Airborne Geophysics over the Dolly Varden VMS and Low Sulphidation Epithermal Silver Deposits, Northwestern BC, Canada

Sean E. Walker
CW Geophysics Inc.
Edinburg, Scotland
walker@cwgeophysics.ca

Christopher Campbell
CW Geophysics Inc.
Vancouver, BC CAN
campbell@cwgeophysics.ca

Jean M. Legault*
Geotech Ltd.
Aurora, ON, CAN
jean@geotech.ca

Carlos Izarra
Geotech Ltd..
Aurora, ON, CAN
carlos.izarra@geotech.ca

Karl Kwan
Geotech Ltd.
Aurora, ON, CAN
karl.kwan@geotech.ca

Geoffrey Plastow
Geotech Ltd.
Aurora, ON CAN
Geoffrey.plastow@geotec.ca

Ben Whiting
Dolly Varden Silver Corp.
Vancouver, BC CAN
benwhiting@telus.net

Robert Van Egmond
Dolly Varden Silver Corp.
Vancouver, BC CAN
ravexplore@hotmail.com

SUMMARY

Results from helicopter VTEM time-domain electromagnetics that include aeromagnetics and gamma ray spectrometrics and later ZTEM natural field helicopter electromagnetics are compared over the Dolly Varden Mine region that hosts both potential VMS Pb-Zn base metal and low sulphidation epithermal silver mineralization, beyond the known vein-type Ag deposits and showings.

There are few well-defined discrete targets within the VTEM data set. The magnetic data have defined a network of older fault structures trending NNE, ENE, WNW, and NW. These structures are interpreted to be related to extensional basin formation. Prominent in the radiometrics is a potassium anomaly over the Red Point area, consistent with a quartz-K-feldspar-chlorite-pyrite zone, interpreted as a VMS feeder. ZTEM resistivity and magnetic geophysical anomalies suggest the presence of broad, generally flat lying resistive and magnetic units at depth. At Red Point and along the Tiger-Evindsen Corridor, ZTEM displays moderate to high resistivity and low magnetics, which suggest the presence of strong potassic-silicic alteration, related to low sulphidation epithermal systems.

The airborne geophysical results over the Dolly Varden mine region provide valuable insights on the detectability of similar Ag rich Eskay Creek type HS VMS and Brucejack style LS epithermal deposits. The principal VMS deposits seem immune to clear or discrete identification as EM conductors using VTEM, likely due to their Pb-Zn rich/Cu poor mineralogy; whereas, unlike VTEM, the ZTEM seems to clearly define high resistivity regions surrounding the known deposits that would seem to be consistent with their K-Si-altered low sulphidation epithermal origin.

Key words: case study, helicopter, EM, aeromagnetics, radiometrics.

INTRODUCTION

The historic Dolly Varden mine region that is situated 40 km southeast of Stewart in the Skeena Mining District of northwestern British Columbia (Figure 1), which is host to both base and precious metal deposits, including the prolific Eskay Creek gold-silver mine that produced 3.6 million oz. gold and 180 million oz. silver before closing in 2008 (www.dollyvardensilver.com). Situated in the Kitsault River Valley, just 25 km north of Kitsault, the 8,800 hectare Dolly Varden property hosts four historically active mines, including Dolly Varden, Torbrit, North Star and Wolf dating back to the early 1900's, which have produced >20 million ounces of past high-grade silver in 1920's and 1950's until production ceased in 1959. Subsequent exploration in the region had been sporadic until the mid-1980's when the Ag-rich deposits of the Kitsault Valley, originally thought to be "vein"-style silver system were recognized having both high sulphidation (HS) volcanogenic massive sulphide (VMS) potential, similar to Eskay Creek, as well as low sulphidation (LS) epithermal potential, similar to the Brucejack Au-Ag deposit (Figure 1) also found in the district (Higgs, 2015).

In 2010 a combined helicopter VTEM (versatile time domain electromagnetic; Witherly et al., 2004) radiometric and aeromagnetic survey was flown over the property; and in 2011 exploration began in earnest, focusing on VMS targets and included a helicopter ZTEM (z-axis tipper electromagnetic; Lo and Zang, 2008) and aeromagnetic survey in 2012, as well as follow-up ground geophysics that included ground and borehole IP and EM (Higgs, 2015). Our paper focuses on the airborne geophysical results from these two surveys over the Dolly Varden region, based on the work of Campbell and Walker (2013).

