Identifying prospective areas for sediment- and volcanic- hosted gold deposits using Full Tensor Gravity Gradiometry

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Abstract

Gold deposit in the Crescent Valley, Nevada is hosted in sediment and volcanic sequences that are covered by younger Quaternary valley fill. The presence of these surficial deposits tend to inhibit traditional geological analysis for mineral exploration, thus geophysical exploration becomes particularly important for assessing geology and resources under cover.

Airborne Full Tensor Gradiometry survey was flown over Montezuma - Vasquir project in Crescent Valley, in order to map under cover geological features that are thought to be related to Au mineralization in the area.

The gravity gradiometry data when combined with available public-domain geoscientific data such as magnetic, Shuttle Radar Topographic Mission (SRTM) etc., produces an excellent integrated interpretation tool for assessing subsurface geology and subsequent target generation.

The joint interpretation in this study depicts inferred geologic units showing their extent and estimated depth of burial, interpreted faults and priority areas for mineral exploration targeting. The generated target areas will be a focus for the exploration for both volcanic-hosted and sediment-hosted gold deposits

Introduction

In Crescent Valley, Nevada important structures which control gold mineralization including the ore itself are buried under Quaternary cover of varying depths. The available geological map (Figure 1) and the SRTM terrain digital model (Figure 2) provide little information over the Valley area that could be related or assist in indication for mineralization.

Traditionally, geochemical exploration is the most effective and economical technique for locating and defining the presence of gold anomalies in areas of thick overburden such as most of Greenstone Belts, areas of lateritic cover like Australia and most of the tropical areas where as result of weathering process thick soil overburden has been formed. Geochemical Au anomalies are defined by a succession of samples with elevated Au concentrations that form a certain pattern on the surface, occurring in clusters or as isolated samples in areas of low sample density.

However, where transported overburden is present and thick exceeding 50m like in the Crescent Valley, the use of geochemistry to indicate underlying Au mineralization is severely limited. Even where transported overburden is less than 10 m, other factors, such as thick clay, may restrict geochemical signals from reaching the surface. In some cases, Au in surficial cover occurring over mineralization may have been sourced from upslope. In this type of scenario geophysical exploration becomes extremely vital.

Airborne full tensor gravity gradiometry surveys have been successfully flown in the past for volcanic-hosted and intrusion-related, gold mineralization. In 2003 for example Airborne Gravity Gradiometry was flown over Birimian Greenstone Belt, in Mali Africa to resolve granitic-metasediment contact zones that serve as conduits for gold mineralizing hydrothermal fluids to reach the surface. The application of airborne gradiometry under surficial cover deposits is feasible due to the fact that structures controlling gold mineralization including intrusive and faults provide adequate density contrast with the host sediments that is detectable with airborne gravity hence they become ideal gravity targets.

In addition to mapping and direct detection of the intrusive bodies associated with volcanisms, full tensor gravity invariants resolve complex sets of structures that are linked to the intrusion. The evidence for hydrothermal injection includes the presence of alteration zones and multi-directional faults and splays that may be radiating from main fault zones.

This study presents the application of airborne gravity Gradiometry in locating structures beneath sediment cover that controls gold mineralization and generate inferred subsurface geology map.

Regional Setting

The Montezuma-Vasquir project is located within and along the eastern margin of the Northern Nevada Rift and thus rift-associated tectonics and volcanism dominate the geology of a large portion of the project area (Figure 1 and 2). Near-surface Tertiary basalt and andesite flows are pervasive throughout the rift. Deep intrusive bodies located along the rift corridor comprise the sources for the Miocene volcanism (Stewart and Carlson, 1978).

A major northwest structural trend is prominent within the rift and a secondary east-northeast structural trend routinely crosscuts the rift. In the central portion of the valley are a few volcanic conduit which plunges to the east and connects to the inferred deep Tertiary diabase intrusive body (Figure 1). There are two less magnetic anomalies associated with volcanic necks that are located in the center of the Crescent Valley. These volcanic necks are plug-like and do not appear to have reached the surface.

These structural zones are important controls on volcanism, mineralization and alteration. Although not prolific, Mesozoic and Paleozoic sedimentary units do occur within the rift.

