# Geological setting of the Granite Mountain batholith, south-central British Columbia

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**Abstract**

The Granite Mountain mapping project, initiated in 2013 and continued in 2014, was implemented to clarify the contact relationships and terrane affinity of the Granite Mountain batholith (Late Triassic), host to the Gibraltar porphyry Cu-Mo deposit. The batholith is included in Quesnel terrane because, on its northeast margin, it intrudes the slightly older Burgess Creek stock, which itself intrudes an assemblage of Upper Triassic sedimentary and volcanic rocks correlated with the Nicola Group, the defining stratigraphic unit of Quesnel terrane. These Nicola rocks have yielded Late Triassic conodonts from one locality, and consist mainly of volcanogenic sandstone (locally gritty to pebbly), intercalated with conglomerate, mafic and felsic volcanic breccia, siltstone, limestone and basalt. The Nicola rocks, and possibly the northern part of the Granite Mountain batholith, are overlain by a younger assemblage that includes slate, siltstone, sandstone and conglomerate, and is correlated with the Dragon Mountain succession (Lower to Middle Jurassic), another characteristic element of Quesnel terrane. A narrow belt of rocks along the southwest margin of the Granite Mountain batholith is assigned to the Cuisson Lake unit. It consists mainly of chlorite schist, foliated limestone and skarn, and was derived from a succession of feldspathic volcaniclastic ±volcanic rocks intercalated with limestone. These rocks were previously included in the Cache Creek Complex, but herein are correlated with the Nicola Group. The Granite Mountain batholith, and rocks of the Nicola Group, Cuisson Lake unit, Burgess Creek stock, and Dragon Mountain succession, form a panel of Quesnel rocks that is bounded to the east and south by rocks of Cache Creek terrane. The eastern boundary is an unexposed north-northwest striking fault that may record more than 20 km of sinistral strike slip. The southern boundary of the Quensel panel is an east- trending fault that juxtaposes the Cuisson Lake unit against Early Cretaceous tonalite of the Sheridan Creek stock, which apparently intrudes Cache Creek rocks farther south. This structure is inferred to be a south-dipping thrust or reverse fault that formed in conjunction with greenschist facies metamorphism and the development of south-dipping foliations in the Sheridan Creek stock, the Cuisson Lake unit, and the southern part of the Granite Mountain batholith.

**Keywords:** Granite Mountain batholith, Burgess Creek stock, Late Triassic, tonalite, diorite, Nicola Group, Cache Creek Complex, Dragon Mountain succession, Sheridan Creek stock, Gibraltar porphyry Cu-Mo deposit, Quesnel terrane, Cache Creek terrane

## 1. Introduction

In 2013, the British Columbia Geological Survey initiated a two-year bedrock-mapping project to clarify the geological setting, terrane affinity, and structural history of the Granite Mountain batholith (Late Triassic), which hosts the Gibraltar porphyry Cu-Mo deposit (Fig. 1). This project builds on the work of Ash et al. (1999a, b), who challenged the long-held view (Drummond et al., 1976; Bysouth et al., 1995) that the Granite Mountain batholith was part of Cache Creek terrane. Instead, Ash et al. (1999a, b) proposed that the batholith is part of Quesnel terrane, and that it was juxtaposed against Cache Creek rocks along post-Triassic faults. Furthermore, Ash et al. (1999a, b) argued that ductile shear zones in the Gibraltar deposit formed during this post-Triassic deformation, suggesting that Gibraltar might not be a porphyry deposit, or at least that mineralization had been significantly remobilized.

Mapping in 2013 covered a small area on the northeast margin of the Granite Mountain batholith, where volcaniclastic rocks that Tipper (1978) assigned to a Jurassic siliciclastic assemblage were re-interpreted by Ash et al. (1999a, b) as Nicola Group (Late Triassic) of Quesnel terrane. The main

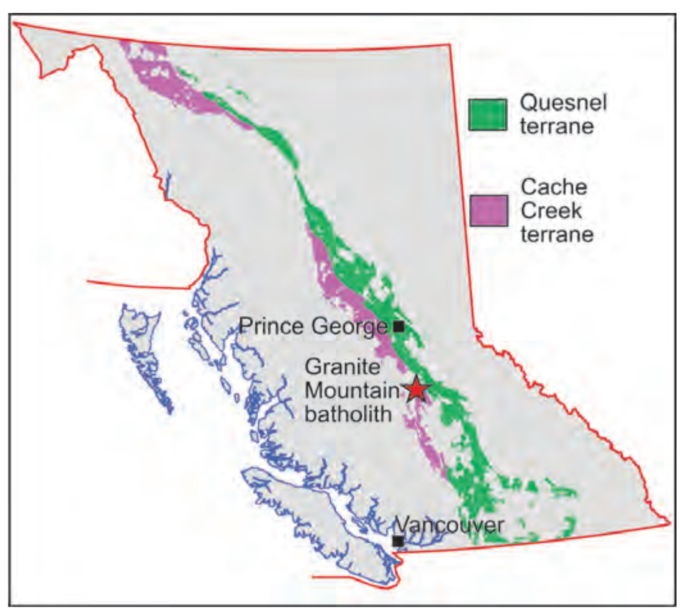


**Fig. 1.** Location of the Granite Mountain batholith and distribution of Quesnel and Cache Creek terranes in British Columbia.

conclusion was that these rocks are part of the Nicola Group (Schiarizza, 2014). Mapping in 2014 encompassed the entire Granite Mountain batholith, including rocks that are in contact with it to the north, east and south (Fig. 2), and confirmed that the Granite Mountain batholith is in a panel of Quesnel terrane.

## 2. Regional setting

The Granite Mountain batholith outcrops on the Fraser Plateau, seven to eighteen kilometres east of the Fraser River, within the traditional territories of the Northern Secwepemc te Qelmucw and Tsilhqot'in First Nations (Fig. 2). The community of McLeese Lake, on Highway 97, is 10 km south-southwest of the Gibraltar ore deposits, and is linked to the mine site by paved road. Networks of logging and Forest Service roads occur throughout the region and provide good access to most parts of the Granite Mountain map area.

Previous studies that have contributed to the geologic interpretation of the Granite Mountain area include: regional mapping of the Quesnel River (93B) map area by Tipper (1959, 1978); geological mapping of the Granite Mountain batholith by Panteleyev (1978) and Ash et al. (1999a, b); and detailed studies of geology and mineralization within and near the Gibraltar deposits by Sutherland Brown (1958, 1967, 1974), Eastwood (1970), Simpson (1970), Drummond et al. (1973, 1976), Bysouth et al. (1995), Raffle (1999), Ash and Riveros (2001), Oliver et al. (2009), Harding (2012), van Straaten et al. (2013), and Mostaghimi et al. (2014).

Quesnel terrane is an important metallogenic province that occurs along most of the length of the Canadian Cordillera (Fig. 1; Nelson et al., 2013). It is characterized by a Late Triassic to Early Jurassic magmatic arc complex that formed along or near the continental margin of western North America. Quesnel terrane is flanked to the east by Proterozoic and Paleozoic siliciclastic, carbonate, and volcanic rocks of pericratonic affinity and locally, an intervening marginal basin assemblage comprising mid to Late Paleozoic oceanic basalt and chert of Slide Mountain terrane. Late Paleozoic through mid-Mesozoic oceanic rocks of Cache Creek terrane are west of Quesnel terrane, and are interpreted as part of the accretion-subduction complex that was responsible for generating the Quesnel magmatic arc.

At the latitude of McLeese Lake, rocks of Quesnel terrane crop out mainly in a northwest-trending, 30 km-wide belt, 20 km east of the Granite Mountain batholith (Fig. 2). The terrane is represented mainly by Middle to Upper Triassic volcanic and sedimentary rocks of the Nicola Group, together with abundant Late Triassic to Early Jurassic calcalkaline and alkaline intrusions (Logan et al., 2010). Lower to Middle Jurassic siliciclastic sedimentary rocks along the western margin of the terrane, assigned to the Dragon Mountain succession (Logan and Moynihan, 2009), were derived from, and deposited on, Quesnel terrane (Petersen et al., 2004; Logan and Moynihan, 2009).

The Cache Creek Complex includes exposures of chert, argillite, basalt, limestone, sandstone, gabbro, and serpentinite west of the main Quesnel belt (Logan et al., 2010). The complex is not well dated in the McLeese Lake area, although one limestone exposure, 10 km east of the southern part of the Granite Mountain batholith, yielded Permian fossils (Tipper, 1978). Contiguous, but better-studied parts of the Cache Creek Complex to the south and north, include rocks ranging from Carboniferous to Early Jurassic (Cordey and Read, 1992; Read, 1993; Struik et al., 2001).

The Granite Mountain batholith is exposed north of McLeese Lake. It occurs west of the main Quesnel terrane belt, but is inferred to comprise the south end of a separate, north-trending panel of Quesnel rocks that is faulted against Cache Creek terrane to the east and south (Fig. 2). This panel also includes Late Triassic volcaniclastic and volcanic rocks correlated with the Nicola Group, exposed on the northeast margin of the Granite Mountain batholith, and conglomerates and finer-grained rocks correlated with the Lower to Middle Jurassic Dragon Mountain succession.

Granitic rocks that postdate the Late Triassic-Early Jurassic intrusions of Quesnel terrane include Middle Jurassic plutons within Quesnel and Cache Creek terranes north and northeast of the Granite Mountain batholith, and Early Cretaceous stocks in Cache Creek terrane south of the batholith (Fig. 2). The youngest rocks in the region include Eocene volcanic and local sedimentary rocks, Oligocene-Pliocene siliciclastic sequences along parts of the Fraser River, and widespread Miocene-Pleistocene basalt of the Chilcotin Group (Fig. 2).

## 3. Geologic units of the Granite Mountain area

The Granite Mountain area (Fig. 3) is underlain mainly by a north-trending belt of rocks assigned to Quesnel terrane, including the Nicola Group (Middle and Upper Triassic), the Burgess Creek stock (Late Triassic), the Granite Mountain batholith (Late Triassic), and the Dragon Mountain succession (Lower to Middle Jurassic). Rocks included in the Cache Creek Complex (Cache Creek terrane) form a poorly exposed belt east of the Quesnel rocks. A narrow belt of rocks, mainly chlorite schist, limestone, and skarn, along the south and southwest margin of the Granite Mountain batholith is referred to as the Cuisson Lake unit, and is tentatively correlated with the Nicola Group. Early Cretaceous tonalite of the Sheridan Creek stock is the southernmost unit in the map area, and is in fault contact with the Cuisson Lake unit and the Granite Mountain batholith.

### 3.1. Nicola Group

Rocks reassigned to Nicola Group on lithostratigraphic grounds (Ash et al., 1999a; Schiarizza, 2014) are exposed in the northern part of the map area, where they are cut by the Burgess Creek stock and are overlain, structurally and/or stratigraphically, by the Dragon Mountain succession (Fig. 3). Originally, the Nicola rocks were included in the upper (Lower to Middle Jurassic) part of the Quesnel River Group by Tipper (1978), and were assigned to an unnamed unit of suspected Early Jurassic age by Panteleyev (1978).

