Mineralization, Alteration and Structure of the Taseko Lakes Region (NTS 092O/04), Southwestern British Columbia: Preliminary Analysis[1]

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INTRODUCTION

This two-year research project will investigate the characteristics of the volcanoplutonic architecture and associated porphyry-epithermal mineralization in the Taseko Lakes region, located in southwestern British Columbia (Fig 1). The study will integrate detailed geological, structural and alteration mapping, petrology, isotope geochemistry and geochronological analyses, with the aim of developing a conceptual geological model for the structural and economic evolution of the area to assist in the application of predictive exploration. Parts of the field area were previously mapped by McLaren (1990) and Israel and Kennedy (2001). This paper focuses on the structural and economic geology of the area.

The paper presents preliminary field observations concentrating on four main areas within the Taseko Lakes region: the Hub, which is a suspected Cu-Mo porphyry system; the Northwest Copper showing, which is an areally extensive, suspected epithermal Cu-Au showing; the Twin Creeks area, where anomalous Cu, Mo and Au values have been identified from prospecting and stream sediment samples (McLaren, 1990); and the Tchaikazan fault.

REGIONAL GEOLOGICAL SETTING

The project area is located within the Coast Belt, along the boundary between the southeast Coast Belt and southwest Coast Belt (Monger and Journeay, 1994; Fig 1, 2). The southeast Coast Belt includes rocks of the Bridge River accretionary complex, the Cadwallader arc terrane and overlying clastic rocks of the Tyaughton-Methow Basin. The southwest Coast Belt consists mainly of Middle Jurassic to mid-Cretaceous plutonic rocks, as well as Early Cretaceous volcanic and associated rocks of the Gambier Group. This geographic area is located at the eastern limit of the Coast Plutonic Complex, and it is along this boundary that many Cu-Mo-Au showings are located in the southern Coast Belt (McLaren, 1990).

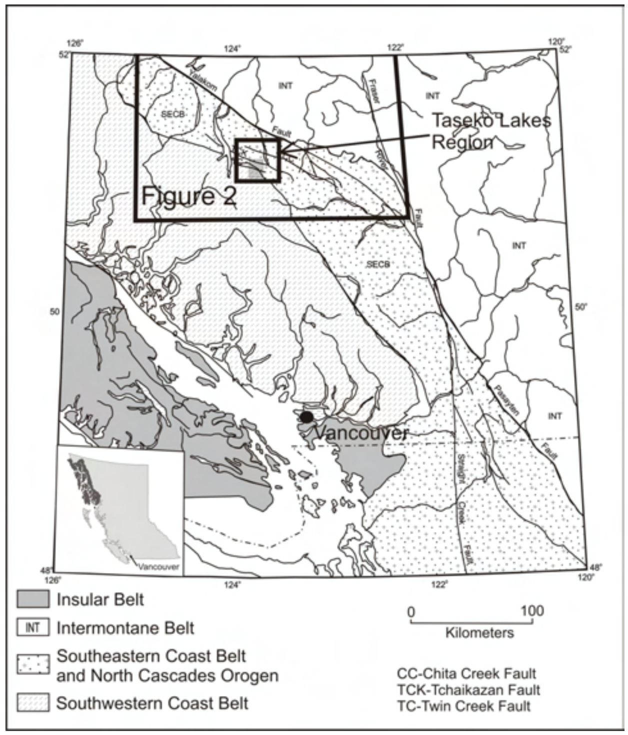

Figure 1. Orogenic belts of southwestern British Columbia (*modified from* Israel and Kennedy, 2001), showing the location of the Taseko Lakes region.

The Tchaikazan fault is a major strike-slip fault that strikes southeast through the field area (Fig 2, 3; Umhoefer et al., 1994). The bedrock to the northeast of the Tchaikazan fault is mainly clastic sedimentary rock from the Tyaughton-Methow Basin, including the Relay Mountain, Jackass Mountain and Taylor Creek groups (Fig 2). The bedrock to the southwest of the Tchaikazan fault forms the East Waddington thrust belt, which is a northeast-verging fold and thrust belt that deforms Triassic to Cretaceous volcanic and clastic sedimentary rock (Fig 2; Rusmore and Woodsworth, 1991; Umhoefer *et al.*, 1994; Mustard and van der Heyden, 1994; van der Heyden *et al.*, 1994; Schiarizza *et al.*, 1997; Rusmore *et al.*, 2000). The Powell Creek Formation, a Late Cretaceous package of volcanic and volcaniclastic rock that is abundant in the field area, occurs on both sides of the Tchaikazan fault. Mid-Cretaceous contraction of the southeast Coast Belt resulted in mostly southwest-verging thrust faults (Journeay and Friedman, 1993); however, in the field area, most thrust faults verge to the northeast and are correlated with the East Waddington Fold and Thrust Belt (Rusmore and Woodsworth, 1994). A system of regional-scale dextral strike-slip faults devel-

