Geochemical and Physical Variations in the Late Triassic Nicola Arc and Metallogenic Implications, Central British Columbia (NTS 092P, 093A, N): Preliminary Results

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Introduction

The Late Triassic Nicola Group marine arc sequence in south-central British Columbia and its northward continuation, the Takla Group, largely define the Quesnel oceanic arc terrane (Figure 1). The terrane hosts most of the alkalic copper-gold deposits and prospects in BC, including Mount Milligan, Lorraine, Mount Polley, Afton/Ajax and Copper Mountain. Additional alkalic porphyry copper-gold deposits, most importantly Galore Creek, occur in the Stikine Terrane, which is generally accepted to represent the continuation of the Quesnel arc (e.g., Nelson and Colpron, 2007). Porphyry copper-gold (±silver±platinum group element) deposits related to alkalic magmatism are rare globally but well represented in BC. They are scattered over a combined strike length of approximately 1600 km.

Exploration for alkalic porphyry copper-gold deposits in BC is challenging because of poor exposure and locally thick glacial overburden. Moreover, unlike their calcalkalic cousins, alkalic porphyry deposits have more cryptic alteration footprints (e.g., Jensen and Barton, 2000). This project aims to provide new exploration guidelines by looking at along-strike variations in the Quesnel volcanic arc and identifying physical, chemical and volcanological characteristics unique to areas where porphyry copper-gold mineralization is known. Fieldwork initiated in June 2009 and observations presented herein are preliminary.

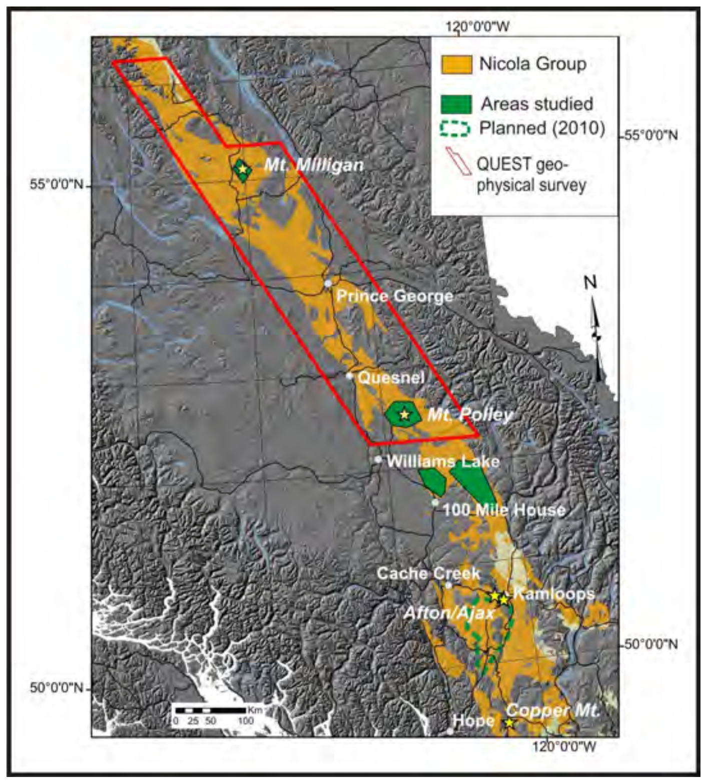

Figure 1. Location of areas studied in 2009 and major alkalic copper-gold porphyry deposits (yellow stars) hosted by the Nicola and Takla groups, which largely define the Quesnel Terrane in central British Columbia. Figure compiled using digital-elevation data from GeoBase (Canadian Council on Geomatics, 2010) with post-processing by K. Shimamura (Geological Survey of Canada); BC Geological Survey MINFILE database (porphyry occurrences; MINFILE, 2010); and the tectonic assemblage map of the Vancouver area (Journeay et al., 2000).

