

Case Study of Four VTEM Surveys for Gold Exploration in Ghana

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SUMMARY

The Airborne EM techniques are an integral exploration technology in the search for gold deposits along the greenstone belts in southwest Ghana. Modern airborne systems can detect potentially gold-hosting graphite zones in the basement to a depth of 400 m or more and can detect conductive structures which are important for gold mineralization but may not contain significant graphite. Careful evaluation of primary and secondary structures can be used in conjunction with known geology to locate areas of potential mineralization.

Geotech's VTEM helicopter time domain EM prospecting system has performed surveys for a wide variety of deposit styles around the world. The results of four case studies are presented here that demonstrate the performance of VTEM in the identification of gold targets based on the recognition of discrete conductive features and a structural analysis of the conductivity and magnetic outcomes along the greenstone belts in Ghana, Figure 1.

Key words: gold exploration, Ghana, VTEM airborne EM

ANALYSIS TECHNIQUES

Layered-Earth Inversions

To assist interpretation, layered-earth inversions (LEI) were carried out on the EM data. The LEI algorithm models the EM data (Farquharson and Oldenburg, 1993, Ellis 1998), assigning a conductivity to each layer resulting in a conductivity-depth section for each sounding. The resulting smooth-model conductivity-depth function can be displayed in plan for various depth intervals (DI), which are believed to be less sensitive to the depth position of conductors than thin conductivity depth slices of the LEI model.

Profile Analysis

For discrete plate-like targets, the VTEM system produces two main types of responses; those termed inductively thin or double-peaked responses (DPR) and those termed inductively thick or single-peak responses (SPR). Wide conductive zones create what are termed Horizontal Conductive Responses (HCR). These basic shapes are shown in profile form in Figure 2.

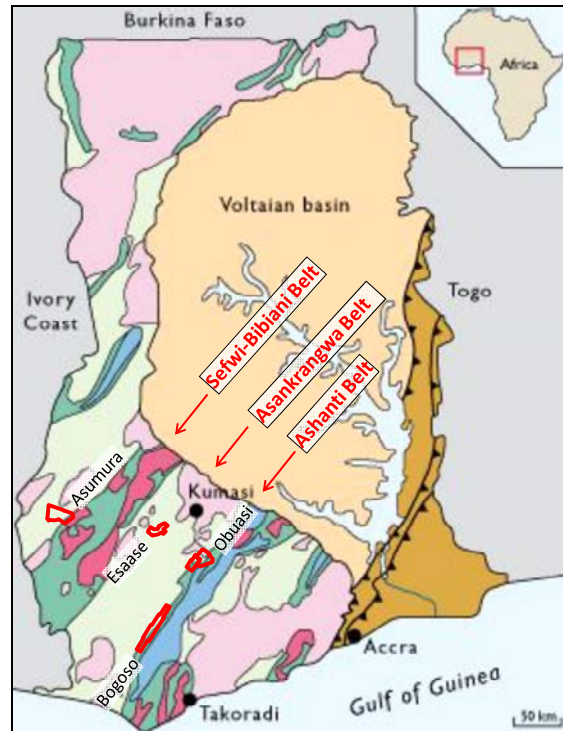


Figure 1: Survey locations in Ghana.

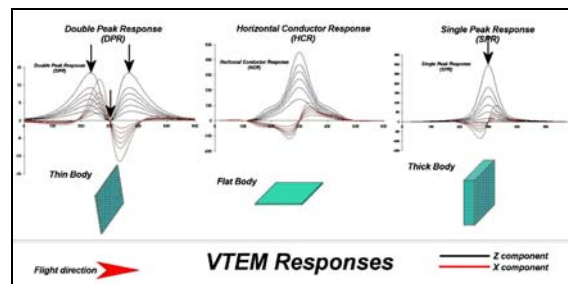


Figure 2: Examples of VTEM responses.

REGIONAL GEOLOGICAL SETTING

Ghana occupies the south-eastern lobe of the Man Precambrian Shield of the West African craton. The Proterozoic Birimian belt in the Man Shield hosts nearly all of the known gold deposits in Ghana, Burkina Faso and Côte d'Ivoire.