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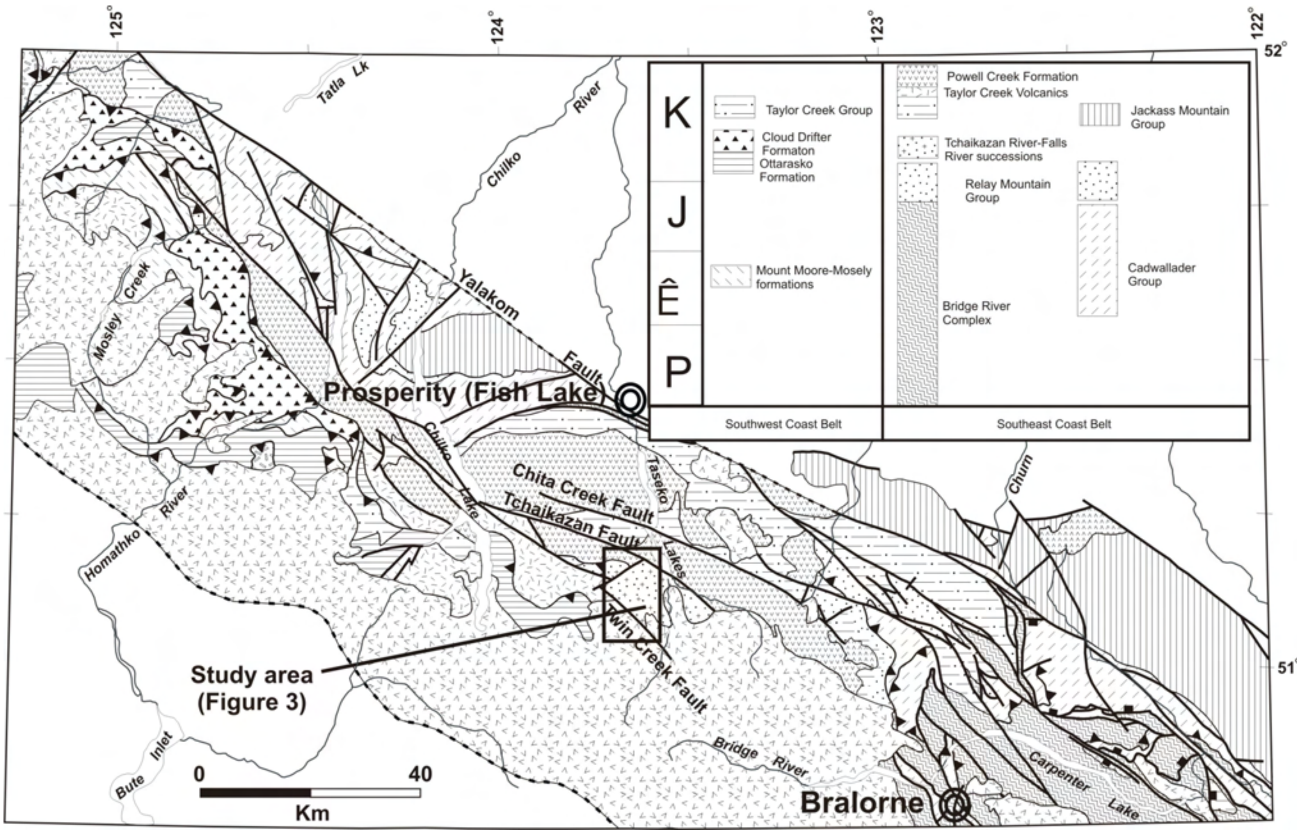

Figure 2. Regional geology of the southeast Coast Belt (*modified from* P. Schiarizza, unpublished data), showing the locations of the nearby Bralorne and Prosperity mineral deposits.

oped in the southeast Coast Belt from latest Cretaceous to Eocene time (Umhoefer and Schiarizza, 1996; Schiarizza *et al.*, 1997). These faults include the Tchaikazan, Twin Creek, Chita Creek and Yalakom faults (Fig. 2, 3), and they appear to cut all other structures in the area. In total, these structures are believed to have accommodated as much as several hundred kilometres of offset (Umhoefer and Schiarizza, 1996). Sinistral faults occur locally and are demonstrably older than the Eocene dextral faults (Israel *et al.*, in press). It is not yet known if these faults predate mid–Late Cretaceous contraction or if they are kinematically linked to the Cretaceous thrusts.

LITHOLOGICAL UNITS

Paleozoic Rocks

TWIN CREEKS SUCCESSION

The lone unit of Paleozoic rock in the study area is the Twin Creeks succession. The unit occurs as a few fault lenses within the Twin Creeks area (Fig 4) and is composed mainly of marine sedimentary rock of Permian age. These rocks consist of siltstone turbidite sequences and arkosic and grey sandstone. In areas proximal to faults, the unit appears heavily oxidized and rusty in colour. The minimum age for the succession, based on a U-Pb zircon date from a crosscutting aplite dike, is 251 ±16 Ma (Israel and Kennedy, 2001).

MESOZOIC ROCKS

The majority of the study area is underlain by several rock units of Cretaceous age. These units, from oldest to youngest, include the Tchaikazan River succession, Falls River succession, Taylor Creek Group and Powell Creek Formation (Israel and Kennedy, 2001; Israel *et al.*, in press). The Tchaikazan and Falls River successions consists mainly of intermediate submarine volcanic rock and relatively fine grained marine sedimentary rock. The Powell Creek Formation is composed of subaerial purple andesitic flows and volcaniclastic rocks.

TCHAIKAZAN RIVER SUCCESSION

The Tchaikazan River succession is the most areally extensive unit in the Twin Creeks region (Fig 4). It consists of a sediment-dominated facies and a volcanic-dominated facies. The sedimentary facies consists of clastic marine sedimentary rocks of varying grain size interbedded with minor andesitic flows. The volcanic facies comprises intermediate volcanic conglomerate and breccia, clastic marine sedimentary rock and andesite flows. These flows consist of porphyritic, massive and amygdule-rich units. These facies grade into one another, making the distinction between them at times somewhat arbitrary. Fossil evidence suggests an age as old as 140 Ma (Berriasian) for the Tchaikazan succession, whereas U-Pb dates from abraded zircon fractions from a crosscutting intrusion (McLaren, 1990; Israel and Kennedy, 2001) suggest an age older than 102 ±2 Ma, which is consistent with fossil evidence.