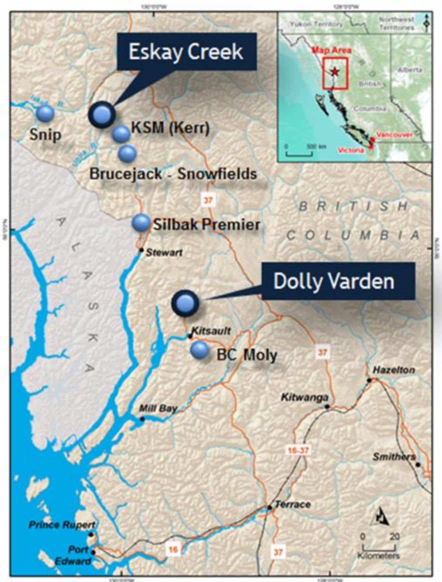

Figure 1: Dolly Varden Project location in northwestern BC (after www.dollyvarden silver.com).

Geology and Mineralization

The Property is underlain by the Stikine Terrane at the western margin of the Intermontane Belt. Volcano-sedimentary rocks of the Lower to Middle Jurassic Hazelton Group host all the known deposits on the property. The Hazelton Group rocks at Dolly Varden include intermediate volcanic and volcaniclastic rocks of the Betty Creek Formation and bimodal volcanic and sedimentary rocks of the Salmon River Formation (www.dollyvardensilver.com).

The principal silver-base metal deposits of the Kitsault River valley had been interpreted as vein mineralization by early workers. Devlin and Godwin (1986) reinterpreted the main deposits to be volcanic exhalative in origin. Deposits of this type are formed as sub-aqueous hot-spring type deposits on the seafloor, as products of hydrothermal solutions that have vented from sub-seafloor fracture and fault systems. Furthermore, the silver deposits of the upper Kitsault valley are mapped with important geological similarities to the Eskay Creek deposit, providing an analog for exploration on the Property.

The most prominent mineralized zone on the Property is an aerially extensive sheet of chemical sediment ("exhalative") mineralization (the "DVT Exhalite") that extends from the Dolly Varden mine, on the west, passing though the North Star underground workings and ending in the Torbrit mine, on the east. The DVT Exhalite body forms an almost continuous sheet, mostly ranging in true thickness from 3 to 38 m, which extends from the Dolly Varden West zone to Moose-Lamb; where it is exposed for a strike length of 1.5 km on surface and is truncated on both extremities by late faults of unknown displacement (www.dollyvardensilver.com).

METHOD AND RESULTS

Airborne Geophysics

Although the Dolly Varden property has been subjected to a great deal of historical work with known deposits and showings mapped, there are still large areas that have been under-explored. The two airborne geophysical surveys (VTEM and ZTEM) were designed to aid in moving the project beyond the current surface- and near-surface dominated known showings and workings, and to aid in the exploration of further economic mineralization. The VTEM data were interpreted in order to identify regional resistivity trends and any discrete conductive responses. Magnetic data were interpreted to understand the distribution of magnetic material within the survey area generally, and to map geologic structure specifically. In addition to a 2D visual interpretation, a 3D inversion using the UBC-GIF MAG3Dinv software was undertaken (Campagne, 2013) in order to build a quantitative model of the subsurface magnetic susceptibility structure. The gamma ray spectrometer data were interpreted to identify zones of alteration and geologic variation. The ZTEM data were inverted and modelled by Geotech Ltd. using both their in-house proprietary Av2dtopo program in 2D and in 3D using the UBC-GIF MT3Dinv software. The ZTEM data provides information about large-scale structures and geologic units with conductivity contrasts. The results from each of these datasets were compiled with the existing geological, topographic, geochemical and drilling information.

VTEM Results

There is a pervasive, laterally variable near-surface response within the VTEM data. In some areas these lateral variations represent geologic variation; however in some areas they are due to noise associated with flight height variation while surveying in rugged terrain. The mid-time VTEM B_Z field results are presented in Figure 2.