The lithology of southwest Ghana is dominated by turbiditic sedimentary and volcanic rocks of the Birimian Supergroup and unconformably overlying fluvial sediments of the Tarkwaian Group. Various granitoid intrusions are also present. All these rock units have been metamorphosed to

greenschist assemblages. The Birimian Supergroup is composed largely of phyllites, schists, greywackes, volcanoclastics and metavolcanic hypabyssal rocks.

The regional structural setting is a bedrock sequence of north-easterly trending, isoclinally folded, troughs of Upper Birimian (2.17 Ba) with intervening anticlinoria of meta-sediments and minor meta-volcanics of Lower Birimian (2.18 Ba) greenstone formations. Locally the former are overlain by the Tarkwaian Group.

CASE STUDIES

General Geophysical Character

Common to all the survey areas are prominent regional faults trending northeast. These are thrust faults that have been reactivated and often contain graphite, making them conductive features, which tend to dominate the EM images. The gold mineralization is often along these structures; however the correlation with the graphite is variable, since the graphite and gold were deposited independently.

Although sulphides often accompany the ore, it is in low enough percentage that a noticeable increase in conductivity is rarely visible. Crossing structures, visible in the EM and magnetic data, play a key role in the targeting, often more so than conductivity highs.

Bogoso Area, Ashanti Trend

During 2007, 3 872 line-km of geophysical data was flown for Golden Star Resources Ltd. over the company's Prestea, Bogoso, Mansiso, Asikuma projects in a N121E direction with a 100 m line spacing, (Coyoli, 2008).

Local Geology for Bogoso

The Bogoso district is located ~100 km southwest of the giant 32 Moz Ashanti deposit and 15 km northeast of the 6 Moz Prestea deposit. All three gold deposits and numerous other prospects are located along the Central Fault Zone (CFZ), which forms the boundary between Birimian rocks to the west and Tarkwaian rocks to the east. The Main Crush Zone (MCZ), the largest fault within the CFZ, contains the bulk of the mineralization in the Bogoso district.

The location of deposit groups imply that any additional major groups are likely be concentrated at or near intersections of the MCZ and other larger discordant faults that traverse the entire width of the CFZ, particularly where their intersection also corresponds to a change in the strike of the MCZ.

Target Models

Known gold mineralization in the area can be used to identify a geophysical signature associated with major deposits. For the Bogoso and Prestea area, the primary target model is linear zones of high conductivity, these being expressions of graphite in the prominent shear zone. The amount of graphite may be proportional to the amount of secondary porosity in the thrust fault plane, which is accentuated by cross-cutting structures. Thus potential mineralization, which is also believed to be associated with porosity, is indicated by the intensity of conductivity associated with shear zones and cross-cutting structures.

A second target model is a siliceous-style of gold mineralization characteristic of quartz-veining and attendant

hydrothermal alteration, appearing as magnetic lows caused by magnetite destruction.

Geophysical Character over the Property

Figure 3 shows a detailed image of the vertical gradient over the published geology (Allibone et al. 2002). The location of the MCZ is apparent from the change in magnetic texture between the Tarkwaian and Birimian. The volcanoclastic units are highs, however the MCZ is not a clear anomaly.

From the magnetic tilt angle (not shown), a number of the major cross structures (magnetic lows or disruptions) are visible, trending from northeast to east-west, often crossing the pit locations.

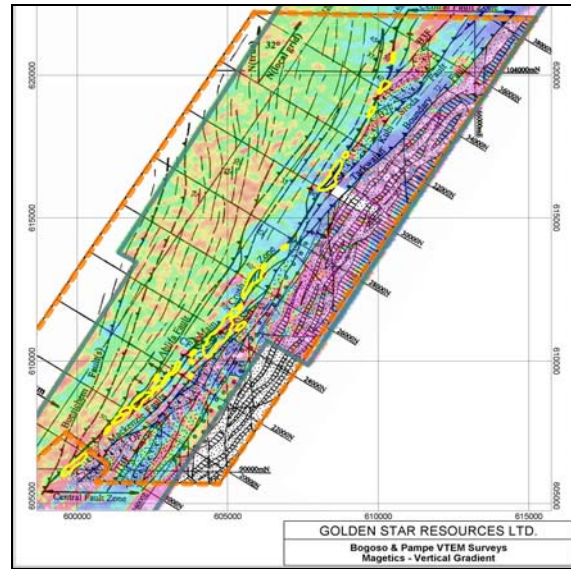


Figure 3: Vertical gradient of magnetic data and geology from Allibone 2002. Zoomed in to Bogoso/Prestea area.