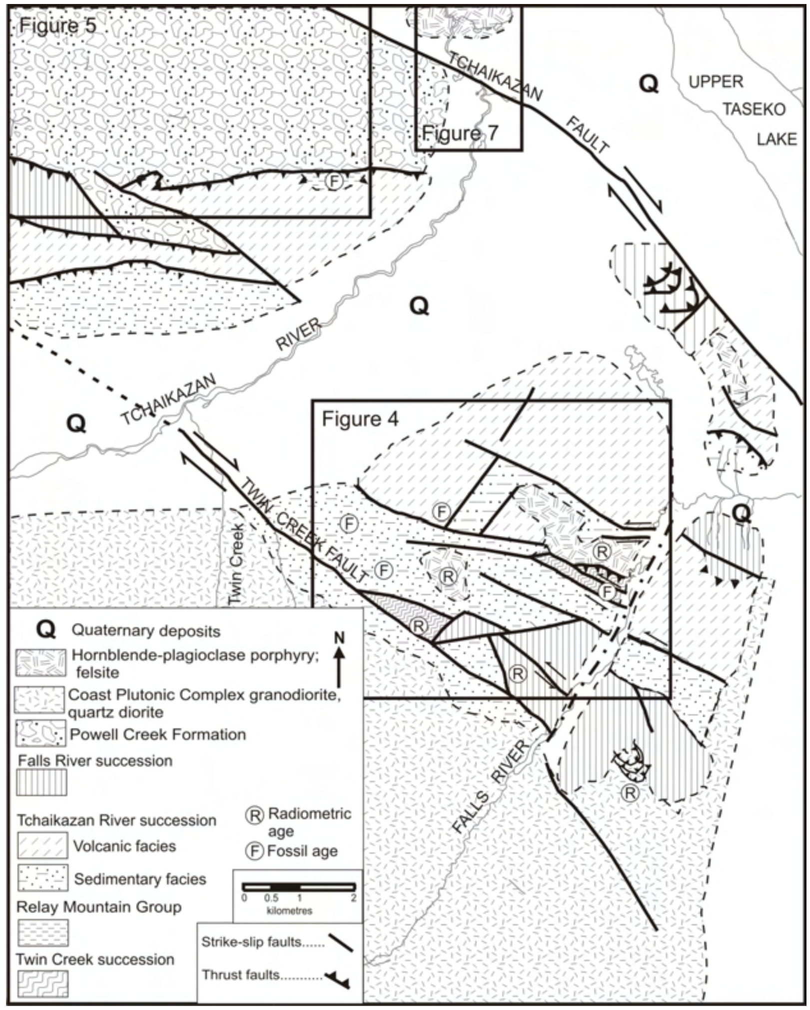

Figure 3. Geology of the Taseko Lakes region (*modified from* Israel *et al.*, in press), showing the locations of the Twin Creeks (Figure 4), Northwest Copper (Figure 5) and Tchaikazan River valley (Figure 6) areas.

FALLS RIVER SUCCESSION

The Falls River succession is another areally extensive unit in the Twin Creeks area. It contains slightly more volcanic rock than the Tchaikazan River succession and generally consists of andesitic flows, volcanic conglomerate and minor medium to fine-grained clastic sedimentary rock. Many of the andesitic flows are clast rich and grade into conglomerate and breccia units. Possible peperite occurs on the contacts between andesitic flows and sedimentary rock. Uranium-lead zircon dating of a partially welded tuff within the unit has given the Falls River succession an age of 102 to 110 Ma (Israel and Kennedy, 2001). The age is further constrained to be older than 103 ±0.5 Ma, based on a U-Pb zircon date from the crosscutting Mount McLeod batholith (Israel and Kennedy, 2001).

TAYLOR CREEK GROUP

The Taylor Creek Group occurs in the area north of the Tchaikazan fault, in the mapped areas of the Northwest Copper showing (Fig 5) and in the Tchaikazan River valley (Fig 6). It consists of marine sedimentary rock, varying from interbeds of sandstone and siltstone (Fig 5D) to well-bedded grey sandstone, which are predominantly Albian (113–97.5 Ma) in age (Garver, 1992). The sandstone-siltstone interbeds likely represent turbidite sequences. The Taylor Creek Group is cut by the Tchaikazan Rapids pluton, establishing that the unit is older than 76 Ma (Israel and Kennedy, 2001).

POWELL CREEK FORMATION

The Powell Creek Formation is well exposed throughout the northwestern part of the field area, particularly in the Northwest Copper area (Fig 5, 7). Abundant exposures of purple and red, massive andesite flows, together with resedimented volcanic breccia, form much of the area (Fig 7A). The formation is deeply weathered and good, continuous stratigraphic sections are separated by hundreds of metres of weathered debris (Israel, 2001).

The volcaniclastic rocks vary from tuffaceous horizons to massive, angular, intermediate volcanic breccia. Figure 7 shows the detailed stratigraphy of a 340 m section (measured as accurately as possible perpendicular to dip) of well-exposed andesite flows and massive volcaniclastic rocks trending southeast. Volcanic breccia units range in thickness from 15 cm to 30 m. Typically maroon/purple and polymictic with subrounded clasts, they have highly undulating and often erosive bases (Fig 7B). Andesite is the dominant clast composition within these brecciated units. Clast size is variable; basal parts are often dominated by centimetre-scale clasts (Fig 7C), whereas clast size increases toward the top of the section, where lahar-style deposits are common. Red, massive andesite flows are dominantly plagioclase phyric (Fig 7D) and moderately propylitically altered. Highly fractured/quenched flow tops form sharp stratigraphic boundaries with overlying volcanic breccia. Way-up structures are rare, but fining of volcaniclastic flow units is the most useful tool in the determination of stratigraphic top for the unit.

Several generations of highly altered plagioclase porphyry dikes are located within the Northwest Copper area. They show varying orientations and dips, and it has been proposed by Israel and Kennedy (2001), because of an aeromagnetic anomaly, that they are linked to a deeper seated pluton beneath the Powell Creek Formation.

Intrusive Rocks

MOUNT MCLEOD BATHOLITH

The most extensive igneous body in the area is the Mount McLeod batholith, which occurs in the southernmost part of the Twin Creeks area. All plutonic rocks in the area are, by definition, part of the Coast Plutonic Complex. It comprises medium to coarse-grained, hornblende-rich granodiorite. Areas of the batholith contain decimetre-scale enclaves of finer grained material of similar composition. Previous U-Pb dating on the batholith has given ages of 101.1 ±0.3 Ma from titanite constraints to 103.8 ±0.5 Ma from $^{238}U/^{206}Pb$ zircon ages (Israel and Kennedy, 2001).

GRIZZLY CABIN PLUTON

The Grizzly Cabin pluton outcrops as an ellipse-shaped intrusion. Parts of the intrusion show irregular intermingling of heterogeneous rock types (Fig 4E), whereas other areas show a single homogeneous phase. The homogeneous zones comprise medium to fine-grained hornblende-biotite quartz diorite, whereas the heterogeneous areas show segregation of medium to fine-grained hornblende diorite and quartz monzodiorite. The intrusion cuts all other visible rock units and has been previously U-Pb dated, from three abraded zircon fractions, to about 102 to 99 Ma. Another zircon fraction recorded the crystallization age of the rock at 101.5 Ma (Israel and Kennedy, 2001).

TCHAIKAZAN RAPIDS PLUTON

The Tchaikazan Rapids pluton dominates the mapped area to the north of the Tchaikazan fault. The pluton is a plagioclase-hornblende porphyry with plagioclase phenocrysts up to 2 cm in size. Much of the pluton has undergone significant clay alteration. It cuts the Taylor Creek Group, which is the only rock unit that it contacts, but is itself cut by the Tchaikazan fault. From previous U-Pb dating, the intrusion has a minimum crystallization age of 76 Ma (Israel and Kennedy, 2001).