There are few well-defined discrete targets within the VTEM data set. The majority of responses are broad anomalies that could be the result of bedrock conductors, lateral conductivity variations within geological units and/or contacts between geologic units. The decay characteristics of these responses were classified based on the profile data. Their spatial extent was determined using gridded images of early (gate 22 = 0.29 ms), mid (gate 36 = 2.02 ms) and late (gate 40 = 3.52 ms) time channel Z component B-field amplitudes. A total of five early-time, three mid-time and five late-time zones were identified and area presented in Figure 2.

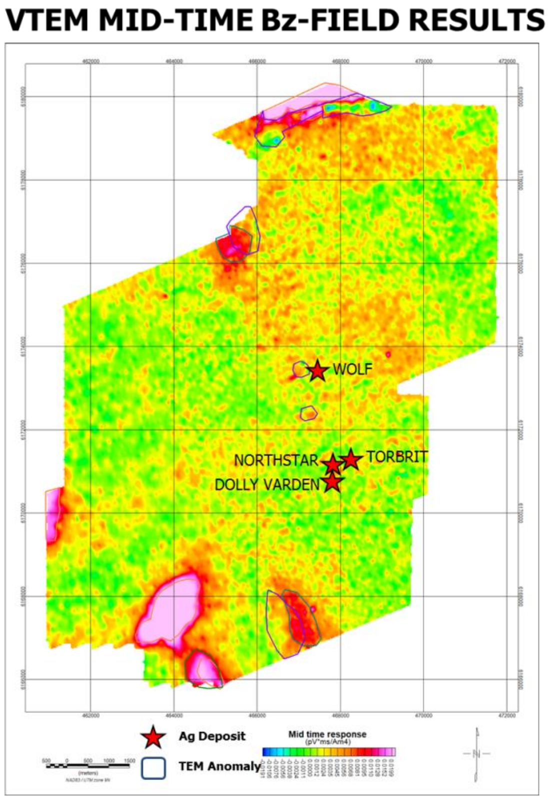

Figure 2: VTEM mid-time B_Z-field results, with locations of known Ag deposits, showing early, mid-and late time anomaly polygons (after Campbell and Walker, 2013).

Figure 3 presents VTEM resistivity-depth imaging results, along with anomaly polygons from Figure 2, for a depth slice 250m below surface, using Geotech's proprietary RDI software. The results indicate that the Dolly Varden silver deposits occur in a broad region of high resistivity, but no discrete anomalies (conductive or resistive) are associated with the occurrences. However, they also reveal the presence of a NNW-SSE trending resistivity low feature, extending from the north to the deposit region that correlates with a regional geologic fault structure.

Magnetic Results

Higgs (2015) describes mapping structure using aeromagnetics: “Mapping in 2011 and 2012, and interpretation of geophysical ZTEM and magnetic data have defined a network of older fault structures trending north-northeast, east-northeast, west-northwest, and northwest. These structures are interpreted to be related to extensional basin formation controlling the deposition of Hazelton Group rocks during Jurassic time.”

The magnetic TMI data contain a great deal of information about structure and geology. A major northeast structure hosts what appears to be a mafic dyke (Figure 4). This feature crosscuts the geology and runs directly through the Dolly Varden mine. Derivative-based products show trends associated with high spatial frequency features that follow some of the major geological trends. The 3D inversion results (Figure 5) show similar trends and also confirm that the depth extent of some of these features is limited.

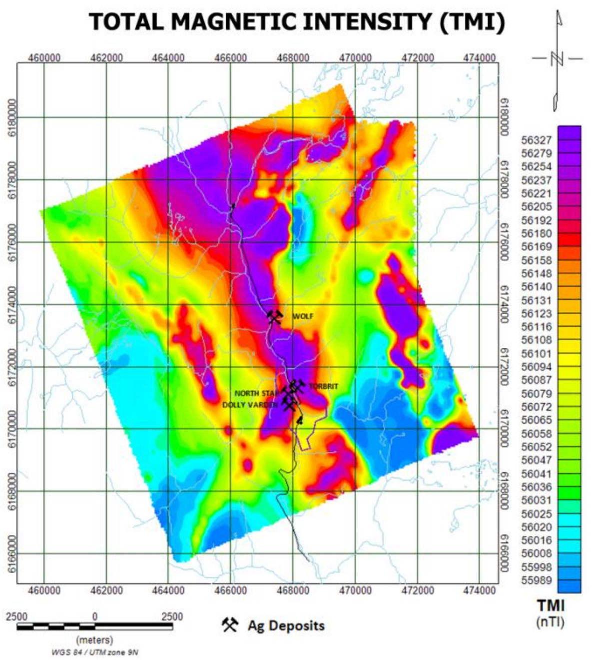

Figure 4: Total magnetic intensity (TMI) image from VTEM survey, with locations of known Ag deposits; UTM graticule is 2 km.

