HELICOPTER AFMAG (ZTEM) EM AND MAGNETIC RESULTS OVER SEDIMENTARY EXHALATIVE (SEDEX) LEAD-ZINC DEPOSITS AT HOWARD'S PASS IN SELWYN BASIN, YUKON.

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SUMMARY

In 2008 Geotech flew a regional scale 24,675 line-km survey covering a 25,000 km2 area (1 km line spacing) in the Selwyn Basin. The survey footprint straddles east-central Yukon and overlaps into the western Northwest Territories. In March 2013 Yukon Geological Survey purchased the survey data, and in November 2013, re-leased the data publicly. The Selwyn Basin area is prospective for SEDEX-style Pb-Zn-Ag mineralization and the ZTEM survey data provide insights into regional structures and plutons in the region. The Howard's Pass SEDEX deposits at the southeastern edge of the Selwyn Basin survey area host a combined ~250 million tonne resource with ~4.5% Zn and ~1.5% Pb.

Major NW-SE to ESE and minor NNW-SSE linear conductive trends correlate with known regional geologic, structural and inferred mineral trends. Circular conductive anomalies surrounding resistivity highs reflect po-rich hornfels surrounding intrusive plutons. 2D-3D computer inversions reveal a correlation between enhanced conductivity along strike and the clustering of deposits at Howard's Pass.

Key words: Airborne, ZTEM, electromagnetics, magnetics, 2D-3D inversion, Selwyn Basin, SEDEX.

INTRODUCTION

The Selwyn Basin, which extends from Alaska to northern British Columbia (Figure 1), is considered one of the most productive Zn-Pb-Ag sedimentary exhalative (SEDEX) regions in the world, with more than a dozen major dozen deposits identified. The SEDEX deposits at Macmillan Pass and Howard's Pass in east-central Yukon (Fig. 1) are believed to have the highest potential for development (Goodfellow, 2007). Howard's Pass, in particular, is world class, with an estimated mineral potential of ~250M tonnes at 4-5% zinc and 1-2 % lead contained in 15 separate deposits that extend over a 37.5 km strike length (Kirkham et al., 2012). The Howard's Pass deposit is owned by Chihong Canada Mining Ltd. (Vancouver, CAN) and is currently in pre-development (www.chihong mining.ca). This study presents the results from a large regional EM survey over flown in 2008 (Witherly, 2013) with the ZTEM (z-axis tipper electromagnetic) helicopter EM and magnetic system (Lo and Zang, 2008) that covers a >20,000 km2 area of the Selwyn Basin, approximately 80km northeast of Ross River, Yukon (Fig. 2), focusing on the Howard's Pass SEDEX deposit responses.

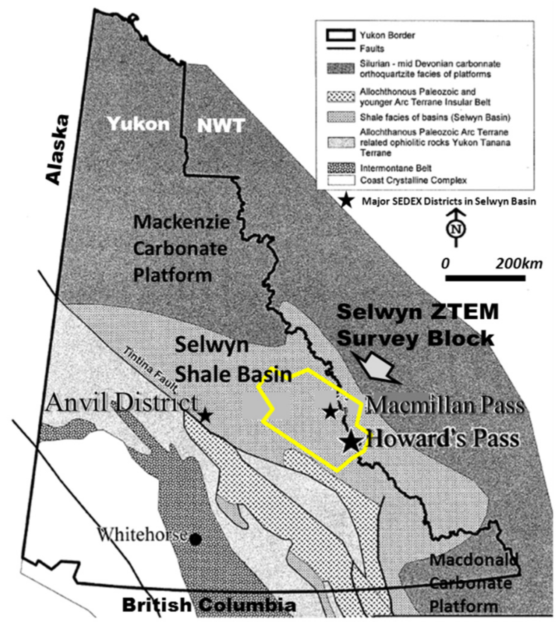

Figure 1: Regional geology of Yukon, showing outline of ZTEM survey block (yellow) and SEDEX districts in Selwyn Basin (modified after Burgoyne, 2005).