STRUCTURAL GEOLOGY

The Taseko Lakes region has undergone at least three separate phases of deformation: sinistral/reverse slip faults, mid to Late Cretaceous compressional deformation, and dextral strike-slip faults. This section will focus on three areas mapped in detail: Twin Creeks, Tchaikazan River valley and Northwest Copper. The purpose of the detailed mapping was to determine the geometry and kinematics of the structures and to deduce their role, if any, in localizing or offsetting mineralization.

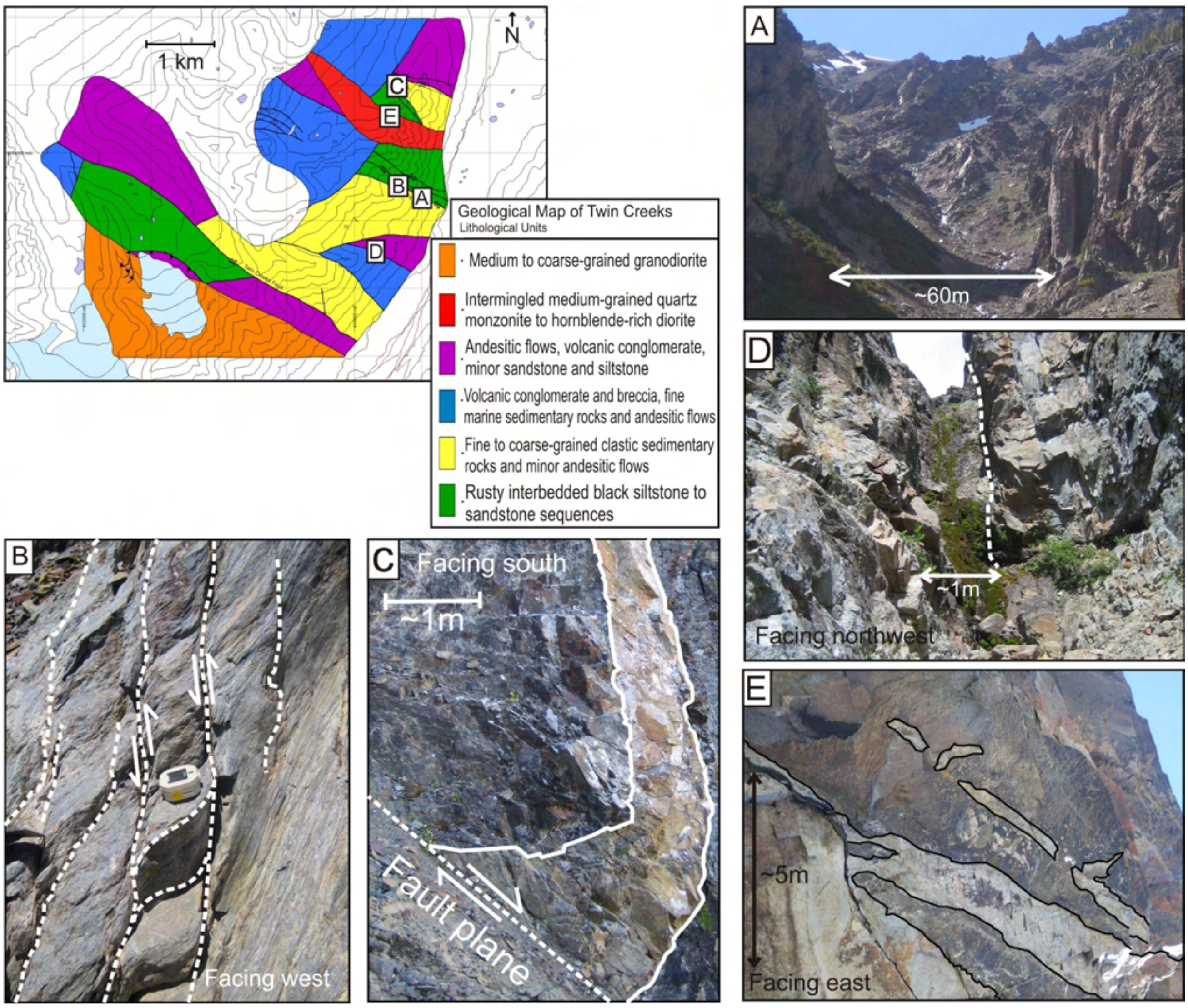

Figure 4. Geology of the Twin Creeks region, showing locations of photographs: A) sinistral/reverse shear zone; B) deflected foliations giving a sinistral shear sense with respect to the shear zone; (C) dike that has undergone drag folding, giving dextral movement sense next to fault zone; D) suspected dextral fault zone running parallel to the Twin Creeks fault; and E) intermingling of quartz monzodiorite (light grey) and diorite (dark grey) from within the Grizzly Cabin pluton.

Twin Creeks Area

Several northwest-striking and nearly vertical shear zones occur in the Twin Creeks area (Fig 4A). The fault zones are discontinuous along strike, as they are crosscut by later structures. These later crosscutting faults tend to have northeast orientations and unknown senses of movement. Many of them are inferred and were inaccessible during this field season. The shear zones are generally wide, ranging from 10 to 60 m in thickness. Very well developed shear fabrics, with sigmoidal asymmetry providing a sinistral shear sense, are common (Fig 4B) and slickenside lineations indicate a component of reverse movement. Siltstone units appear to accommodate most strain, with the more competent andesite units containing only a weak shear fabric (Fig 4B).

