# Southern Nicola Project: Granite Creek Area, Southern British Columbia (Parts of NTS 092H/07, 10)

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*KEYWORDS*: Nicola Group, Eastgate–Whipsaw metamorphic belt, Tulameen complex, Tulameen coal basin, mineralization

## INTRODUCTION

The Southern Nicola Project area is located on the eastern boundary of Manning Park, about 15 km southwest of the town of Princeton (Figure 1), in southern British Columbia. Tectonically, the project area lies at the western edge of Quesnellia, just inboard of the bounding Pasayten fault, and includes the southernmost exposures of the Late Triassic Nicola Group.

Mapping by Rice (1947), Preto (1972) and Monger (1989) has outlined the essential distribution of Nicola Group strata in the Princeton area (NTS 092H/SE) and their relationships to younger intrusive and volcano-sedimentary sequences. To the east of the Similkameen River, rocks of the Nicola Group are assigned to the 'eastern belt' (Preto, 1979; Mortimer, 1987) and display an alkalic affinity; these rocks host the important porphyry and skarn deposits of the Copper Mountain area (Preto, 1972). To the west, the rocks of the Nicola Group have not been assigned to any of the three major belts, although Mortimer (1987) suggested they may belong to the calcalkaline 'western belt'.

The western boundary of the study area is defined by the eastern edge of the Jurassic–Cretaceous Eagle Plutonic complex. Rocks adjacent to the complex, correlated with the Nicola by Rice (1947) and Monger (1989), show significant lithological differences to the immediately adjacent Nicola volcanic rocks and have been renamed the 'Eastgate–Whipsaw metamorphic belt' (Massey et al., 2009). This belt may be equivalent to the Late Permian–Early Triassic Sitlika–Kutcho sequences, including volcanic rocks and intrusions from the Ashcroft area (Childe et al., 1997), about 150 km north-northwest of Princeton.

Mapping in 2008 focused in the area to the southwest of Princeton (Figure 1). In 2009, mapping continued northwards from Whipsaw Creek into the Granite Creek and Tulameen River areas, concentrating on the Nicola Group rocks. Field observations were limited by lack of access or outcrop in the Arrastra Creek area and to the west of Lodestone Mountain.

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## PREVIOUS WORK

The area west of Princeton has a mining history dating from the discovery of placer gold in the 1860s. The first geological reports were those of Bauerman (1885), as part of the Boundary Commission Expedition of 1859–1861, and Dawson (1877). Subsequent regional mapping in the area was undertaken by Camsell (1913), Rice (1947), Preto (1972, 1979), Coates (1974) and Monger (1989). Coal-bearing units of the Princeton Group have been described by Camsell (1913), Shaw (1952), Donaldson (1973) and Evans (1978, 1985), while industrial minerals have been described by Read (1987, 2000). Comprehensive studies of the geology and petrology of the Tulameen complex have been published by Findlay (1963, 1969), Rublee (1994), Nixon (1988) and Nixon et al. (1997). No systematic mapping of Quaternary deposits, soils or terrain features has been undertaken in the area, although Hills (1962) provided some observations and discussion of the glacial and postglacial history of the area.

## GEOLOGY

The results of the 2009 mapping program are summarized in Figures 2 and 3.

### *Stratified Units*

#### PERMIAN (?) TO LATE TRIASSIC EASTGATE–WHIPSAW METAMORPHIC BELT

The Eastgate–Whipsaw metamorphic belt had previously been included in the Nicola Group, but is lithologically distinct. To the south, in the Eastgate area, it is quite heterogeneous, yet has been divided into three northwest-trending lithological assemblages, which show increasing metamorphic grade from east to west (Massey et al., 2009). Only the amphibolite unit continues north into the southwestern corner of the Granite Creek area. The belt is separated from schistose volcanic rocks of the Nicola Group by the Similkameen Falls fault (Massey et al., 2009), although the latter is not exposed in this area. The belt is intruded by rocks of the Eagle Plutonic complex along its western margin.

