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

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Abstract

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

An Airborne Full Tensor Gradiometry survey was flown over the Montezuma and Vasquir projects 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 other geoscience data such as magnetics, EM, 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 lateral extent, interpreted faults and priority areas for mineral exploration targeting. The generated target areas will be a focus for 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 area that could be related to or assist in identification of mineralization.

Traditionally, geochemical exploration is the most effective and economical technique for locating and defining the presence of gold anomalies in areas of overburden such as most Greenstone Belts, areas of lateritic cover such as Australia, and most tropical areas where as a result of weathering 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 exceeds 50m in thickness such as in Crescent Valley, the use of geochemistry to indicate underlying Au mineralization is severely limited. Even where transported overburden is less than 10 m thick, other factors, such as thick clay, may restrict geochemical signals from reaching the surface. In some cases, Gold 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 the 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 to areas with surficial cover is feasible due to the fact that structures controlling gold mineralization, including intrusives and faults, provide adequate density contrast with the host sediments for detection with airborne gravity, therefore these areas 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 can be 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 control gold mineralization and generating an inferred subsurface geology map.

Regional Setting

The Montezuma and Vasquir projects are 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 areas (Figures 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 regularly crosscuts the rift. In the central portion of the valley are a few volcanic conduits which plunge to the east and connect to the inferred deep Tertiary diabase intrusive body (Figure 1). Two less magnetic anomalies associated with volcanic necks are located in the center of 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 abundant, Mesozoic and Paleozoic sedimentary units do occur within the rift.

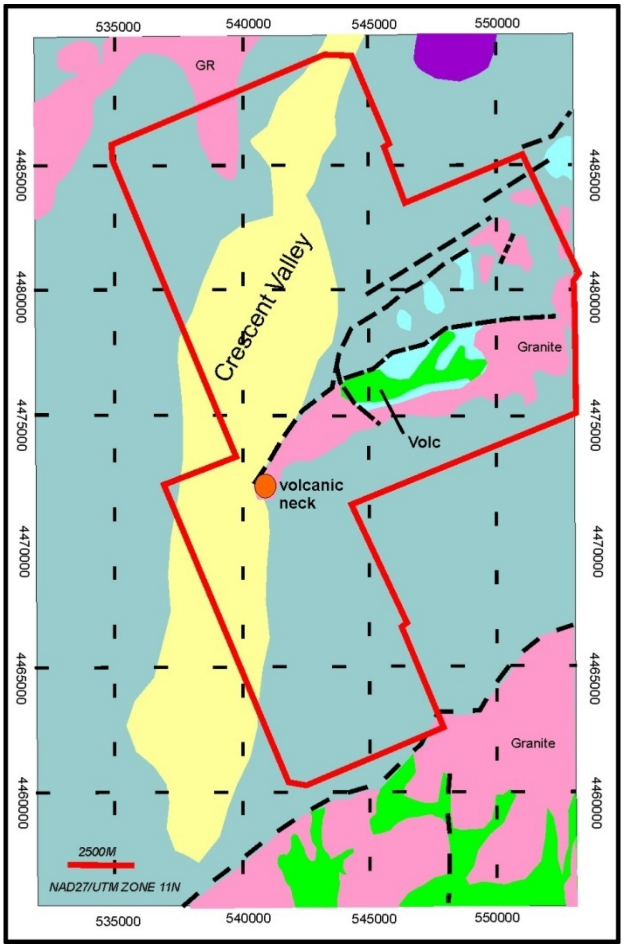

Figure 1. A Simplified geological map of Montezuma-Vasquir areas, modified from Stewart & Carlson, 1978.

