

Current thinking on Dawson Range Tectonics and Metallogeny

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1.0 Introduction

With the price of gold currently exceeding \$US1240/oz (*as of June 29, 2010*) and the continued gradual upward trend of gold prices, the search for new gold targets in Yukon has become an increasingly attractive exploit, particularly in light of the three notable new bedrock discoveries, including: (i) Underworld Resources Ltd., White Gold property 90 km south of Dawson City, recently taken over by Kinross Gold; (ii) Kaminak Resources, Coffee property 120 km south of Dawson City; and (ii) ATAC Resources Ltd, Rau property, 50 km northeast of Keno City.

Although gold exploration is generally targeting mineralization in the 'Tintina Gold Belt', the area of most intense interest continues to be the under-explored Dawson Range (Fig. 1). The Dawson Range Mineral Belt in west-central Yukon has historically been recognized as a 125 kilometre northwest-trending corridor of mineral deposits from the Mt. Nansen epithermal gold-silver deposit in the southeast to the Casino porphyry copper-gold-molybdenum deposit to the northwest (Hart, 1998; Fig. 2). The 2008-2009 discovery of the Golden Saddle and Arc deposits on the White Gold property and the 2010 discovery of significant mineralization in drill core at the Coffee Property (Supremo and Latte Zones) has extended the belt a further 50 kilometres to the northwest and a number of additional gold occurrences continue along the trend a further 75 kilometres to the Yukon-Alaska border (Fig. 2). If one follows this same general trend the Pogo deposit is encountered in Alaska approximately 125 kilometres west of the border. Mineralization styles within the Dawson Range Mineral Belt consists of porphyries, epithermal veins and breccias, skarns, structurally hosted veins and breccias to name a few, plus placer gold deposits in many of the creeks draining the belt.

The Dawson Range Mineral Belt lies at the northern apex of the Intermontane terranes (Fig. 1). It is primarily underlain by Paleozoic metamorphic rocks of the Yukon-Tanana terrane (Fig. 2). It extends northwest from the northern termination of mainly Triassic arc rocks of Quesnellia and Stikinia, which enclose late Paleozoic to early Mesozoic oceanic rocks of the Cache Creek terrane to the south. The region is intruded by a number of Mesozoic and early Cenozoic plutons, some of which are associated with economically important polymetallic mineralization. The region is bounded by the Tintina fault to the northeast and Denali fault to the southwest. Both are crust-penetrating, dextral strike-slip faults with several hundred kilometres of Cenozoic displacement. Within this fault-bounded domain, the northern Intermontane terranes are dissected by numerous older faults, including a dominant set of northwest-trending, dextral strike-slip faults of the Teslin fault system.