Figure 4 displays the 92 m conductivity depth slice from the LEI, which is dominated by the MCZ and other parallel faults. The known gold mineralization, shown in yellow, appears coincident with conductivity highs but there are some small satellite deposits that are not anomalously conductive. This implies that resistive mineralization can occur along faults that lack sufficient graphite to be conductive.

Figure 5 shows profiles and LEI for a VTEM line through Chujah Main Pit. The Pit is centered on the MCZ, a west dipping conductor. The Tarkwaian rocks to the east show as resistors. A shallow dipping conductor to the west may represent graphitic phyllites.

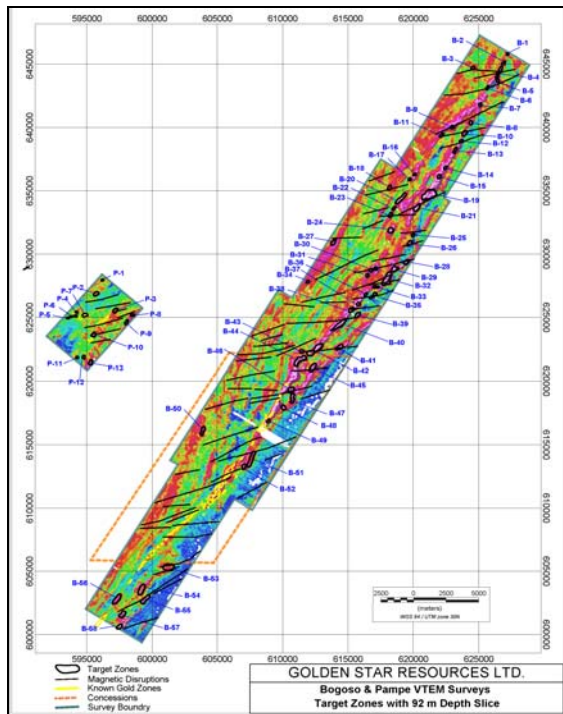


Figure 4: Bogoso Targets over 92 m conductivity depth slice.

Target Zones

The primary determinant for selecting the Target Zones (TZs) is the presence of the primary structures where they have been cut by cross-structures, preferably along the MCZ. Figure 4, above, shows the TZs placed over the 92 m depth slice from the LEI.

Of the fifty-eight TZs within the Bogoso block, three were identified as high-priority, all represent strong conductors or conductors with favorable structural settings. B-40, Figure 6, is a strong conductor along the MCZ.

Obuasi Mine, Ashanti Trend

Pelangio Exploration Inc. flew a total of 3 458 line-km of VTEM over their Obuasi property during 2007 and 2009, (Holbrook 2008 and Geotech 2009) with a 100 m line spacing. Pelangio’s Obuasi project is also on the Ashanti Belt, and is on strike and northeast of AngloGold Ashanti’s world-class Obuasi gold deposit.

Geophysical Character

The ore at the Ashanti and Côte d’Ivoire mines appears to be associated with an increase in graphite, however, the amplitudes are not anomalous in comparison to many of the conductivity anomalies seen along the thrust faults. For other known deposits there are only weak or no anomalies.

The conductance for the DI of 20 m to 50 m may be suitable for detecting shallow silica flooding and corresponds to some identified gold anomalies. However, the conductance from the 50 m to 200 m DI is believed to best represent the location of significant graphite.