In the map area, the Nicola Group consists of sandstone

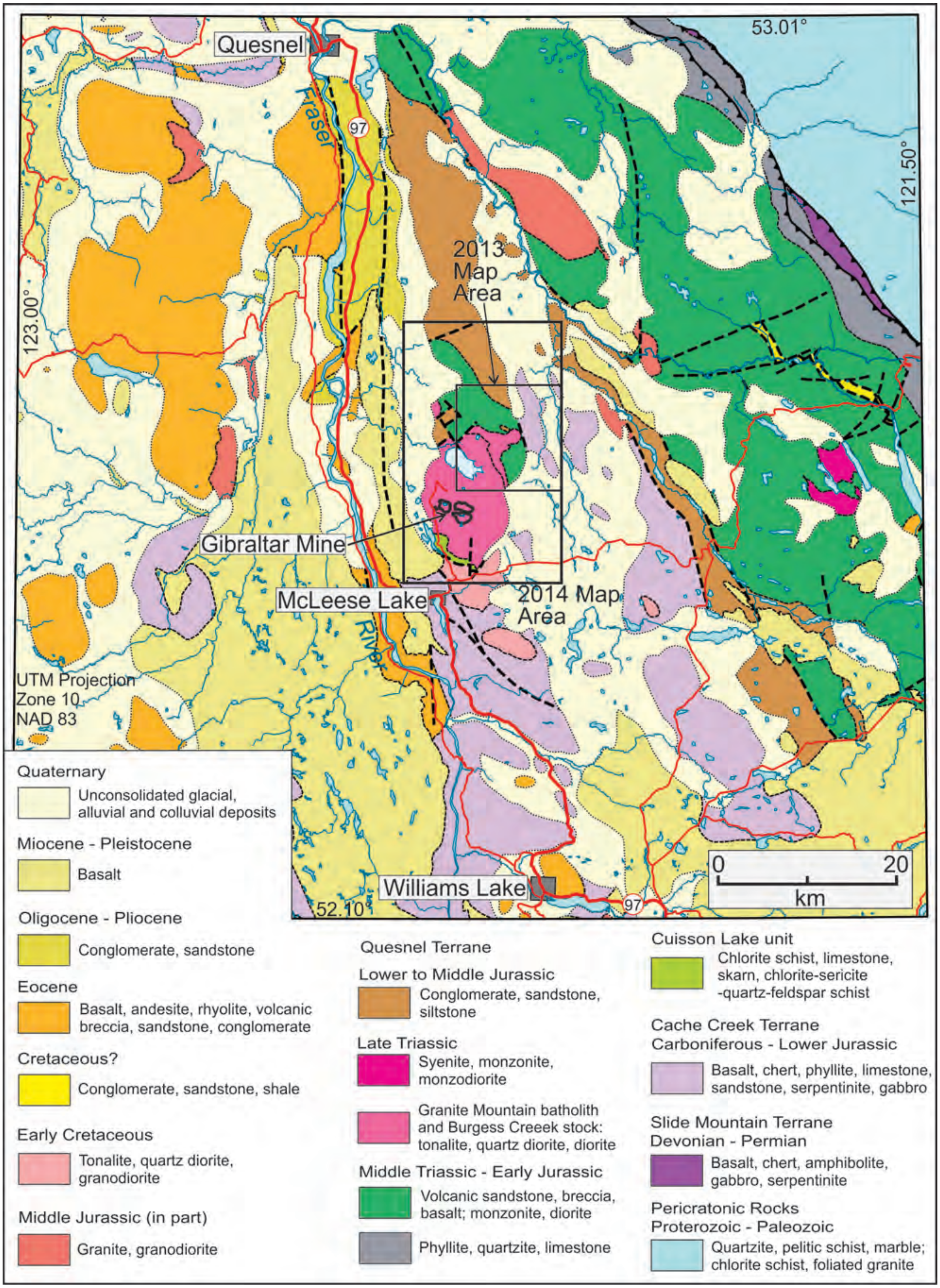


**Fig. 2.** Geological map of the area between Williams Lake and Quesnel, showing the location and setting of the Granite Mountain batholith.

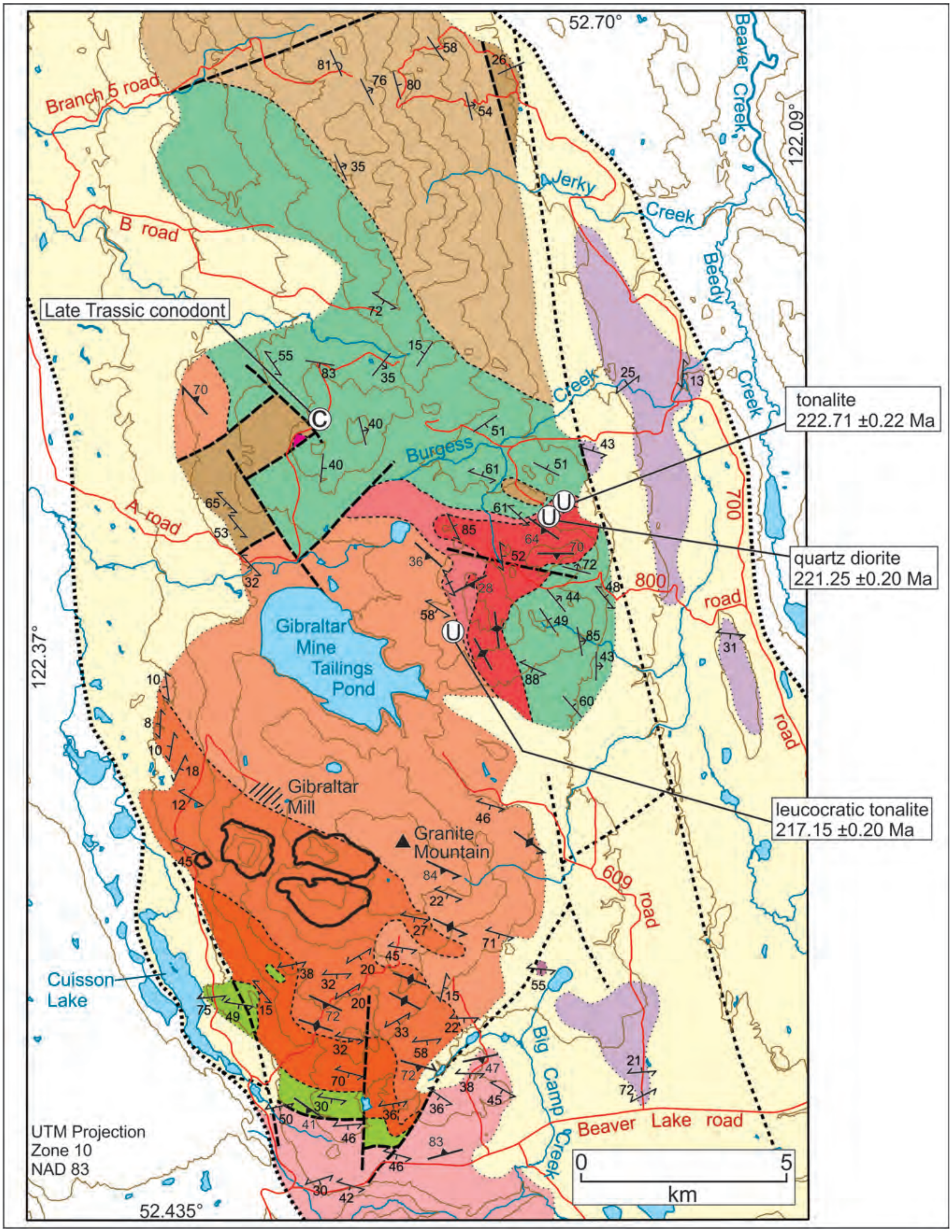


**Fig. 3a.** Geology of the Granite Mountain map area, based on 2013 and 2014 fieldwork. U-Pb zircon ages from Richard Friedman, University of British Columbia, written communication March 2014; conodont identification by M.J. Orchard, Geological Survey of Canada, written communication April 2014. Heavy black lines delineate Gibraltar mine pit areas.

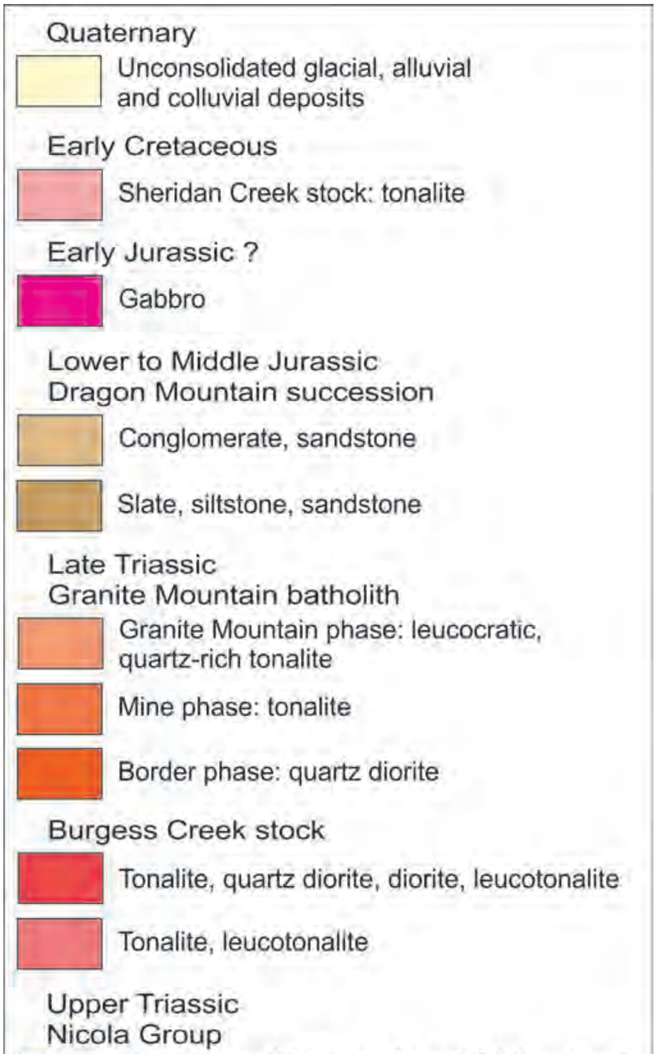


**Fig. 3b.** Legend for Fig. 3a.

and gritty to pebbly sandstone, with local intercalations of conglomerate, mafic and felsic volcanic breccia, siltstone, limestone, and basalt (Schiarizza, 2014). Most of the group was mapped in 2013; the 2014 program expanded the known Nicola Group distribution a few km northward (Fig. 3) where small scattered outcrops of green feldspathic sandstone, gritty to pebbly sandstone, and conglomerate are typical of the predominant rock types in better exposed sections to the south (see Schiarizza, 2014 for detailed descriptions).