Chloritization and silicification of the rocks proximal to these sinistral faults is common. Minor pyrite and arsenopyrite are rarely associated with these faults. An Ar/Ar cooling age of illite, collected from a sinistral fault fabric, is 89 Ma (Israel *et al.*, in press). This is similar to the age of

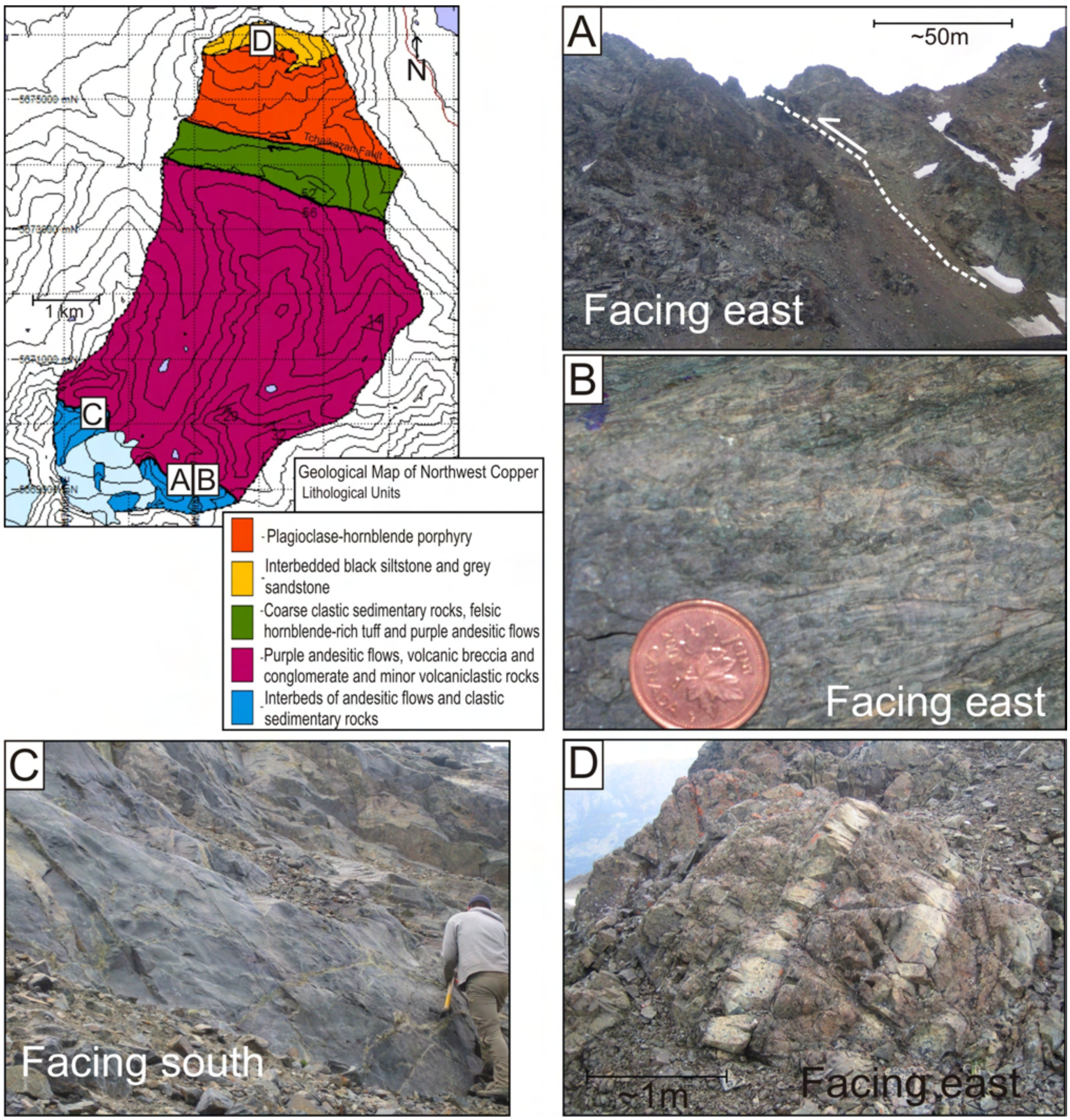

Figure 5. Geology of the Northwest Copper area, showing locations of photographs: A) north-verging thrust fault; B) significantly chloritized mylonite sample from the fault shown in (A); C) dense quartz-epidote veining in andesite located in the hangingwall of the thrust fault shown in (A); and D) siltstone and sandstone interbeds of the Taylor Creek Group, north of the Tchaikazan fault.

other significant sinistral faults in the region, particularly a system of reverse-sinistral faults, located approximately 50 km southeast of the area (Fig 2), that hosts the Bralorne gold veins and has been constrained to between 91 and 86 Ma in age (Leitch *et al.*, 1991).

Smaller scale dextral-slip faults are also present throughout the Twin Creeks area (Fig 4C). They are characterized by smaller zones of damaged fault zone material, consisting generally of highly fractured and foliated clastic sedimentary rocks (<10 m thickness). Other smaller dextral faults in the region show little deformation in the surrounding wallrock and are characterized more by slickensided surfaces and the narrow linear gullies in which they are found (Fig 4D). The majority of these smaller scale dextral faults strike southeast, similar to the Tchaikazan fault.

Northwest Copper

North to northeast-verging thrust faults occur in the Northwest Copper area (Fig 5A). The best exposed thrust fault in the area hosts mylonite that has undergone significant chlorite and epidote alteration (Fig 5B). The mylonite forms a zone approximately 1 to 2 m thick and was likely

