TREK Geological Mapping Project, Year 2: Update on Bedrock Geology and Mineralization in the TREK Project Area, Central British Columbia (parts of NTS 093B, C, F, G)

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Introduction

The Interior Plateau region of British Columbia is considered to have high exploration potential as it hosts a variety of deposit types including Late Cretaceous and Eocene epithermal Au and Ag deposits (e.g., Blackwater, Capoose and Wolf) and porphyry Cu and Mo deposits (e.g., Endako and Chu) ranging in age from Late Jurassic to Eocene. Exploration activity has historically been hindered by a limited understanding of the character and distribution of prospective units owing to the masking effects of overlying Eocene and Neogene basalt flows and extensive glacial till cover. The **T**argeting **R**esources through **E**xploration and **K**nowledge (TREK) project is a Geoscience BC initiative to integrate geophysical, geological and geochemical data in order to improve our geological understanding and, ultimately, reduce the risk associated with exploration in such a poorly understood region (Clifford and Hart, 2014).

As a component of the TREK project, a targeted regional mapping program was undertaken to provide new geological information to integrate with existing geochemical and geophysical datasets. Interpretation of available aeromagnetic and gravity data was utilized to plan traverses and aid in delineating geological features (Aeroquest Airborne Ltd., 2014; Buckingham, 2014). This was particularly useful for redefining the boundaries of Eocene and Neogene basalts (Angen et al., 2015b). During the regional mapping campaign (Figure 1), 87 samples were collected for geochemical assay. Some samples reflect new mineral occurrences and even new styles of mineralization within the region. A discussion of selected samples provides value for interested explorers.

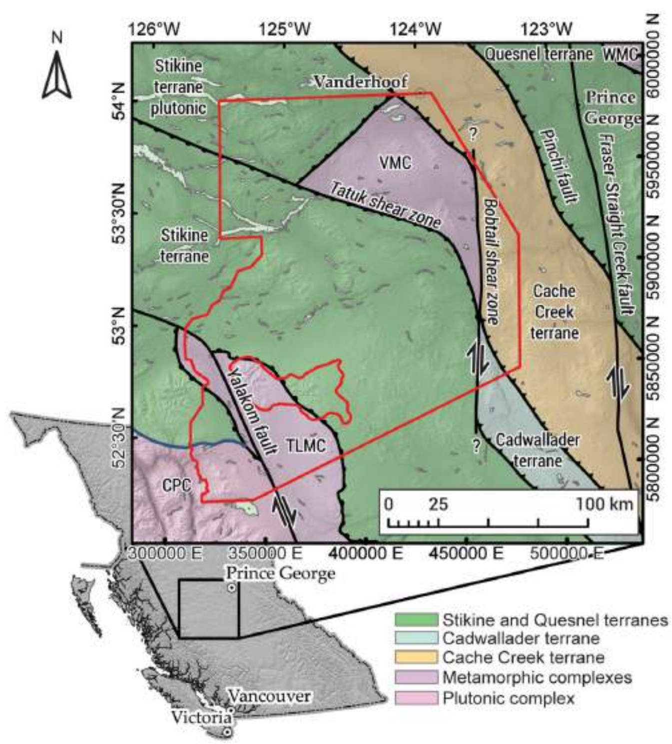

Figure 1. Location of the **T**argeting **R**esources through **E**xploration and **K**nowledge (TREK) study area in central BC. Outline of study area in red. Faults are interpreted from aeromagnetic and gravity data (Aeroquest Airborne Ltd., 2014; Buckingham, 2014). Tectonic domains are modified after Massey et al. (2005). Abbreviations: CPC, Coast Plutonic Complex; TLMC, Tatla Lake metamorphic complex; VMC, Vanderhoof metamorphic complex; WMC, Wolverine metamorphic complex.

Geological Setting

The TREK study area is underlain predominantly by the Stikine island-arc terrane with minor exposure of oceanic

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Cache Creek terrane in the east (Figure 1). Both terranes are extensively mantled by overlap assemblages. The southwestern part of the study area is underlain by intrusions and associated metamorphic rocks of the Coast Plutonic Complex. These three tectonic domains are separated by metamorphic complexes and major faults: the Tatla Lake metamorphic complex and Yalakom fault in the west, and the Vanderhoof metamorphic complex and Bobtail shear zone in the east. The TREK mapping project is focused on the geology and mineralization of the Stikine terrane and overlap assemblages. The oldest Stikine terrane rocks belong to the Paleozoic Stikine assemblage (Monger, 1977; Gunning et al., 2006) or the Asitka Group (Lord, 1948). Unconformably overlying the Asitka Group are the Upper Triassic marine sedimentary rocks of the Lewes River Group and submarine volcanic rocks of the Stuhini Group (Souther, 1977). These are in turn unconformably overlain by the predominantly subaerial volcanic and associated sedimentary rocks of the Early to Middle Jurassic Hazelton Group (Tipper and Richards, 1976; Marsden and Thorkelson, 1992; Gagnon et al., 2012). Middle Jurassic accretion is documented by obduction of Cache Creek blueschist onto Stikine terrane (Mihalynuk et al., 2004). Erosion of the uplifted Cache Creek terrane produced the chert-rich detritus preserved in the Middle Jurassic to Early Cretaceous Bowser Lake Group overlap assemblage (Evenchick and Thorkelson, 2005). Continued erosion and unroofing produced the muscovite-rich metamorphic detritus preserved along with continental-arc volcanic rocks in the Early to mid-Cretaceous Skeena Group (Bassett, 1995). Subsequent continental-arc magmatism is recorded by the Late Cretaceous Kasalka Group and associated Bulkley and Blackwater plutonic suites and the Eocene Ootsa Lake and Endako groups and associated Quanchus Plutonic Suite. Flood basalts of the Miocene to Pleistocene Chilcotin Group unconformably cover low-lying areas (Andrews and Russell, 2008), while isolated shield volcanoes and cinder cones of the Miocene to Pliocene Anahim Volcanics define a northeast-trending hotspot track (Kuehn et al., 2015).

Stratigraphy

The eight volcanic and sedimentary sequences covered by this study, from oldest to youngest, are: Early to Middle Jurassic Hazelton Group; Middle to Late Jurassic Bowser Lake Group; Early to Late Cretaceous Skeena Group; Late Cretaceous Kasalka Group; Eocene Ootsa Lake Group; Eocene Endako Group; Neogene Chilcotin Group; and Neogene Anahim Volcanics.

Hazelton Group

The Early and Middle Jurassic Hazelton Group of Tipper and Richards (1976) comprises three formations that from oldest to youngest include: Telkwa, Nilkitkwa and Smithers. Gagnon et al. (2012) subdivided the Hazelton Group into a lower interval of dominantly arc-related volcanic rocks of Hettangian-Sinemurian age and an upper interval of mainly clastic rocks of Pliensbachian to Callovian age that are separated from the lower interval by a regionally diachronous unconformity. In the Nechako River area, the Hazelton Group consists of a marine sequence of rhyolite to basalt fragmental rocks intercalated with sedimentary rocks that comprise the Middle Jurassic, Bajocian Entiako and Naglico formations (Tipper, 1963; Diakow et al., 1997).

