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A. Zagorevski[1], M.G. Mihalynuk[2], N. Joyce[1], K. Martin[3]

[1] Geological Survey of Canada, 601 Booth St., Ottawa, Ontario
[2] Geological Survey and Resource Development Branch, BC Ministry of Energy and Mines, 1810 Blanshard St.,Victoria, British Columbia
[3] Department of Earth Sciences, University of Ottawa, 120 University Private, Ottawa, Ontario

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Characterization of volcanic and intrusive rocks across the British Columbia – Yukon border GEM 2 Cordillera

A. Zagorevski[1], M.G. Mihalynuk[2], N. Joyce[1], K. Martin[3]

[1] Geological Survey of Canada, 601 Booth St., Ottawa, ON K1A 0E8

[2] Geological Survey and Resource Development Branch, BC Ministry of Energy and Mines, 1810 Blanshard St.,Victoria, BC V8W 9N3

[3] Department of Earth Sciences, University of Ottawa, 120 University Private, Ottawa, ON K1N 6N

Foreword

The Geo-mapping for Energy and Minerals (GEM) program is laying the foundation for sustainable economic development in the North. The Program provides modern public geoscience that will set the stage for long-term decision making related to investment in responsible resource development. Geoscience knowledge produced by GEM supports evidence-based exploration for new energy and mineral resources and enables northern communities to make informed decisions about their land, economy and society. Building upon the success of its first five-years, GEM has been renewed until 2020 to continue producing new, publically available, regional-scale geoscience knowledge in Canada's North.

During the summer 2014, GEM's new research program has been launched with 14 field activities that include geological, geochemical and geophysical surveying. These activities have been undertaken in collaboration with provincial and territorial governments, northerners and their institutions, academia and the private sector. GEM will continue to work with these key collaborators as the program advances.

Introduction

Copper porphyry deposits are globally the most important source of Cu and Mo and an important source of Au-Ag. Copper porphyry districts in northern Cordillera are temporally associated with transition from normal calc-alkaline to alkaline magmatism (e.g., Logan and Mihalynuk 2014a), which suggests a major change in the subduction geometry and/or melting regime within the sub-arc lithosphere. Although this phenomenon has been documented in the northern Cordillera, its significance for the tectonic setting and metal endowment of prospective plutonic suites remains a major knowledge gap in the understanding of Cordilleran porphyry districts.

Characterization of volcanic and intrusive rocks across the BC-Yukon border is an activity aimed at developing an updated regional geologic framework for magmatism in the Stikine and Yukon-Tanana terranes in southern Yukon and northern British Columbia (Fig. 1). A key outcome of the activity will be integration of volcanic cap to plutonic roots of Mesozoic to Cenozoic arc belts in the northern Cordillera, especially where the calc-alkaline to alkaline transition has been documented, and where potential for additional deposit discoveries remains high. In 2014, reconnaissance activities were focussed on constraining the age and petrology of voluminous Late Triassic to early Jurassic magmatism in northwestern Stikine terrane.

Geological background

Mesozoic magmatism was prolific in northwestern Stikine terrane with volcanic rocks, hypabyssal plutons and more deeply exhumed batholiths extending across more than half of this terrane. Products of Mesozoic magmatism are best preserved and studied in northwestern British Columbia. There they can be broadly subdivided into Stikine, Copper Mountain, Texas Creek and Cone Mountain plutonic suites (Fig. 2; e.g., Woodsworth et al. 1991; Anderson 1993; Logan et al. 2000). These are temporally equivalent to the Stikine, Taylor Mountain, Aishihik (Minto phase), and Long Lake plutonic suites in Yukon and Alaska.