Paleontologic and geochronologic data corroborate assigning these rocks to the Nicola Group. Five limestone samples collected during the 2013 field season were processed for conodonts at the Geological Survey of Canada's microfossil laboratory in Vancouver. One of these samples, collected 4 km north of the Gibraltar tailings pond (Fig. 3), from a unit comprising narrow limestone lenses interleaved with green volcanic sandstone (Fig. 4), yielded a single conodont fragment, identified as *Norigondolella* cf. *navicula*, of probable Lower Norian age (M.J. Orchard, Geological Survey of Canada, written communication, April 2014). Furthermore, a sample collected by Jim Logan (British Columbia Geological Survey) from this same locality in 2005 yielded a conodont fragment of Middle or Late Triassic age (Orchard, 2006; GSC Loc. No. C-307484). Moreover, samples from the Burgess Creek stock, which clearly intrudes the sedimentary succession (Schiarizza, 2014), have yielded Late Triassic U-Pb zircon ages (Fig. 3; see below), demonstrating that the rocks reassigned to the Nicola Group are pre-Jurassic.

### 3.2. Burgess Creek stock

The Burgess Creek stock comprises a heterogeneous assemblage of tonalites, quartz diorites, and diorites that intrude the Nicola Group on the northeast margin of the Granite Mountain batholith (Fig. 3). The stock was first mapped and named by Panteleyev (1978) who considered it to be younger than the Granite Mountain batholith. Bysouth et al. (1995) also

**Fig. 4.** Nicola Group limestone interleaved with green volcanic sandstone, 4 km north of the Gibraltar tailings pond.

mapped it as a younger unit, but Ash et al. (1999a, b) concluded that these rocks were part of the batholith, and referred to them as border phase quartz diorite (unit EJGb). Schiarizza (2014) mapped the Burgess Creek stock and Granite Mountain batholith as separate entities, but did not establish which was older. U-Pb zircon geochronology on samples collected during the 2013 field season show that rocks from the Burgess Creek stock are 4-5 Ma older than the adjacent Granite Mountain phase of the batholith (see below). The term Burgess Creek stock continues to be used herein, although it could be considered a relatively old border phase of the batholith, as suggested by Ash et al. (1999a, b).

The Burgess Creek stock was shown as a single unit by Schiarizza (2014), but here is subdivided into two units: a mixed unit that includes tonalite, quartz diorite and diorite phases; and a tonalite unit consisting almost entirely of leucocratic tonalite (Fig. 3). The mixed unit includes most rocks assigned to the Burgess Creek stock by Schiarizza (2014). The tonalite unit partially envelops the mixed unit to the west, northwest and north, and includes some rocks previously assigned to the stock, and some, in the northwest, that were previously included in the Granite Mountain batholith (Schiarizza, 2014).

The tonalite unit consists of light grey, light grey-weathered, medium- to coarse-grained, equigranular hornblende-biotite tonalite. It is typically leucocratic, with 7-10% mafic minerals (hornblende > biotite), 30-40% quartz, and 50-60% plagioclase, although varieties with up to 15% mafic minerals are not uncommon. Leucotonalite, with only a few per cent chloritized mafic grains, forms local narrow dikes or poorly-defined patches with indistinct contacts with the enclosing tonalite.

The mixed unit of the Burgess Creek stock includes tonalite, quartz diorite, diorite and leucotonalite. Tonalite is predominant, and includes leucocratic varieties, very similar to those of the tonalite unit, as well as darker varieties that contain up to 30% mafic minerals (Fig. 5). A less abundant, but equally widespread, phase comprises greenish-grey, light brownish-grey-weathered, medium- to coarse-grained hornblende-biotite quartz diorite. It typically contains 20-30% mafic minerals, 5-10% quartz, and 60-70% plagioclase, but quartz content is highly variable, such that some rocks are diorites and others are mafic tonalites. Locally, this phase contains irregular mafic patches several centimetres to tens of centimetres in size, consisting mainly of hornblende and magnetite, intergrown with minor amounts of quartz and plagioclase. A third component of the mixed unit comprises fine-grained diorite, consisting of hornblende (30-40%) and plagioclase. It is most common as screens and xenoliths within tonalite, but is the main rock type in some exposures along the southeast margin of the stock. It is typically equigranular, but locally displays a porphyritic texture, with phenocrysts of hornblende and/or plagioclase scattered through a fine-grained dioritic groundmass. The youngest component of the mixed unit is leucotonalite, which occurs as dikes, commonly 1-30 cm thick but locally much thicker, that cut all other rock types. The dikes consist of quartz and plagioclase with only a few per cent chloritized mafic minerals. They display a variety of textures, including fine-grained aplitic, coarse-grained with pegmatitic patches, and porphyritic, comprising phenocrysts of quartz ±plagioclase ±hornblende in a fine-grained leucotonalite groundmass.

**Fig. 5.** Mafic tonalite, mixed unit, northwestern part of the Burgess Creek stock.

A sample of leucocratic tonalite, collected from the tonalite unit along the northeast margin of the Burgess Creek stock yielded a U-Pb zircon age of 222.71 ±0.22 Ma, and a sample of quartz diorite, collected from the mixed unit 350 m to the southwest, yielded a U-Pb zircon age of 221.25 ±0.20 Ma (Richard Friedman, University of British Columbia, written communication March 2014). These determinations establish a Late Triassic age for the Burgess Creek stock. The fact that the tonalite yielded an older age than the quartz diorite was unexpected, as tonalites within the mixed unit, which are similar in appearance to the dated tonalite of the tonalite unit, commonly display crosscutting relationships indicating they are younger than the quartz diorite phase. The radiometric ages suggest there are tonalites of multiple ages within the stock.

The Burgess Creek stock is in contact with the Nicola Group to the north and southeast, and with the Granite Mountain phase of the Granite Mountain batholith to the west. The stock cuts across Nicola Group stratigraphy, and an intrusive contact is exposed in an outcrop along its southern margin near the east end of the stock. This intrusive relationship is corroborated by observations elsewhere, including dikes of tonalite and quartz diorite cutting the Nicola Group near the contact, xenoliths of Nicola rock in the stock near the contact, and a zone of skarn-altered rocks in the Nicola Group along the southeastern margin of the stock (Schiarizza, 2014). The contact between the Burgess Creek stock and the Granite Mountain batholith is well constrained east of the Gibraltar tailings pond. Although the contact is covered, indications of faulting are lacking, and the Granite Mountain phase is inferred to cut the Burgess Creek stock on geochronologic grounds (Fig. 3; see below).

### 3.3. Granite Mountain batholith

The Granite Mountain batholith is mainly exposed in a northwest elongate, 15 x 10 km, elliptical area (Fig. 3). As recognized by previous workers (Panteleyev, 1978; Ash et al., 1999a, b; Bysouth et al., 1995), the batholith is subdivided into three northwest-trending map units that become progressively more felsic from southwest to northeast. The units, following the terminology of Bysouth et al. (1995) are: Border phase (quartz diorite); Mine phase (tonalite); and Granite Mountain phase (leucocratic tonalite). A fourth phase, also recognized by previous workers, comprises leucotonalite, which occurs as dikes that intrude all three map units.

A large part of the batholith, including the Gibraltar open pits, the tailings pond, and all the area in between, was not examined in this study because of industrial activity related to the Gibraltar Mine. The contact between the Mine phase and the Granite Mountain phase in this area is based on the map of Ash et al. (1999b).

**Fig. 6.** Quartz diorite, Border phase of the Granite Mountain batholith, 3.8 km east-southeast of the south end of Cuisson Lake.

#### 3.3.1. Border phase

The Border phase consists mainly of light to medium greenish-grey, brownish-grey-weathered, medium- to coarse-grained quartz diorite, locally grading to diorite or tonalite. It consists of saussuritic plagioclase accompanied by 25-40% chloritized hornblende, and 2-15% quartz. Textures are equigranular, typically weakly to strongly foliated, and rarely isotropic (Fig. 6). In two isolated exposures, several km apart, the unit comprises complex mixtures of fine, medium and coarse-grained hornblende diorite to quartz diorite, cut by veins and dikes of leucocratic quartz diorite. Elsewhere, the quartz diorite typically displays a uniform composition at the scale of an individual outcrop, although it is commonly cut by dikes of the leucotonalite phase.

**Fig. 7.** Tonalite, Mine phase of the Granite Mountain batholith, 3 km southeast of the Granite Lake pit.

#### 3.3.2. Mine phase

The Mine phase occurs northeast of the Border phase, and hosts the orebodies at the Gibraltar Mine. It comprises medium- to coarse-grained, equigranular, isotropic to well-foliated tonalite, commonly with 15-25% chloritized mafic grains (mainly or entirely hornblende) and 25-30% quartz, together with saussuritic plagioclase, sericite and epidote (Fig. 7). More mafic varieties, with 25-35% chloritized mafic minerals and 15-25% quartz are common in the southeastern part of the unit, and leucocratic rocks, with 15% mafic grains and subequal proportions of quartz and plagioclase occur locally near the contact with the Granite Mountain phase. Compositions are typically uniform in any given area, but a few outcrops in the southeastern part of the unit contain complex mixtures of different tonalite phases, defined by variations in grain size and modal abundance of quartz and mafic minerals. Contacts with the border phase are not well exposed, but Mine phase tonalites near the contact are generally mafic-rich and quartz-poor, suggesting it is gradational.

Oliver et al. (2009) reported that a sample of Mine phase tonalite yielded a U-Pb zircon laser ablation age of 211.9 ±4.3 Ma. To establish more precise crystallization ages, samples collected in 2014 have been submitted for U-Pb zircon geochronology using the CA -TIMS method (Chemical Abrasion-Thermal Ionization Mass Spectroscopy).

#### 3.3.3. Granite Mountain phase

The Granite Mountain phase is the predominant component of the Granite Mountain batholith, forming more than half its areal extent. It comprises light grey, light grey to white-weathered, isotropic to well-foliated, coarse-grained leucocratic tonalite. A typical rock in the southern part of the unit contains approximately equal proportions of quartz and plagioclase, and 10-12% chloritized mafic minerals (Fig. 8). To the north, quartz is slightly more abundant than plagioclase, and commonly forms very coarse (8-12 mm) aggregates. These quartz-rich tonalites commonly have 5-10% mafic minerals, with more biotite than hornblende.

**Fig. 8.** Leucocratic tonalite, Granite Mountain phase of the Granite Mountain batholith, 450 m southeast of Granite Mountain.

The contact between the Granite Mountain and Mine phases appears to be gradational where it is fairly well constrained southeast of the Gibraltar mine. A traverse from the Granite Mountain phase (10% mafics, equal proportions of plagioclase and quartz) into the Mine phase shows, first, a slight increase in mafic content (15% mafics, equal proportions of plagioclase and quartz), and then a further increase in mafic content coupled with a decrease in quartz (20% mafics, 35% quartz, 45% plagioclase). The Granite Mountain phase is differentiated from the tonalite unit of the Burgess Creek stock (equally leucocratic), because the latter unit has less quartz and is finer grained.

Exposures of leucocratic tonalite 5 km north-northwest of the Gibraltar tailings pond are tentatively assigned to the Granite Mountain phase, but are separated from the main part of the Granite Mountain batholith by a fault-bounded block containing exposures of the slate-sandstone unit of the Dragon Mountain succession. This outlier may be connected to the main part of the batholith at depth, because a vertical diamond drill hole collared in Dragon Mountain rocks in the west-central part of the fault block extended through the sedimentary succession to end in tonalite that was correlated with the Granite Mountain phase (Barker and Grubisa, 1994, Hole 94-3).