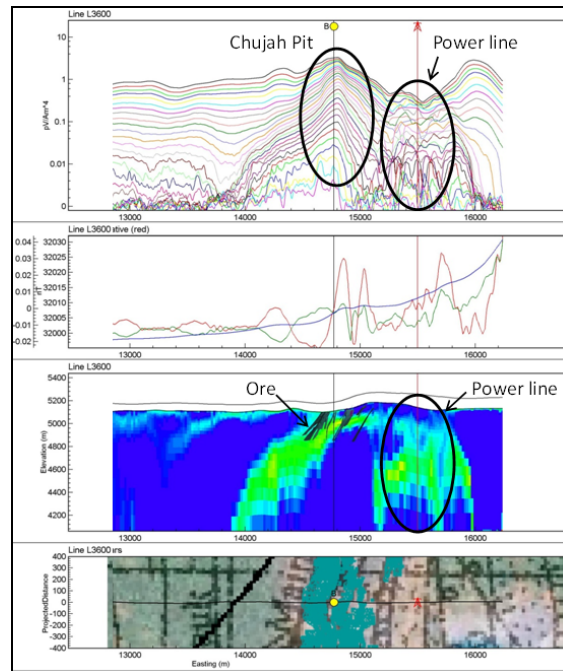


Figure 5: Line through Chujah Main Pit.

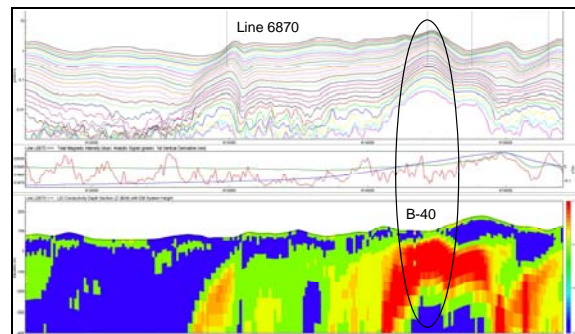


Figure 6: Bogoso EM profiles and LEI for Target Zone B-40.

Figure 7 shows the conductive SPR and DPR feature picks are largely positioned along the main thrust package with some isolated conductors away from the thrust faults that appear to be associated with cross-cutting structures.

Within the survey there are nineteen areas where gold mineralization has been shown to exist. For these areas the geophysical indicators are mixed, however many of the exploration areas possess a shallow resistor over a deep conductor.

Target Models

The target model for the Obuasi Gold Project is based on the recognition that gold mineralization in the Obuasi district is associated with prominent shear zones which frequently host graphite. Thus the primary determinant for selecting TZs is the presence of large conductors as indicated by the 50 m to 200 m DI, Figure 8.

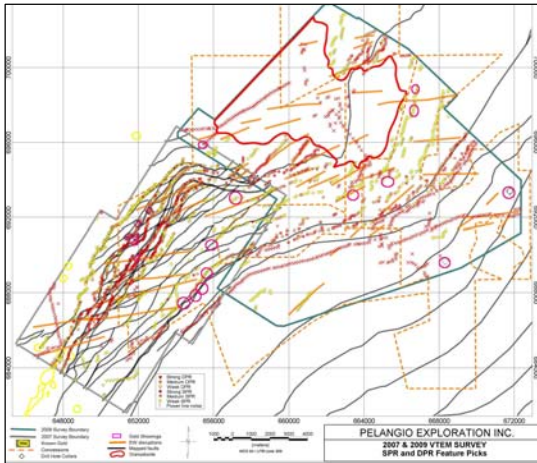


Figure 7: Location of discrete feature picks (red, orange and yellow dots).

Of secondary importance are structures cross-cutting the northeast thrust faults at high angles which are potential structural traps for the gold mineralization. Although these cross-cutting structures are seen as critical to gold placement along the northeast faults, they are difficult to detect from the magnetic data alone and their presence can often be inferred by wide zones in the conductors along the thrust faults.

Quartz-veining and attendant hydrothermal alteration are also characteristic for the gold mineralization and may appear as magnetic lows. Broad silicified zones may manifest as lows in the conductance DI. These lows do correspond to some of the smaller known ore deposits in the survey area.

Priority Target Zones

Of the fifty-one TZs identified for Obuasi, four were identified as high-priority. TZ-12, Figure 9, contains a large conductor located along strike of the Ashanti deposit. It is also marked by high conductivity SPR responses and has a soil Au anomaly through its widest part where the magnetic data indicates that a N80E structure passes through it. This is a possible location for Obuasi-style gold mineralization system.