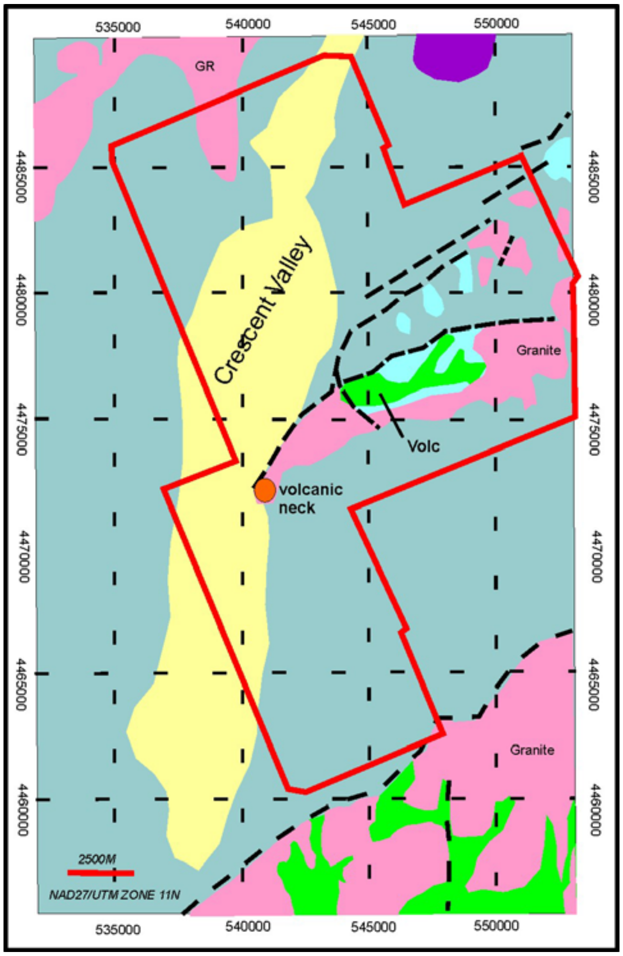

Figure 1. A Simplified geological map of Montezuma-Vasquir areas, modified from Stewart & Carlson, 1978.

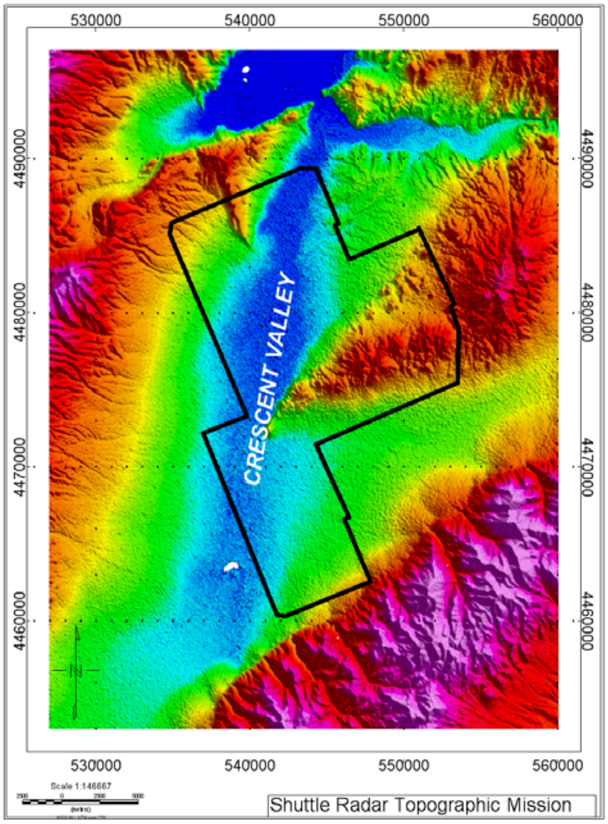

Figure 2. Survey outline over Shuttle Terrain Topographic Mission (SRTM) digital terrain model. The deep blue is an area of Crescent.

Methodology and Results

The measured gradient free air data was leveled, full tensor noise reduced (FTNR) and terrain corrected prior to evaluation and interpretation. Optimum density for terrain correction is critical to accurately separate geological signals from terrain related signals. A range of density corrections ranging from 2.0 g/cc – 3 g/cc was analyzed to determine the best density value which closely removes the effect of terrain in the free air measured data.