Stikine plutonic suite (ca. 228-210 Ma)

The Stikine suite (Fig. 1) comprises calc-alkaline diorite to monzogranite plutons that are exposed throughout northwestern British Columbia from Iskut River area to Atlin Lake. The Stikine suite is locally associated with ultramafic rocks including pyroxenite, hornblendite and minor dunite. These ultramafic rocks are assigned to the Polaris suite by Woodsworth et al. (1991). The Stikine plutonic suite is known to host Cu-Mo mineralization (e.g., ca. 222 Ma Schaft Creek: Scott et al. 2008; ca. 219 Ma Icy Pass: Oliver and Gabites 1993).

Stikine plutonic suite is much less prevalent in Yukon, where it is mostly represented by small plutons, such as the Tally Ho gabbro (ca. 214 Ma: Hart 1996). Pyroxene Mountain Suite clinopyroxenite and hornblendite (ca. 220 Ma: Ryan et al. 2013) are temporal equivalents of the Polaris Suite. The paucity of Stikine plutonic suite in Yukon is partly due to Latest Triassic erosion as evidenced by abundance of ca. 210 Ma zircon in the granitoid-bearing Mandana Member conglomerate of the Lewes River Group (N. Joyce, unpublished data) and abundant ca. 215-208 Ma boulders of K-feldspar porphyritic biotite granite (Hart et al. 1995) in the Whitehorse Trough. Farther to the northwest, the Taylor

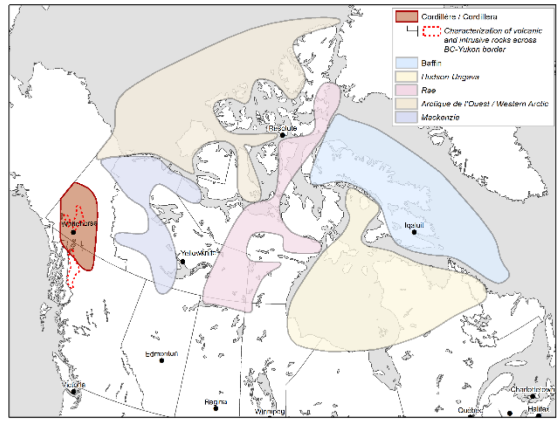

Figure 1 Geomapping for Energy and Minerals Project areas

Mountain batholith granodiorite in Alaska represents a continuation of Late Triassic magmatism that may be equivalent to the Stikine-Quesnel arc (ca. 212 Ma in Dusel-Bacon et al. 2007).

Copper Mountain plutonic suite (210-200 Ma)

The Copper Mountain suite (Fig. 2) comprises a diverse suite of predominantly small-volume alkaline plutonic and hypabyssal rocks (Anderson, 1993; Logan et al., 2000; Woodsworth et al., 1991) that are locally associated with volcanic and epiclastic rocks (Logan and Koyanagi 1994; Mihalynuk et al. 2012). Copper Mountain suite plutons range from pyroxenite, gabbro and monzodiorite to biotite syenite (Anderson, 1993; Logan et al., 2000; Woodsworth et al., 1991), and distinctive silica undersaturated, feldspathoid-bearing dikes and stocks. This suite is highly prospective for Cu-Au porphyry deposits as exemplified by the Galore Creek deposit (ca. 210 Ma: Logan and Mihalynuk 2014b). The regional distribution is of the Copper Mountain suite is poorly constrained, especially silica-saturated members, but alkaline plutons appear to form a north-trending belt from Zippa Mountain to Telegraph Creek. Similar alkaline plutons have not yet been recognized in Yukon.

Texas Creek plutonic suite (200-189 Ma)

The Texas Creek suite (Fig. 2) comprises diverse lithologies ranging from granodiorite to

