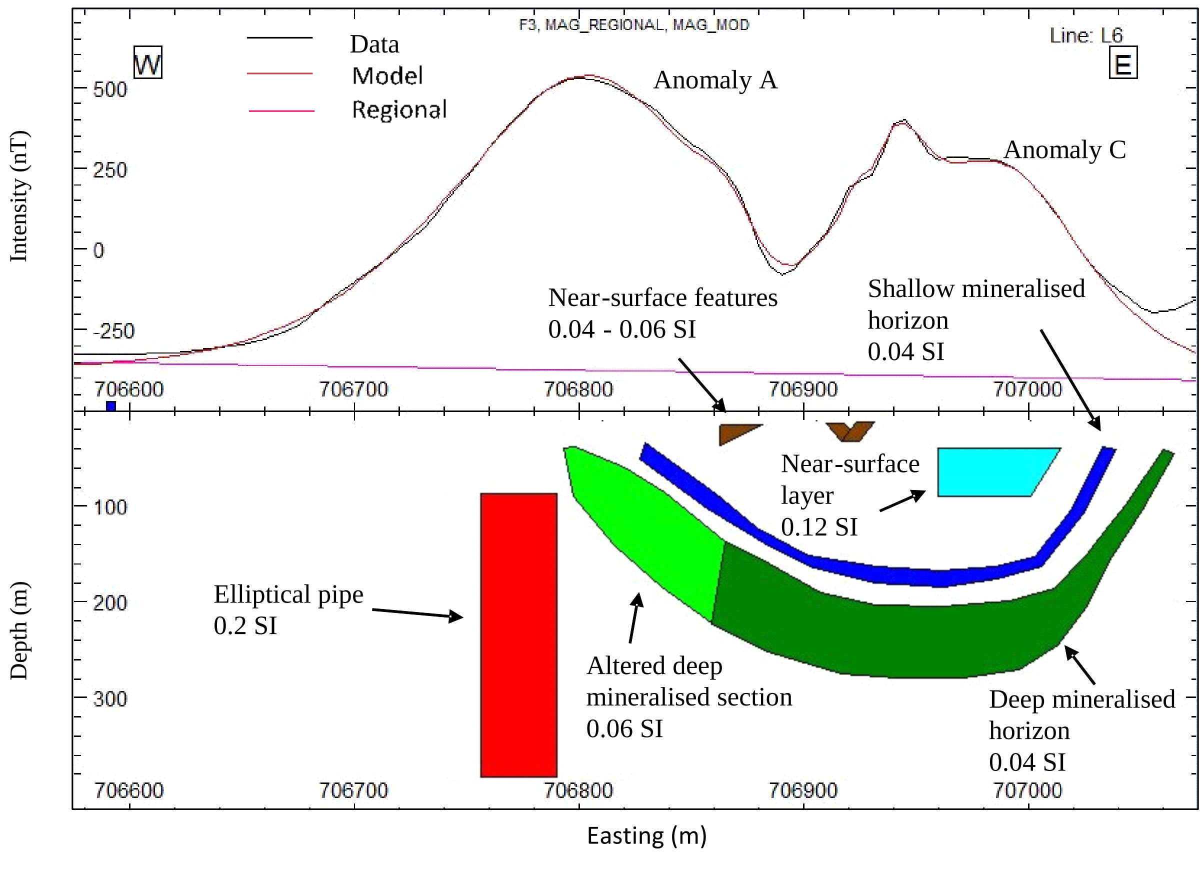


Figure 4. TEM profiles and forward models across the Gurubang deposit locality. a_1. Profile 590N a_2. Model profile 590N b_1. Profile 490N b_2. Model profile 490N. v = h.

Forward modelling of the TEM data (Figure 4) shows the presence of two mineralised horizons; a shallow thin layer (5 – 10 m) and a deeper thick layer (40 – 50 m). The TEM data indicates that the mineralisation conforms to the general strike orientation, dip and dip direction of the regional geological framework (NNW-SSE). The modelled layers were given dips ranging between 45^o – 60^o for the western limb and 55^o – 70^o for the eastern limb. These dips were based on the approximate dip of the geology and best fit to the data.

The modelled data shows an open to close synform structure. Previous geochemical research performed on the collected drill core samples indicate that the shallow layer represents a semi massive "ore equivalent" pyrrhotite-rich horizon, while the deeper layer represents a massive mineral horizon (Castle 1976; Argaud, 1976; and Cooke, 1977).