Lower Hazelton Group

Telkwa Formation

The Lower Hazelton Group comprises volcanic rocks of Hettangian-Sinemurian age (Tipper and Richards, 1976; Gagnon et al., 2012) that are locally represented by the Telkwa Formation. It is composed of maroon and green andesitic lapilli tuff with abundant plagioclase (up to 40%) ±pyroxene±hornblende phenocrysts. Volcanic boulder conglomerate with a red tuffaceous matrix and well-rounded clasts occurs locally. Anderson et al. (1998) report planar crossbeds, flame structures, and cut-and-fill structures in rich bedded tuffs north of Knewstubb Lake, indicating shallow subaqueous deposition (Figure 2). One such tuff yielded corresponding zircon and titanite ages of 195.2 ±1.1 Ma and 195.9 ±0.7 Ma, respectively (Struik et al., 2007). Similar andesitic lapilli tuffs and reworked crystal tuffs are observed south of the Nechako Reservoir and northeast of the Capoose prospect (MINFILE 093F 040; BC Geological Survey, 2015).

Upper Hazelton Group

The Upper Hazelton Group comprises sedimentary and volcanic rocks of Pliensbachian through Callovian age (Tipper and Richards, 1976; Gagnon et al., 2012). Locally, thick sections of lava flows and volcaniclastic rocks are not well age-constrained either by fossils or isotopic means. Following Diakow et al. (1997), the Upper Hazelton Group is subdivided into the Entiako and Naglico formations in this region. Possible correlations are suggested.

Entiako Formation

The Entiako Formation consists of a lower marine tuffaceous sedimentary unit of Toarcian to Bajocian(?) age and an upper unit of intermediate to felsic volcanic and epiclastic members (Diakow and Levson, 1997; Diakow et al., 1997). Included with the undifferentiated Entiako Formation are thin-bedded variegated siltstone, fine lithic sandstone and ash tuff that correlate with the Quock Formation (Thomson et al., 1986; Gagnon et al., 2012). These are well exposed in a roadcut at the turnoff for the Blackwater mine access road where it departs from the Kluskus-Ootsa Forest Service road (Figure 2). Here, thinly bedded (0.25–5.0 cm), grey, cream, black and pyritic cherty siltstone, argillite and fine ash tuff beds are folded and faulted into a south-southwest-verging thrust panel. The unit shows soft sediment deformation and normal fault displacements.

Liesegang Basalt: This unit is characterized by abundant flattened amygdules, and hematitic Liesegang rings (Figure 3a). Coherent flow units (2.5–4 m thick), commonly with brecciated flow-tops or bases are locally separated by intraflow fragmental lapilli tuffs, and block breccias occur rarely. The flows are aphyric, sparsely plagioclase-phyric to crowded (1–2 mm, 20–35%) to trachytic with variably hematized and chloritized pyroxene and/or hornblende phenocrysts (2 mm, 2–5%).

The upper and lower contacts of the unit are not exposed but it is stratigraphically above rocks tentatively assigned to the Telkwa Formation south of the Nechako Reservoir in a shallow west-dipping sequence. The Liesegang basalt unit is again observed adjacent to the Telkwa Formation in the eastern Tatuk Hills. It also occurs stratigraphically below quartz-feldspar lapilli tuff of the Entiako Formation in two localities where it is close to the brick-red ash-lapilli lithic tuff and flow-banded rhyolite-dacite units described below: ~1 km south of the turnoff for the Blackwater access road, and south of the Key stock along the Blue Forest Service road (Figure 2).

Red Tuff: Nonwelded, brick-red lithic lapilli tuff and ash tuff is best exposed south of the Key stock along the Blue Forest Service road (Figure 2). Fine-grained bedded ash horizons are defined by abundance and crystal size of white feldspar. Lapilli up to 10 cm are predominantly of purple plagioclase-phyric andesite with lesser red dacite and beige rhyolite (Figure 3b). This unit may correspond to the Toarcian Eagle Peak Formation defined in the Skeena-Nass area (MacIntyre et al., 1994), formerly the Red Tuff Member of the Nilkitkwa Formation (Tipper and Richards, 1976).

Red Dacite: White, grey, purple and red flow-banded dacite and spherulitic rhyolite is traced around the southern margin of the Key stock. Some occurrences were previously mapped as Ootsa Lake Group and Entiako Formation. Flow bands are contorted and locally exhibit quartz-filled vugs (Figure 3c). A similar maroon flow-banded dacite occurs below Entiako Formation quartz-feldspar lapilli tuff along the Kluskus-Ootsa Forest Service road, ~1 km south of the Blackwater access road and on the western flank of Fawnie Dome.

Entiako Lapilli Tuff: A white-weathering quartz-feldspar crystal-lithic lapilli tuff—conspicuous by the presence of lithic clasts of maroon/red tuff, and flow-laminated and quartz eye–bearing rhyolite clasts—crops out south of the Key stock, on the western flank of Fawnie Dome, and at the Entiako Formation type section (5 km marker on the Kluskus-Malaput Forest Service road; Diakow et al., 1997). Red tuff clasts indicate that this distinctive lapilli tuff postdates the brick-red ash tuff described above (Figure 3d). Purple- to pink-weathering plagioclase and quartz crystal lithic tuff extends from the developed 3TS prospect (MINFILE 093F 055, 093F 068) toward the northwest where it is truncated by the Laidman batholith (this study; Diakow and Levson, 1997; Figure 2). Here the tuff is lithic dominated, rhyolitic and monomict. Rounded to broken plagioclase, K-feldspar and quartz phenocrysts average 2–5 mm, and comprise 20–25% each within a siliceous salmon-pink matrix that lacks foreign maroon lithic clasts.

Naglico Formation

Overlying the Entiako felsic tuffaceous units, apparently unconformably (Diakow et al., 1997), are pyroxene-phyric coherent basalt, breccia, conglomerate and pyroxene-rich sandstone and epiclastic deposits. Age constraints include a probable early Bajocian fossiliferous limestone (south of the Capoose pluton) and latest early Bajocian, or early late Bajocian, bivalves and ammonites from siltstone, sandstone and conglomerate southeast of the 3TS prospect (MINFILE 093F 055, 093F 068).

Interlayered and graded coarse plagioclase- and pyroxene-crystal sandstone, lithic conglomerate and plagioclase-pyroxene–phyric basalt overly parallel-laminated, variegated beds of cherty siltstone and sandstone at the Entiako Formation type section (Diakow et al., 1997). On Fawnie Dome, pink K-feldspar–phyric dacite of the Entiako Formation is overlain by massive, amygdaloidal pyroxene-plagioclase–phyric coherent basalt. The basalt is characterized by stubby white plagioclase laths (1–3 mm, 30%) and sparse equant pyroxene phenocrysts (2–4 mm, 10–12%) within a fine-grained matrix of plagioclase, pyroxene and disseminated magnetite. Chlorite and spotty epidote alteration is ubiquitous.

Bowser Lake Group

Ashman Formation

Middle Jurassic clastic rocks of the Ashman Formation in the TREK study area comprise a deep-water facies of fine-grained mudstone and siltstone with limy lenses and an overlying eastward-thickening wedge of conglomerate, sandstone and siltstone (Diakow et al., 1997).