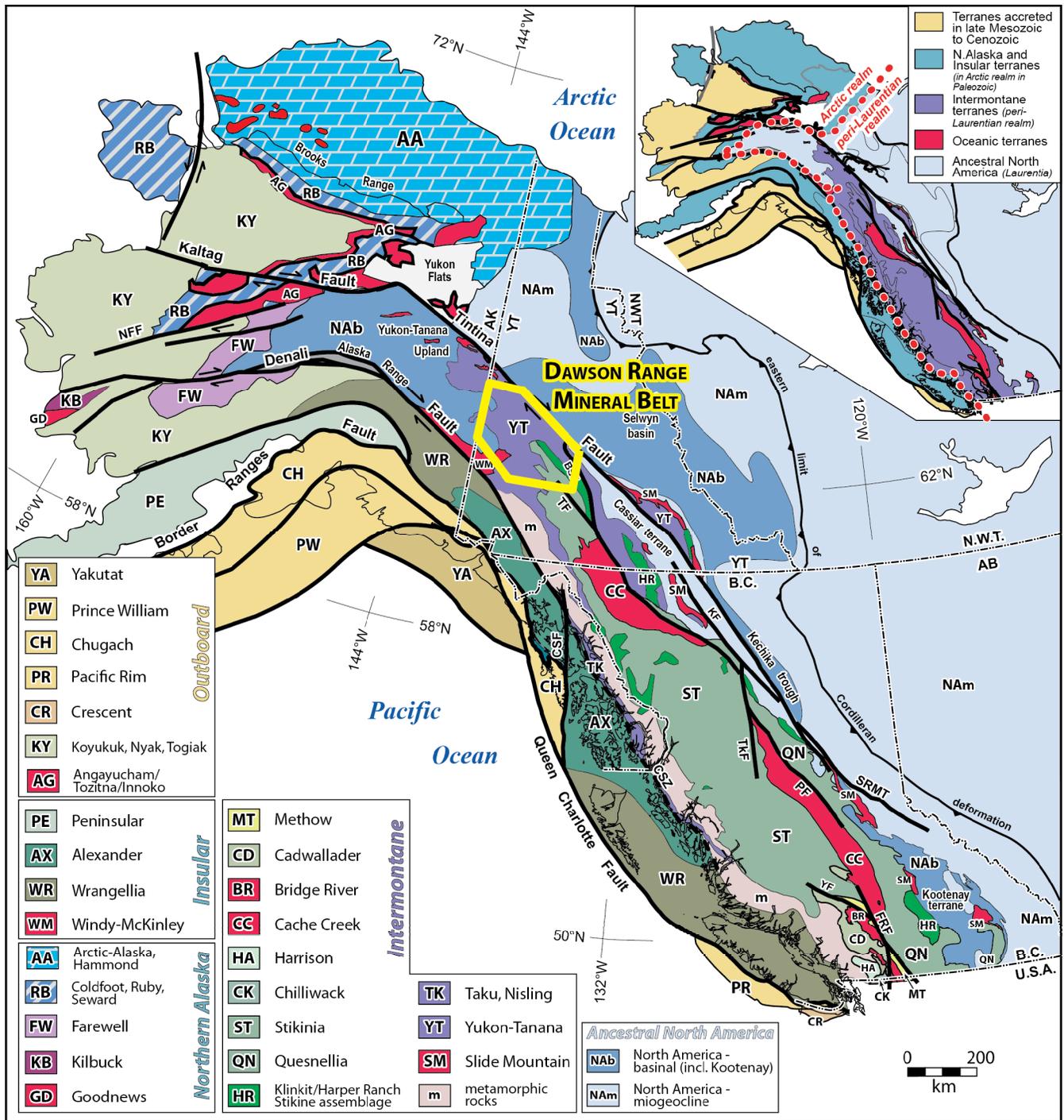


Figure 1. Terranes of the Canadian-Alaskan Cordillera. Inset shows terrane groupings and tectonic realms. Yellow polygon shows location of Dawson Range Mineral Belt in western Yukon. Abbreviations for major post-accretionary faults: BSF – Big Salmon fault; CSF – Chatham Strait fault; CSZ – Coast shear zone; FRF – Fraser River fault; KF – Kechika fault; NFF – Nixon Fork-Iditarod fault; PF – Pinchi fault; SMRT – southern Rocky Mountain trench; TkF – Takla-Finlay-Ingenika fault system; YK – Yalakom fault. Other abbreviations: AB – Alberta; AK – Alaska; B.C. – British Columbia; NWT – Northwest territories; YT – Yukon. After Colpron et al. (2007a).