Esaase Project, Asankrangwa Gold Belt

During 2007, 2 266 line-km of VTEM was flown for Keegan Resources Inc. over the company's Esaase property. It was flown with a 200 m line spacing in a N150E direction, Asiamah (2008). Located within the 150 km long, northeast trending Asankrangwa gold belt (Figure 1) situated between the flanking Ashanti belt and the Sefwi belt. The Asankrangwa Belt is covered by the Lower Birimian Sediments.

The survey covers the Esaase resource, which can be used to attempt to identify a geophysical signature associated with mineralization.

The resource follows northeast trending lineations, where a system of gold-bearing quartz veins is hosted in Birimian rocks.

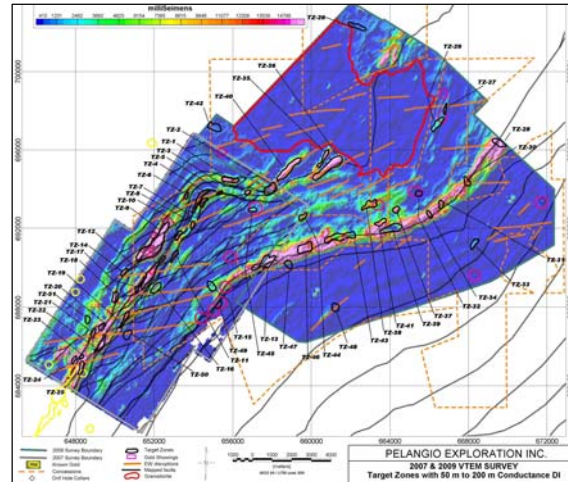


Figure 8: Obuasi Target Zones over conductance in the 50 m to 200 m depth interval. Color pallet is linear, 0 to 5 000 millisiemens.

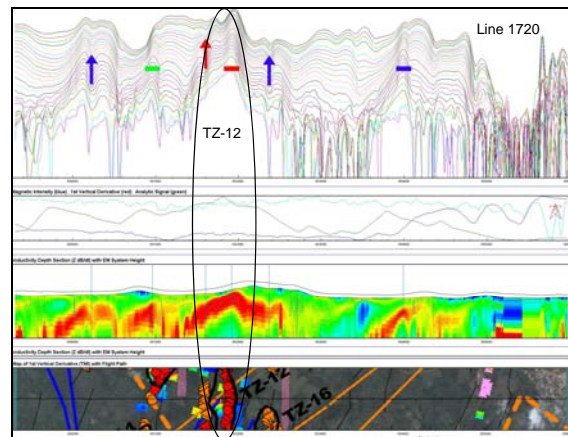


Figure 9: Obuasi EM profiles and LEI for Target Zone TZ-12.

Geophysical Character over the Property

The magnetic tilt angle, Figure 10, shows minor structures that are trending east-west, which appear to disrupt the mineralized area. The magnetic data is dominated by north-south dykes cutting across the main northeast geologic strike for the belt. The dykes are broken along the mineralization trends, indicating the dykes can be used to help locate crossing structures that are related to gold.

EM Channel 15 (Figure 11) shows strong conductors due to the presence of graphite within the north-east fault zone. Within the survey area, conductance lows do not strongly correspond to gold assays from the soil survey (not shown) except for the resource area and the mineralization directly northeast of it.

Since the known mineralization within the survey is neither a conductive feature nor a magnetic feature, the presence of mineralization must be inferred from other geophysical signatures known to be associated with gold mineralization such as structural elements in the data.

The majority of the SPR and DPR feature picks are located along the northeast trending thrust faults. Some isolated picks

away from the thrust faults appear to be associated with cross-cutting structures.

Target Zones

The position of the mineralization along the thrust fault is likely controlled by cross-cutting structures, mainly visible through the magnetic data but also in the conductivity data. Of secondary importance is the presence of large conductors, indicating more graphite and thus more secondary porosity. Also of secondary importance is the presence of resistive areas as indicated by the 30 m LEI depth slice (not shown) indicating possible siliceous-style mineralization.