Gamma Ray Spectrometer Results

Garrow (2011) provides an assessment of the gamma-ray spectrometry that in turn comprises a portion of the VTEM survey package: "…Prominent in the geophysics is a potassium gamma ray spectrometer anomaly over the Red Point area, confirming the 1990 geological mapping that characterized the zone as a quartz-K-feldspar-chlorite-pyrite zone. Elevated levels of base and precious metals are present in that zone. This large zone of alteration is interpreted as a feeder zone to a high-sulphidation VMS target. Other potassium radiometric anomalies near the Tiger, Torbrit East, south of the North Star, and near the Wolf zones are associated with volcanogenic chemical sediments (exhalite) mapped in the 1990 program.”

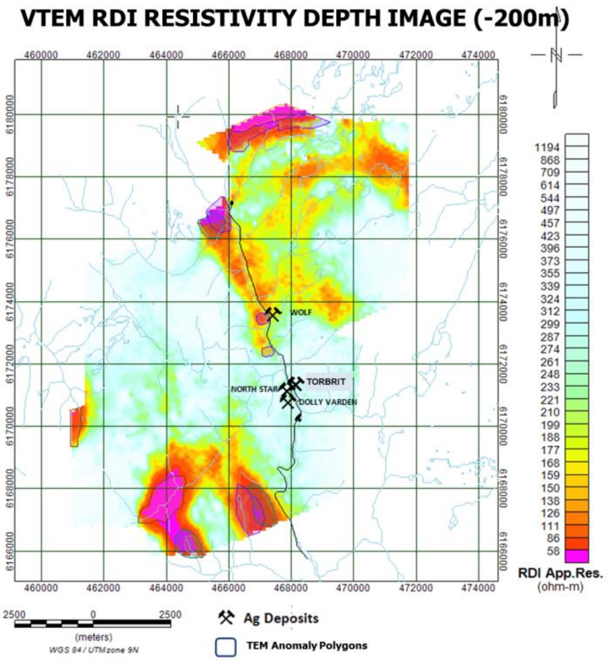

Figure 3: VTEM RDI resistivity-depth slice (200m below surface) with interpretation (Purple polygons – early-time anomalous zones, green polygons – mid-time anomalous zones and orange polygons – late-time anomalous zones) and locations of known Ag deposits,; UTM graticule is 2 km.

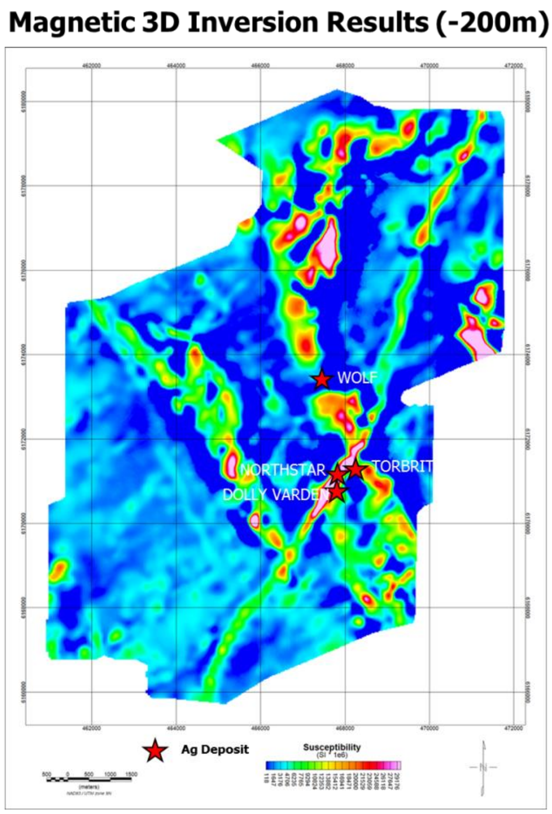

Figure 5: Magnetic inversion results: 200 m depth slice (below surface) from 3D magnetic susceptibility model, , with locations of known Ag deposits; UTM graticule is 2 km (after Campbell and Walker, 2013).