A sample of coarse-grained, quartz-rich leucocratic tonalite, collected from the Granite Mountain phase west of the Burgess Creek stock in 2013, yielded a U-Pb zircon CA-TIMS age of 217.15 ±0.20 Ma (Fig. 3; Richard Friedman, University of British Columbia, written communication March 2014). Ash and Riveros (2001) reported that the Granite Mountain batholith has a magmatic age of 215 ±0.8 Ma, apparently from a U-Pb zircon determination on a sample collected from the Granite Mountain phase 1.5 km north-northeast of the Gibraltar mill site (Ash et al., 1999a). Oliver et al. (2009) reported that a sample from the Granite Mountain phase yielded a U-Pb zircon laser ablation age of 209.6 ±6.3 Ma.

### 3.3.4. Leucotonalite dikes

Leucotonalite dikes with a variety of textures, but characterised by low (0-5%) mafic content, are a ubiquitous but volumetrically minor component of the Granite Mountain batholith, and are found in all three map units. They are commonly equigranular, fine (aplitic) to coarse-grained, variably oriented, and a few centimetres to tens of centimetres thick (Fig. 9). Porphyritic varieties contain quartz ±plagioclase phenocrysts, several mm in size, in a groundmass of mainly finer quartz and plagioclase. Thick quartz-plagioclase porphyry units, several tens of metres wide, occur locally in the Border phase and Mine phase.

Ash and Riveros (2001) reported that leucotonalite dikes in the Pollyanna pit of the Gibraltar Mine yielded a U-Pb age of 212 ±0.4 Ma, without providing details. A sample collected in 2014, from a thick quartz-plagioclase porphyry dike that cuts Mine Phase tonalite 4 km southeast of the Gibraltar Mine, was submitted for U-Pb zircon geochronology using CA-TIMS.

## 3.4. Dragon Mountain succession

Lower to Middle Jurassic sedimentary rocks in the region that were included in the upper part of the Quesnel River Group by Tipper (1978), were referred to as the Dragon Mountain succession by Logan and Moynihan (2009). The succession is well represented by a belt of exposures that extends from near Quesnel southward to the northern part of the Granite Mountain map area (Fig. 2). Logan and Moynihan (2009) showed that, near Quesnel, these rocks rest stratigraphically above the Nicola Group. They subdivided the Dragon Mountain succession into two units: a lower unit of mainly phyllite and siltstone; and an upper unit of predominantly conglomerate. These same two units are recognized in the Granite Mountain map area.

### 3.4.1. Slate-sandstone unit

The slate-sandstone unit is juxtaposed against the Nicola Group and the Granite Mountain batholith in a fault-bounded

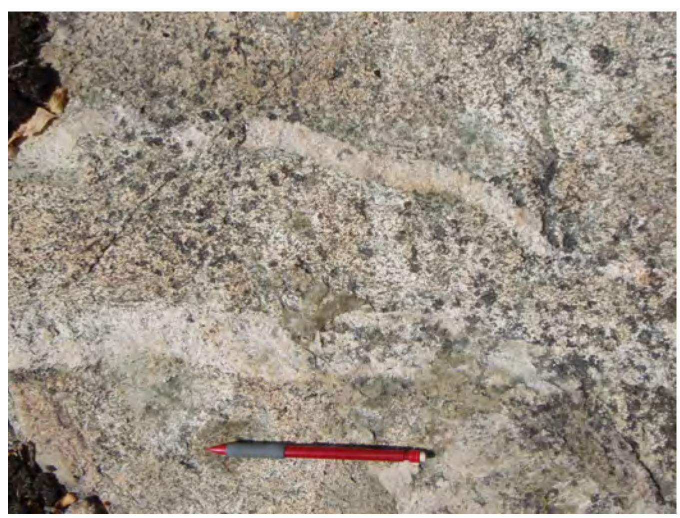

**Fig. 9.** Leucotonalite dikes cutting Mine phase tonalite, Granite Mountain batholith, 2.5 km southeast of the Granite Lake pit.

block north-northwest of the Gibraltar tailings pond; forms a small outlier north of the Burgess Creek stock; and is exposed in a narrow fault-bounded sliver against the conglomerate unit at the north end of the 700 road (Fig. 3). The unit consists mainly of dark grey slate with laminae and thin interbeds of lighter grey siltstone and, less commonly beds of fine- to medium-grained yellowish-brown-weathered quartz-rich sandstone (Fig. 10). Locally, in the fault block northwest of the Gibraltar tailings pond, the unit also includes poorly defined beds of pebble conglomerate. The conglomerate contains subrounded to subangular clasts of intermediate to mafic volcanic rock, quartz-phyric rhyolite, and uncommon fine- to medium-grained tonalite. The clasts are supported by a mixed matrix that includes foliated sericite and chlorite, and sand-sized quartz, feldspar and rock fragments.

The basal contact of the slate-sandstone unit is not exposed in the Granite Mountain map area, but the small outlier north of the Burgess Creek stock is inferred to rest unconformably above the Nicola Group, and the rocks north-northwest of the Gibraltar tailings pond are, at least in part, above the Granite Mountain batholith. The latter interpretation is based on a diamond drill hole in the west-central part of the fault block, which was collared in Dragon Mountain rocks but extended through the sedimentary succession to end in tonalite correlated with the Granite Mountain phase (Barker and Grubisa, 1994, Hole 94-3). The slate-sandstone unit is undated in the Granite Mountain map area, but 13 km to the north, along the French Creek road, it contains Early Jurassic (Late Pliensbachian) fossils (Petersen et al., 2004; Logan and Moynihan, 2009).

**Fig. 10.** Decimetre- to mm-scale sandstone-siltsone-mudstone fining-upward sequences with abundant soft-sediment deformation structures; slate-sandstone unit of the Dragon Mountain succession, 550 m north of the Burgess Creek stock.

**Fig. 11.** Conglomerate, Dragon Mountain succession, conglomerate unit, north end of the 700 road.

### 3.4.2. Conglomerate unit

The conglomerate unit of the Dragon Mountain succession forms a single northwest trending belt in the northern part of the map area. Rocks in the belt dip and young to the east. They occur above the Nicola Group, exposed to the southwest, and are apparently truncated to the east by an unexposed north-northwest trending fault that separates them from the Cache Creek Complex. In contrast to the Nicola Group the unit consists of coarse conglomerate over stratigraphic intervals of many hundreds of metres and contains a highly diverse clast suite, including coarse-grained tonalite. Green feldspathic sandstone, which forms 10-15% of the unit, is not readily distinguished from sandstones in the underlying Nicola Group.

The conglomerates generally weather to a light brown or brownish-green, but locally are light purplish-grey. They contain angular to subrounded pebbles and cobbles in a sandy matrix that includes feldspar, quartz and lithic grains (Fig. 11). The clasts consist mainly of light grey to green volcanic rocks with various combinations of plagioclase, hornblende and pyroxene phenocrysts, but fine-grained, equigranular, diorite, quartz diorite and tonalite, dark green mafic volcanic rocks and quartz-phyric rhyolite are also represented. Less common clasts include limestone, chert, and coarse-grained equigranular tonalite. The conglomerate forms massive intervals, many tens of metres thick, with little or no apparent stratification. Local well-stratified intervals include thick to very thick beds of moderately sorted pebble-cobble conglomerate, intercalated with thin to medium beds of sandstone, pebbly sandstone and siltstone. These stratified intervals commonly contain graded beds and cut-and-fill features that show tops-to-the-east.

The conglomerate unit dips and youngs to the east-northeast, away from the underlying Nicola Group. The base of the unit is not exposed, and is not well constrained. Of note, however, is the apparent absence of the slate-sandstone unit, which typically forms the base of the Dragon Mountain succession (Logan and Moynihan, 2009). This suggests that the western boundary of the conglomerate unit might be a fault which has cut out the basal part of the succession.

### 3.5. Early Jurassic? gabbro

Dark green, coarse-grained gabbro forms an isolated exposure a short distance southeast of the A road, about 3.6 km north of the Gibraltar tailings pond (Fig. 3). The gabbro displays an isotropic texture and consists of clinopyroxene (70%, 3-6 mm), fewer and smaller plagioclase grains, and 1-2% biotite flakes. Locally it is cut by narrow veins of fine-grained leucocratic diorite. Contacts are not exposed, but the gabbro is apparently in a fault block underlain mainly by the slate-sandstone unit of the Dragon Mountain succession. It is suspected to have intruded these Lower Jurassic rocks, based on correlation with an ultramafic-mafic intrusive unit that intrudes the slate-sandstone unit where it was intersected in exploration diamond drill holes cored 3.5 km to the southwest (Barker and Grubisa, 1994). Similar gabbro is a component of Early Jurassic Alaskan-type ultramafic-mafic intrusive complexes that are scattered throughout Quesnel terrane in central and southern British Columbia (Logan et al., 2010; Schiarizza et al., 2013).

### 3.6. Cache Creek Complex

The Cache Creek Complex underlies the eastern part of the map area, but is not well exposed. Good exposures occur along parts of Burgess Creek, but outcrops elsewhere are small and widely scattered. The exposures consist mainly of chert, limestone and basalt. Chert is most common, is grey to greenish-grey, and occurs as lenses and layers, ≤1-6 cm thick, separated by partings and thin interbeds of grey phyllite or slate (Fig. 12). Limestone is finely crystalline, medium to dark grey, and weathers light or medium grey. Along Burgess Creek it forms centimetre- to metre-scale lenses and layers interleaved with chert, but exposures southeast of the lake at the head of Big Camp Creek may represent a limestone unit many tens of metres thick. Small exposures of medium to dark green, rusty-brown-weathered basalt occur along the 609 road, along Burgess Creek, and in cutblocks south of the Burgess Creek logging road. The latter exposures are heavily altered with carbonate, and locally contain fragments and lenses of grey limestone.

An isolated set of exposures northwest of the small lake at the head of Big Camp Creek (Fig. 3) includes grey chert with a sugary recrystallized texture, and rusty hornfels consisting mainly of actinolite, epidote, biotite and quartz, with disseminated pyrrhotite and pyrite. These rocks are cut by a unit of greenish-grey hornblende-plagioclase porphyry.

### 3.7. Cuisson Lake unit

The Cuisson Lake unit, consisting mainly of chlorite schist, limestone and skarn, forms a narrow belt in the southwestern part of the map area, between the Granite Mountain batholith and the Sheridan Creek stock. These rocks were considered part of the Cache Creek Complex by Drummond et al. (1976), Panteleyev (1978) and Bysouth et al. (1995). Ash et al. (1999a) interpreted the unit as an intensely deformed and recrystallized mafic phase of the Granite Mountain batholith, but Ash and Riveros (2001) revised this interpretation to suggest that it might include both melanocratic phases of the Granite Mountain batholith and basaltic volcanic rocks of the Cache Creek Complex. Most rocks in the unit are well foliated and recrystallized, such that protolith mineralogy and texture are not preserved. Current mapping suggests that the unit is derived mainly from a succession of feldspathic volcaniclastic±volcanic rocks intercalated with limestone that is locally altered to skarn. The unit also includes sericite-chlorite-quartz-plagioclase schists that may have been derived from quartz dioritic intrusive rocks.