Nicola Group

The Nicola arc sequences are dominated by submarine basaltic to andesitic augite±plagioclase–phyric lavas and associated volcaniclastic rocks. The Nicola Group derives its name from exposures south of Nicola Lake near Merritt (Dawson, 1879) and has been studied in most detail in

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south-central BC, where it has been subdivided into an eastern, central and western belt (e.g., Preto, 1977; Mortimer, 1987). The eastern belt is dominated by distal volcano-sedimentary facies derived from augite-porphyritic basalt and andesite. Compositionally similar proximal deposits, including lavas, occur in the central belt. The western belt consists principally of lavas and volcaniclastic rocks ranging from basalt to rhyolite. Recent and ongoing mapping by the BC Geological Survey (e.g., Schiarizza and Blingh, 2008; Schiarizza et al., 2008) north and east of 100 Mile House subdivides the Nicola Group in that area into a lower volcano-sedimentary unit containing black argillite, limestone and volcaniclastic rocks; a middle unit containing submarine augite-phyric basalt and basalt breccia; and an upper unit containing partially subaerial polymictic volcaniclastic rocks. A common characteristic throughout the entire strike length of the Nicola Group is the presence of augite(±plagioclase)–phyric basalt and associated monomictic breccia. Similar rocks are also widespread in the Stuhini and Takla groups, the latter being the northern equivalent of the Nicola Group (e.g., Mortimer, 1987; Nelson and Bellefontaine, 1996; Dostal et al., 1999).

Composition of the Nicola Group Volcanic Rocks

A number of workers (e.g., Barrie, 1993; Lang et al., 1995; Bath and Logan, 2005; Logan and Bath, 2005; Breitsprecher et al., 2007, 2008) have investigated the geochemistry of the Late Triassic and Early Jurassic intrusive rocks of the Nicola Group and its equivalents, many of which have associated porphyry copper-molybdenum and copper-gold mineralization. Mineralized alkalic igneous suites in BC are compositionally varied and range from silica-saturated monzonite (e.g., Mount Milligan; Barrie, 1993; Jago and Tosdal, 2009) to strongly silica-undersaturated monzonite and syenite (Galore Creek; Schwab et al., 2008).

In contrast, the geochemistry of the volcanic hostrocks has received comparatively little attention. Mortimer (1987) identified three compositionally distinct but areally overlapping groups of volcanic rocks between Copper Mountain and the Iron Mask area. Group 1 is shoshonitic and comprises strongly augite-porphyritic basalt, locally analcime bearing, and picrite. Group 2 consists of augite- and plagioclase-phyric basalt and andesite belonging to the low-potassium calcalkaline series, and group 3 is composed of petrographically heterogeneous andesite and basalt of tholeiitic to transitional affinity. Shoshonitic lavas from group 1 are stratigraphically above group 2 and 3 rocks.

Basaltic rocks with shoshonitic affinity have also been reported from the Mount Polley (Logan and Bath, 2005) and Mount Milligan areas (Barrie, 1993); basalt at Mount Polley is locally analcime phyric. Similar geochemical characteristics suggest a genetic relationship between the alkalic intrusive rocks and the extrusive shoshonitic rocks at Mount Polley, and the latter are thought to be relatively high in the Nicola Group stratigraphic sequence (Logan and Bath, 2005). At Mount Milligan, in contrast, the ca. 186–182 Ma intrusive rocks are significantly younger than the Late Triassic volcanic hostrocks (Mortensen et al., 1995; Nelson and Bellefontaine, 1996).