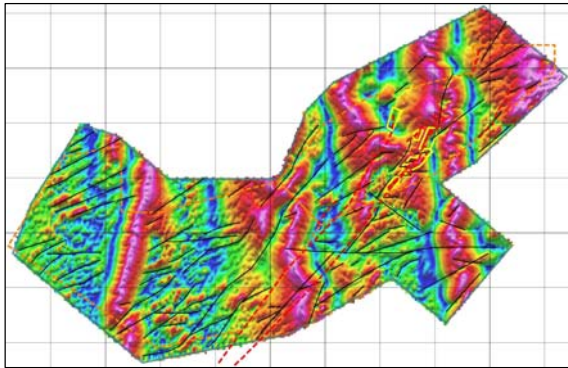


Figure 10: Magnetic tilt angle with crossing structures.

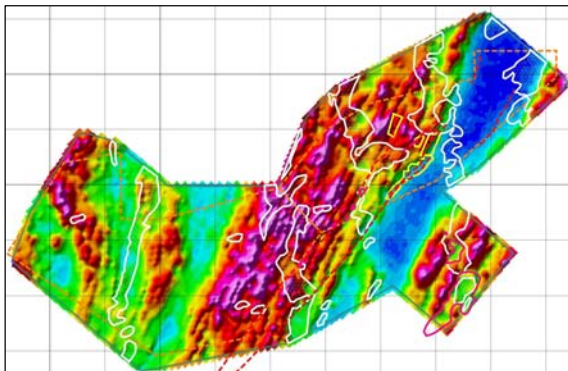


Figure 11: EM Channel 15. Resource area is shown in yellow.

Two of the twenty-eight TZs, were identified as high-priority. TZ-25 (Figure 12 above) shows a conductor that appears to be within an interpreted dyke. It is parallel to and near a mapped mineralization trend. There is a feature pick at the northeast end of it and it shows a soil geochemistry high.

Asumura Project, Sefwi-Bibiani Belt

During 2007, Geotech carried out a 557 line-km VTEM survey for Keegan Resources Inc. over the company's Asumura property in Ghana with nominal 200 m line spacing in a N150E direction with respect to UTM north, Asiamah (2008).

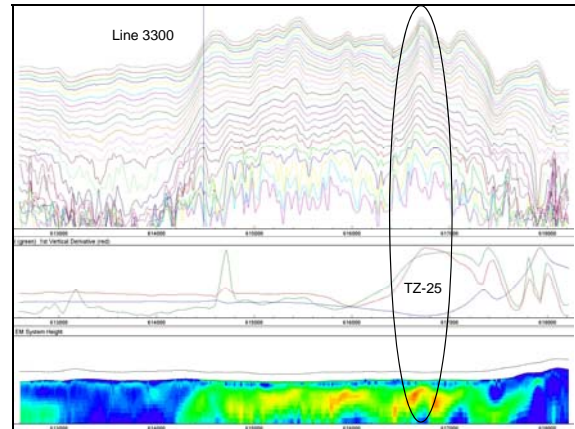


Figure 12: Esaase EM profiles for Target Zone TZ-25.

It is located within the Sefwi-Bibiani Belt, the second most significant gold-bearing belt in Ghana after the Ashanti Belt.

The survey area is located 65 km southwest from Newmont's Ahafo deposits, which are considered to have similar mineralization styles as what is possible in the Asumura area. At Ahafo, gold mineralization is associated with sulphides, graphite and quartz in close proximity with northeast trending structures along fractured, brecciated and silica invaded parts of the shear zones. These tend to parallel the Birimian fold structures. Gold may also appear as disseminated "stockwork" type deposits.

Target Models

Graphite, although possibly present within the survey area, does not indicate gold mineralization. In this target model, the faults may be conductive due to argillic alteration and increased porosity, while the volcanics and granitoids may form resistive zones within the sedimentary host. Ore hosting breccias within the igneous rocks may also appear as conductive.

It is known that the mineralization is trapped in tension gashes, faults and shears, stockworks, and in the hinge zones of the folds. In this target model, some of these structures may be revealed in magnetic data and the increased porosity may be visible as weak conductive features. In the immediate vicinity of mineralization, hydrothermal alteration may appear as magnetic lows caused by magnetite destruction. Quartz veining and surrounding halo of silica flooding may be resistive.