The most common component of the Cuisson Lake unit is green, well-foliated schist consisting mainly of fine-grained chlorite, epidote, actinolite, plagioclase, calcite and quartz (Fig. 13). Narrow lenses of epidote-calcite are commonly oriented parallel to the schistosity, and dark green 1-3 mm clots of porphyroblastic actinolite occur locally. Relict grains of plagioclase (< 2 mm) are variably altered with sericite, epidote and calcite and, although common, may only be obvious in thin section. At one locality in the central part of the belt, relict grains of plagioclase (accompanied by rare quartz) display variations in abundance and size that define a vague stratification,

**Fig. 12.** Chert and phyllite, Cache Creek Complex, Burgess Creek.

**Fig. 13.** Chlorite schist, Cuisson Lake unit, 1.8 km east-southeast of the south end of Cuisson Lake.

suggesting derivation from a feldspar-rich siliciclastic rock. A bedded protolith is also suggested at a nearby outcrop, 400 m to the southeast, where the schist locally displays what appear to be primary 1-2 mm laminae.

Light-grey finely crystalline limestone is common in the central and eastern parts of the Cuisson Lake belt, where it forms a series of lenses or layers intercalated with chlorite schist (Fig. 14). Platy foliation within the limestone, concordant to schistosity in adjacent chlorite schists, is defined by narrow partings of chlorite±sericite. Narrow lenses of magnetite and/or specularite skarn, variably mineralized with chalcopyrite, are associated with the limestone in the central part of the belt, forming the Iron Mountain mineral occurrence. Skarn is more extensive in the northwestern part of the belt, east of central Cuisson Lake, where it forms the predominant rock type across the entire width of the unit. The skarn here is massive, contains epidote, actinolite, garnet, chlorite, calcite and quartz (Fig. 15), and is commonly cut by veins containing quartz, chlorite, calcite and epidote.

Light grey to greenish-grey sericite-chlorite-quartz plagioclase schists are a relatively minor component of the Cuisson Lake unit, but occur locally along the entire length of the belt. These schists consist mainly of well-foliated sericite, chlorite and fine-grained recrystallized quartz, but also include single and multiple grains (<2 mm) of relict plagioclase, variably altered with calcite, epidote and sericite. They commonly occur near the contact with the Granite Mountain batholith, and may have been derived from quartz dioritic intrusive rocks.

**Fig. 14.** Limestone, Cuisson Lake unit, 2.2 km east-southeast of the south end of Cuisson Lake.

**Fig. 15.** Skarn, Cuisson Lake unit, 300 m east of central Cuisson Lake.

The contact between the Cuisson Lake unit and the Granite Mountain batholith is not exposed, and is closely constrained in only two places, near the northwest and east ends of the belt. It is suspected to be an intrusive contact because: 1) evidence of faulting where it is closely constrained is lacking; 2) sericite-chlorite-quartz plagioclase schists in the unit may represent quartz dioritic dikes related to the Granite Mountain batholith; and 3) a small exposure of skarn enveloped by quartz diorite, east of the north end of the unit (Fig. 3), may be an enclave of the Cuisson Lake unit within the batholith. The southern contact of the Cuisson Lake unit, with the Sheridan Creek stock, is likewise not exposed, but is inferred to be a south-dipping fault. This interpretation is based mainly on a marked increase in foliation intensity, and local development of mylonitic fabrics, in both units as the contact is approached.

Most previous interpretations correlate the Cuisson Lake unit with the Cache Creek Complex. Observations presented here suggest that it was derived mainly from feldspathic volcaniclastic±volcanic rocks intercalated with limestone. Hence a more likely correlation is with the Nicola Group of Quesnel terrane.

### 3.8. Sheridan Creek stock

Light grey, isotropic to well foliated tonalite in the southern part of the map area is part of the Sheridan Creek stock (Early Cretaceous). Most of the tonalite has a fairly uniform composition, comprising 20% hornblende, 25-35% quartz and 45-55% plagioclase (Fig. 16). It is typically medium grained (2-3 mm grain size), but outsized prismatic hornblende crystals, up to 8 mm long, are characteristic. Fine-grained leucocratic tonalite to quartz diorite locally forms narrow dikes or irregular patches in the predominant tonalite phase, and a relatively melanocratic (25% hornblende) fine- to medium-grained quartz diorite is the main phase at one isolated exposure in the northwestern part of the stock.

The north side of the Sheridan Creek stock is juxtaposed against the Cuisson Lake unit. The contact is not exposed, but is inferred to be a south-dipping fault because south-dipping foliation in both units intensifies, with local development of mylonitic fabrics, as the contact is approached. The stock is apparently hosted by the Cache Creek Complex, which crops out to the east and south (Fig. 2; Ash et al. 1999b), but contacts are not exposed. Ash and Riveros (2001) reported that the stock yielded a U-Pb zircon age of 108.1 ±0.6 Ma.

## 4. Structural geology of the Granite Mountain area

Mesoscopic structural features and contact relationships within the Granite Mountain map area will be discussed in terms of three domains: a northern domain, which includes

**Fig. 16.** Hornblende tonalite, Sheridan Creek stock, 4 km southeast of the lake at the head of Big Camp Creek.

the Nicola Group, Burgess Creek stock and Dragon Mountain succession; a southern domain, which includes the Granite Mountain batholith, the Cuisson Lake unit, and the Sheridan Creek stock; and an eastern domain which comprises the Cache Creek Complex. Subsequent sections will discuss the map-scale faults within the area, and a final section presents a brief structural synopsis which places the structures in a regional context.

The structural geology of the Gibraltar mine, which was not examined during the present study, is not discussed. A detailed structural analysis of the Gibraltar deposit is ongoing (Mostaghimi et al., 2014).

### 4.1. Northern domain

The southern part of the Nicola Group comprises a fairly uniform, right-way-up homoclinal panel that dips at moderate angles to the east-northeast (Fig. 3). This panel is crosscut at a high angle by the eastern part of the Burgess Creek stock. Bedding orientations are more variable in the poorly-exposed central and northern parts of the Nicola belt, indicating structural complications that are not understood. The Nicola Group is overlain to the northeast, structurally or stratigraphically, by the conglomerate unit of the Dragon Mountain succession which, like Nicola rocks to the south, forms a homoclinal panel that dips and youngs to the east-northeast. Bedding in the small outlier of the Dragon Mountain slate-sandstone unit south of Burgess Creek is folded, but dips are gentle and mainly southwest to northwest, in contrast to nearby Nicola exposures, which dip at moderate angles to the northeast. The slate-sandstone unit also dips gently within the fault block to the west, although bedding observations are rare.

The characteristic well-developed slaty cleavage of the Dragon Mountain slate-sandstone unit dips steeply, mainly to the northeast but locally to the southwest, and is axial planar to mesoscopic folds of bedding which, together with bedding-cleavage intersection lineations, plunge gently to the northwest. In one exposure northwest of the Gibraltar tailings pond, the southwest-dipping slaty cleavage is deformed by south to southeast-plunging mesoscopic folds and crenulations, and an associated east-dipping crenulation cleavage. A weak to moderately developed cleavage, also with steep dips to the northeast or southwest, cuts siltstone, limestone, and some breccia units of the Nicola Group, but is not developed in most units of the group, nor in the Dragon Mountain conglomerate unit. The cleavage, typically defined by oriented chlorite and/or sericite, is accentuated by variably flattened lithic fragments in breccia units. Mesoscopic folds were observed at only one locality in the Nicola Group, south of the Burgess Creek stock. Here, folds developed in uncleaved, thin- to medium-bedded volcanic sandstone plunge at moderate angles to the north and verge to the west (north-striking, steeply-dipping short limbs enclosed by moderately east-northeast-dipping long limbs).

The Burgess Creek stock locally displays a weak, northeast to southwest-dipping foliation, parallel to, and presumably the same age as, cleavage within the Nicola Group and Dragon Mountain slate-sandstone unit. The stock also contains local narrow, steeply dipping, high-strain zones, defined by well foliated, locally mylonitic rock, ranging from 40 cm to 30 m wide. These zones occur in the mixed unit, are typically near and parallel to its margins, and are crosscut by younger tonalite and leucotonalite phases of the stock. They are inferred to have formed during emplacement and construction of the stock. A well-foliated zone that dips gently to the southeast in the west-central part of the stock is probably younger (Fig. 3). It is localized within a quartz porphyry unit, and locally displays C-S fabrics indicating northwest-directed thrust movement.

### 4.2. Southern domain

The southern domain comprises the Granite Mountain batholith, the Cuisson Lake unit and the Sheridan Creek stock. These rocks are characterized by a foliation that dips at moderate to gentle angles to the south. This foliation (S1) is strong throughout the Cuisson Lake unit, but is of variable intensity in plutonic rocks of the Granite Mountain batholith and Sheridan Creek stock, and is typically weak to absent in the northern part of the Granite Mountain phase. Weakly foliated plutonic rocks display an isotropic igneous texture overprinted by discontinuous sericite foliae, and may show a slight flattening of chloritized mafic clots. Strongly foliated rocks (Fig. 17) comprise anastomosing networks of sericite-rich and chlorite-rich foliae that enclose lenses of flattened quartz and saussuritic (but internally unstrained) plagioclase. These foliations accommodated mainly flattening strain, but in two locations in the Granite Mountain phase, southeast of Granite Mountain, local zones of well-foliated rock display C-S fabrics showing top-to-the-north shear. Outcrops of both the Cuisson Lake unit and Sheridan Creek stock, near their mutual contact, display similar extremely strong foliations, but unequivocal kinematic indicators were not observed.

The S1 foliation in the Granite Mountain batholith is locally cut by a crenulation cleavage that strikes east-southeast

**Fig. 17.** Mine phase tonalite with well-developed, gently dipping S1 foliation, Gibraltar Mine road.

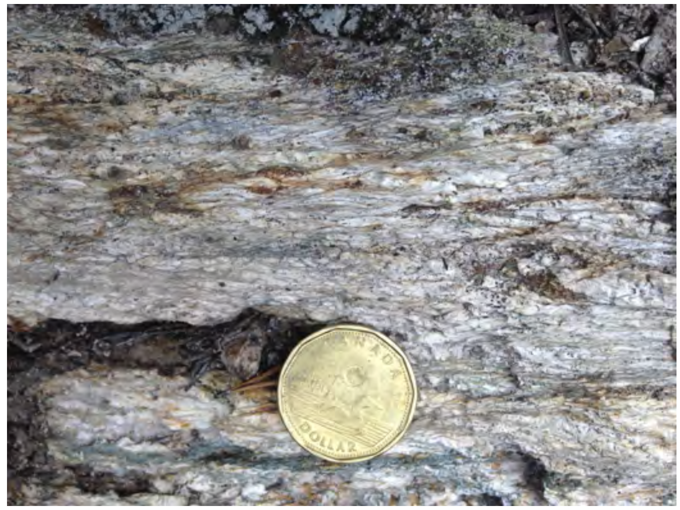

**Fig. 18.** Southeast striking, steeply dipping sinistral shear zone in leucocratic tonalite of the Granite Mountain phase, 1 km southeast of Granite Mountain. Note shear bands extending diagonally from top right to middle left. Looking down on flat outcrop surface with top of photo facing southwest.