Terrain correction was computed using a proprietary 3-D prism modelling package which uses grids and prisms to compute the gravity effect of each defined layer.
For this particularly study the density of 2.67g/cc was chosen as the optimum density to be used throughout the interpretation

Data Enhancement

The data used for interpretation was high pass filtered at 10km wavelength in order to remove regional, low frequency signals that are not necessarily related to the geology of interest.
The technique is primarily intended to improve the data quality by highlighting the density contrast between different geological features. In addition to highlighting

density contrast, the rotational invariants provide an alternative way to visualize all six tensor components from a single image. Information such as contacts, lithological units, and 3D-shaped targets such as the intrusive bodies is greatly improved.

The enhancement technique computes the rotational invariant-1 (R-1) and rotational invariant-2 (R-2). The invariant tensors are rotated about the Z-axis and the computed response retains its shape and orientation regardless of the direction rotated. The technique was described by Pederson & Rasmussen (1990).

In their paper Mataragio and Kieley (2009) discuss in detail the use of rotational invariants citing an example of the massive sulphide hosted in steeply dipping ultramafic intrusions.

Interpretation and Discussion

The measured terrain corrected (2.67g/cc) and full tensor noise removed (FTNR) data for all the tensor components are displayed in Figure 3.

The vertical component of the gravity gradient Tzz is closely related to the sub surface geology. It directly delineates deep intrusive bodies located along the rift corridor as figure 4 illustrate. These include both granitic and volcanic units which have moderate to strong gravity responses whereas areas faulting and alterations show gravity low response, represented by light to deep blue in figure 4.

Tertiary andesite and basalt flow dominate the north and northeast portions of the survey. The anomalies appear as small to relatively large and deep intrusive (PRJ 2005), they posses moderate to strong gravity response (Figure 4).

The southwest portion is dominated by Tertiary andesitic flow and breccia and undifferentiated sedimentary and volcanic in places with significant carbonate sequences mostly occurring beneath the valley fills. The central part of the southern portion of the survey area is dominated by a strong NW trending linear gravity feature that has been cross cut by a secondary NE trending feature.

The eastern portion of the survey is dominated by moderate to strong gravity responses, suggesting a mixture of granite (less dense) andesite and basalt flow (dense).

The central portion of the survey area comprises of a series very strong gravity anomalies over moderately anomalies. These have been referred as volcanic necks and are interpreted to be plug-like intrusive which have no surface expression.

A prominent N20W structural trend within the rift and a secondary east-northeast structural trend are also clearly resolved as shown in white dotted lines. Previously (PRJ 2005) magnetic lows located along the N20W faults on the western side of the project area were interpreted to be the result of magnetite-destructive hydrothermal alteration, these magnetic low areas correlate well with areas of gravity lows thus confirming, fracturing and hydrothermal alteration of magnetite bearing rocks.

Tyz and Txz tensor components generally outline central axes of the features in north-south and east-west directions. Txx and Tyy delineate edges of the features in east-west and north-south directions respectively, for example Txx clearly defines the edges of a prominent N20W fault giving a high low high response. Txy maps all other features within that are oriented at an angle with respect to north-south, in this case all NW and NE trending features are resolved using this particular tensor component.

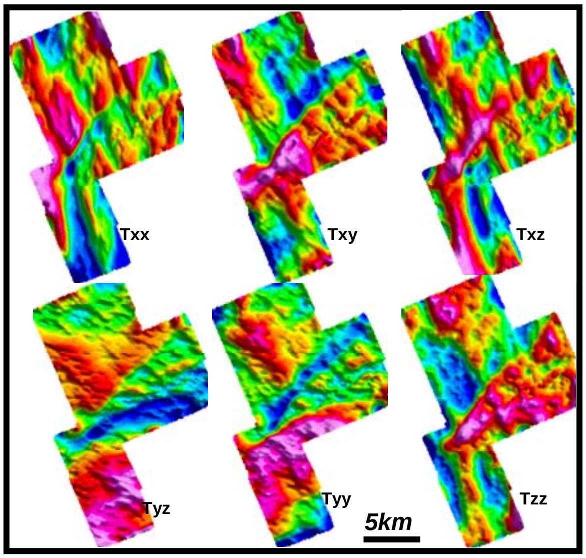

Figure 3. Terrain corrected (at 2.670g/cc) and full tensor processed images. Each tensor outlines different attributes of geology.