Although EM is credited with the discovery of the Clear Lake SEDEX in central Selwyn Basin, stream and seep geochemistry, lithogeochemistry, mapping and prospecting, along with drilling are primarily used in the region (Goodfellow, 2007). Airborne geophysics has not been extensively used in SEDEX exploration of the Selwyn Basin, due to the lack of magnetic contrasts and similar conductivities of ores to the host black shales (Goodfellow, 2007; Witherly, 2014). Ground geophysics including magnetic, EM, SP, gravity, VLF and resistivity have been used at Howards Pass, but have proven ineffective at defining/discriminating the mineralized SEDEX horizons. However gravity and resistivity in particular were able to define stratigraphy under areas of cover (Burgoyne, 2005). Indeed the 2008 ZTEM survey of eastern Selwyn Basin (Figure 2) was commissioned by Exploration Syndicate Inc. (ESI) to map regional lithologies and structures related to SEDEX deposits below thick overburden and sedimentary cover, based on resistivity contrasts (M. Zang, ESI, pers. comm., 2008).

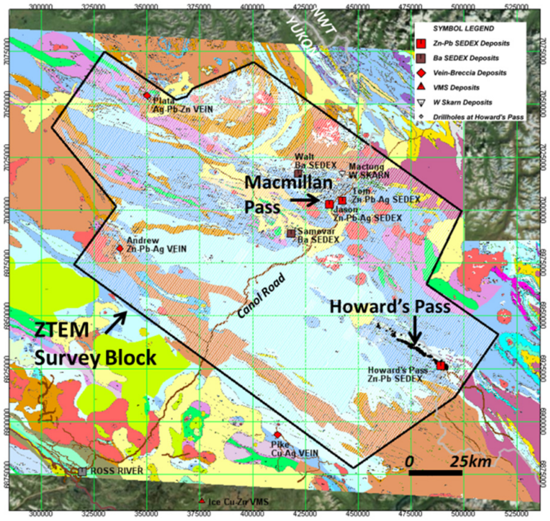

Figure 2: ZTEM survey block (black) and flight lines (white) over Selwyn Basin geology (Gordey and Makepiece, 1999) showing mineral deposits (after Lewis, 2009) and drillholes at Howard's Pass.

While the SEDEX deposits in Selwyn Basin were initially discovered in the early 1950's to late 1970's (Goodfellow, 2007) and extensively explored since then (Witherly, 2014) airborne geophysical coverage in the Selwyn Basin is limited, with only a regional magnetic survey by the Geological Survey of Canada publically available. The 2008 Selwyn Basin ZTEM survey, recently purchased by the Yukon Geological Survey (Witherly, 2013), is one of the few available airborne AFMAG EM-magnetic data sets (i.e., Mt. Milligan; Steffer et al., 2009) that also covers a variety of SEDEX and other types of mineral deposits (Carne et al., 2013), as shown in Figure 2. Legault et al. (2013) have also presented ZTEM passive EM and VTEM time-domain EM and magnetic survey results over the Nuqrah Cu-Pb-Zn-Ag SEDEX deposit in Saudi Arabia.

GEOLOGY AND MINERALIZATION

The Selwyn Basin is a northwest trending Paleozoic deep water sedimentary basin mainly composed of black shales and cherts that host SEDEX and stratiform barite deposits (Figure 1-2). The three SEDEX base metal districts that occur in the Selwyn Basin of Yukon (Anvil, Macmillan Pass and Howard's Pass - Fig. 1) are related to major episodes of mafic volcanism. SEDEX deposits occur in fault-bounded grabens and formed in reduced sulphur-rich settings from hydrothermal vents located along extensional faults. Except for stratiform barite, the other mineral deposits in the Selwyn Basin (see Fig. 2) postdate its deposition and are related to Mesozoic and Cenozoic tectonic and related intrusive events (Goodfellow, 2007).