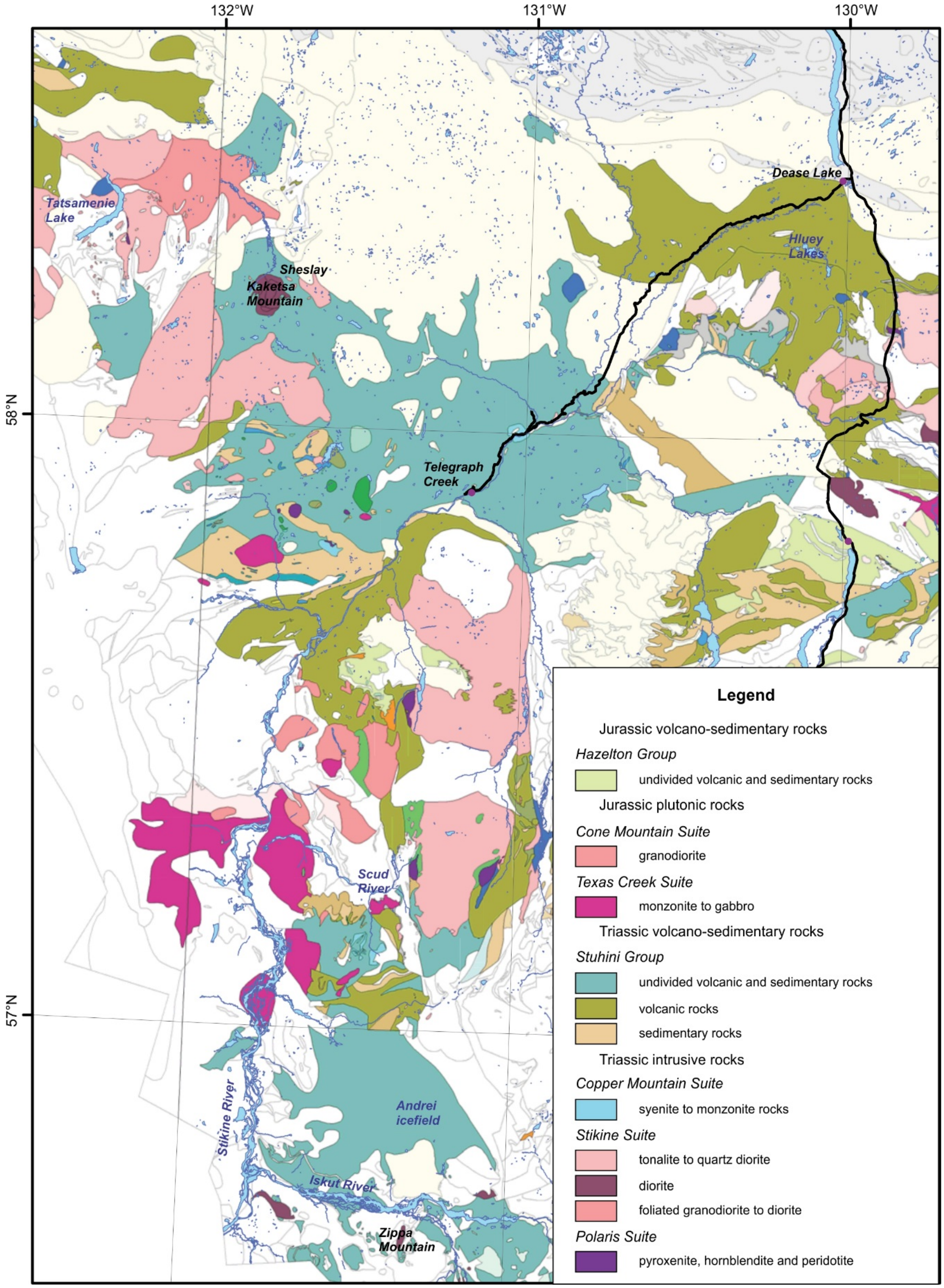

Figure 2: Simplified geology of the northern Stikine terrane showing the distribution of Triassic and Early Jurassic plutonic suites

K-feldspar megacrystic monzogranite to syenite (Anderson, 1993; Logan et al., 2000; Woodsworth et al., 1991). These plutons have variable alkaline to calc-alkaline affinities. They are exposed in a broad northwest trending belt in NW British Columbia (e.g, Logan et al. 2000). This suite is associated with precious metal vein mineralization at past-producing Silbak, Premier, Johnny Mountain and Snip mines and at the massive, recently permitted, KSM (Kerr-Sulphurets-Mitchell) cluster of porphyry deposits.