Fieldwork and Preliminary Observations in 2009

Geochemical sampling concentrated on coherent basalt flows or large clasts from volcaniclastic breccias in four areas (Figure 1): 1) around the Mount Milligan deposit; 2) around the Mount Polley deposit; 3) areas north of 100 Mile House, including exposures near the Lac La Hache porphyry prospect; and 4) exposures east of 100 Mile House and north of Highway 24. The latter area has no known alkalic mineralization. Magnetic susceptibility measurements were routinely taken from coherent and volcaniclastic rocks, and samples from all areas are currently being analyzed for physical properties and whole-rock geochemistry. Although detailed geochronological constraints are scarce, the Late Triassic volcanic hostrocks at Mount Polley, which are constrained between 204 and 201 Ma (Logan and Mihalynuk, 2005), are temporally more closely related to the mineralization than those at Mount Milligan, where mineralization significantly postdates the volcanic rocks.

In the exposures around Mount Polley and the Lac La Hache property, weakly altered coherent volcanic rocks have relatively high magnetic susceptibilities of 35–85 $\times 10^{-3}$ SI units, except where affected by chlorite and epidote alteration. In those cases, magnetite is destroyed and susceptibilities are commonly below 5×10^{-3} SI units (Figure 2A, B). This contrasts with the Mount Milligan area and northeast from Lac La Roche, where relatively unaltered coherent basalt has low magnetic susceptibilities of 0.3–2 $\times 10^{-3}$ SI units. Only two samples from Mount Milligan have high values of 20–25 $\times 10^{-3}$ SI units.

The groundmass and some phenocrysts (possibly former olivine) within volcanic rocks are commonly hematite stained in the Mount Polley and Lac la Hache areas but rare in the other areas studied. Red sandstone and polymict breccias and conglomerates have been mapped near these deposits and are interpreted to have been subaerially deposited (Figure 2; Logan and Bath, 2005; Schiarizza and Blingh, 2008).

Analcime-phyric basalt that is macroscopically identifiable as alkalic in composition has been observed only in the Mount Polley area thus far, but whole-rock geochemistry is expected to provide further insight.