Black shale interbedded with fine sandstone and fossiliferous greywacke is exposed at the Buck showing (MINFILE 093F 050), on the Blackwater mine access road (kilometre 0.5 to 2.5) and west of Chedakuz Creek (Diakow and Levson, 1997). At the Buck showing, black mudstone, parallel-laminated argillite and siltstone comprise an upward-facing sedimentary panel ~50 m thick that grades upward into pyroxene-porphyry basalt and volcaniclastic rocks of the Nechako Formation. The same stratigraphic relationships also occur along the Blackwater mine access road.

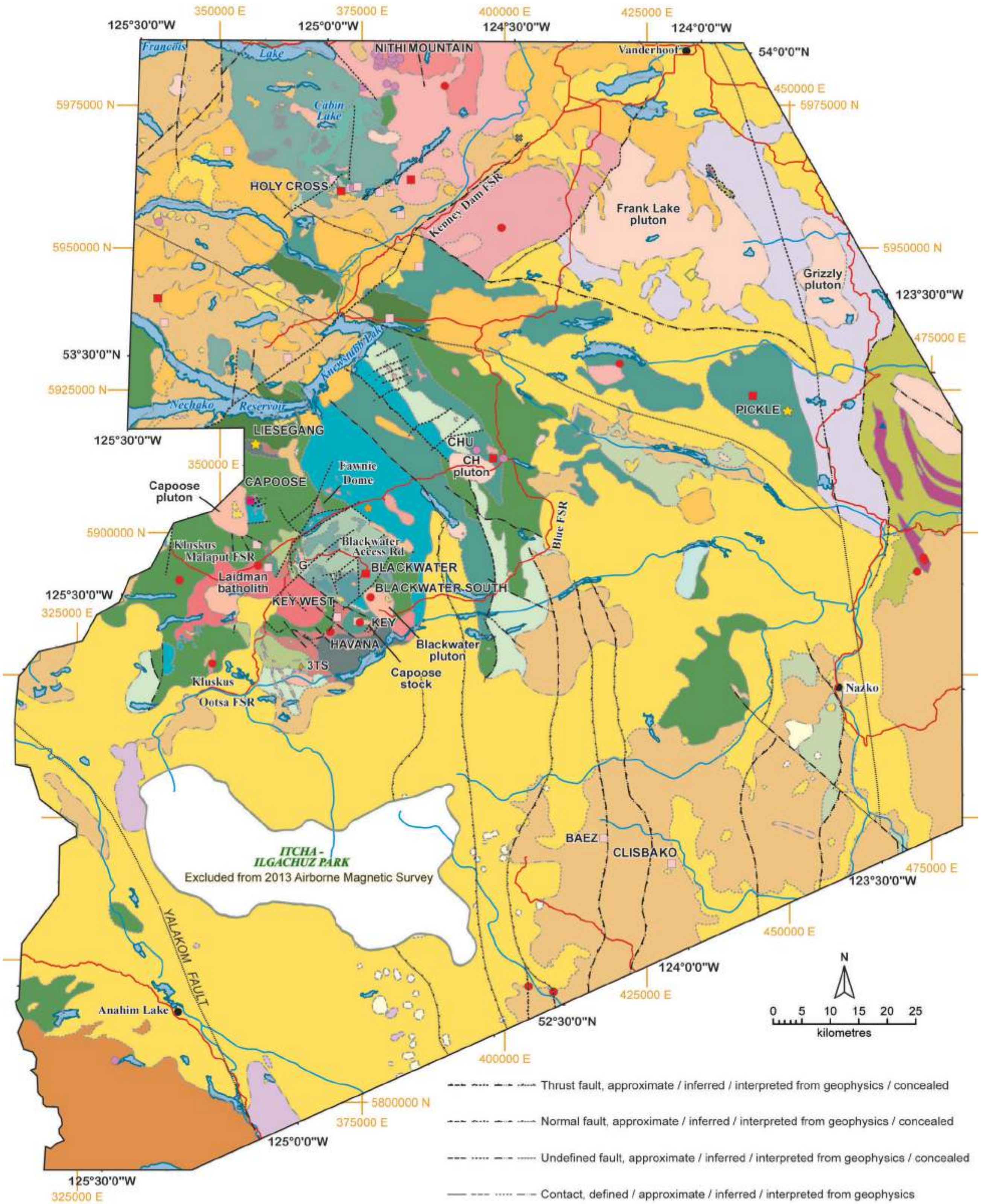
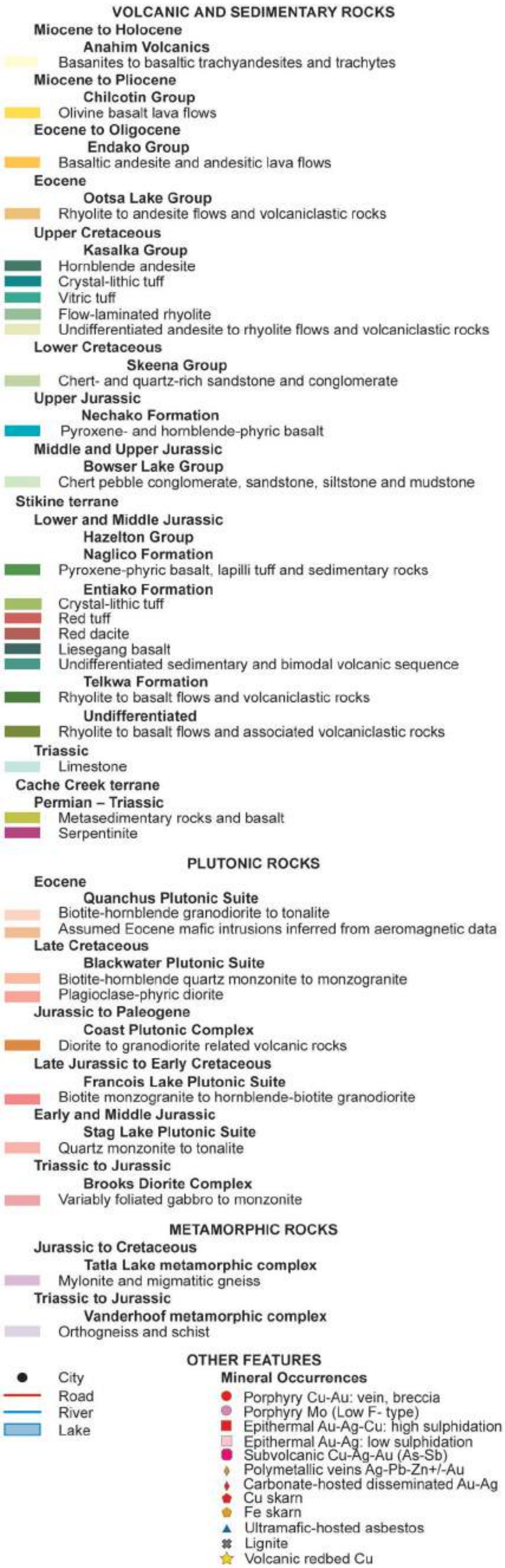


Figure 2: Bedrock geology of the **T**argeting **R**esources through **E**xploration and **K**nowledge (TREK) study area. Abbreviations: FSR, Forest Service road; G, G-pluton. Modified after Angen et al., 2015a. Legend continued on the following page.