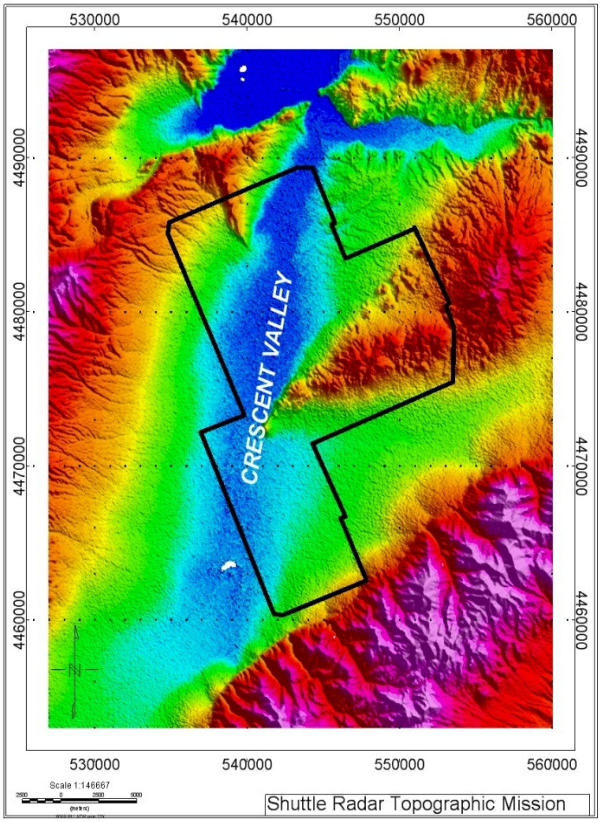

Figure 2. Survey outline over Shuttle Terrain Topographic Mission (SRTM) digital terrain model. The deep blue is an area of Crescent.Valley

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 which density value best removes the effect of terrain in the free air measured data.

Terrain correction was computed using a proprietary 3-D prism modelling package that 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 about 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 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 subsurface geology. It directly delineates deep intrusive bodies located along the rift corridor (Figure 4). Granitic and volcanic units show moderate to strong gravity responses, whereas areas of faulting and alteration show gravity low response, represented by light to deep blue in Figure 4.

Tertiary andesite and basalt flows dominate the north and northeast portions of the survey. The anomalies appear as small to relatively large and deep intrusives (PRJ 2005and possess moderate to strong gravity responses (Figure 4).

The southwest portion is dominated by Tertiary andesitic flows and breccias and undifferentiated sedimentary and volcanics in places with significant carbonate sequences occurring mostly 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 flows (dense).

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

A prominent N20W structural trend within the rift and a secondary east-northeast structural trend are also clearly resolved (white dotted lines, Figure 4). Magnetic lows located along the N20W faults on the western side of the project area were previously (PRJ 2005) 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 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.

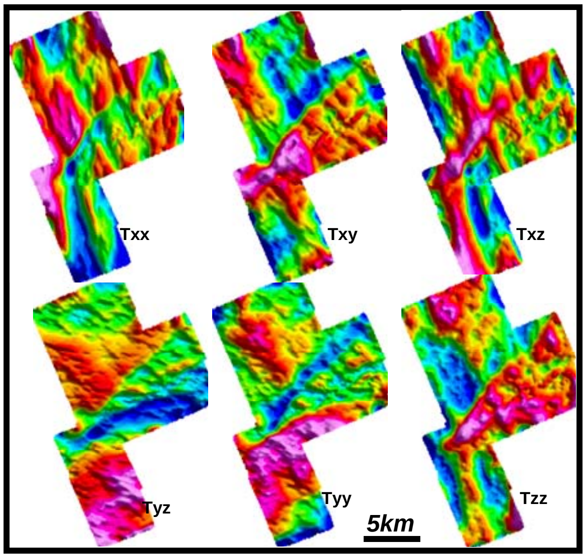

Figure 3. Terrain corrected (at 2.670g/cc) and full tensor processed images. Each tensor outlines different attributes of geology.