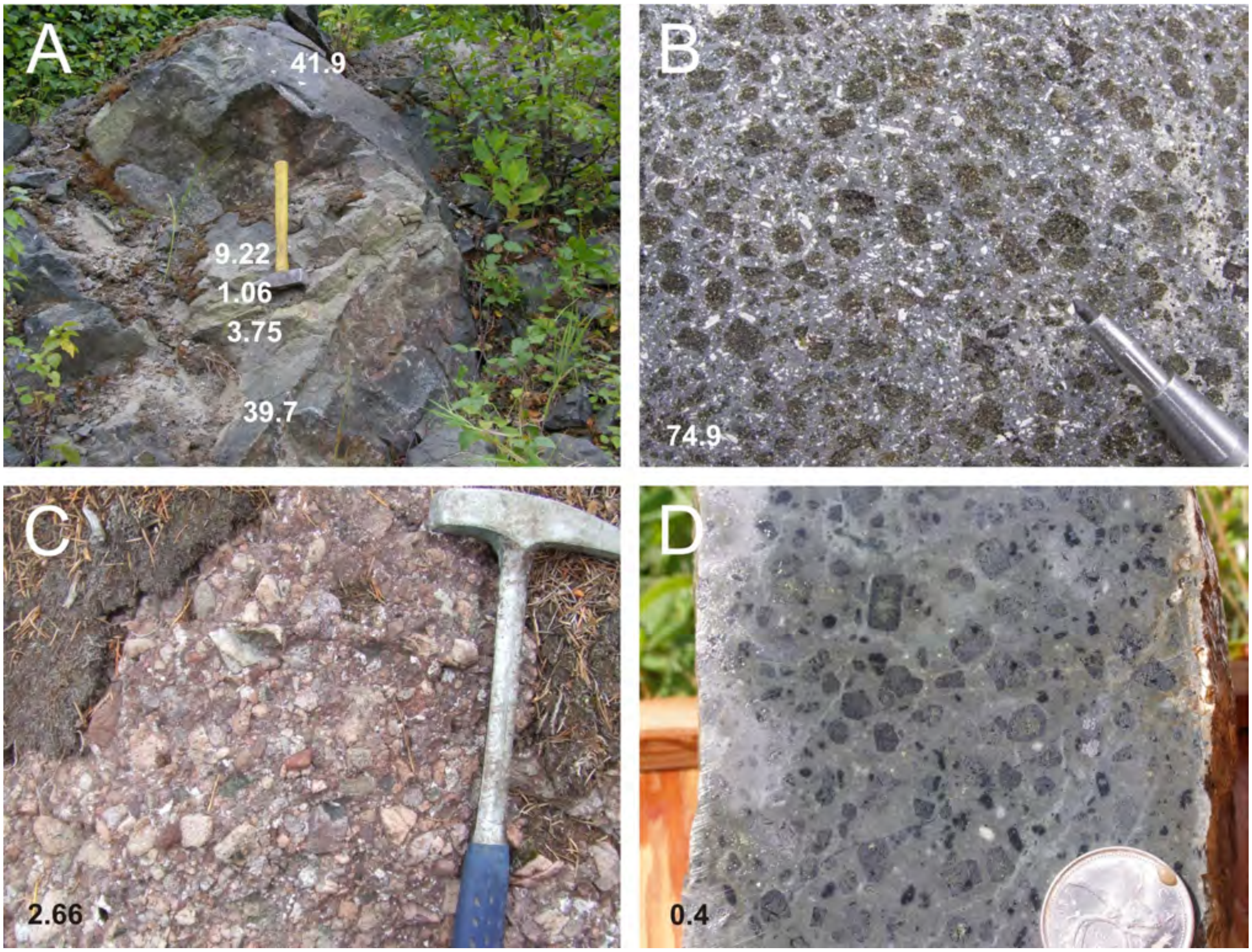

Figure 2. Rock types from the study areas in central British Columbia, showing magnetic susceptibility values (x 10^{-3} SI units): **a)** basalt with local chlorite and epidote alteration, possibly reflecting pillow margins, northeast of Lac La Hache (UTM Zone 10, 605473E, 5773358N, NAD 83); **b)** coherent pyroxene- and plagioclase-phyric basalt near Mount Polley (UTM 591321E, 5814995N); **c)** possible subaerially deposited volcaniclastic conglomerate, 10 km northeast of Mount Polley, (UTM 582376E, 5827795N); d) coherent augite-phyric basalt, 2.5 km south of Mount Milligan (UTM 433079E, 6105548N).

Discussion and Possible Implications

The higher magnetite content of coherent basalt near areas with copper-gold mineralization may indicate that the arc has been more oxidized in those areas compared to elsewhere. Alternatively, there may also be a general evolution from lower to higher magnetite content as the arc evolves and deposits are associated with the stratigraphically higher portions of the arc assemblage.

Highly magnetic volcanic hostrocks in some areas may obscure aeromagnetic signatures of magnetite-rich alteration zones associated with alkalic porphyry copper-gold deposits. However, both distal propylitic and seafloor alteration can introduce epidote and chlorite, and destroy magnetite. Extensive distal propylitic alteration may have the potential for generating distinctive magnetic lows in the periphery of the mineralization. In contrast, where the deposits significantly postdate the host volcanic rocks and where these have low magnetic susceptibility, magnetite introduced during hydrothermal alteration can be more evident in aeromagnetic data.

Outlook

Despite the limited data available at this point, arc segments hosting mineralization are apparently distinctive based on magnetic susceptibility and distribution of alkalic basalt. Whole-rock geochemistry and additional physical property data from samples of all areas visited will provide further constraints on potentially prospective volcanic rocks. Determination of ferric/ferrous iron ratios will be routinely performed on least-altered coherent volcanic rocks to establish the relationship between magnetic susceptibility and oxidation state of the magmas. Detailed petrographic work will be undertaken to identify the nature and type of magnetite-destructive alteration, which will be crucial for interpreting aeromagnetic signatures around alkalic porphyry copper-gold deposits.

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