An isolated outcrop of white-weathering chert pebble–granule conglomerate and lithic sandstone, crops out north of Fawnie Dome (Diakow and Levson, 1997). The conglomerate is well sorted, massive or thickly bedded and clast-supported. It is composed of white, grey, black and pale green subangular to well-rounded chert pebbles (4–15 mm). The conglomerate has been silicified, probably due to the pyroxene diorite intrusion that forms the hilltop 300 m to the south. Ashman Formation conglomerate is well exposed in the Nechako Range (Diakow et al., 1997).

Nechako Formation

Coarse pyroxene-phyric basalt breccia, pyroxene-phyric clast-dominated polymict conglomerate and rare fine-grained bedded epiclastic units underlie the area north of Top Lake, south of the Capoose prospect (Fawnie Nose), and the western flank of the Nechako Range (Diakow and Levson, 1997). North of Top Lake, the fault-bounded unit includes a dominantly effusive lower member of coarse pyroxene-phyric basalt with stubby to equant euhedral black pyroxene phenocrysts (0.5 by 1 mm, up to 10 mm, 15–20%) and white tabular, subhedral plagioclase phenocrysts (2–3 mm, 20%) within a black, green or red hematitic fine-grained matrix. This is overlain by an upper member of pyroxene-dominated polymict fragmental and epiclastic rocks that fines upward into well-bedded fossiliferous siltstone, sandstone and wacke. Contacts are not exposed but sedimentary facing directions suggest the sedimentary units overlie the pyroxene basalt. The volcanic rocks are intruded by coarse crowded pyroxene-plagioclase sills (2–4 m thick) and fine-grained equigranular pyroxene diorite dikes (1–2 m wide). The dikes display vesicular margins.

Thickly bedded, chaotic matrix-supported polymict volcanic boulder conglomerate, with rare well-bedded normal-graded sandstone and siltstone intervals, dominate the upper member. These units are exposed along the Kluskus-Ootsa Forest Service road, south of Fawnie Dome (Figure 2), and in drilling northwest of the Black Bear prospect (MINFILE 093F 075; Webster, 2013). Lithic clasts include intermediate to felsic volcanic rocks that are black, green and maroon; aphyric to plagioclase–, plagioclase+hornblende– and plagioclase+pyroxene–phyric; and weather white. Matrix to the conglomerate is a pyroxene-crystal–rich litharenite derived primarily from volcanic sources. Upsection, the volcanic stratigraphy fines and is replaced by thinly bedded, interlayered sandstone and siltstone, calcareous fossiliferous wacke and argillaceous mudstone. Calcareous centimetre-thick beds of quartz, plagioclase and chert/rhyolite lithic wacke weather yellow and contain abundant belemnoids, bivalves and coaly plant fragments. Early Callovian ammonites and numerous other less diagnostic fossils were reported from similar sedimentary rocks located 800 m southeast (Collection GSC C-143395, as discussed in Diakow et al. 1997).

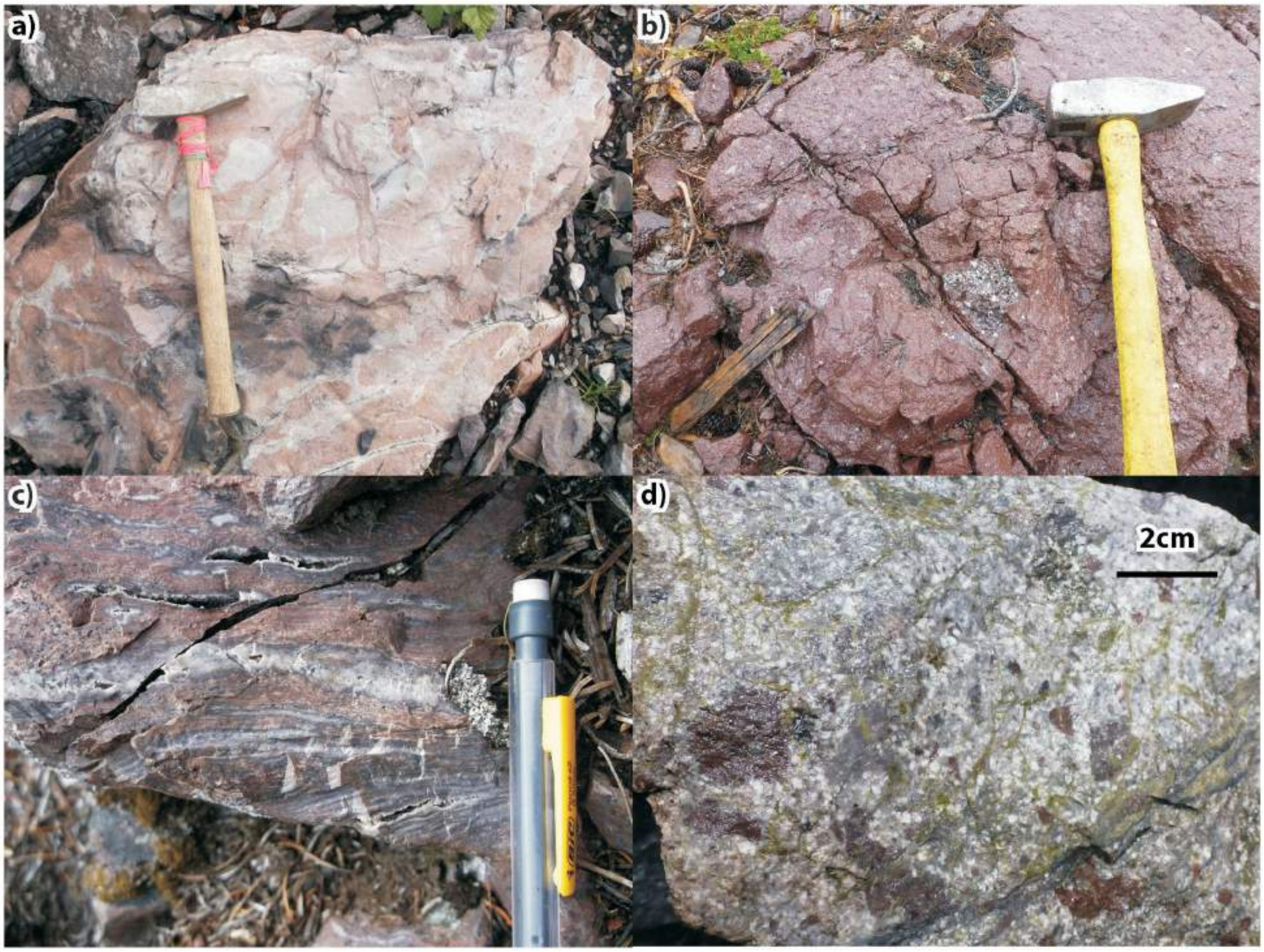


Figure 3: Characteristic features of newly identified members of the Entiako Formation: **a)** hematitic Liesegang rings developed in basalt at the new Liesegang volcanic redbed-copper showing; **b)** lithic lapilli tuff characteristic of the Red tuff unit; **c)** flow-banded rhyodacite of the Red dacite unit with quartz-filled vugs along flow bands; **d)** crystal-lithic lapilli tuff with distinct red to purple lapilli derived from the underlying Red tuff unit.