Temporal correlatives of the Texas Creek suite are voluminous in Yukon. The Minto pluton and correlative rocks to the west , currently included in the Aishihik suite form temporal equivalents and host the active Minto Cu-Au-Ag mine (ca. 201-197 Ma: Hood 2012; Ryan et al. 2013). These large hornblende-biotite granodiorite plutons are characteristically foliated, magmatic epidote-bearing and were likely emplaced and mid-crustal depths (Hood 2012). These rocks are coeval with the Lower Hazelton Group that unconformably overlies Late Triassic strata (e.g., Brown et al. 1996).

Long Lake plutonic suite (189 – 180 Ma)

Plutons of the Long Lake suite comprises large batholiths of non-foliated orthoclase porphyritic quartz monzonite that postdate the foliated hornblende-biotite granodiorite of the Aishihik suite (Hart 1996). The Long Lake Suite likely forms the plutonic equivalents to the Nordenskiöld Formation volcanic rocks in Yukon. The Cone Mountain plutonic suite in British Columbia (Brown et al. 1996) forms the temporal equivalent of the Long Lake plutonic suite, where it is characterized by hornblende-biotite granodiorite to quartz monzonite. These rocks are coeval with the upper Hazelton Group (Brown et al. 1996).

Goals and objectives

Lack of modern regional geochronological coverage precludes identification of the broad temporal and chemical trends in volcanic and plutonic belts. Identification of these trends is the paramount to understanding regional tectonic controls on known magmatism and mineralization, and to guide future mineral exploration. To help span these existing knowledge gaps, we have initiated reconnaissance studies aimed at temporal and chemical variations within the Stikine, Copper Mountain, Texas Creek and Cone Mountain plutonic suites in British Columbia and Aishihik and Long Lake plutonic suites in Yukon. Our field studies have been complemented by archival collections made during previous field campaigns. Such use of archival materials is both expeditious and economic and includes re-analysis of mineral separates by Ar-Ar and U/Pb geochronologic techniques.

Preliminary results

Stikine plutonic suite

Previously mapped Stikine suite plutons were sampled in the Iskut, Telegraph Creek, Sheslay and Tatsamenie Lake areas. The plutons appear to be very diverse and composite and include phases that range from gabbro to monzogranite that can generally subdivided into three types. The first type, exposed east of Tatasamenie Lake and south of Telegraph Creek, is characterized by strongly foliated hornblende-biotite tonalite-granodiorite-diorite (Fig. 3A). Locally, hornblende contains conspicuous altered pyroxene cores. The second type comprises isotropic to weakly foliated hornblende±biotite gabbro, diorite and quartz diorite (Fig. 3B). These rocks are associated with porphyry-style mineralization at the Star Cu-Au deposit and, to the west, underlie Kaketsa Mountain. In addition, similar plutonic rocks were identified in "undivided" Stuhini Group west-southwest of Dease Lake, where they host chalcocite-bearing