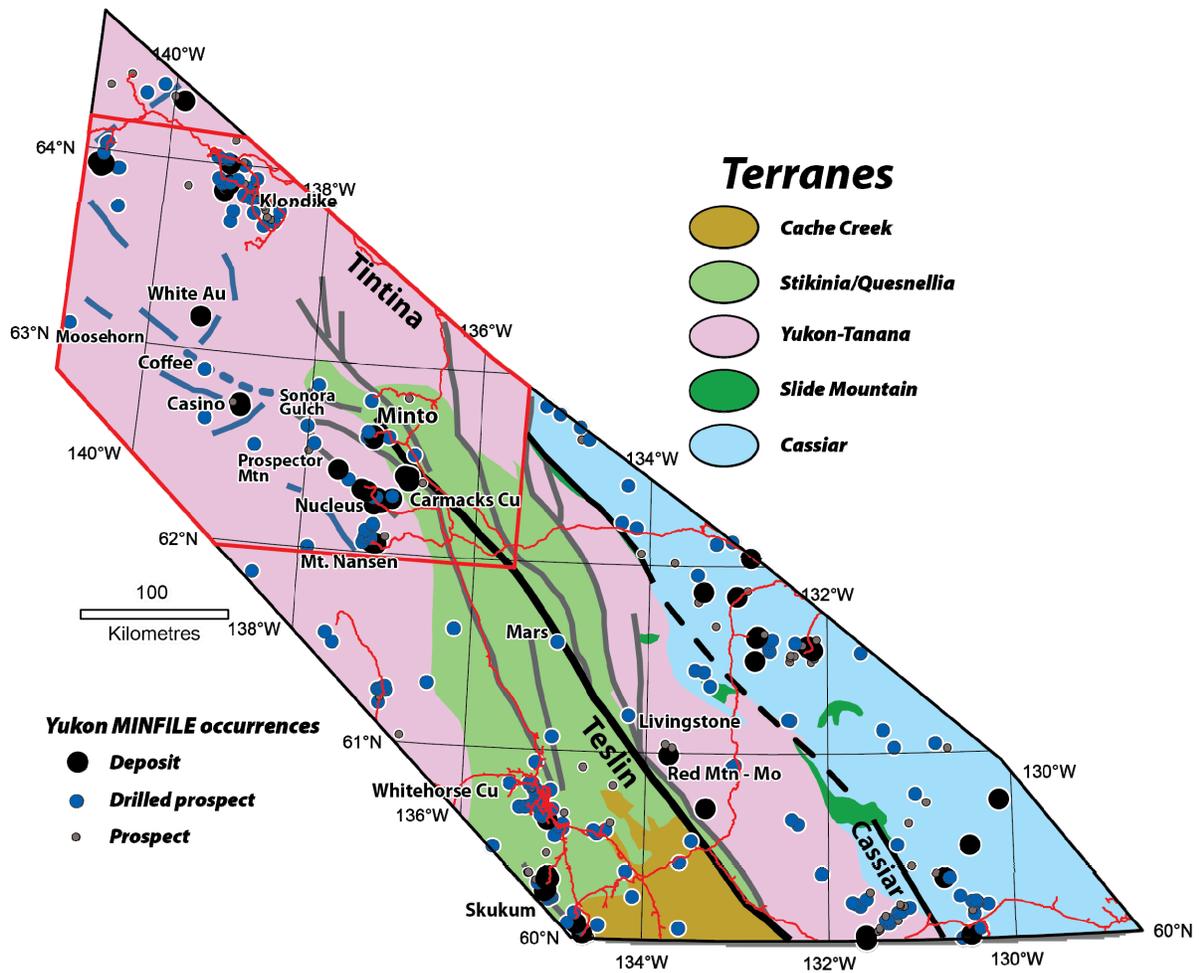


Figure 2. Simplified terrane map for central Yukon (derived from update to Yukon Digital Geology in preparation). Copper-gold deposits and prospects (from Yukon MINFILE database) and major regional structures are shown. Red polygon outlines location of Dawson Range Mineral Belt in western Yukon.

Historically, the search for bedrock sources of the Klondike gold has fuelled sporadic mineral exploration efforts since the turn of the 20th century. Since the late 1960's numerous polymetallic porphyry and epithermal deposits and occurrences have been discovered within the belt (Hart, 1998). Initially, a single event of porphyry - epithermal mineralization was invoked to explain metallogenic trends in the belt (Hart, 2002). However recent focused exploration and detailed research throughout the belt has significantly improved our understanding of this under-explored mineral belt.

A new metallogenic framework is emerging from available data that shows the Dawson Range Mineral Belt to represent a composite, polymetallic belt, where mineralizing events are superimposed upon one another and are genetically associated with Jurassic (Minto Mine; Carmacks Copper Deposit), Early to mid-Cretaceous (Tinta Deposit, Nucleus Deposit), and Late Cretaceous (Casino Deposit) magmatic intrusive episodes. Also significant is the growing recognition of the role that regional fault systems played in ground preparation and controls of these various mineralizing events.

In this report we provide preliminary information outlining the regional tectonic setting of the Dawson Range and some of the key structural and magmatic elements that appear to be associated with mineralization. This report builds on two PowerPoint presentations prepared by Yukon Geological Survey and available as separate downloads. **Presentation 1** (Colpron and Bennett; presented at the GAC Cordilleran section workshop on Porphyry Settings, April 27, 2010 in Vancouver; ~16 MB) summarizes the regional tectonic, structural and metallogenic settings of the northern Intermontane terranes. **Presentation 2** (Bennett, Colpron and Burke; ~6 MB) outlines property scale controls on gold mineralization occurring in the White Gold district, including a preliminary comparison between styles of mineralization occurring within the Golden Saddle deposit of the White Gold property (Kinross Gold) and the Supremo and Latte zones of the Coffee property (Kaminak Resources).