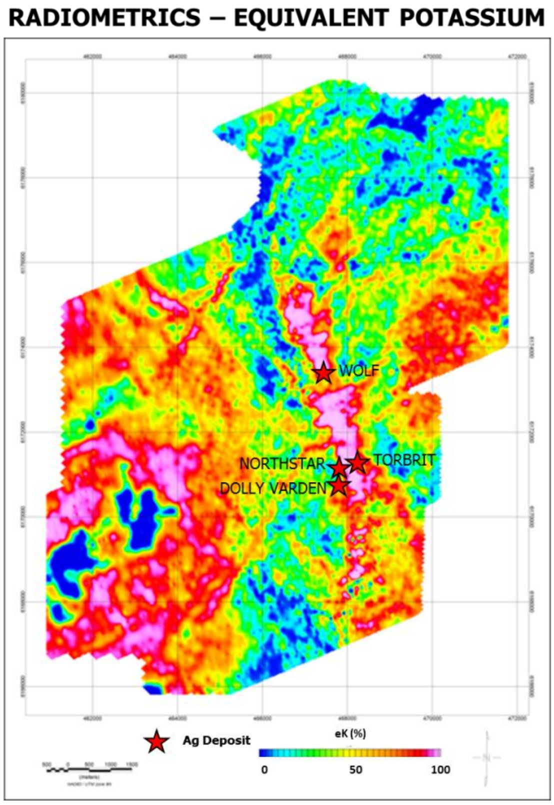

Figure 6: Gamma ray spectrometry: Potassium equivalent pseudo-colour image, with locations of known Ag deposits; UTM graticule is 2 km.

ZTEM data define large-scale resistivity trends and contacts between geological units and/or structures having discernible conductivity contrasts. The total divergence data (Figure 7) combines the along-line and cross-line data from a given component (i.e., 180 Hz in-phase) into a single image and highlights structures in the line direction. Contrasting zones of high apparent conductivity (warm colours) and high apparent resistivity (cool colours), in particular the resistive anomaly that coincides with the known Dolly Varden silver deposits.

The primary method for quantifying these features within the data is via 2D and 3D inversion; the inversions are then used to produce a pseudo 3D resistivity model. A horizontal slice through the 3D resistivity model at 300 m depth (Figure 8) highlights the major conductive and also resistive trends. Interestingly, all the known deposits occur in zones of high resistivity, consistent within K-Si alteration associated with low-sulphidation epithermal deposits (Hoschke, 2011) or possibly reflecting the DVT exhalite in the mine corridor.

The spectrometer data highlight the geological variations within the survey area, with the potassium pseudo-colour image in Figure 6 in particular clearly showing anomalous potassium along the Wolf-Torbrit-North Star-Dolly Varden mine corridor. Similar lineaments are defined that also match structures identified from the magnetics (Figure 4-5).

ZTEM Results

Higgs (2015) presents a summary of the ZTEM survey results:
"Combined ZTEM and inverted aeromagnetics allows discrimination between sedimentary and volcanic units at up to 1 km depth. This has aided the interpretation of basin depth and the geometry of its boundaries and bounding structures. ZTEM resistivity and magnetic geophysical anomalies suggest the presence of broad, generally flat lying resistive and magnetic units at depth. These may be the expression of deep magnetic units of the Stuhini Volcanics. Alternatively, those geophysical responses could be associated with "buried intrusions" located approximately 0.5 to 1 km below the Kitsault Valley. One anomaly is located beneath and to the west of the Surprise and Copper Cliff Showing. Another is located on the east side of the Kitsault River in the footwall of Moose Lamb Fault beneath the Torbrit Mine. In some places, such as at Red Point and along the Tiger-Evindsen Corridor, ZTEM displays moderate to high resistivity while magnetic responses are low. This response possibly suggests the presence of strong silicic alteration of tuffaceous volcanic rocks."