**Fig. 19.** High-strain zone, dipping steeply to the south-southwest, cutting weakly foliated Mine phase tonalite, 4.2 km southwest of Granite Mountain. View is to the east.

and dips steeply, mainly to the south-southwest. Associated crenulation lineations, and rare mesoscopic folds of S1, plunge gently to the southeast. In one Mine phase exposure, 1.9 km south-southeast of Granite Mountain, there are two crenulation cleavages at a low angle to one another; one strikes 098º and dips steeply south, and the other, younger cleavage strikes 118º and is vertical. Schists within the Cuisson Lake unit locally display a southeast-plunging crenulation lineation that may be equivalent to those seen in the Granite Mountain batholith. South-plunging kink folds and crenulations, with north-striking, steeply-dipping axial surfaces, appear to be younger structures, and were observed to deform schists of the Cuisson Lake unit and a south-dipping high-strain zone in the Sheridan Creek stock.

Narrow, steeply dipping high-strain zones with east-southeast trends are a striking but relatively uncommon feature in Granite Mountain and Mine phase rocks east, south and southwest of Granite Mountain (Fig. 3). They range from 10 cm to 10 m wide, clearly crosscut the S1 foliation, and have an orientation that is similar to the local crenulation cleavage in these rocks. The zones are up to 10 m wide in the Granite Mountain phase, where they typically display features (C-S fabrics and shear bands) indicating sinistral shear (Fig. 18). High-strain zones in the Mine phase (Fig. 19) are typically less than 1 m wide; most do not display clear indications of non-coaxial strain, although one narrow zone that cuts a quartz-feldspar porphyry dike in the Mine phase, 5.1 km south of Granite Mountain, accommodated dextral shear.

### 4.3. Eastern domain

The eastern domain, comprising the Cache Creek Complex, includes well-foliated chert-phyllite units, as well as limestone and basalt, which show little or no foliation. The fabric of the chert units is composite, and is defined by platy layers and lenses of chert and a well-developed phyllitic cleavage, in the thin phyllite interbeds, which is typically parallel to the chert layers. In addition, chert-phyllite units commonly display narrow slip surfaces at a low angle to this foliation, which define local truncations and discontinuities of the chert layering (Fig. 12). Narrow limestone lenses in predominantly chert intervals along Burgess Creek are parallel to the foliation and, where contacts are observed, appear to be bounded by narrow shear zones.

Foliation in the eastern domain most commonly dips at low to moderate angles to the north. It is deformed by north to northwest-plunging mesoscopic folds along the southern part of the 609 road, and by east-southeast-plunging folds on the low ridge south of the 800 road, where the foliation dips mainly to the south. Gently dipping foliation along Burgess Creek is locally cut by two weak crenulation cleavages, one dipping steeply south and the other dipping steeply to the east-southeast.

**4.4. East-trending faults**

An east trending fault is inferred to mark the contact between the Cuisson Lake unit and the Sheridan Creek stock in the southwestern part of the map area (Fig. 3) because a south-dipping foliation in both units becomes progressively stronger (locally mylonitic), as the contact is approached. It may be a north-directed thrust fault, because similar south-dipping foliation in the Granite Mountain phase to the north locally grades into a C-S mylonite that shows top-to-the-north sense of shear.

An east-southeast trending fault is inferred from an apparent 300 m sinistral offset of the southern contact of the Burgess Creek stock (Fig. 3). Farther west, within the stock, this fault offsets the contact between the mixed unit and the tonalite unit. The orientation of this structure is similar to the sinistral high-strain zones mapped in the Granite Mountain phase to the south, but it is unknown if they are the same age.

**4.5. Northeast-trending faults**

A prominent northeast-trending fault in the southern part of the map area truncates the Cuisson Lake unit, an east-trending fault that bounds the Cuisson Lake unit to the south, and the Border and Mine phases of the Granite Mountain batholith (Fig. 3). The fault juxtaposes these units against the Sheridan Creek stock to the southeast. The northeast extension of this fault apparently separates the Granite Mountain phase of the batholith from the Cache Creek Complex. Sinistral movement along this fault is inferred from the distribution of Sheridan Creek tonalite, and because several outcrop-scale sinistral faults with similar strikes, and steep to moderate southeast dips, are in the Sheridan Creek stock near the inferred fault trace.

Northeast-trending faults in the area north of the Gibraltar tailings pond are inferred from truncations of map units and topographic lineaments, but were not directly observed. Predominantly normal-sense movement is inferred on the faults that bound the slate-sandstone unit of the Dragon Mountain succession. Near the north boundary of the map area, an east-northeast trending fault with sinistral and/or north-side-down movement is inferred from the truncation of the contact between the Nicola Group and Dragon Mountain conglomerate unit.

**4.6. North and north-northwest trending faults**

A north-trending fault in the southern part of the map area marks a 750 m offset of the Cuisson Lake unit and adjacent map units. The fault is not exposed, but the apparent offset of the south-dipping map units suggests dextral and/or west-side-down displacement. The Cuisson Lake unit is also offset by a north-northwest trending fault 2300 m farther west, which was defined, in part, by diamond drilling of the Sawmill mineral deposit. This structure dips at moderate angles to the west, and is thought to have more than 300 m of west-side-down displacement (Bysouth et al., 1995). Northwest-trending faults inferred north of the Gibraltar tailings pond show offsets and juxtapositions of map units that suggest some combination of dextral and/or west-side-down vertical displacements. North to north-northwest striking outcrop-scale faults in this area, and in the Granite Mountain batholith to the south, commonly show a dextral component.

A major north-northwest trending fault that may not be related to those described previously is inferred to separate rocks of Quesnel terrane, including the Dragon Mountain succession, the Nicola Group, and Burgess Creek stock, from the Cache Creek Complex to the east. This fault is notable because it reverses the regional arrangement of these terranes, in which Cache Creek rocks are typically west of Quesnel terrane. One possible explanation is that this structure marks a Middle Jurassic or younger sinistral offset of the previously established terrane boundary. Weak support for this interpretation comes from near the west end of the Cache Creek exposures along Burgess Creek, where a prominent vertical fault that strikes 160, parallel to the trace of the major fault inferred to the west, has well-developed calcite slickenfibres that indicate sinistral slip (Fig. 20).

**4.7. Regional significance of structures**

The major structural features of the northern domain (steeply dipping, northwest striking foliation and associated folds) are parallel to the structural grain of the Cordillera, and probably formed during Cordilleran-wide contractional deformation that began in the early Middle Jurassic. These structures postdate local syn-plutonic high-strain zones in the Burgess Creek stock, which likely formed during Late Triassic construction of the Quesnel arc. The major structural feature of the southern domain (south-dipping foliation in the Sheridan Creek stock, the Cuisson Lake unit, and the southern part of the Granite Mountain batholith) likely formed during structural juxtaposition of the Sheridan Creek stock with rocks of Quesnel terrane during Cretaceous or younger structural reworking of the Quesnel-Cache Creek boundary. This juxtaposition may have formed in concert with sinistral displacement along the

**Fig. 20.** South-southeast striking vertical fault with calcite slickenfibres showing sinistral sense of shear; Cache Creek Complex, Burgess Creek. View is to the west.

north-northwest trending fault at the Quesnel-Cache Creek boundary in the eastern part of the map area. Structures in the Cache Creek Complex (eastern domain) bear no obvious relationship to those within the north and south domains. They may include structures that initially formed during accumulation as a subduction-related accretionary complex in the Triassic and Early Jurassic, variably overprinted during younger tectonic events. The youngest structures in the map area (north to northwest trending faults with mainly dextral and/or west-side-down displacement, and northeast trending faults with sinistral and/or vertical displacement) are probably related to Cretaceous to Eocene Cordilleran-wide strike-slip tectonics (Struik, 1993).

## 5. Mineral occurrences

Mineralization at the Gibraltar Mine is hosted in Mine phase tonalite of the Granite Mountain batholith, but porphyry-style mineral occurrences are also known in the Border phase and the Granite Mountain phase. Copper mineralization also occurs within the Cuisson Lake unit adjacent to the batholith, and at several locations within the Nicola Group near the Burgess Creek stock (Fig. 21).

### 5.1. Gibraltar Mine

The Gibraltar Cu-Mo deposit includes four open pits, Granite Lake (MINFILE 093B 013), Pollyanna (MINFILE 093B 006), Gibraltar East (MINFILE 093B 012) and Gibraltar West (MINFILE 093B 007), and adjacent mineralized zones, including Gibraltar North (MINFILE 093B 011), which have yet to be exploited (Fig. 21). The mine operated from 1972 to 1998, was shut down from 1999 to 2003, has been in production since it was reopened by Taseko Mines Ltd. in 2004, and has a projected mine life extending to 2037 (van Straaten et al., 2013). Production from 1972 to 1998 was 322 million short tons grading 0.367% Cu, and from 2004 to the first quarter of 2011 was 77 million short tons grading 0.324% Cu and 0.010% Mo (van Straaten et al., 2013).

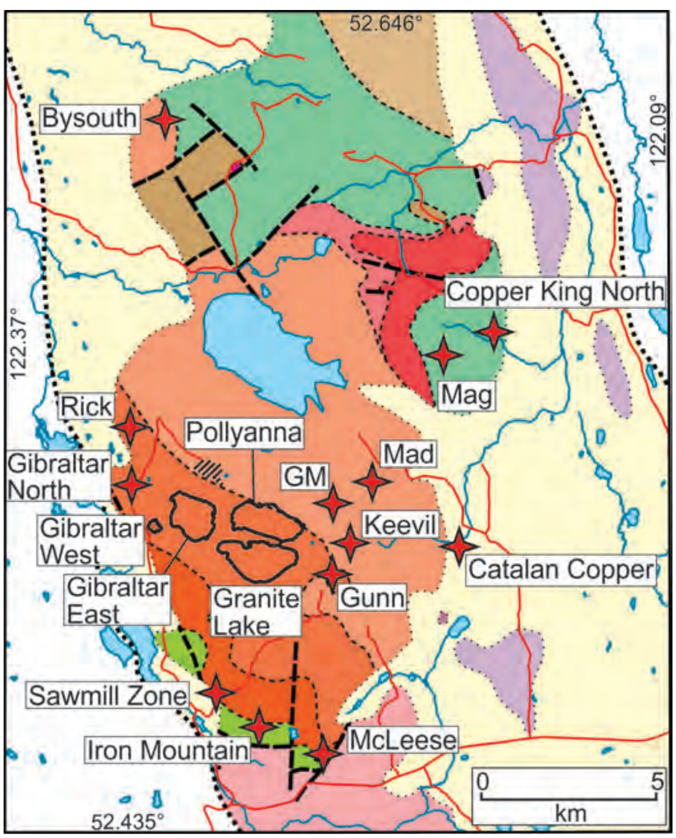


**Fig. 21**. Main mineral occurrences in the Granite Mountain map area. Base map is derived from Fig. 3.

The Gibraltar deposits are described by Sutherland Brown (1974), Simpson (1970), Drummond et al. (1973, 1976), Bysouth et al. (1995), Ash and Riveros (2001), Oliver et al. (2009), Harding (2012), van Straaten et al. (2013), and Mostaghimi et al. (2014). Mineralization conists mainly of disseminated and vein-hosted chalcopyrite, but also includes molybdenite, mainly in quartz veins, minor amounts of bornite in the east, and substantial amounts of sphalerite in the northwest. Re-Os radiometric ages on molybdenite, reported by Harding (2012), are Late Triassic and range from 210.1 ±0.9 Ma to 215.0 ±1.0 Ma. These determinations, similar to the age of the host batholith, together with the styles of vein and disseminated mineralization, are consistent with an origin as a calcalkaline porphyry deposit (Oliver et al., 2009; van Straaten et al., 2013). A unique feature of the Gibraltar deposits however, is a strong association of ore with high-strain zones, including south-dipping foliations and south-dipping top-to-the-north shear zones. These structures are considered by many to be the same age as the mineralization (Drummond et al., 1976; Bysouth et al., 1995; Oliver et al., 2009), but Ash et al. (1999a, b) suggested that the deformation is younger. The relationship between mineralization and deformation is currently under investigation (Mostaghimi et al., 2014).