The Howard's Pass SEDEX deposits were discovered in 1972 using regional stream sampling for lead-zinc. Extensive soil sampling, trenching, mapping and drilling continue to guide exploration. The local geology in Howards Pass consists of Hadrynian to Cambrian basement phyllites and coarse clastics units that outcrop to the southeast of the property. These are followed by a thick sequence of Cambrian-Ordivician age Rabbitkettle limestones and calcareous mudstones. These are overlain by the Ordivician to Silurian Road River Group black shales that consist of Howard's Pass Fm carbonaceous mud-stones at the base, and flaggy and siliceous mudstones at the top. The Howard's Pass Fm. includes the sulphide-rich Active Member unit that contains all the known zinc and lead mineralization at Howard's Pass (see Fig. 3). The Road River Group is overlain by Devonian to Mississippian Lower and Upper Earn Group mudstones. The rocks have been intruded locally by Cretaceous felsic intrusions. The geology can be structurally complex, with the deposits to the southeast lying on the south limb of a large ~N-300O trending regional syncline, whereas to the northwest they lie on a steeply dipping, NW-trending contact, as shown in Figure 3b (Burgoyne, 2005; O'Donnell, 2009; Kirkham et al., 2012).

The mineralized horizon at Howard's Pass, referred to as the "zinc corridor", trends NW-SE and extends for 37.5km, with the 15 drilled deposits and zones that are offset/separated by interpreted faults. The Active Member is generally 20-30m thick and consists of laminated, fine-grained sphalerite and galena with minor pyrite. Higher grade zones, like XY Central (45.11 Mt indicated @ 5.17% Zn & 2.49% Pb) and Don (36.90 Mt indicated @ 5.63% Zn & 2.11% Pb), are coarser grained, exhibit sulphide-remobilization, contain multiple lenses and occur near the base of the Active Member (Goodfellow, 2007; Kirkham et al., 2012).

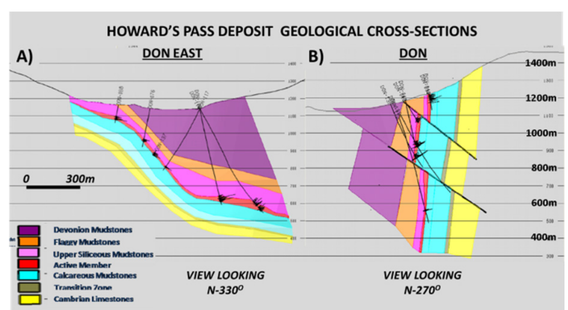

Figure 3: Howard's Pass geological cross-sections at Don East (A) and Don deposits (B), showing complex structure, drillholes, and geologic units across HP valley (modified after O'Donnell, 2009).

PASSIVE AEM AND MAGNETIC RESULTS

The ZTEM passive AFMAG (Labson et al., 1985) helicopter EM and aeromagnetic survey at Selwyn Basin was flown be-tween May to October, 2008 (Witherly, 2013). It consisted of 24,675 line-kilometres of coverage using 1000 line-spacings and 500m in-fills along N-035O oriented survey lines (Fig. 2). ZTEM tipper data (Tzx in-line & Tzy cross-line) were acquired at 5 frequencies (30-360Hz). Readers can refer to Legault et al., (2012) for additional descriptions of the ZTEM system and theory.

REGIONAL SURVEY RESULTS

The regional ZTEM and magnetic results in Selwyn Basin were presented by Carne et al. (2013) and Witherly (2014). Figure 5 presents the total divergence (DT; Lo and Zang, 2008) image of the ZTEM In-phase tipper at 90Hz. The DT image highlights resistive (blue) and conductive (red) signatures, in particular the circular anomalies associated with igneous intrusions and the surrounding po-rich metamorphic aureoles. More importantly the many prominent NW-SE trending and secondary NNW-SSE conductive and resistive lineaments are defined that relate to both shale-rich and siliceous or carbonate-rich sedimentary units, as well as porous fault-fracture zones, which were not visible in the magnetic results. These include very well defined lineaments over Howard's Pass, as shown in Figures 5-6. Carne et al. (2013) and Witherly (2014) also point out the relationship between these conductive lineaments that form 10-20km wide trends along which the majority of significant mineral deposits, showings and prospects in Selwyn Basin are situated.