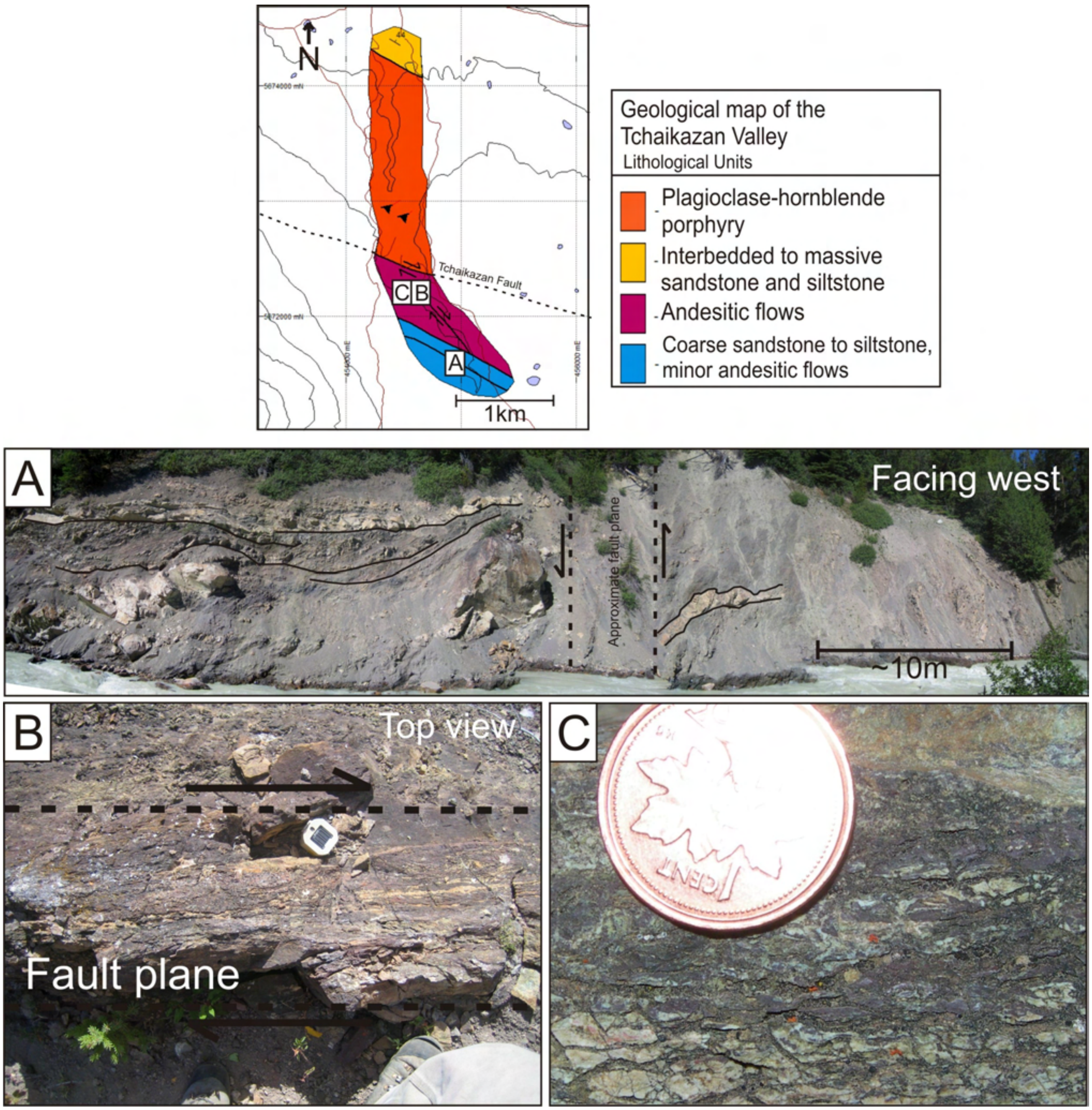

Figure 6. Geology of the Tchaikazan River valley area, showing locations of photographs: A) major fault zone representing either the Tchaikazan fault or a smaller parallel structure; B) small dextral fault interpreted as antithetic to the Tchaikazan fault; and C) well-bedded, fresh grey sandstone.

formed in andesitic rocks of the Powell Creek Formation. Asymmetric shear fabrics within the mylonite indicate a top-to-the-northeast shear sense (*i.e.*, contractional). The hangingwall above the mylonite is believed to be the Tchaikazan River succession, which is located stratigraphically below the Powell Creek Formation. The hangingwall immediately above the fault is densely epidote veined and hosts some sulphide minerals, such as pyrite, arsenopyrite and possibly some chalcopyrite. These sulphide minerals occur within the epidote veins as well as in small (<10 cm) alteration halos surrounding the veins (Fig 5C). These were the only exposures of mylonite observed in the area: all other faults were much more brittle in nature, hosting fault gouge and cataclasite rather than mylonite. Compressional deformation in the region is correlated with the East Waddington thrust belt (EWTB; Rusmore and Woodsworth, 1994).

Tchaikazan River Valley

Dextral strike-slip faults occur in the area on a variety of scales and cut all other structures. Movement along the faults occurred largely during the Eocene (Schiarizza *et al.*, 1997; Israel and Kennedy, 2001). The Tchaikazan fault is the largest dextral fault in the field area. Outcrop is rare but it is exposed in the Tchaikazan River valley as thick zones (>50 m) of damaged wallrock. The fault zones comprise clastic sedimentary rocks that have been highly deformed and sheared to form gouge layers as well as cataclasite, and enclaves of relatively undeformed country rock (Fig 6A). Smaller antithetic faults are associated with the main faults. These smaller faults (<1 m wide) have suspected dextral movements inferred from asymmetric kinematic indicators from within the fault (Fig 6B, C).

The EWTB formed during a period of compressional deformation in the mid-Cretaceous, from approximately 87 to 84 Ma (Umhoefer *et al.*, 1994). The Tchaikazan and Twin Creek faults may be correlated with other regional dextral faults, including the Chita Creek and Yalakom faults to the north, that together would form a fault system known as the Yalakom fault system. This system is believed to have evolved together as a left-stepping system and has accommodated approximately 120 to 130 km of dextral offset (Schiarizza *et al.*, 1997). The Tchaikazan fault has accommodated approximately 7 to 8 km of dextral offset (Mustard and van der Heyden, 1997). Schiarizza *et al.* (1997) suggested a sinistral component to the Tchaikazan fault prior to the more recent dextral movement, based on