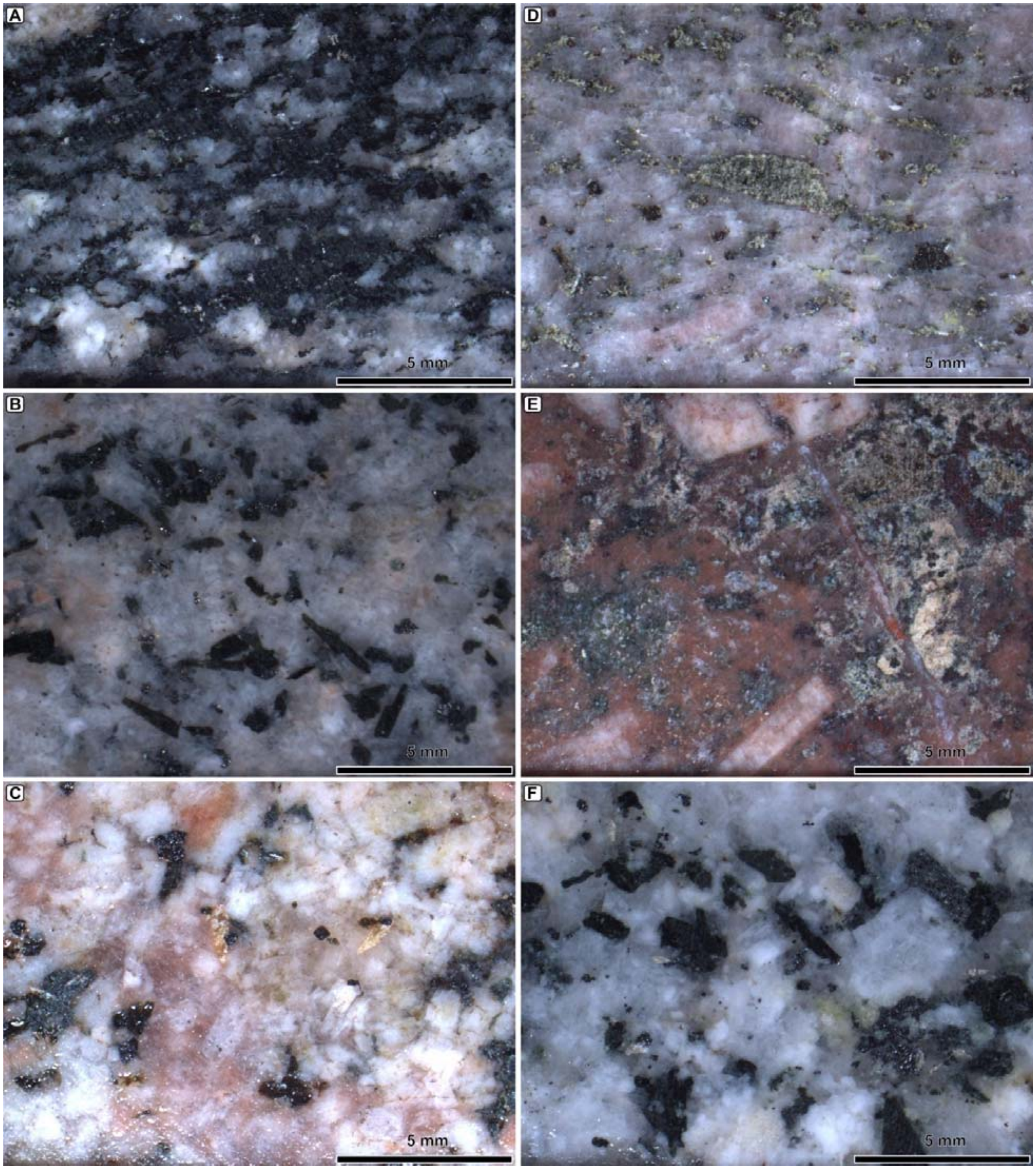

Figure 3: Representative photographs of plutonic rocks. A. Nightout pluton foliated hornblende-biotite granodiorite, Stikine plutonic suite. B. Kaketsa Mountain hornblende quartz diorite, Stikine plutonic suite. C. Biotite monzogranite, Stikine plutonic suite. D. Zippa Mountain clinopyroxene-garnet syenite, Copper Mountain suite. E. Burgundy Ridge altered tabular K-feldspar porphyry, Copper Mountain suite. F. Weakly foliated hornblende-biotite granodiorite, Texas Creek plutonic suite

quartz veins. The third type comprises locally porphyritic biotite monzogranite (Fig. 3C). Due to the reconnaissance nature of our mapping and sampling, contact relationships between phases were not established; however, the presence of at least three regionally distinct phases in the Stikine suite suggest that further subdivision of this suite may be warranted.