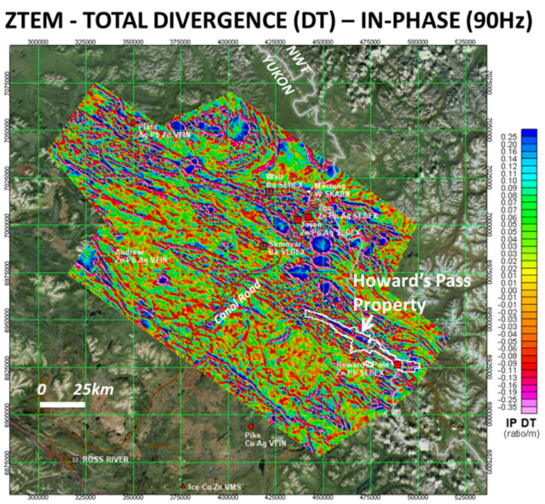

Figure 4: ZTEM total divergence (DT) for 90Hz In-phase component, highlighting low (blue) and high (red) resistivity features over intrusions, stratigraphy and other geology.

HOWARD'S PASS SURVEY RESULTS

The ZTEM total divergence image from Figure 4 is shown over a smaller 70x80km area that focuses on the Howard's Pass SEDEX region in Figure 5. It highlights a thin, NW-SE trending conductive lineament that extends through the >37km long "zinc-corridor" deposit area as defined by drilling. Each of the 15 known SEDEX deposits, defined by ddh clusters and labelled by name (ref. Kirkham et al., 2012), overlie the Howard's Pass (HP) ZTEM conductor. Because the mineralized Active Member is thin (<30m), the HP conductor must also encompass the surrounding Howard's Pass Fm. black shales units to be resolvable in the AEM results. As shown, the HP ZTEM conductor flanks the southwest edge of a broader, 1-2km wide, high resistivity unit (carbonates), that is in turn flanked by another thin conductive lineament (barren shale units) on its north-eastern edge. The conductive band that hosts HP is the most prominent in the area and extends for ~70km - pinching to the northwest, just outside the focus area, and terminating to the SE where basement rocks outcrop (ref., Gordey and Makepiece, 1999).

Figure 6 presents a resistivity-depth slice at 300m obtained from 2D ZTEM inversions (ref. Legault et al., 2012) across a 35x50km model region that is centred on the Howards Pass SEDEX deposits. It shows a narrower, slightly less uniform and more variably conductive trend along Howard's Pass de-posit area than previously seen in the raw ZTEM data images. Interestingly, most of the deposits appear to be grouped/ clustered within areas of higher conductivity along strike (see Fig. 6), in particular the larger tonnage deposits at Anniv, Don-Don East and XY. Similar on-strike conductivity variations are observed in the 3D inversion (not shown) obtained using UBC MT3dinv code (ref. Holtham and Oldenburg, 2008). This suggests possible enhanced mineralization in areas of thicker black shale sub-basins that are being defined with AEM. Alternately, this might simply reflect separation of the mineralized and shale horizons by fault-displacement. Both inversions show better strike continuity at greater depths (>500m).

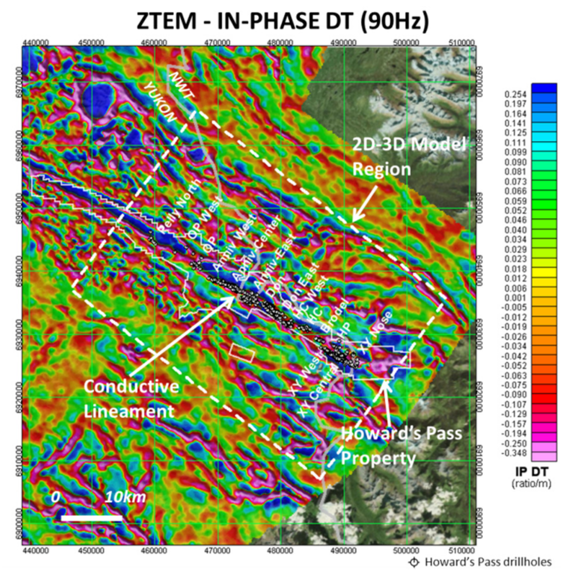

Figure 5: ZTEM 90Hz In-phase DT, over focus area at Howard's Pass, highlighting conductive lineament and HP drill holes, known deposits and 2D-3D model region discussed below.