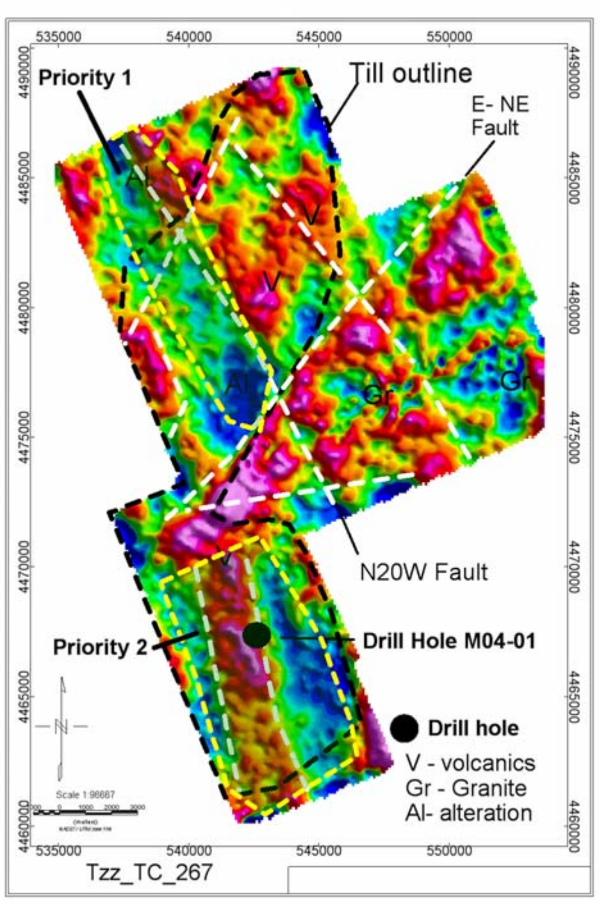

Figure 4. Terrain corrected Tzz (at 2.670g/cc) and full tensor processed image. Black dotted line marks the area of till cover. Tzz maps several gravity highs and lows that are not completely covered by till.

Interpretation

The computed R-1 in Figure 5A, highlights contacts between volcanic and granitic intrusions and also areas of alterations with respect to the host sediments, as mapped in the Tzz (B) the middle hand image.

Figure 5C is the computed R-2 image, it enhances overall shape of the volcanic, granitic and other intrusions in the survey area. Individual density variations are distinguished from within the overall shape of the intrusions by suppressing the longer wavelength background signal. The cylindrical, plug-like shapes observed in these anomalies are interpreted to be caused by steep gradient which imply that these targets are vertical or sub-vertical and are referred as volcanic neck.

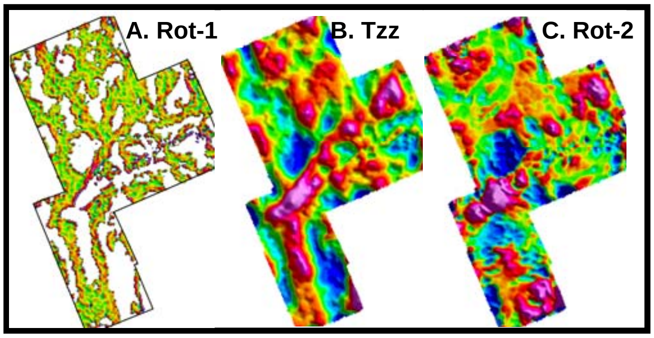

Figure 5: Computed Rotational Invariants; R-1 and R-2, outlining contacts, edges and shapes of various individual volcanic as well as granitic intrusions within Montezuma. Vasquirproject. Tzz in the middle is included for reference.

Faults and Alteration Mapping

Generally, geologic features, such as faults, faults, lithological contacts, joints and fractures, etc. are reflected as lineaments in most potential field data. Gravity gradient data uses filtered and full tensor noise reduced data to compute the horizontal invariants from which the interpretation of lineaments is based. This computation uses a combination of two horizontal tensor components TxxTyyTyx and TxzTyz to produce lineament grids.

One of the most striking features from the FTNR processing is how it increases the signal to noise ratio of the two pairs of the horizontal components Txx, Tyy, Tyx and Txz, Tyz. The FTNR processing allows the extraction of information that may be visually difficult to discern in the Tzz data.