The magnetic signature associated with the southern Gurubang deposit is due to its content of magnetic "non-ore" minerals, mainly pyrrhotite (Castle, 1976; and Cooke, 1977). A two-layered model (shallow and deep mineralised horizons) provides a poor fit to the observed magnetic data. The average susceptibility of the two layers range from 0.03 – 0.05 SI and were given widths based on the widths of the mineralisation intercepted by the previously sampled drill cores (Castle, 1976; Argaud, 1976; and Cooke, 1977). Magnetic values within this range were trialled but did not achieve a good match to the data. Increasing the magnetisation by a factor of two provides a closer match to the intensity of the observed data but the shape was still a poor fit. Magnetic model (Figure 5) provided the best fit to the observed data. It suggested that the magnetisation of the mineralisation alone could not explain the broader magnetic signatures (anomaly A and C). A vertical elliptical pipe body and various magnetic near-surface features were incorporated into the two-layered model. The elliptical pipe may be representative of an intrusive Tertiary basaltic volcanic plug, which are known to occur within the immediate region (McQueen, 1994). The high frequency signals in the observed data were successfully modelled using the integrated near-surface features of varying magnetic susceptibilities. The dip of the bodies was based on achieving the best fit to the data. The near-surface features are potentially related to the Tertiary basalt cover unit (Glen and Lewis, 1994), an intermittent dyke intrusion, or possibly outcropping gossanous material containing maghemite leached from the deeper mineralisation (Cooke, 1977). The magnetic susceptibility of the western section of the deeper 'mineralised' layer was also increased from 0.04 to 0.06 SI and may be an alteration zone caused by the intrusion of the elliptical pipe.



(Figure 5. 2.5D magnetic model associated with the suspected Gurubang mineralisation. Line 6 x-section outlining the two-layered model with additional bodies.

The primary anomaly complex (Figure 6) constitutes a mixture of altered shallow marine sediments (Figure 6 b), a relatively large potentially igneous intrusive pipe and the southern Gurubang mineralisation. The basement geology has a lower magnetic signature (Figure 6 a) relative to the area hosting the mineralisation (Cooke, 1977), and appears to strike 330º – 340º NNW–SSE. Features, such as the near-surface anomalies, have strike orientations like that of the current strike orientation of the overall geology. This suggests that near-surface emplacement was prior to most recent folding event at around 400 – 380 Ma (Foster and Gray, 2000).

The high-resolution magnetic and TEM surveys effectively highlight the primary anomaly complex of interest, as well as deeper basement features. Some of these features included geological boundaries, faults and folds (Figure 6 a). The high-resolution magnetic method was limited in its ability to delineate the mineralisation from the surrounding geological features (e.g. intrusive volcanic pipe). In terms of directly targeting mineralisation, it could be considered a useful tool under the guise that the magnetisation of the deposit is clearly divisible from the surrounding rock. The high-resolution gravity method was less effective in delineating the mineralised zone from the surrounding lithologies.