Figure 7 compares the 3D ZTEM resistivity and 3D magnetic susceptibility (mag-susc.) sections, obtained using UBC Mag3d (Li and Oldenburg, 1996), over the Don deposit, one of the higher tonnage and more deeply explored at Howard's Pass, with many drillholes extending below 800m depths, as shown in Figure 3. Figure 8a highlights the shallow buried but >500m wide resistivity low that matches the known width of the Don deposit and extends to similar depths. Resistivity highs on either side coincide with flanking carbonate units. Figure 8b shows a buried, weak but visible mag-susc. high that correlates with the deposit and extends to depth. Higher mag-susc. values at 1.5-2km depth likely reflect the deeper basement metamorphic units.

CONCLUSION

Regional ZTEM and magnetic survey data over a 23,000 km2 area of Selwyn Basin reveal major NW-SE to ESE and minor NNW-SSE linear conductive trends that correlate with known regional geologic, structural and inferred mineral trends. In addition, circular conductive anomalies surrounding resistivity highs reflect po-rich hornfels surrounding intrusive plutons. The ZTEM and magnetic results at Howard's Pass SEDEX district have been analysed at the property and deposit scale using 2D-3D computer inversion to better define their relation to geology. Their study appears to reveal a correlation between enhanced conductivity along strike and the clustering of deposits at Howard's Pass. This could be explained either by enhanced mineralization in areas of thicker black shale sub-basins or simply separation of the mineralized and shale horizons by fault-displacement.

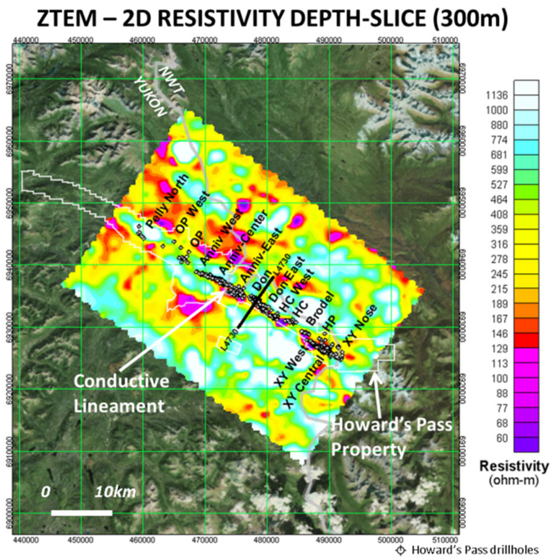

Figure 6: ZTEM Resistivity depth-slice (z=300m) from 2D Inversion (Tzx In-line) over detailed grid at Howard's Pass, highlighting conductive lineament over deposits and location of L4730 model section in Fig. 7.

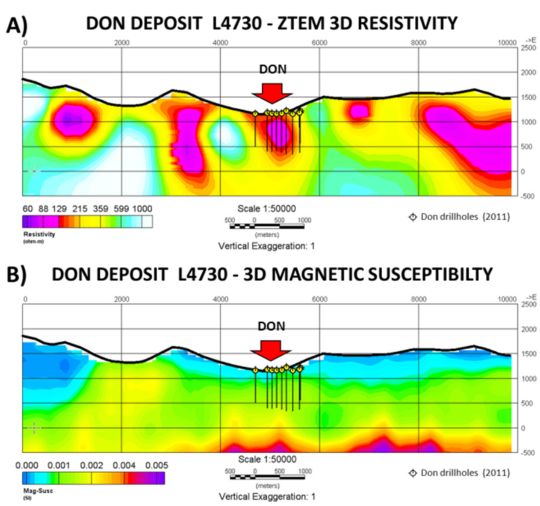

Figure 7: Don Deposit L4730: A) ZTEM UBC 3D resistivity cross-section and B) UBC 3D Magnetic Susceptibility sections, with 2011 drillholes, showing high conductivity and slightly higher magnetic susceptibilities across deposit.

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