### 5.2. Rick (MINFILE 093B 062)

The Rick occurrence is in Mine Phase tonalite 1-2 km north of the Gibraltar North zone (Fig. 21). Copper and zinc mineralization was discovered in 1998 during an exploration program covering the southern part of the Copper Ace property for United Gunn Resources Ltd. (Payne, 1999b; Ash et al., 1999a). Diamond drill programs carried out by Copper Ridge Explorations Inc. in 2006 (3 holes) and 2007 (13 holes) were focused on coincident soil and geophysical anomalies in an area measuring about 1200 m east-west by 800 m north-south, which includes the mineralized outcrops (Dawson, 2007; Hodge and Dawson, 2008). Thirteen of fourteen holes drilled in this area intersected copper mineralization, but some contained only minor disseminations, and in others mineralized intersections were narrow. Mineralization comprises chalcopyrite ±molybdenite, as disseminations and in quartz veins, and locally includes bornite or sphalerite. Significant gold values were returned from some narrow intervals, including 0.425 g/t Au and 3.43% Cu over 1.6 m in hole CA-06-02 (Dawson, 2007), and 6.3 g/t Au and 684 ppm Cu over 0.5 m in hole

CA07-09 (Hodge and Dawson, 2008).

### 5.3. Gunn (MINFILE 093B 003)

The Gunn prospect comprises porphyry-style copper-molybdenum mineralization in Mine phase tonalite about 1 km east of the Granite Lake pit. This area was explored by Gunn Mines Ltd. in the late 1960s, and the geology and mineralization is briefly described by Cannon (1968) and Eastwood (1970). Mineralization encountered during current mapping comprises sheeted veinlets, 1-2 mm wide and spaced 2-6 cm apart, consisting mainly of pyrite, chalcopyrite, chlorite and sericite. The sheeted veinlets dip steeply south, and are in Mine phase tonalite, which displays a weak foliation dipping gently south. The same outcrop includes a south-dipping quartz vein, 5-16 cm wide that contains patches of heavily-disseminated molybdenite, and local blebs of chalcopyrite along its margins.

### 5.4. Sawmill zone (MINFILE 093B 051)

The Sawmill zone is along the south margin of the Granite Mountain batholith, about 1 km east of the south end of Cuisson Lake. Mineralization was first intersected in diamond drill holes cored in 1979, which targeted a large I.P. anomaly. Subsequent drill programs by Gibraltar Mines Ltd. have outlined a resource (non-NI-43-101 compliant) reported as 75.5 million short tons grading 0.244% copper (Bysouth et al., 1995). Mineralization is in Border phase quartz diorite, along its contact with the Cuisson Lake unit, but is also hosted in local units of tonalite, similar to Mine phase tonalite, and quartz porphyry (Bysouth, 1990). It consists mainly of pyrite, chalcopyrite and molybdenite in veins and shears accompanied by quartz, chlorite, carbonate, sericite and epidote. Gypsum veins, containing chalcopyrite and minor bornite, also occur (Bysouth, 1990). The mineralized zone is truncated to the west by a west-dipping fault, referred to as the Sawmill fault, suspected to have more than 300 m of west-side-down displacement (Bysouth et al., 1995).

### 5.5. McLeese (MINFILE 093B 050)

The McLeese occurrence comprises copper mineralization hosted mainly in Border phase quartz diorite near the southeastern tip of the Granite Mountain batholith. Mineralization was discovered and explored with trenches and short diamond drill holes during exploration carried out by Sheridan Copper Mines Ltd. and Granite Mountain Mines Ltd. in 1970 and 1971 (Meyer, 1971a, b). It comprises chalcopyrite, pyrite, malachite and azurite that occur in east-striking vertical fracture zones, as disseminations along foliation planes and, locally, in quartz veins adjacent to gently dipping shears (Meyer, 1971a, b). Border phase quartz diorite is the main host, but the adjacent Cuisson Lake unit hosts rare mineralized quartz veins (Meyer, 1971a). Traverses through this area in 2014 encountered minor amounts of chalcopyrite and malachite disseminated in quartz diorite.

### 5.6. Keevil (MINFILE 093B 002) and GM

The Keevil and GM occurrences comprise substantial zones of porphyry-style Cu-Mo mineralization in the Granite Mountain phase, east and northeast of the Gibraltar Mine. The Keevil occurrence was explored by Keevil Mining Group Ltd. in the 1960s. Mineralization is mainly in an northeast-trending zone, about 650 m long by 120 m wide, and includes chalcopyrite and malachite disseminated in foliated and sheared tonalite, malachite as coatings on joint surfaces, and molybdenite, locally with chalcopyrite and malachite, in quartz veins that are up to 1 m thick (Armstrong, 1968; Eastwood, 1970).

The GM occurrence is 1-1.5 km north-northwest of the Keevil zone. This mineralization was intersected in diamond drill holes cored by Boliden Westmin Ltd. (owner, at that time, of the Gibraltar Mine) in 1998. This drill program was designed to test a large chargeability anomaly that had been outlined by an I.P. geophysical survey conducted in 1997 (Rydman, 1998). Four of five vertical holes intersected significant mineralization, consisting mainly of chalcopyrite, pyrite and molybdenite in quartz veins. An oxide zone, with significant amounts of malachite, azurite, cuprite, tenorite and limonite, was encountered in two of the holes, and three holes intersected chalcocite in a near-surface supergene enrichment zone (Rydman, 1998). An array of recent drill pads attests to subsequent exploration of this occurrence, but results have not been made public.

### 5.7. Mad (MINFILE 093B 052)

The Mad showing is in the Granite Mountain phase about 1.3 km east-northeast of the GM occurrence. It comprises a few occurrences of copper sulphides, presumably chalcopyrite, that were located during a soil geochemical survey conducted over the Mad claim group by Exeter Mines Ltd. in 1973 (Mark, 1973).

### 5.8. Bysouth (MINFILE 093B 061)

The Bysouth occurrence is 5.3 km north of the Gibraltar tailings pond, in tonalite that is mapped as an outlier of the Granite Mountain phase. It comprises two separate mineralized zones, one with molybdenite and the other with chalcopyrite. The molybdenum mineralization was encountered in a diamond drill hole cored by Gibraltar Mines Ltd. in 1986 on their Ze claim group. Drill hole 86-65 intersected silicified tonalite which enclosed a 30 m zone of leucotonalite cut by molybdenite-bearing quartz veins (Bysouth, 1987). Copper mineralization consists of pyrite, chalcopyrite, malachite and azurite in a silicified breccia zone that cuts tonalite about 100 m south of drill hole 86-65 (Ash et al., 1999a; Reid, 2005). This area was explored with a diamond drill program conducted by Bell Resources Corporation in 2004, who had optioned the Copper Ace North claims from Copper Ridge Explorations Inc. These drill holes intersected variably altered intrusive units, locally with anomalous concentrations of Mo and Cu, but did not encounter the high-grade breccia zone exposed at surface (Reid, 2005).

### 5.9. Iron Mountain (MINFILE 093B 004)

The Iron Mountain occurrence comprises a series of iron oxide-rich skarn lenses in the Cuisson Lake unit, 1-2.5 km east-southeast of the south end of Cuisson Lake. They were staked as the Iron Mountain group in 1952, and have seen intermittent exploration by a number of operators, mainly in the 1950s and 1960s (Sutherland Brown, 1958; Philp, 1968). The skarn lenses consist of specular hematite or magnetite, with lesser amounts of epidote, garnet, clinopyroxene, chalcopyrite and malachite (Sutherland Brown, 1958). Individual lenses range from a few cm to 2 m wide, and occur over a strike length of about 1500 m along the north side of the Cuisson Lake unit (Sutherland Brown, 1958).

### 5.10. Catalan Copper (MINFILE 093B 068)

The Catalan Copper occurrence, 2 km north of the lake at the head of Big Camp Creek, comprises copper and molybdenum mineralization that was intersected in a diamond drill hole cored by Stikine Gold Corporation in 2007. The hole (CC-07-04) was drilled to test a linear magnetic anomaly on the AP claim group. It intersected foliated andesitic volcanic rocks cut by an intrusive suite that includes feldspar porphyry, diorite and quartz diorite. The mineralization comprises pyrite, chalcopyrite and minor molybdenite that form disseminations, veinlets and stockworks in the volcanic rocks (Mirko et al., 2007).

The Catalan Copper occurrence is in a covered area east of the Granite Mountain batholith. Rocks intersected in diamond drill hole CC-07-04 are likely Nicola Group cut by an intrusive suite related to the Burgess Creek stock. Diamond drill hole CC-07-01, cored 300 m to the east, intersected rocks that are probably part of the Cache Creek Complex, described by Mirko et al. (2007) as mélange, comprising incoherent graphitic argillite with blocks of limestone. These two drill holes are inferred to constrain the location of a north-trending fault contact between Quesnel and Cache Creek terranes.

### 5.11. Mag and Copper King North

The Mag and Copper King North are minor occurrences of chalcopyrite in the Nicola Group southeast of the Burgess Creek stock. The Mag occurrence includes mineralization encountered in two diamond drill holes cored by Gibraltar Mines Ltd. in 1985, to test an I.P. anomaly that was spatially associated with exposures of magnetite-epidote-garnet skarn on the Mag claim group (Bysouth, 1985). These holes encountered minor amounts of chalcopyrite in quartz-carbonate veins and quartz-epidote-chlorite-carbonate-cemented breccia (Bysouth, 1985). This area was explored as part of the Copper King property for United Gunn Resources Ltd. in the late 1990s. Payne (1999a) reports that minor amounts of disseminated pyrite and chalcopyrite occur in a package of silicified limestones and volcaniclastic rocks, which is apparently a southward extension of the skarn zone.