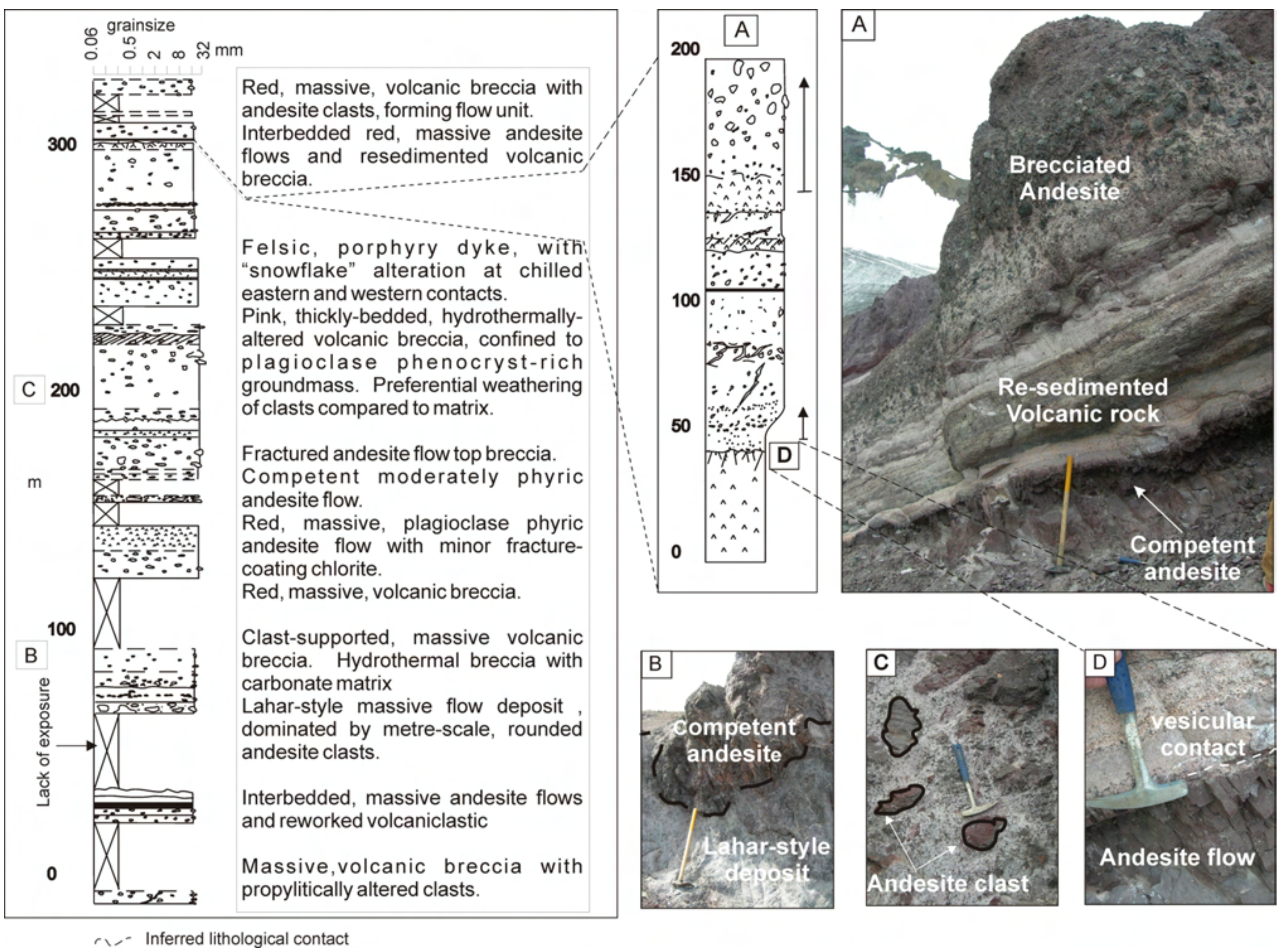

Figure 7. Schematic stratigraphic column of a 340 m measured section from the Northwest Copper area (left): A) detailed stratigraphic representation of 2.9 m of volcanic and reworked volcanic rocks; B) contact between a competent andesite flow (above) and a lahar-style deposit (below); C) brecciated andesite flow with large competent clasts in a fine-grained matrix; and D) vesicular contact between a competent andesite flow and a reworked volcanic flow.

apparent sinistral offset of Lower Jurassic sedimentary rock to the west of the study area. The relative timing of this truncation has been given by a batholith (the Dickson-McLure) that apparently plugs the Tchaikazan fault and has a K-Ar age of 86 Ma (Schiarizza *et al*., 1997).

MINERALIZATION

Mineralization in the study area is characterized by a number of porphyry and suspected epithermal deposits. This study has focused on two such deposits within the region, the Hub and Northwest Copper (Fig 3). The primary focus of this year's fieldwork was detailed geological trench mapping in areas of the Hub at a scale of 1:100. Figure 8 shows a representative trench map from the Hub area, illustrating lithology and its relationship to mineralization and alteration. Approximately 300 m of exposure was mapped using the Anaconda method of trench mapping. The Anaconda method is a method of mapping geological trenches that utilizes detailed mapping techniques in order to accurately record lithological information and structural and crosscutting relationships, as well as hydrothermal veining, mineralization and alteration.

Hub Showing

H. Warren from the University of British Columbia first identified the Hub showing in the 1940s. The area is dominated by the interaction of two main rock types, granodiorite and a magnetite±biotite-cemented breccia, both of which act as hosts to mineralization. The Hub is located approximately 4 km southeast of the Northwest Copper showing and is also at a much lower elevation. One of the key questions to be answered regarding these two areas is whether the Hub represents a deep-seated porphyry system. And if so, is the Northwest Copper showing the shallow epithermal-style mineralization related to this plutonic environment? The Hub outcrop forms a southeast-trending exposure that parallels the Tchaikazan River. Granodiorite forms the primary igneous phase and contains large, hexagonal biotite crystals that are readily identifiable with the naked eye (Fig 8F). The granodiorite is not dated, but its relationship with several crosscutting feldspar porphyry dikes allows a relative timing of intrusive events to be interpreted. The granodiorite displays a complex intrusive relationship, interfingering with the second most abundant lithology, a dark grey-black, magnetite±biotite-cemented