Skeena Group

Sedimentary rocks with late Albian to early Cenomanian palynomorphs are reported from the area along the Entiako River where it enters the Nechako Reservoir (Diakow et al., 1997). These rocks are age correlative with the Skeena Group which is characterized elsewhere in the Interior Plateau by polylithic chert-rich conglomerate, mudstone and muscovite-bearing sandstone (Bassett and Kleinspehn, 1997). Age equivalent chert pebble conglomerate, chert-rich sandstone and siltstone of the Nazko and Redstone belts are also included with the Skeena Group (Riddell, 2011).

Kasalka Group

The stratigraphy of the Kasalka Group is described in detail by Kim et al. (2016). It is composed of a basal conglomerate, felsic to intermediate volcaniclastic rocks, flow-banded rhyolite, and locally columnar-jointed andesite flows. It is well exposed in the vicinity of the Blackwater mine, including a prominent ridge that follows the eastern faulted(?) contact with the Laidman batholith, and southeast of Cabin Lake (Figure 2). Observations from drillcore at the Blackwater mine indicate that the Kasalka Group was deposited unconformably on the Ashman Formation (Looby, 2015). This is in contrast with observations along the Blackwater access road where the Ashman Formation is overlain by Nechako Formation basalt, suggesting that the Kasalka Group was deposited onto a significant erosional surface.

Ootsa Lake Group

The Ootsa Lake Group covers the majority of the southeast quadrant of the map area and a significant portion of the region west of Knewstubb Lake (Figure 2). It is composed of predominantly felsic flows and associated volcaniclastic rocks. A basal conglomerate locally contains plutonic clasts (Andrew, 1988). This is overlain by acicular hornblende-bearing dacite, biotite-phyric ash flows, and perlitic vitreous black dacite locally with up to 1% pyroxene phenocrysts (Mihalynuk et al., 2008; Bordet, 2014). White, pink and grey, locally flow-banded rhyolite and rhyolitic lapilli tuff with up to 5% quartz, 7% plagioclase and 2% biotite phenocrysts locally dominates the Ootsa Lake Group (Diakow et al., 1997; Bordet, 2014). The U-Pb and Ar-Ar constraints indicate that Ootsa Lake Group volcanism persisted from 54.6 to 46.6 Ma (Bordet et al., 2014). Based on new correlations, the extent of Ootsa Lake Group rocks in the vicinity of the Blackwater mine has been significantly reduced (Figure 2; Kim et al., 2016).

Endako Group

The Endako Group consists of metre-thick, commonly vesicular flows with pumiceous margins or flow-brecciated tops and bottoms, with rare entablature columnar-jointed sections in the vicinity of Kenney Dam. Basalt textures include the following: coarsely vesicular to pumiceous aphyric flows; fine-grained green- and brown-mottled matrix containing glomeroporphyritic plagioclase and sparse ophitic pyroxene crystals; and medium-grained felted matrix of vitreous plagioclase laths (0.5–0.8 mm, 75%), sparse equant pyroxene phenocrysts (1.0 mm, 5–7%), and very fine grained disseminated magnetite (Angen et al., 2015b).

Chilcotin Group

Chilcotin basalts underlie a substantial area south of Batnuni Lake. The basalt is orange to deep red weathering, vesicular to pumiceous and generally subhorizontal. In cross-section it shows fluidal lamination with entrained angular blocks and lapilli and locally, in plan view, good polygonal jointing is preserved in the thicker units. The basalt is coarsely porphyritic with 2.5–5.0 mm phenocrysts of olivine and pyroxene comprising 5–7% within a commonly aphyric matrix. Thicker flows are characterized by a felted matrix of translucent plagioclase laths (1.0 mm, 30%) and pyroxene and olivine phenocrysts (1–2.5 mm, 7–10%). The Cheslatta Lake suite, herein included with the Chilcotin Group, contains distinct xenoliths of dunite to lherzolite (Anderson et al., 2001; Angen et al., 2015b).

Anahim Volcanics

The Anahim volcanic rocks form a series of small, 1–3 km diameter, volcanic cones composed of dark grey and red unconsolidated scoriaceous breccia as well as trachyandesite, trachyte, phonolite, and lesser alkali basalt and basanite flows and dikes (Kuehn, 2014; Kuehn et al., 2015). These volcanic rocks are interpreted as the product of a hotspot currently located near Nazko (Figure 2; Souther, 1977; Kuehn, 2014; Kuehn et al., 2015).

Plutonic Suites

Brooks Diorite Complex

The Brooks Diorite Complex is composed of unfoliated to gneissic, fine- to coarse-grained mafic intrusions including hornblende±biotite diorite, monzodiorite, monzonite, and gabbro (Wetherup, 1997). It is exposed southeast of the Kenney Dam road (Figure 2). Crosscutting relationships with more foliated phases cutting less foliated ones indicate that the complex is synkinematic with respect to steeply dipping, northwest-striking foliation. It has not yet been dated but may correlate with the Late Triassic foliated Stern Creek Plutonic Suite of the Endako batholith defined by Villeneuve et al. (2001).

Stag Lake Plutonic Suite

The Stag Lake suite is compositionally heterogeneous, but in general more mafic than younger suites. It comprises gabbro, diorite, quartz monzodiorite, quartz monzonite and monzogranite. A megacrystic monzogranite, with concentrically zoned pale pink K-feldspar crystals up to 5 cm long, was observed southeast of Francois Lake (Figure 2); it is interpreted to correspond to the Caledonia phase, described by Struik et al. (1997), immediately to the north in which the K-feldspar megacrysts are pale pink to beige. The Stag Lake suite ranges in age from 180 to 161 Ma (Villeneuve et al., 2001).

Francois Lake Plutonic Suite

The Francois Lake Plutonic Suite includes fine- to coarse-grained biotite monzogranite and hornblende-biotite granodiorite (Villeneuve et al., 2001). Intrusions belonging to this suite are exposed in the north-central portion of the map area where they host Mo porphyry mineralization at Nithi Mountain (MINFILE 093F 012) and in the vicinity of Laidman Lake where they comprise the Laidman batholith (Figure 2). The recently closed Endako mine is also hosted in Francois Lake suite granodiorite immediately north of Francois Lake (Figure 2). The presence of pink or orange K-feldspar is ubiquitous. It was emplaced between 157 and 145 Ma (Villeneuve et al., 2001).

Laidman Batholith

The Laidman batholith is a coarse-grained biotite-hornblende quartz monzonite to granodiorite that underlies approximately 200 km^2 including parts of both the Kluskus-Malaput and Kluskus-Ootsa Forest Service roads. Internal heterogeneities in the reduced-to-pole total magnetic intensity (Aeroquest Airborne Ltd., 2014) across the batholith suggest it includes at least two separate phases. A sample was collected for U-Pb zircon geochronology, to test whether an internal annular high reflects an intrusion of the same age or younger.