Horizontal invariants are computed as follows:

$$Invar\_TxyTxxTyy = \sqrt{\left(Txy^2 + \left(\frac{Tyy - Txx}{2}\right)^2\right)} \ldots(i)$$

$$Invar\_TxzTyz = \sqrt{\left(Txz^2 + Tyz^2\right)} \ldots\ldots\ldots\ldots(ii)$$

Equations i and ii are horizontal tensor invariants with respect to rotations about the z-axis. This means that just as it is true for Tzz, a map of invariants will look exactly the same for a given anomaly shapes no matter which direction the source is oriented.

Images in figure 6 show the horizontal invariants TxzTyz mapping linear features across the survey area. Major fault trending NW-SE is evidently resolved. The NE trending fault is also imaged with some breaks

Targets

Targets Priority 1 – Volcanic-Hosted Gold

Since the Montezuma-Vasquir project is made up by the geology of the Northern Nevada Rift, volcanic-hosted gold targets are ranked as high priority targets. Volcanic-hosted mineralization is typically located near N20W faults exhibiting magnetite-destructive hydrothermal alteration, and more specifically, occurs at or near the intersection of these faults with west-east magnetic lineaments. Areas meeting these criteria are identified as prospective target areas on the Montezuma-Vasquir project interpretation map (Figure 4 and 6). These target areas are prioritized based on the interpreted extent and intensity of alteration and the structural setting.

Target Priority 2 – Sediment-Hosted Gold

Identifying prospective areas for sediment-hosted gold deposits within the Montezuma-Vasquir project area is difficult because favorable sedimentary lithologies do not crop out and are difficult to detect directly in geophysical data.

However, previous study by PRJ using the ModelVision polygon models have identified probable locations for favorable sedimentary lithologies. The undifferentiated sedimentary and volcanic (Usv) unit most likely to contain a significant component of carbonate sequences are likely to contain gold. In addition, drilling by Montezuma Mines Inc. in the southeast portion of the survey (Figure 4 drill hole location) has confirmed the presence of gold-bearing carbonate rocks within these usv (drill hole QM04-01). Areas associated with gravity high in south, southeast portion of the survey area could be potential targets for sediment-hosted gold deposits.

Conclusions

Full tensor processed, free air, and terrain corrected data generate a composite data set for which a detailed and a prospect-level interpretation can be done. It resolves important geologic features under cover that are important for gold mineralization

Rotational tensor invariants computations facilitate the removal of background gravity response therefore enhancing the volcanic intrusions, faults and alteration zones that are important controls in gold mineralization

Lineament analysis of the horizontal tensor invariants highlights both linear and multi-directional, complex structures associated with volcanism.

Full tensor gravity data outlines inferred geologic units, faults and priority areas for mineral exploration targeting. These target areas focus on the exploration for both volcanic-hosted and sediment-hosted gold deposits.

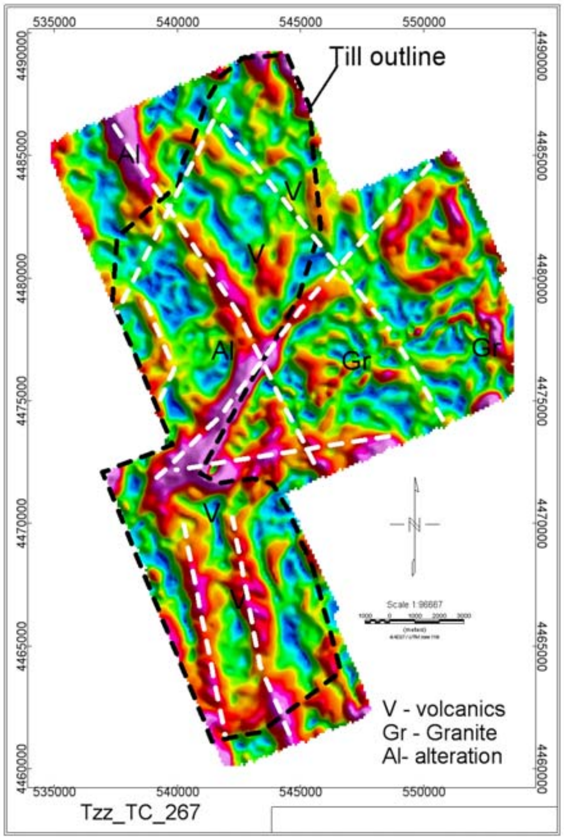

Figure 6: A. invariant TxxTyyTxy B Invariant TxzTyz C. Invariant TxxTyyTxy showing the radial-like structures D. terrain corrected Tzz for comparison

Acknowledgements

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