2.0 Mesozoic crustal structure and tectonic setting of the northern Intermontane terranes (Presentation 1**)**

Recent advances in understanding of the tectonic and structural frameworks of the northern Cordillera results from digital compilation of the Yukon regional geology (Gordey and Makepeace, 1999) and integrated geoscience studies such as the Lithoprobe SNORCLE transect (Cook and Erdmer, 2005), the Ancient Pacific Margin NATMAP project (Colpron and Nelson, 2006), and subsequent Targeted Geoscience Initiatives in collaboration between the Yukon Geological Survey (YGS), the Geological Survey of Canada (GSC), and university and industry partners. These studies resulted in extensive, new regional bedrock mapping by YGS and GSC across central Yukon (**Slide 6**) and produced crustal-scale seismic surveys (**Slides 12-18**). Comprehensive geochemical, geochronological, paleontological and mineral deposit database have been developed in parallel and are in constant evolution. These resources are available through the YGS website (www.geology.gov.yk.ca). This wealth of new information provides the basis for an update to the Yukon Digital Geology in preparation (anticipated release in Winter 2011 – **Slide 5**). This information is being refined by ongoing regional studies across west-central Yukon, including regional bedrock mapping and new aeromagnetic surveys in SW McQuesten and northern Stevenson Ridge, funded by the GEM-Edges program (**Slide 7**).

The Yukon-Tanana terrane is the oldest exposed element of the northern Intermontane terranes (**Slide 2**). It consists of a series of superposed mid- to late Paleozoic continental arcs (and back-arc) that developed on top of a metasedimentary basement (Snowcap assemblage; Colpron et al., 2006; Piercey and Colpron, 2009). The Yukon-Tanana arcs are interpreted to have developed along the western edge of the Laurentian plate, from which they were separated by a marginal ocean basin preserved in the Slide Mountain terrane (**Slides 2, 9**) (Nelson et al., 2006). The Snowcap assemblage is interpreted as rifted fragments of the late Proterozoic-early Paleozoic Laurentian continental margin that were rifted away in Devonian time (Nelson et al., 2006; Piercey and Colpron, 2009). The Slide Mountain ocean is interpreted to have closed in Late Permian to Early Triassic time (Beranek, 2009; Beranek et al., 2010; Nelson et al., 2006; Colpron et al., 2007a; Mortensen, 1992).

The Yukon-Tanana terrane is the foundation upon which subsequent early Mesozoic arcs of Stikinia and Quesnellia were developed. These two terranes form the backbone of the Intermontane belt in British Columbia where they enclose exotic rocks of the Cache Creek terrane (**Slide 2**); a subduction complex that incorporate elements of late Paleozoic arc, late Paleozoic-early Mesozoic oceanic rocks, and seamounts with late Paleozoic carbonate of Tethyan affinity. The Late Triassic to Early Jurassic plutonic suites of Quesnellia and Stikinia have produced major Cu-Au-Mo deposits in the B.C. Cordillera (**Slide 3**) and extends into central Yukon where it hosts the Minto mine (Capstone Mining Corp.; <http://capstonemining.com/s/Minto.asp>; **Slide 27**) and the Carmacks Copper deposit (Western Copper Corporation; <http://www.westerncoppercorp.com/index.php/properties/carmacks/snapshot/>) (**Slides 4, 26**).

The northward termination and regional distribution of the Intermontane terranes (Yukon-Tanana, Quesnellia and Stikinia) around exotic elements of the Cache Creek terrane is interpreted to result from entrapment of Cache Creek ocean during oroclinal collapse of the Quesnellia-Stikinia arc between Late Triassic and Middle Jurassic time (Mihalynuk et al., 1994; Mihalynuk et al., 2004) (**Slide 28**). Evolution of this orocline was associated with development of a series of SW-vergent thrusts (King Salmon, Nahlin), possibly including early expressions of the Teslin-Thibert fault, which separate Quesnellia from Cache Creek terranes in northern B.C.