Geophysical Character over the Property

The magnetic tilt angle, Figure 13, shows east-west trending features that may be related to the gold mineralization.

The 92 m conductivity depth slice (Figure 14) shows a highly conductive north-northeast trending zone in the vicinity of the Ebenezer Fault, indicating the presence of graphite. The other mapped faults are not generally seen as strong conductors although portions of the Bia Fault appear conductive. As with Bogoso, the location of known gold mineralization from soil assays (not shown) presents a mixed conductivity signature with some weak conductor and some resistive features.

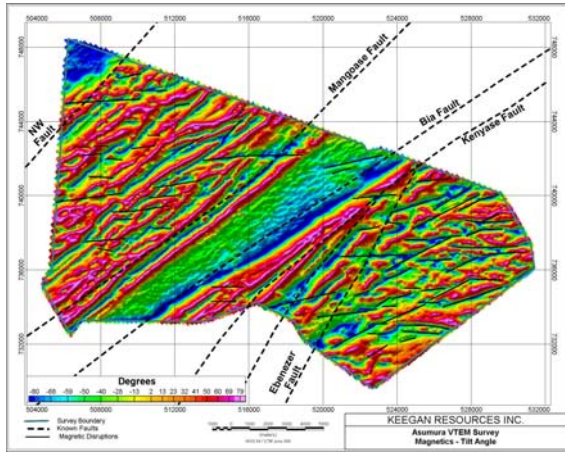


Figure 13: Magnetic tilt angle with crossing structures.

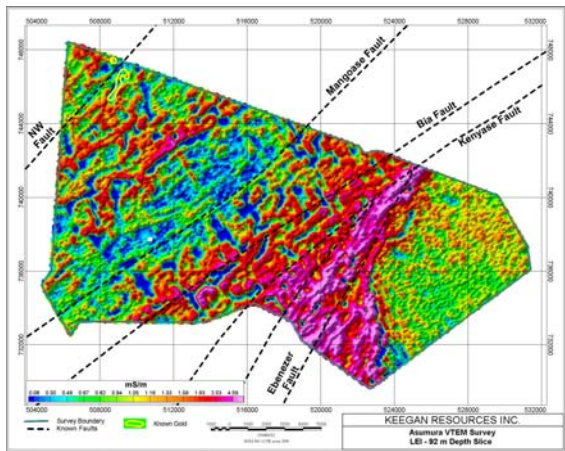


Figure 14: 92 m conductivity depth slice from LEL.

The feature picks all lie near the Ebenezer fault and splay off of it. There are no feature picks near the known gold locations, as is expected since there are no conductors located directly over these locations.

Target Zones

Of importance is the presence of shallow resistive areas seen in the 50 m to 100 m DI (not shown), indicating silica flooding. Resistive areas within this DI, in conjunction with an indication of structural complexity in the magnetics, are selected as target zones. Another factor in selecting TZs is the presence of conductors that appear associated with crossing structures or disturbances in the nominal geologic strike as observed in the magnetic data. The large conductors selected as SPR and DPR do not appear to be gold endowed from the soil assays and are only considered targets where there is evidence of crossing structures.

Of the fifty-five TZs (not shown), four were identified as high-priority, TZ-36 (Figure 15) is a strong deep conductor within the Wagyakrom Trend containing SPR and DPR. It is a resistor at the 30 m depth slice, indicating possible shallow silica or graphite destruction. An east-west structure is interpreted from the magnetics. The conductivity and IP response from a ground survey are high, indicating a significant amount of graphite associated with this TZ.

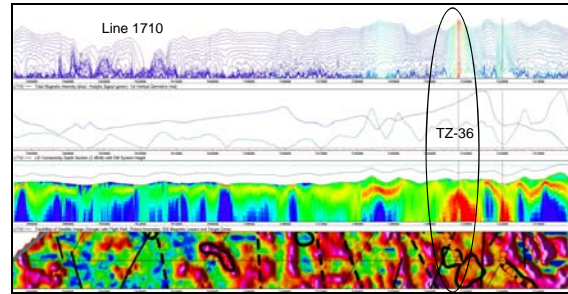


Figure 15: Asumura EM profiles for Target Zone TZ-36.

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