Copper Mountain plutonic suite

Copper Mountain suite (Fig. 2) plutons are compositionally and chemically diverse and commonly form composite bodies. Field observations were made and samples collected from representative bodies at Zippa Mountain (see Coulson et al. 1999 for detailed description; Fig. 3D), Andrei Icefield (Mihalynuk et al. 2012), Hluey Lakes (Logan et al. 2012) and along Telegraph Creek Road. Alkaline rocks at Andrei icefield host high grade Cu-Au porphyry mineralization associated with trachytic tabular K-feldspar porphyritic syenite (Burgundy Ridge). Several phases of tabular, locally megacrystic, K-feldspar porphyries are present: pre-alteration porphyry is locally completely replaced by calc-silicate alteration assemblage (Fig. 3E), which is cut by finer grained tabular K-feldspar porphyritic syenite with conspicuous fresh biotite. Along Telegraph Creek road, the Tahltan pluton contains at least four different phases. Early pyroxenite is cut by gabbro, diorite and pink aplite. At Hluey Lakes, the stock is varitextured, with medium-grained trachytic K-feldspar porphyrititc biotite syenite (Logan et al. 2012), locally containing varying concentrations of K-feldspar megacrysts up to 3 cm long.

Texas Creek, Cone Mountain suites and other rocks

The Texas Creek and Cone Mountain suite plutons were examined at several localities where they are characterized by diorite, granodiorite (Fig. 3F) and K-feldspar megacrystic monzogranite. In some cases these rocks strongly resemble plutons of known or expected Eocene age. Volcanic rocks of presumed Jurassic age were investigated in the Hoodoo Mountain area (see Mihalynuk et al. 2012) to test temporal correlation with either the Texas Creek or Cone Mountain suites. Additional compilation work is being carried out southeast of Hoodoo Mountain area to complement studies of Late Triassic to Middle Jurassic magmatic and sedimentary rocks in NW British Columbia conducted by J-A. Nelson and J. Kyba (BCGS).

Aishihik and Long Lake suites

Archived zircon mineral separates from Aishihik and Long Lake suites were analyzed using Sensitive High-Resolution Ion Microprobe (SHRIMP II, Ottawa) to constrain the timing of magmatism in Yukon. These samples yielded ^{207}Pb-corrected ^{206}Pb/^{238}U ages ranging from ca. 187 to 180 Ma (N. Joyce, unpublished data), consistent with older determinations from northern BC and Yukon (see Mihalynuk et al. 1999 for review), and confirming that some of the Aishihik suite is significantly younger than magmatic rocks associated with mineralization at the Minto mine (Hood 2012). These analyses facilitated reconnaissance fieldwork in Yukon by P. Sack and M. Colpron (Yukon Geological Survey) which focussed on Jurassic Cu-Au-Ag porphyry potential in Yukon. Further geochronological work is aimed at separating phases of this suite for more effective, focused mineral exploration.

Conclusions

Reconnaissance mapping and sampling was conducted across the northern Stikine terrane to characterize Mesozoic plutonic suites that are known producers of precious metal vein and porphyry-style mineralization. Preliminary results demonstrate a need to further subdivide plutonic suites and to constrain the timing relationships between various phases as an aid to more focused mineral exploration. In 2014, the inaugural year of our GEM 2 activity, the primary focus has been on plutonic rocks. Prior to fieldwork in 2015, we will utilize Ar-Ar and U-Pb geochronology and geochemistry to constrain the age and further characterize barren and mineralized plutons through analysis of new and archived samples. Select plutons of presumed Eocene age will be investigated further as they are compositionally similar to the older suites and locally host Mo-Cu-Bi-Pb veins (K. Martin, B.Sc. thesis in progress, University of Ottawa). Results arising from 2014 fieldwork will form a basis for integrating volcanic and plutonic frameworks in subsequent years.

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