The majority of the Laidman batholith is composed of pale grey to pink, generally coarse-grained quartz monzonite containing numerous (centimetre–metre sized) fine-grained hornblende diorite xenoliths. Tabular, twinned pink to salmon-red K-feldspar and white to grey plagioclase laths, typically 5–10 mm, comprise 75–80% of the rock with vitreous subangular quartz grains up to 8%. Mafic minerals include black stubby prisms and crystal aggregates of hornblende (2–4 mm, 7–10%); black, euhedral fresh biotite (2 mm, 2–4%); and trace amounts of sphene and magnetite as discrete grains and crystal aggregates. North of the Kluskus-Ootsa Forest Service road are outcrops of pink weakly altered, coarse-grained hornblende-biotite leucogranite. Stubby to euhedral twinned crystals of K-feldspar (3–15 mm, 40%) and vitreous, anhedral to rounded quartz (2–12 mm, 35–40%) comprise the majority of the granite. Intergrown with the K-feldspar are stubby crystal aggregates of plagioclase (20%), biotite (2 mm, 1–3%) and traces of shredded hornblende and magnetite.

A K-Ar biotite cooling age of 141 ±4 Ma and U-Pb titanite crystallization age of 148.1 ±0.6 Ma (Diakow and Levson, 1997), as well as three U-Pb zircon ages of 148.3 ±0.3, 148.8 ±0.5 and 147.2 ±0.3 Ma (Poznikoff et al., 2000) establish a Late Jurassic age for the northwestern portion of the Laidman batholith.

Blackwater Plutonic Suite

The Blackwater suite is a series of granodiorite to quartz monzonite intrusions of latest Late Cretaceous age. It is distinguished from the early Late Cretaceous Bulkley suite that crops out further west by its younger age. It includes the Capoose pluton, G-pluton, Blackwater pluton, Key stock, and several small unnamed bodies.

Capoose Pluton

The Capoose pluton is a northwest-trending body that underlies approximately 145 km^2 centred on Capoose Lake. Historically it had been grouped with exposures of similar hornblende-biotite quartz monzonite and granodiorite that extend as far south as Laidman and Moose lakes and referred to as the Capoose batholith (Diakow and Levson, 1997). However, on the Total Magnetic Intensity (TMI) reduced-to-pole map the Capoose pluton is surrounded by an annular magnetic anomaly (Aeroquest Airborne Ltd., 2014). Exposures of the southern part of the pluton are deeply weathered and overlain by up to 5 m of coarsely granulated material. The intrusion is pale grey and pink and comprises medium- to coarse-grained equigranular hornblende-biotite granite, potassium feldspar megacrystic hornblende-biotite quartz monzonite and granodiorite. In hand specimen zoned, tabular pinkish crystals of K-feldspar are typically 4–6 mm; but exceed 1.5 cm in the megacrystic variety and generally comprise 25 to 30% of the rock. White, subhedral, stubby plagioclase laths of about the same size are intergrown with K-feldspar. Quartz grains are generally less than 2 mm and comprise 20–25% of the rock. Mafic minerals include; tabular hornblende (3–6 mm, 5%), euhedral biotite books (2–3 mm, 7%) and accessory amounts of titanite (3–4 mm) and magnetite which occur interstitial or as inclusions in feldspar. Published age determinations on the pluton includes a K-Ar biotite age of 67.1 ±4.6 Ma (Andrew, 1988) and two U-Pb zircon ages of 64.1 +5.4/–7.7 Ma and 69.6 ±0.4 Ma (Friedman et al., 2001).

G-pluton

The G-pluton is an equigranular to quartz-phyric hornblende-biotite granite that crops out on the Blackwater mine access road at kilometre 3. In outcrop it is massive to weakly jointed, unaltered and locally contains miarolitic cavities. Marginal phases are fine grained and quartz± plagioclase–phyric, while the interior of the pluton is typically medium grained and equigranular. Pink potassium feldspar (30%) forms tabular crystals typically 2–5 mm long, occasionally up to 10 mm, or occurs as irregularly distributed matrix intergrown with white euhedral 2–3 mm plagioclase laths (20–25%). Grey, vitreous quartz grains are generally subrounded to euhedral (3–5 mm, 20–25%). Interstitial to feldspar and quartz are weak chlorite-altered, 1–3 mm hornblende crystals and vitreous euhedral 2–4 mm biotite books that comprise approximately 5–7% of the rock. Disseminated magnetite and pyrite are accessory minerals.

A Late Cretaceous U-Pb zircon crystallization age for the G-pluton, which is older than previously suspected, and new intrusive relationships that further constrain the age of the rhyolite country rock in the area (i.e., to be older than the pluton) was reported by R. Whiteaker (pers. comm., 2015). The porphyritic variety closely resembles the quartz-feldspar crystal-lithic lapilli tuff that caps the ridge 5 km southeast.

Blackwater Pluton

The Blackwater pluton is an equigranular, medium-grained biotite±hornblende granodiorite to monzogranite. Its margins are particularly well defined in the total magnetic intensity reduced-to-pole aeromagnetic data. The U-Pb zircon ages from granodiorite of the Blackwater pluton and monzogranite of the Key stock indicate crystallization ages of 69.5 Ma and 68.5 Ma, respectively (Whiteaker, 2015). The Re-Os age of mineralization, as determined from molybdenite hosted in the Blackwater pluton at Blackwater South and molybdenum mineralization at the Key occurrence, returned ages of 66.7 Ma and 68.4 Ma, respectively (Whiteaker, 2015).

Quanchus Plutonic Suite

The Quanchus Plutonic Suite is locally represented by the CH pluton, the Frank Lake pluton and the Grizzly pluton. They are composed of white and black equigranular biotite±hornblende granodiorite containing conspicuous titanite (1–3 mm), magnetite (1–2 mm) and rare tourmaline.

In the CH pluton, the equigranular granodiorite is cut by dikes of fine-grained quartz-phyric granite and sheeted dikes of aplite with coarse pegmatite segregations that are thought to be coeval and comagmatic with the main intrusion. These late stage siliceous phases are thought to be associated with the molybdenite mineralization reported to occur at the Chu developed prospect (Allnorth Consulting Limited, 2007; MINFILE 093F 001). In addition, the pluton is intruded by metre-wide hornblende-porphyry diorite dikes with chilled flow-banded margins that likely postdate crystallization of the main phase granodiorite. Diakow et al. (1995) reported K-Ar hornblende and biotite ages for the CH pluton of 51.8 ±1.8 Ma and 48.8 ±1.3 Ma, respectively. A similar age of 51.8 ±1Ma was determined from U-Pb dating on zircon separates from the same location (Diakow and Levson, 1997). A U-Pb zircon sample from the Frank Lake pluton yielded an age of 55 Ma (no reported errors, Struik et al., 2007).

Mineral Occurrences

The identification of the Blackwater South porphyry Cu-Mo mineralization and confirmation of the Key porphyry Cu-Mo mineralization during the summer of 2014 highlights the continued prospectivity of this region, not only for epithermal style, but also for deeper larger porphyry targets (Whiteaker, 2015). During the TREK mapping campaign, a total of 87 rock samples were collected from both known MINFILE occurrences and newly identified showings. Samples were submitted to Acme Laboratories Ltd. (Bureau Veritas) in Vancouver, BC. A 15 g split from each sample underwent aqua-regia digestion and was analyzed for 37 elements via inductively coupled plasma–mass spectrometry. Samples representing new mineralization, as well as a selection of MINFILE occurrences are discussed below. Rock sample descriptions and geochemical results for selected samples are presented in Table 1.