The crustal structure of the Teslin fault is imaged as an east-dipping series of reflectors in two seismic surveys across southern and central Yukon (**Slides 12-18**). In Line 3 of the Lithoprobe SNORCLE survey, Cook et al. (2004) interpreted the Teslin fault to extend down to approx. 4 seconds TWT (~12 km; **Slide 13**); although east-dipping reflectivity could possibly be interpreted to extend down to ~8 seconds TWT (~20 km) where it appears to flatten in the lower crust (**Slide 14**). Intermittent east-dipping reflectivity along Line 1 of the Carmacks survey across northern Whitehorse trough (Buffett et al., 2006; White et al., 2006; Colpron et al., 2007b; White et al., in prep.) also suggests that Teslin fault extends to mid- to low crustal depths (**Slides 17-18**). Thus, the Teslin fault represents a major crustal break that may have originated during early Mesozoic collapse of the Intermontane terranes; its southern extensions in B.C. are locally associated with early Mesozoic blueschist occurrences (Erdmer et al., 1998; Mihalynuk et al., 2004).

The early Mesozoic collapse of the Intermontane terranes was associated with rapid exhumation of the metamorphic rocks of the Yukon-Tanana terrane in Early Jurassic time, as recorded by argon cooling ages on micas (**Slides 21-23**). Cu-Au mineralization at Minto apparently formed in this rapidly evolving geodynamic setting. Rapid exhumation of the Yukon-Tanana terrane was coeval with rapid foundering of the Whitehorse trough (**Slide 19**); an Early to Middle Jurassic basin that probably originated in a forearc setting, but rapidly evolved into a synorogenic piggyback basin within the nascent Cordilleran fold-and-thrust belt. This is reflected in the detrital zircon populations of Early Jurassic strata of the Laberge

Group which match exactly igneous ages of surrounding terranes (**Slide 25**; Colpron, Lowey and Gehrels, unpublished data).

Details of the early history of the Teslin fault system is mostly obscured by superposed Cretaceous strike-slip deformation along the Teslin and related faults (**Slides 11, 29**). In northern B.C., approximately 125 km of dextral displacement is interpreted along the Thibert fault (the southern extension of the Teslin) (Gabrielse et al., 2006). In Yukon, the Teslin fault progressively loses displacement to the northwest, such that there is no apparent offset along the fault by the time it reaches the latitude of Carmacks (**Slides 11, 38**). This apparent loss of displacement along Teslin fault can be accounted by progressively 'bleeding' its displacement along second order faults such as the d'Abbadie, Big Salmon and Tadru faults (**Slides 38-40**). Yet, prominent NW-trending magnetic anomalies and the general orientation of mid-Cretaceous plutons suggest that structures of the Teslin system extend westward into the Dawson Range region (**Slide 41**). These may include the Big Creek fault system, associated with Au mineralization in the Mount Freegold camp (e.g., Nucleus deposit; Northern Freegold) and at Sonora Gulch (Northern Tiger; **Slide 47**).

Recent seismic survey and bedrock mapping of the northern Whitehorse trough also provide clues to unravel the deformational history of central Yukon (Colpron et al., 2007b). The overall style of deformation in Whitehorse trough correspond to a southwest-verging fold-and-thrust belt, where folds and thrust faults define a sigmoidal array consistent with dextral transpression in the 'footwall' of the Teslin fault (**Slide 29**). Dextral displacement along faults of the Teslin system is associated with synkinematic emplacement of Early to mid-Cretaceous plutons through central Yukon. This is particularly evident along Cassiar and d'Abbadie faults where localized ductile deformation of the granites indicate deformation between ~125 and 95 Ma (**Slides 32-34**). It has been suggested that emplacement of Early to mid-Cretaceous granites may have occurred in zones of extension within an overall dextral transpressive system (Gabrielse et al., 2006). The overall pattern of deformation that is emerging is one of alternating domains of NE compression and NW extension apparently linked with development of the Teslin dextral wrench system (**Slides 30-31**). The current lack of regional information from the Dawson Range precludes a detailed interpretation of structural regime at this time, but emerging information from ongoing exploration, metallogenetic studies, and planned bedrock mapping as part of the GEM-Edges program suggest that a similar structural style extends into the region (**Slides 55-56**).

It is also evident that faulting along some of these NW-trending structures locally persisted until at least Late Cretaceous time; recent examples have been documented at Minto and Sonora Gulch in central Yukon (**Slides 35-37**).