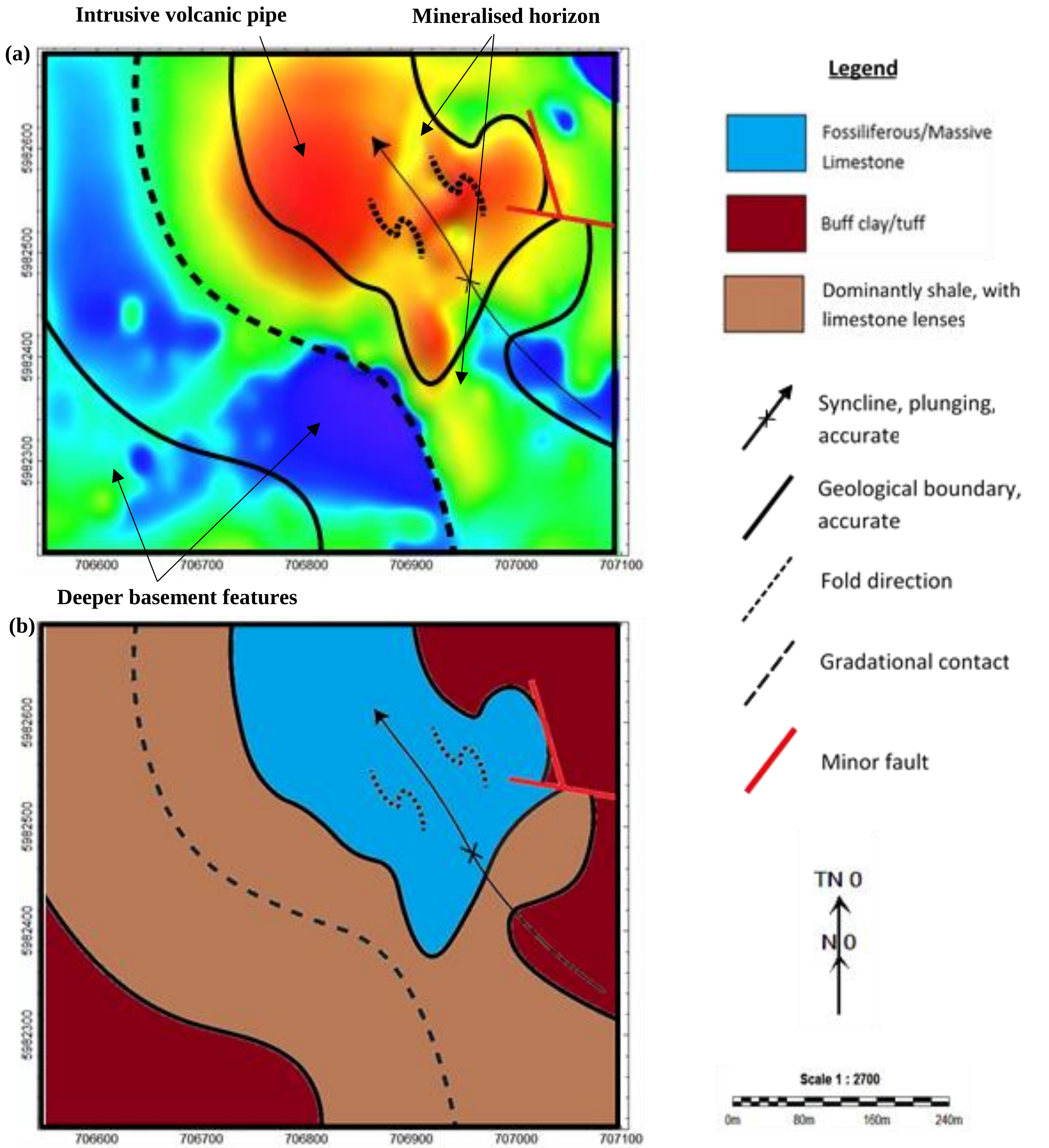


Figure 6. (a) Gurubang magnetic anomaly map with overlaid geological interpretation. (b) Geological diagram based on newly acquired magnetic dataset in conjunction with the interpretation from Cooke (1977).

CONCLUSIONS

A 100 x100 m coincident loop TEM survey proved sufficient in delineating and evaluating the small-scale base metal deposits. The technique was sensitive to the conductive mineralisation abundant in the Gurubang deposit. It was also effective in evaluating the apparent dip of the mineralised layers. It confirmed that the deposit occurs in an open to close synclinal formation and that the mineralisation trends NNW – SSE for the length of the entire surveyed area.

A 5 m spaced, high-resolution magnetic survey proved sufficient in delineating areas of contrasting magnetic signature. However, independently the method is not an effective means of sulphide detection unless the magnetic contributor is already understood. It is unclear whether the 5 m spaced gravity method detected the mineralised zone and may be most effective in situations when the density contrast between the orebody and the host stratigraphy is greater.

A 5 m spaced, high-resolution magnetic and gravity surveys effectively outline the geological framework, as well as some previously unidentified structures, comprising both target areas. The magnetic and gravity survey effectively identified features such as, a large intrusive basaltic pipe/plug and major and minor faults and folds. The magnetic and gravity surveys also identified the general (NNW – SSE) trend of the basement geology in the both deposit areas.

Undertaking a 10 to 20 m spaced, ground-based magnetic and gravity survey would obtain a similar data resolution to the run 5 m spacing surveys. It is assessed that a line spacing of 20 m would suffice in delineating the small-scale deposits. The caesium magnetometer provided excellent high-resolution magnetic data but the method is less robust in vegetated terrain. If the terrain suits a proton magnetometer then a 10 m spaced survey would suffice and provide data with enough detail to evaluate the target small-scale mineralisation.

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