Holy Cross (MINFILE 093F 029)

Two samples of brecciated flow-banded rhyolite with vuggy quartz infill and 1–2% finely disseminated pyrite were collected from the Holy Cross showing. Sample 14EW105A returned 5.62 g/t Ag and 0.349 g/t Au, and sample 14EW108A returned 4.86 g/t Ag, 0.0342 g/t Au and 1075 ppm As (Table 1). The flow-banded rhyolite, hosting the mineralization, forms a series of resistant knobs trending northwest that were interpreted to be intrusive domes (Barber, 1989). The same brecciated flow-banded rhyolite is found at low topography between the knobs and is flanked to the northeast and southwest by weakly foliated Hazelton Group volcanic rocks; these exhibit variable silicification and potassic alteration that is magnetite destructive. The flow-banded rhyolite and associated mineralization at Holy Cross was assigned to the Eocene Ootsa Lake Group based on similarity to other Eocene low-sulphidation epithermal deposits (Lane and Schroeter, 1997). The authors suggest that the rhyolite and mineralization may be Late Cretaceous in age because the associated alteration does not appear to affect the plagioclase- and hornblende-phyric andesite flows, which were dated by Friedman et al. (2001) as 65.7 ±5.4 Ma (K-Ar hornblende). A sample of flow-banded rhyolite collected in 2014 for U-Pb geochronology failed to yield zircons.

Sample 14JA111A was collected from an exceptionally gossanous outcrop of Skeena Group conglomerate that exhibits pahoehoe like flow-top textures interpreted to reflect deposition as a subaerial debris flow (Figure 4a). It returned 3.06 g/t Ag and 100.2 ppm Cu. This is in agreement with a previous report indicating up to 5% disseminated pyrite from silicified conglomerate in the vicinity of the Holy Cross prospect (Barber, 1989).

Key West (MINFILE 092F 613)

The Key West showing consists of poorly exposed, highly quartz-sericite–altered andesitic volcanic rocks, with up to 10% finely disseminated pyrite. In 2010, a grab sample from this showing returned 4.57 g/t Au, 15.1 g/t Ag and 1685 ppm Cu (Torgerson, 2010). An approximately 300 m diameter exposure of hornblende-phyric quartz monzonite is located immediately northeast of the pyritized and silicified andesite. It was assigned to the Late Jurassic Laidman batholith by Diakow et al. (1995) but is tentatively assigned to the Late Cretaceous Blackwater suite, a proposal that will be tested by U-Pb zircon geochronology. Sample 15JL128A was collected from the eastern part of the Key West zone from maroon lapilli breccia with epidote alteration and malachite staining. It returned 0.11 g/t Au, 35.6 g/t Ag, and 0.52% Cu.

Havana (New)

At this locality, magnetite pyrite veinlets with pink K-feldspar alteration haloes were observed rarely in outcrop, but as high density sheeted veinlets in float (Figure 4b). The veinlets cut hornblende-phyric quartz monzonite indistinguishable from the one exposed at Key West approximately 2.5 km to the north. Furthermore, the till immediately west of this locality is extremely gossanous and predominantly composed of quartz-sericite-pyrite–altered andesite similar to the outcrop exposures at Key West (Figure 4c). Sample 15JA109A was collected from the float boulder with sheeted magnetite pyrite veinlets. It returned only 0.18 g/t Ag and 100 ppm Cu.

Table 1. Assay results for selected elements and samples collected during the **T**argeting **R**esources through **E**xploration and **K**nowledge (TREK) mapping project.

Station	Easting[1]	Northing[1]	Comments
14EW062A	363571	5973670	Quartz/sericite(?) altered rhyolite with minor sulphides localized along fracture planes.
14EW066A	348486	5979685	Plagioclase-phyric andesite cut by fault breccia with quartz infill. Sample of 5% disseminated pyrite adjacent to breccia zone.
14EW081A	381865	5924177	Fault breccia with quartz infill contains limonite, hematite and 1% pyrite. Pyrite is entirely within quartz vugs.
14EW105A	369874	5961626	Silica infill around breccia cutting flow-banded rhyolite; 1% disseminated pyrite.
14EW108A	368669	5962936	Silica infill around breccia cutting flow-banded rhyolite; 1–2% pyrite disseminated and on fracture surfaces.
14EW164A	394426	5908901	2% pyrite and <1% molybdenite in rusty weathering tonalite.
14JA111A	369999	5960657	Gossanous polylithic conglomerate with iron-oxide–rich matrix. Common quartz and unidentified aphanitic black veinlets. Pyritohedron vugs observed locally.
14RK144A	354409	5928735	Epidote- and chlorite-altered andesitic lapilli tuff with 1% disseminated pyrite. Very rusty weathered surfaces.
15JA001A	358924	5896673	Veinlets of po, py and black sulphosalts(?) surrounded by silica alteration halo with finely disseminated po (locally up to 10%).
15JA056A	349184	5878682	Up to 10% patchy and disseminated py and po in biotite hornfelsed andesite.
15JA065A	368922	5885929	5% finely disseminated sulphides with py>po in intensely silicified andesite.
15JA067A	369519	5885807	10% finely disseminated and poddy sulphides with py>po>>cpy in intensely quartz sericite–altered andesite.
15JA070A	370233	5885792	1% disseminated pyrite in exceptionally rusty silicified andesite.
15JA074A	369435	5886398	5% finely disseminated and blebby pyrite in quartz sericite altered andesite.
15JA079A	348408	5882051	5% disseminated pyrite in sandstone with quartz sericite alteration overprinting chlorite epidote alteration.
15JA092A	375125	5885739	Up to 10% disseminated sulphides (py>po>sp>>cpy) in felsic lapilli tuff. Sphalerite occurs as dull brown concentric bands around fragments and rarely as up to 1 cm clusters of brown crystals.
15JA093A	375113	5885796	2% py and po and trace cpy in epiclastic coarse-grained biotite-altered sandstone interbedded with lithic lapilli tuff.
15JA109A	369829	5883100	Float sample of sheeted magnetite veinlets with pyrite cores and potassic alteration haloes in quartz monzodiorite.
15JA113A	362091	5916397	Fault breccia with quartz, calcite, adularia infill with 3% finely disseminated py.
15JA125A	356288	5915365	Float sample but veins of same gangue material abundant in outcrop; 3% native Cu and trace malachite in epidote, quartz, calcite vein.
15JA189A	349579	5897824	Up to 2 cm wide magnetite vein with garnet alteration halo.
15JL128A	371457	5885635	Epidote alteration and malachite stain on maroon lapilli breccia.
15RK191A	449302	5921000	Subhorizontal quartz chrysocolla vein 5 cm wide cutting pyroxene-plagioclase–phyric andesite.