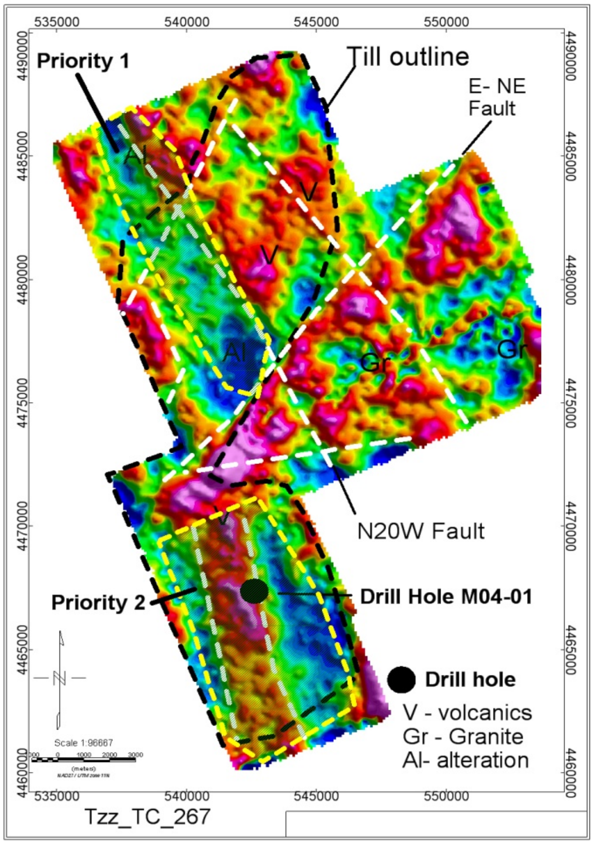

Figure 4. Terrain corrected Tzz (at 2.670g/cc) and full tensor processed image. Black dotted line marks the area of till cover. Tzz maps several gravity highs and lows that are not completely covered by till.

Interpretation of Invariants Data

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

The computed R-2 image (Figure 5C) enhances the 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 gradients, implying that these targets are vertical or sub-vertical, and are referred as volcanic necks.

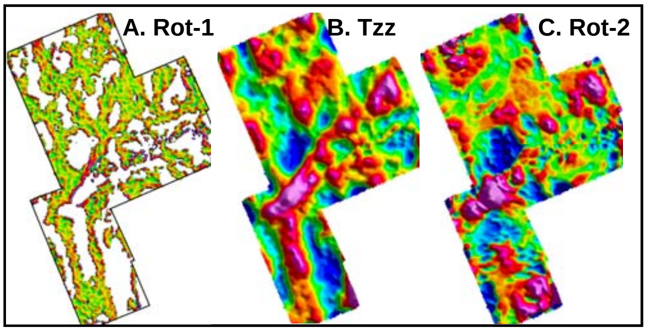

Figure 5: Computed Rotational Invariants R-1 and R-2, outlining contacts, edges and shapes of various individual volcanic as well as granitic intrusions within the Montezuma and Vasquir project areas. Tzz (middle) is included for reference.

Faults and Alteration Mapping

Generally, geologic features such as 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 the increase in 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 shape regardless of the orientation direction of the source.

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

Targets

Target Priority 1 – Volcanic-Hosted Gold

Since the Montezuma and Vasquir project areas are influenced 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 (Figures 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 and Vasquir project areas is difficult because favorable sedimentary lithologies do not crop out and are difficult to detect directly in geophysical data.

However, previous studies by PRJ using the ModelVision polygon models have identified probable locations for favorable sedimentary lithologies. The undifferentiated sedimentary and volcanic (Usv) units containing a significant component of carbonate sequences are most prospective for 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 units (drill hole M04-01). Areas associated with gravity highs in the 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 invariant computations facilitate the removal of background gravity response, thereby 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 should be the focus in exploration for both volcanic-hosted and sediment-hosted gold deposits.

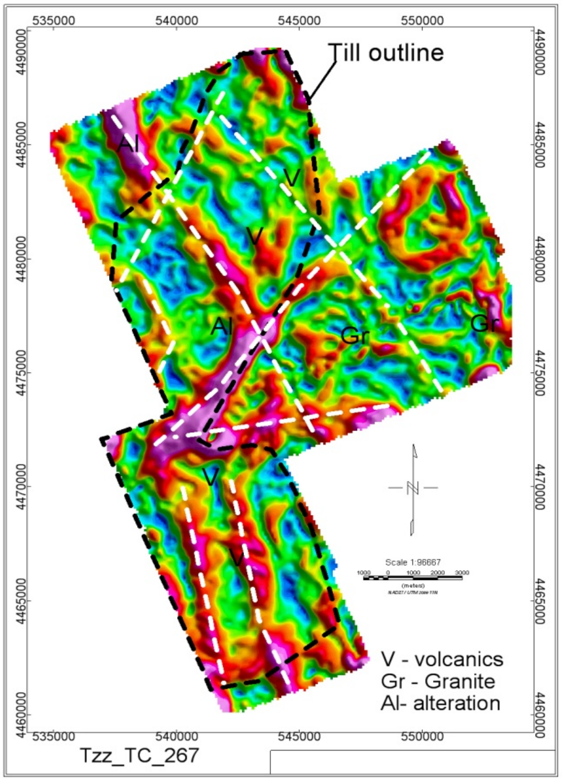

Figure 6: invariant TxxTyyTxy showing major linear features across the survey area.

Acknowledgement

Bell Geospace would like to thank CMQ Resources Inc. and Montezuma Mines Inc. for granting permission to show this data.

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