Another set of structures that may play a significant role in controlling Cu-Au mineralization in the Dawson Range comprises NE- and N-trending faults. These orientation of faults are common in eastern Alaska where they are commonly associated with mid- to Late Cretaceous mineralization, such as at Pogo and Donlin Creek (**Slides 58-59**) (e.g. Szumigala et al., 2002; Werdon et al., 2001; Goldfarb et al., 2004), but they are rare or unrecognized in western

Yukon. One example in the Dawson Range is the Dip Creek fault occurring immediately southeast of the Casino deposit (**Slide 56**). North and northeast-trending structures are also being reported in the vicinity of the White Gold deposit (see below) and possibly as far south as the Livingstone area (**Slides 33-34**) where more than 50,000 ounces of coarse placer gold has been mined intermittently since the Gold Rush era. A close examination of the detailed geophysical surveys in the Dawson Range reveals a number of NE magnetic trends that may reflect structures similar to those present in adjacent Alaska (**Slide 60**).

The timing of these second order structures remains uncertain. In some cases, they appear to be kinematically linked with first-order NW-trending faults. However, some of these N- and NE-trending structures in eastern Alaska clearly postdate the dominant regional trend; they locally offset Quaternary gravels. Further work is required in the Dawson Range and White Gold district in order to resolve the timing and kinematic of these structures. This is one of the objective of planned bedrock mapping under the auspices of the GEM-Edges program.

In summary, the crustal structure of central and western Yukon is dominated by a series of deep penetrating, NW-trending faults related to the Teslin fault system. The overall pattern of deformation corresponds to a dextral transpressive regime, where mid-Cretaceous plutons were emplaced synkinematically into domains of NW- and W-directed extension. These structures likely extend westward into the Dawson Range Mineral Belt, where they appear to exert first-order control on mineralization (see below). Second-order NE- and N-trending faults are currently poorly recognized in western Yukon, but may play an important role in controlling mineralizing systems in the region (see below).

3.0 Dawson Range Mineral Belt ([Presentation 2](#))

For simplicity, mineralization in the Dawson Range Mineral Belt can be considered as the product of three phases of magmatism from the Jurassic through to the Late Cretaceous. Southwest of the Tintina fault, magmatic products that have intruded the Yukon-Tanana terrane, can be divided into three temporally and broadly spatially distinct groups including (**Slide 4**):

- 1) An Early Jurassic belt located closest to the Tintina fault (*Capstone Mining Corp., Minto Cu-Au mine; Western Copper Corp., Carmacks Copper Cu-Au deposit*)
- 2) An Early to mid-Cretaceous belt, immediately west of the Jurassic belt and superimposed on the older belt (*Northern Freegold Resources, Tinta and Nucleus deposits; White Gold district?; Slide 5*)
- 3) A Late Cretaceous belt, the products of which are most commonly located along the western margin of the Dawson Range mineral belt (*Western Copper Corp., Casino Cu-Au-Mo porphyry deposit; the Cyprus Cu-Mo porphyry at Mount Nansen*).

An important characteristic of metal concentration is superposition of these mineralizing events upon pre-existing ores, such that early phase mineralization can be significantly enriched and/or remobilized along active structural corridors to be subsequently re-deposited at structurally and chemically favourable sites (e.g. Mortensen *et al.*, 2003; Bineli-Betsi and Bennett, 2010).

Important regional controls on currently identified mineralized centres include:

- 1) Presence of first-order NW- and NNW-trending fault systems and interior mineralizing structural corridors (e.g. Big Creek Fault zone) that divide the Dawson Range Mineral Belt into a series of broad structural panels (**Slide 6**).
- 2) Proximity to one or all of magmatic suites (1) to (3) outlined above.
- 3) Proximity to locations where two or more magmatic suites are superimposed.

Recent 400 m line spacing aeromagnetic data was acquired in association with the GEM-Edges program in the northern part of the Dawson Range Mineral Belt (**Slides 6,7,8**). Several NW-trending magnetic lineaments are apparent. These NW-trending zones may represent important structural corridors in which to assess mineral potential.

Exploration results from 2008 to early 2010 have greatly assisted in developing a preliminary regional framework in which to understand what is thought to be mineralization that is Early to mid-Cretaceous in age (**Slides 6-7**). Several key geologic criteria are replicated throughout this interior magmatic belt including:

- 1) An intimate association between mineralization and prominent, long-lived, first-order **NW-trending** regional structures (P shears) and **related coeval N- and E-trending** structures (R and R' shears, respectively).
- 2) A **spatial** distribution of deposit types that represent end-members of a **structural-magmatic continuum**, such that structurally-hosted mineralization (veinlets, mechanical breccias and quartz stockworks) prevail within the northern end of the Dawson Range (e.g. White Gold, Coffee), whilst magmatic deposit types (Cu-Au skarn, massive sulphide replacements, porphyries and epithermal veining) coexist with structurally-hosted mineral occurrences at the southern end of the belt (e.g. the Nucleus deposit, Northern Freegold Resources; and the Nightmusic zone at Sonora Gulch, Northern Tiger Resources).
- 3) A **temporal** distribution of deposit types such that early phase, often structurally controlled mineralization is successively overprinted by subsequent mineralizing events, which in the northern part of the belt (White Gold district) represent younger structurally controlled mineralization, whilst in the southern part of the belt (Mount Freegold district) a transition from deeper level skarn and porphyries to higher level epithermal systems occurs.

To date our understanding of the overprinting Late Cretaceous magmatic event is limited, however, emplacement of these magmatic products are closely associated with regional NE-trending normal faults that dissect pre-existing mineralization associated with the Early to mid-Cretaceous magmatic belt (**Slide 7**).

As exploration continues in all three of these magmatic belts, a more detailed geodynamic and metallogenic understanding of these magmatic belts and their associated ore deposits will evolve and help guide exploration within the Dawson Range Mineral Belt.

4.0 White Gold District Mineralization (Presentation 2)

Recent gold discoveries in the White Gold district appear to represent late (i.e. post ductile deformation), possibly high crustal level, structurally-controlled mineralizing systems. No significant magmatic products have been found to date that can be directly related to the gold mineralization. Key pathfinder elements consist of Au-As-Sb +/- Hg +/- barite.

The predominant regional control in the White Gold district is the presence of several structural panels bounded by NW-trending *first-order* fault systems (P shear geometry; **Slide 8**). Three examples are provided (Golden Saddle/Arc deposits, Coffee property and Nucleus deposit) that illustrate the similarities in the structural geometry controlling gold mineralization. Important features to highlight include:

- 1) First-order, presumably crustal-scale, NW- and WNW-trending bounding structures or brittle to brittle-ductile shear zones that subdivide the Dawson Range Mineral Belt into discrete panels or blocks. These are currently interpreted to represent P shears in a riedel shear system (**Slides 8,13,14, 16 and 17**).
- 2) Second-order, N- and NNW-trending structures that host mineralization, and which are interpreted to represent R shears in a riedel shear system (**Slides 10, 15 and 18**).
- 3) Third-order, interior W- and WSW-trending structures that are coeval with second order structures and also host mineralization; these are considered to represent R' structures (**Slides 9, 10, 14, 15 and 19**).

Importantly, the regional controlling structures (second and third order) occur at all scales within the White Gold district. **Slides 11 and 12** are images of mineralized and altered core from the Golden Saddle deposit that clearly demonstrate the small-scale second and third order structures that are associated with mineralization.

Additionally, the similarities in structurally-controlled mineralization within the White Gold region are striking. A comparison of the Supremo zone (N-trending structure), Latte zone (W-trending structure) and the Golden Saddle zone (approximately W-trending structure) is given in **Slides 11 and 12**. Property-scale structural geometry, pathfinder elements, gold

grades, and mineralizing styles are almost identical between the two properties and points to a regionally extensive mineralizing system.

5.0 Implications/ Closing Statements

The reproducible nature of the structural geometry controlling gold mineralization in the Dawson Range Mineral Belt, in addition to a distinct group of pathfinder elements are crucial vectoring criteria for target generation, particularly in the White Gold region.

The similarity in structural geometry from NW to SE through the Dawson Range Mineral Belt indicate the presence of a much larger system than previously recognized, however the sources of the gold bearing fluids remain enigmatic.

Important structures to identify within the belt include:

- 1) First-order NW-trending fault systems (e.g. Teslin, Big Creek faults). These would be equivalent to the P-shears in a riedel system.
- 2) Second-order N-trending faults which host mineralization and would be equivalent to R-shears in a riedel system.
- 3) Third-order E-trending faults which host mineralization and would be equivalent to R'-shears in a riedel system.

Importantly, 2nd and 3rd order structures appear to be coeval and have the potential to host significant mineralization at the intersection of these two structures.

Since the initial White Gold discovery, over 20 junior mining companies have acquired land in the region which has been dubbed "*The White Gold District*". However, companies focusing their attention solely on the White Gold District may be missing opportunities farther afield when considering the geological similarities to the broader mineralizing event that created the Dawson Range Mineral Belt.

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