[1]UTM Zone 10 (NAD 83)

Abbreviations: cpy, chalcopyrite; po, pyrrhotite; py, pyrite; sp, sphalerite

Table 1 (continued)

Analyte	Au	Ag	Mo	Cu	Pb	Zn	Ni	Co	Mn	Fe	As	Sb	Bi	Ba	S	Hg	Te
Units	(ppb)	(ppb)	(ppm)	(ppm)	(ppm)	(ppm)	(ppm)	(ppm)	(ppm)	(%)	(ppm)	(ppm)	(ppm)	(ppm)	(%)	(ppb)	(ppm)
Detection limit	0.2	2	0.01	0.01	0.01	0.1	0.1	0.1	1	0.01	0.1	0.02	0.02	0.5	0.02	5	0.02
Station																	
14EW062A	60.7	1368	9.39	5.31	80.72	107.6	0.7	0.7	3343	1.25	119.8	2.69	0.52	75.8	<0.02	12	0.04
14EW066A	88.2	6111	49.13	124.68	116.2	141.8	3	48.4	1935	5.09	77.8	1.9	20.14	169.3	0.08	14	0.81
14EW081A	350	435	2.32	10.49	1.54	4.6	3	1.5	130	1.31	219.5	5.52	<0.02	25.8	0.22	24	<0.02
14EW105A	349	5619	119.6	65.74	30.8	5.7	0.7	0.6	34	0.9	19.8	16.94	4.8	201.8	0.39	112	1.77
14EW108A	34.2	4859	36.47	7.65	68.34	29.2	0.7	1.4	35	1.96	1074.5	36.49	0.37	75.2	1.08	215	0.36
14EW164A	32.3	3534	49.25	349.36	11.03	83.4	7.1	13.9	235	3.29	1564.7	3.48	4.15	100.2	1.44	<5	1.36
14JA111A	15.6	3056	74.88	100.17	19.59	115.7	9.6	4.2	164	12.2	15.1	3.74	0.08	37	0.05	9	0.47
14RK144A	4.8	939	3.2	5.3	47.46	91.6	2	7.9	751	3.72	44.5	0.58	0.05	72.7	0.9	5	0.7
15JA001A	1	687	0.1	418.45	19.57	43.7	144.8	104.4	782	6.51	16.4	0.28	0.64	25.6	3.16	13	0.36
15JA056A	13.1	844	1.42	71.81	110.8	85.8	4.4	24.8	324	4.12	13.4	0.57	0.07	114.8	1.31	15	<0.02
15JA065A	1.1	124	0.56	51.39	8.67	69.9	20.8	23.2	607	6.18	0.4	0.12	0.05	19.5	4.71	13	0.9
15JA067A	0.3	164	0.86	73.78	19.38	87.6	7.5	19.8	1195	5.12	1.5	0.17	0.04	35.4	2.07	18	0.04
15JA070A	1.2	242	4.4	46.32	49.03	32.7	0.9	1.2	140	1.56	25.1	0.3	0.11	113.6	0.33	13	<0.02
15JA074A	<0.2	118	1.78	26.39	13.65	66.6	3.4	10	622	3.45	6	0.22	0.04	66.8	2.43	15	<0.02
15JA079A	<0.2	348	0.49	100.78	25.78	73	36.1	30.6	802	4.35	24.1	1.86	0.05	66.3	1.02	10	<0.02
15JA092A	19.5	506	0.87	82.87	12.02	3868.4	58.5	23.9	241	3.75	162.7	1.1	10.65	87.7	2.37	<5	0.37
15JA093A	1.8	282	0.48	86.38	16.66	88.1	62.8	21.2	227	2.49	110.5	1.39	0.51	162.5	1.03	9	0.12
15JA109A	0.6	178	1.36	100.54	5.72	86.4	4.1	7.1	1172	4.56	2.3	0.1	0.15	76.7	0.11	6	0.02
15JA113A	0.4	786	0.12	2.85	14.59	102.4	0.8	10.3	1808	4.49	1.9	0.26	0.07	287.9	0.51	<5	<0.02
15JA125A	2.9	7047	0.2	>10000.00	2.54	8.1	1	1.7	435	1.22	26.9	0.05	<0.02	5.9	<0.02	1263	<0.02
15JA189A	103	643	0.17	6.09	41.95	827	1.2	3.4	2636	5.28	35.1	2.33	0.24	39.3	<0.02	<5	0.2
15JL128A	115	35619	0.42	5223.62	5.78	147.5	18.7	34.2	1424	3.43	6.6	0.47	0.16	239.9	0.04	47	0.03
15RK191A	9.8	144	7.47	>10000.00	5.37	12.7	13.7	13.8	470	3.94	9.1	0.82	0.21	18.3	<0.02	362	0.3

Figure 4: a) Gossanous Skeena Group conglomerate with apparent flow-top texture in bottom left corner. Sample collection site for 14JA111A; **b)** sheeted magnetite-pyrite veinlets with K-feldspar alteration haloes at the Havana showing; **c)** gossanous till composed predominantly of quartz-sericite-pyrite–altered andesite at the Havana showing, rock hammer for scale highlighted in red; **d)** native Cu in epidote-calcite-quartz vein float at the Liesegang showing.

Liesegang (New)

Irregular, 1–3 cm wide, epidote veins with minor calcite and quartz are hosted in basalt with pronounced hematitic Liesegang rings at this newly identified mineral occurrence south of the Nechako Reservoir (Figure 2). An angular boulder of the same epidote-dominated vein material was observed to host approximately 4% native Cu with trace malachite (Figure 4d). Sample 15JA125A yielded >1% Cu (over limit) and 7.05 g/t Ag, but only 2.9 ppb Au and 8.1 ppm Zn (Table 1). Given the well-developed Liesegang rings observed in the basalt hosting these veins, this mineralization is interpreted as a volcanic redbed-copper–type mineral showing. This is further supported by the association of the host basalt with brick red tuffs, the gangue mineralogy of the veins, and the association of Cu with Ag, but not Au or Zn, all common features of these deposits (Lefebure and Church, 1996). Volcanic-hosted redbed-copper mineralization is observed elsewhere in BC, most notably at the Sustut Copper deposit, which contains a combined resource of 7.047 million tonnes grading 1.67% Cu and 5.50 g/t Ag at a 0.6% Cu cutoff (Gray, 2003).

Pickle (New)

Another probable volcanic redbed-copper showing occurs at the Pickle showing, where a 5 cm wide, horizontal quartz-chrysocolla vein occurs within locally Liesegang-bearing basalt and andesite. A grab sample from this vein (Table 1, 15RK191A) returned >1% Cu with low Zn and Au, similar to sample 15JA125A. However, at the Pickle showing mineralization contains only 144 ppb Ag. The hostrocks are tentatively assigned to the Entiako Formation Liesegang basalt sequence and the occurrence is likely a volcanic redbed-copper–style of mineralization.

Conclusion

The TREK project is intended to reduce exploration risk in the northern Interior Plateau of British Columbia. Targeted regional mapping has refined our understanding of the geological framework of this region and identified several new stratigraphic units, including the Liesegang basalt, Red tuff and Red dacite units of the Entiako Formation. It has also identified new mineral occurrences including the Havana, Liesegang and Pickle showings. Samples collected during the regional mapping campaign have yielded new assay results that warrant further investigation.

The Late Cretaceous mineralizing event is of utmost importance for companies exploring in this region. The potential extension of this event to include the Havana prospect may lead to future discoveries. Observations at the Holy Cross prospect suggest that it may also be a Late Cretaceous feature, elevating the prospectivity of an already actively explored property.

The ubiquitous development of Liesegang rings in basalt of the Entiako Formation, but not observed in younger basalt of the Naglico and Nechako formations, suggests that a significant hydrothermal system was active prior to emplacement of the Naglico Formation. The high-grade Cu mineralization identified at the Liesegang and Pickle showings indicates that this older basalt is a prospective target for volcanic redbed-copper deposits: a style of mineralization not previously documented in the region.

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