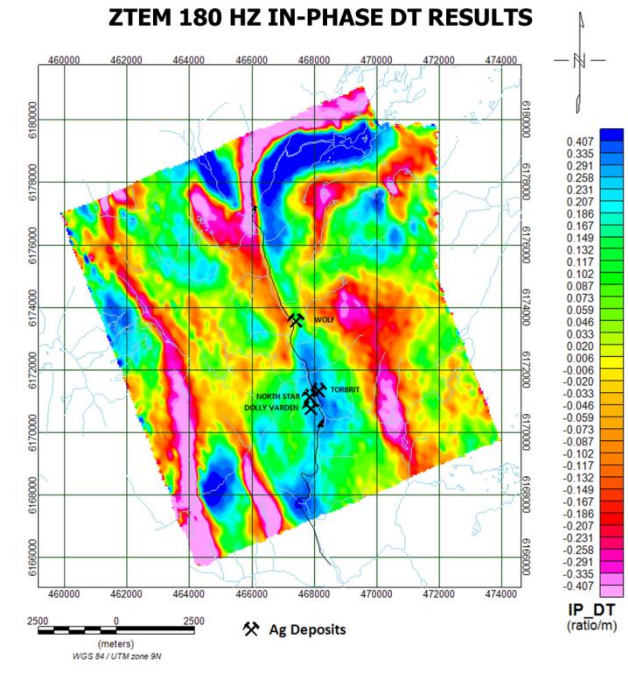

Figure 7: ZTEM In-phase 180 Hz total divergence (DT), with locations of known Ag deposits (hot colours represent higher apparent conductivity and cool colours are higher apparent resistivity); UTM graticule is 2 km.

CONCLUSIONS

The airborne geophysical results over the Dolly Varden mine region provide valuable insights on the detectability of similar Ag rich Eskay Creek type HS VMS and Brucejack style LS epithermal deposits. The principal VMS deposits seem immune to clear or discrete identification as EM conductors using VTEM, likely due to their Pb-Zn rich/Cu poor mineralogy; whereas, unlike VTEM, the ZTEM seems to clearly define high resistivity regions surrounding the known deposits that would seem to be consistent with their K-Si-altered low sulphidation epithermal origin. The reason for the discrepancy between ZTEM and VTEM could be due to either lack of earliest-time (<100μs) data from 2010, or else bird-altitude effects from the rugged topography that more adversely affect the sensitivity of the controlled-source systems relative to natural field, plane-wave sourced types. Although not direct detection tools, magnetics and gamma-ray spectrometry, like ZTEM, are nevertheless useful as geologic mapping tools in support of geochemistry, geologic mapping and drilling for exploration in the Dolly Varden region.

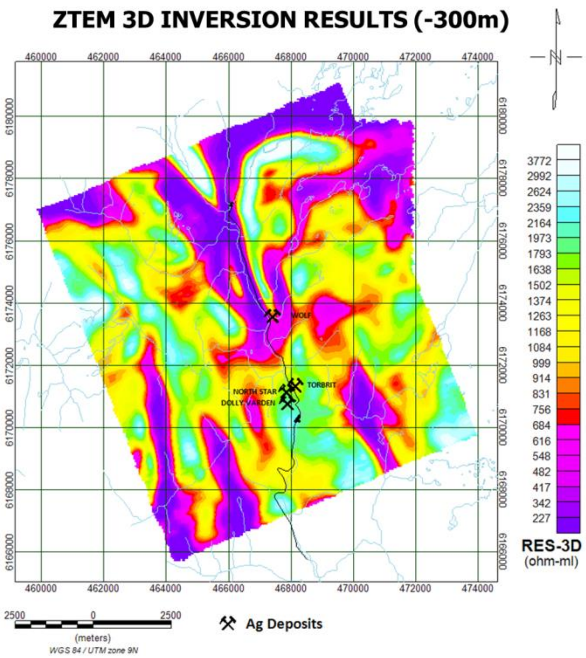

Figure 8: ZTEM 3D inversion results: 200 m depth slice (below surface) from 3D resistivity model (warm colours are low resistivity; cool colours are high resistivity), with location of known Ag deposits; UTM graticule is 2 km.

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