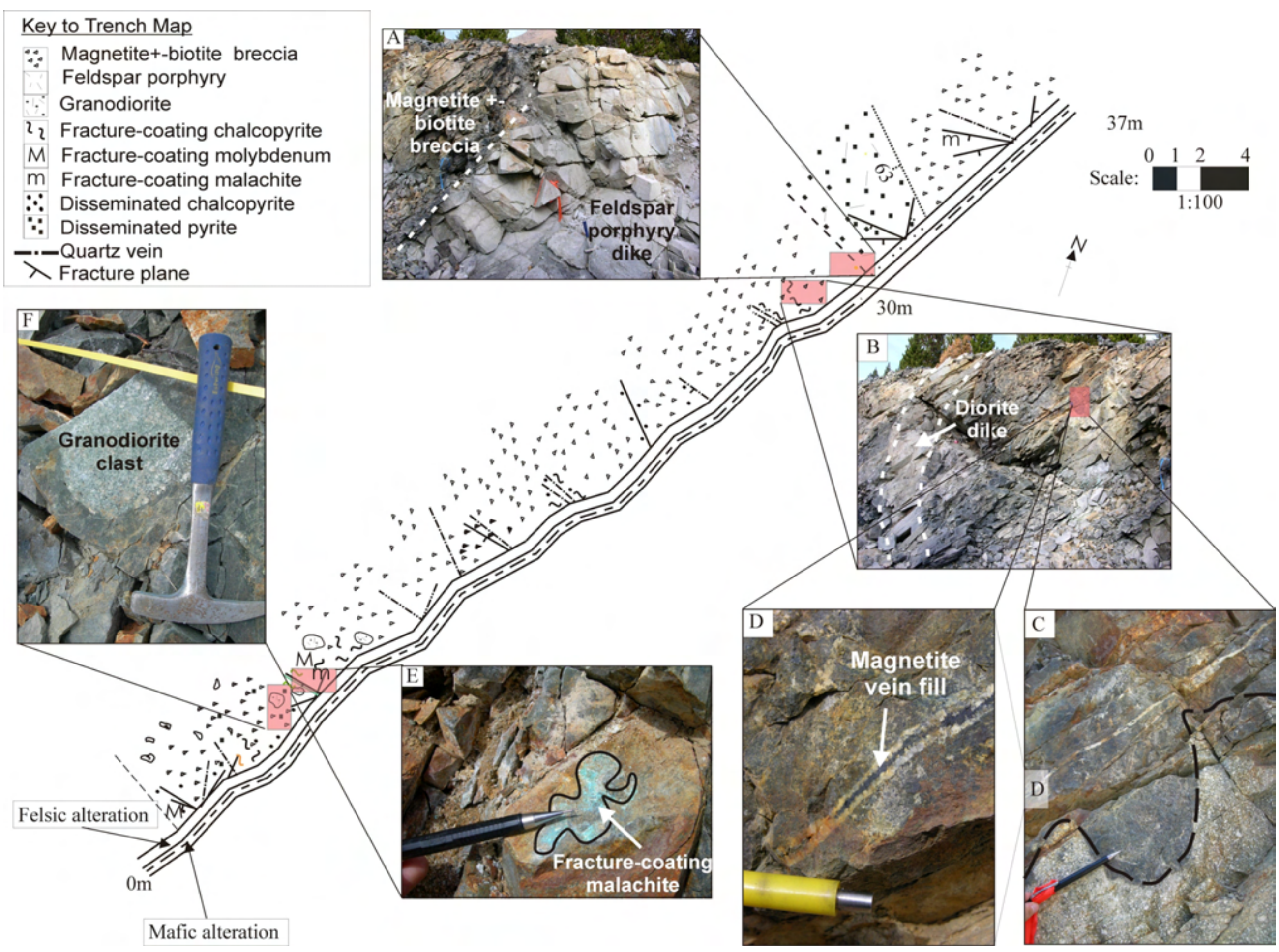

Figure 8. Geology of the Hub trench area, showing locations of photographs: A) lithological contact between magnetite±biotite-cemented breccia and feldspar porphyry dike; B) lithological contact between diorite dike and magnetite±biotite-cemented breccia; C) undulating contact between magnetite breccia and granodiorite; D) quartz vein with magnetite central vein fill; E) fracture-coating malachite on fracture plane; and F) granodiorite clast included within magnetite±biotite-cemented host rock.

breccia. Together, these rock types account for more than 90% of the observed outcrop (Fig 8B, C).

Several felsic dikes crosscut both the granodiorite and the magnetite breccia. These include an intermediate plagioclase-phyric dike with abundant biotite and a late, quartz-feldspar porphyry dike (Fig 8A, B). Part of the future work will be to ascertain whether the magnetite breccia is a replacement or forms as a breccia infill. The granodiorite and magnetite±biotite-cemented breccia are cut by 1.5 cm thick quartz veins that are filled with aphanitic magnetite (Fig 8D).

Mineralization is consistently focused on randomly oriented fracture planes, where fracture-coating chalcopyrite±pyrite is the dominant form of sulphide and often occurs in association with malachite (Fig 8E). The late feldspar porphyry dike contains up to 7% disseminated pyrite and is the most mineralized lithology observed toward the south (Fig 8A). Mineralization is interpreted to increase in concentration to the north, where molybdenite and chalcopyrite are found in association with centimetre-scale quartz veins. These veins show a relative history of emplacement: intrusion of granodiorite, magnetite±biotite-cemented breccia, quartz veins and finally emplacement of the quartz-feldspar porphyry dike.

Northwest Copper Showing

The Northwest Copper showing hosts numerous subcropping quartz-carbonate veins, most of which are not mineralized but may form part of the hypothesized epithermal system.

A 30 m wide, irregular subcropping zone of secondary copper mineralization, consisting of malachite and azurite, occurs at one of the north-northeast-trending ridges (informally known as Ravioli ridge). Associated with these oxides is considerable secondary silica replacement of the hostrocks, which could be interpreted as the result of mobilization of silica and subsequent formation of copper minerals in oxidized zones. Associated with this zone is an 8 m wide zone of silicified vein material containing magnetite infillings. To the southwest, dark green, propylitically altered andesite of the Powell Creek Formation hosts minor disseminated pyrite. Copper oxide mineralization (usually malachite) is distributed sporadically in centimetre-scale coatings throughout the Powell Creek Formation. The malachite mineralization is associated with the highest density of quartz-carbonate veining and is typically associated with maroon, plagioclase-phyric andesite flows.

DISCUSSION AND FUTURE WORK

The economic potential for copper in the area was first identified in the early 1930s and, since then, several prospects have been identified, including the Late Cretaceous Prosperity deposit (formerly known as the Fish Lake deposit), Taseko Empress and Chita showings. The Prosperity deposit is a low-grade Cu-Au resource located approximately 30 km north of field area (Caira *et al.*, 1995). It is hosted in quartz diorite and Early Cretaceous andesite, which are typically associated with quartz-feldspar porphyry dikes (Caira *et al.*, 1995).

The Prosperity deposit displays many similarities to the study area, including the presence of potassically altered rock (characterized by replacement of mafic minerals by biotite), the development of propylitic and phyllic alteration zones, and possibly a similar age of mineralization.

The Twin Creek area hosts several mineral occurrences previously identified by McLaren (1990). Anomalous Cu, Mo and Au values have been identified from prospecting and stream sediment samples. Many of the anomalous Au values have been found proximal to the Twin Creek fault. Whether the mineralization has any relation to the fault has yet to be determined and is a topic of ongoing research.

Continuing research will include extensive U-Pb and Ar/Ar dating of rock units and fault zone materials, in order to better constrain dates of both deformation and mineralization. For example, what is the role of deformation in localizing and/or offsetting mineralization in the field area? Detailed studies of rock types, mineralization and alteration assemblages in both mineralized areas and fault zones will be carried out in an attempt to determine any relationship that exists between fault zone fluids and mineralizing fluids. Samples from fault zones will also be further studied, in order to better understand the kinematics of fault movement and the physical conditions of deformation.

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