The Copper King North occurrence, 1.5 km northeast of the Mag occurrence, was identified during exploration of the Copper King property for United Gunn Resources Ltd. in 1998. The mineralization is described as disseminations and stringers of chalcopyrite in intensely silicified lapilli tuff (Payne, 1999a). Grab samples contain up to 13967 ppm Cu, but the mineralization was described as spotty, lacking lateral continuity (Payne, 1999a).

## 6. Discussion

### 6.1. Terrane affinity of the Granite Mountain batholith

The Granite Mountain batholith is interpreted to be part of Quesnel terrane. This interpretation is based mainly on its association with rocks that are correlated with the Nicola Group (Upper Triassic) the main stratigraphic unit of Quesnel terrane. The Nicola correlation is mainly lithologic (Schiarizza 2014), but is corroborated by Late Triassic conodonts extracted from the succession at one locality and geochronologic data from bounding plutons. The Nicola rocks are intruded by the Burgess Creek stock (Late Triassic), which is in turn intruded by the Granite Mountain phase of the Granite Mountain batholith. The basal unit of the Dragon Mountain succession overlies the Nicola Group north of the Burgess Creek stock, and in the fault block northwest of the Gibraltar tailings pond it apparently overlies the Granite Mountain batholith (Barker and Grubisa, 1994). This relationship provides an additional link between the Granite Mountain batholith and Quesnel terrane, as regional studies suggest that the Dragon Mountain succession represents an intra-Quesnel basin that was derived from, and deposited on, older units of Quesnel terrane (Petersen et al., 2004; Logan and Moynihan, 2009).

Rocks along the southwest margin of the Granite Mountain batholith have commonly been interpreted as Cache Creek rocks altered during batholith emplacement. These rocks are assigned to the Cuisson Lake unit and are suspected, but not proven, to have been intruded by the Border phase of the Granite Mountain batholith. They were derived from a succession of feldspathic volcaniclastic±volcanic rocks intercalated with limestone, and it is suggested herein that they are more readily correlated with the Nicola Group than the Cache Creek Complex. This correlation corroborates assignment of the Granite Mountain batholith to Quesnel terrane.

Hornfelsed Cache Creek rocks form an isolated set of exposures northwest of the lake at the head of Big Camp Creek. These rocks are a little more than 1 km from exposures of the Granite Mountain batholith, and this spatial relationship might be considered evidence for an intrusive relationship. This interpretation is rejected because strong evidence elsewhere shows that the batholith intruded Nicola rocks. The hornfelsed Cache Creek rocks are inferred to be separated from the Granite Mountain batholith by an extension of the northeast-striking fault mapped to the southwest (Fig. 3). The metamorphic overprint may have been caused by hornblende-plagioclase porphyry intrusions identified in the same set of exposures, or the Sheridan Creek stock. It is suspected that these rocks are part of a structural-metamorphic domain, recognized by Ash et al. (1999a, b), that is spatially associated with the Sheridan

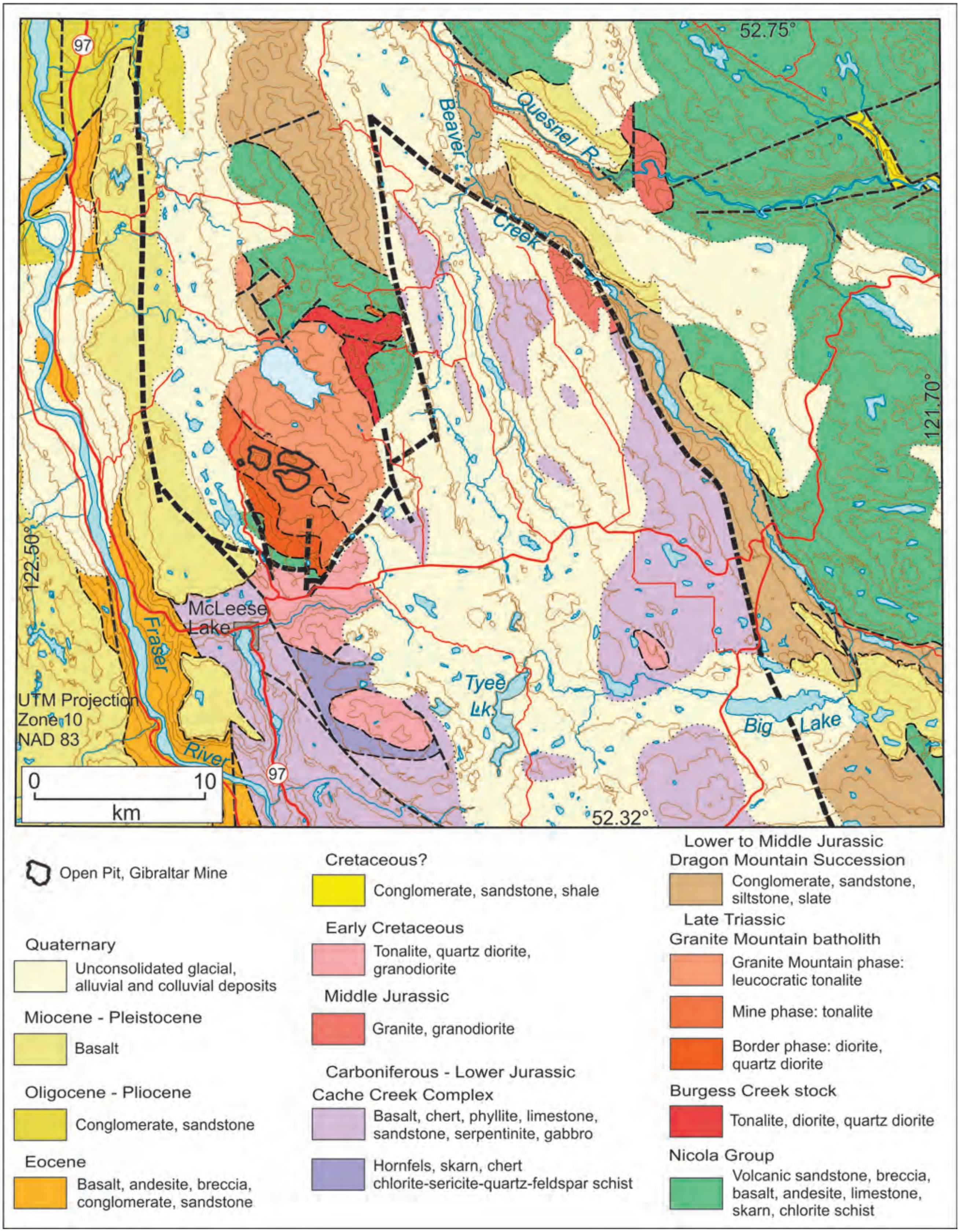


**Fig. 22.** Geologic map of the Granite Mountain batholith and surrounding area. Based on Tipper (1959, 1978), Ash et al. (1999b), Logan et al. (2010), and this study. Bold dashed line denotes fault segments, projected above Neogene and Quaternary cover, that form the boundary between Quesnel and Cache Creek terranes.

Creek stock and a correlative stock to the south (Fig. 22).

The Granite Mountain batholith is a Late Triassic arc pluton (Oliver et al., 2009). Quesnel is an arc terrane characterized by Upper Triassic arc-derived volcanic and sedimentary rocks, and Late Triassic to Early Jurassic calc-alkalic and alkalic arc plutons. Assigning the Granite Mountain batholith to the Quesnel arc places it in a more appropriate setting than an accretionary complex (Cache Creek). Furthermore, as part of the Quesnel arc system, the Granite Mountain batholith conforms and contributes to a pattern defined by parallel belts of calc-alkalic or alkalic plutons that become progressively younger from west to east (Fig. 21 of Schiarizza, 2014). The Granite Mountain batholith is part of a western belt of Late Triassic calc-alkalic plutons that also includes the Guichon Creek batholith, 250 km to the south-southeast, host to the Highland Valley Cu-Mo porphyry deposits.

### 6.2. Structural relationship to Cache Creek terrane

The Nicola Group (including the Cuisson Lake unit), Burgess Creek stock, Granite Mountain batholith, and Dragon Mountain succession form a coherent panel of rocks that is part of Quesnel terrane. This panel is bounded to the east by a north-tapering wedge of Cache Creek rocks. This relationship indicates significant local shuffling of the terrane boundary because, regionally, Cache Creek terrane occurs to the west of Quesnel terrane (Fig. 22). Accordingly, the contact between the Quesnel panel and the Cache Creek wedge is inferred to be a significant north-northwest trending fault that records more than 20 km of sinistral strike-slip displacement, as required to restore the southern end of the Quesnel block to the northern termination of the Cache Creek wedge (Fig. 22). This fault is not exposed, and no obvious strike extensions are apparent in adjacent map areas, although Logan (2008) documented local northwest-trending sinistral fault zones in Quesnel terrane along the Cottonwood River, 50 km north-northwest of the Granite Mountain map area.

The southern boundary of the Quesnel panel is, in part, defined by the east-trending fault that marks the contact between the Cuisson Lake unit and the Sheridan Creek stock in the southwestern part of the map area. The Cuisson Lake unit is correlated with the Nicola Group, and the Sheridan Creek stock apparently intrudes the Cache Creek Complex, so this fault forms the boundary between Quesnel and Cache Creek terranes. This fault is truncated by a northeast-trending sinistral fault to the east, and is locally offset by northerly trending faults with dextral and/or west-side-down displacements. The east-west contact is inferred to be a fault because the south-dipping foliation in both units becomes progressively stronger, and is locally mylonitic, as the contact is approached. It is suspected to be a south-dipping thrust or reverse fault because the south-dipping foliation tracks northward into the Granite Mountain batholith, where it locally grades into a C-S mylonite that shows top-to-the-north sense of shear. The fault is mid-Cretaceous or younger because it cuts the Early Cretaceous Sheridan Creek stock. Temperatures were sufficiently high to generate greenschist facies mineral assemblages in the foliated rocks affected by the deformation.

## 7. Conclusions

The Late Triassic Granite Mountain batholith, host to the Gibraltar porphyry Cu-Mo deposit, is part of Quesnel terrane. It, and associated rocks of the Nicola Group, Nicola-correlative Cuisson Lake unit, Burgess Creek stock and Dragon Mountain succession, form a panel of Quesnel rocks, 15 km wide, that is partially enveloped by exposures of Cache Creek terrane. The southern boundary of this panel is an inferred east-striking fault that juxtaposes the Cuisson Lake unit against Early Cretaceous tonalite of the Sheridan Creek stock. South-dipping foliations in the Sheridan Creek stock, the Cuisson Lake unit, and the southern part of the Granite Mountain batholith formed at the same time as this fault. The eastern boundary of the Quesnel panel is an unexposed north-northwest striking fault that juxtaposes it against the Cache Creek Complex. This fault cuts rocks as young as the Lower to Middle Jurassic Dragon Mountain succession, but its age, dip and movement history are not well constrained. Map-scale relationships suggest that it is a sinistral fault with at least 20 km of displacement.

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