The amphibolite is overall medium grey to black, typically medium to coarse grained and well foliated, and comprises alternating mafic- and felsic-rich layers (Figure 4). It consists of black to greenish black amphibole, white feldspar, quartz and minor biotite and magnetite. The elongate amphibole minerals are usually larger than the subhedral feldspar and quartz. In some outcrops, laminae and thin layers of actinolite quartzite and actinolite-biotite quartzite oc-

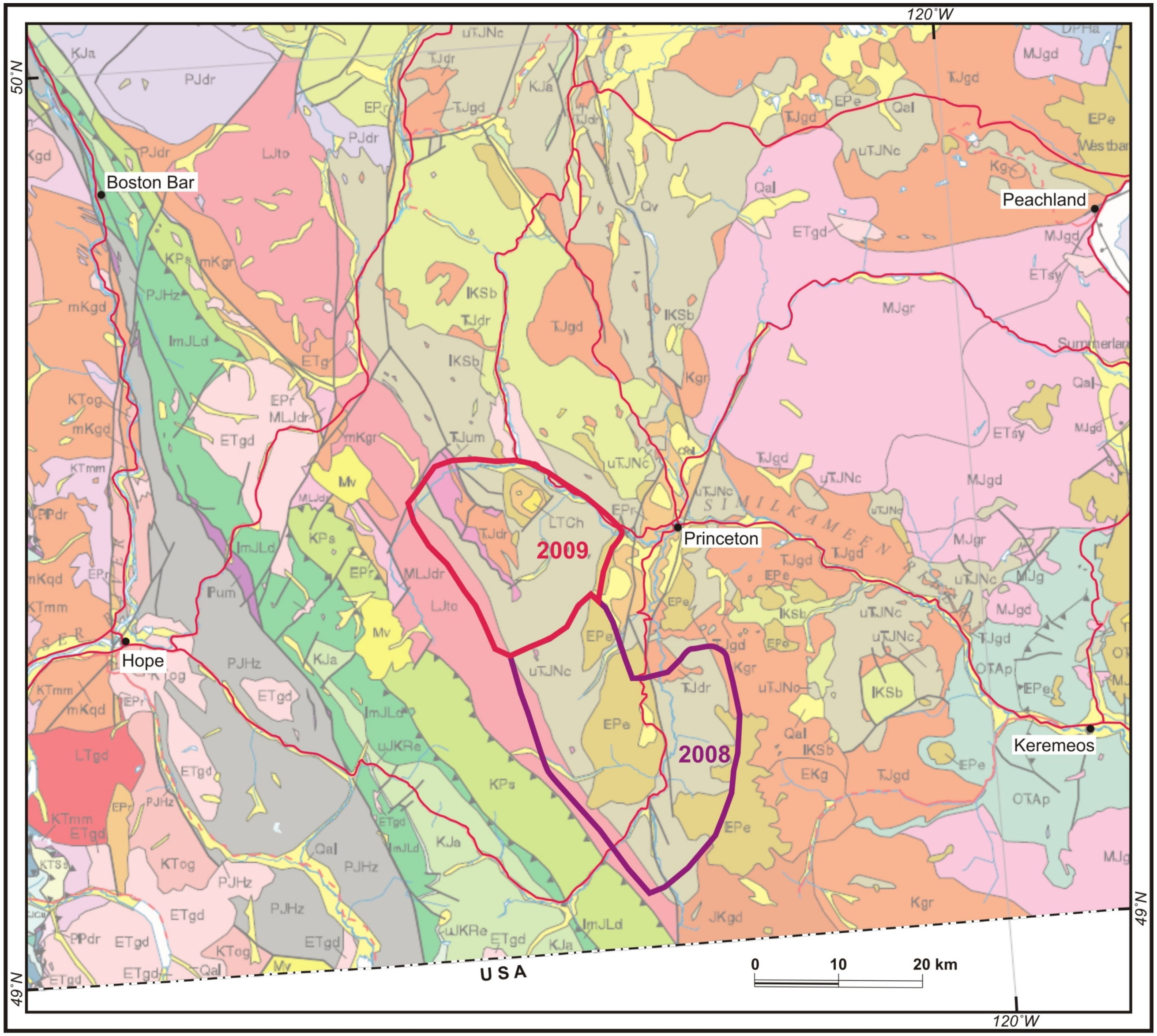


**Figure 1.** Location of the Southern Nicola Project, Granite Creek area, southern British Columbia. Geology base map derived from Massey et al. (2005). Polygons outline the area mapped in 2008 and 2009. Rocks of the Nicola Group are labelled uTJNc; for other units see Massey et al. (2005).

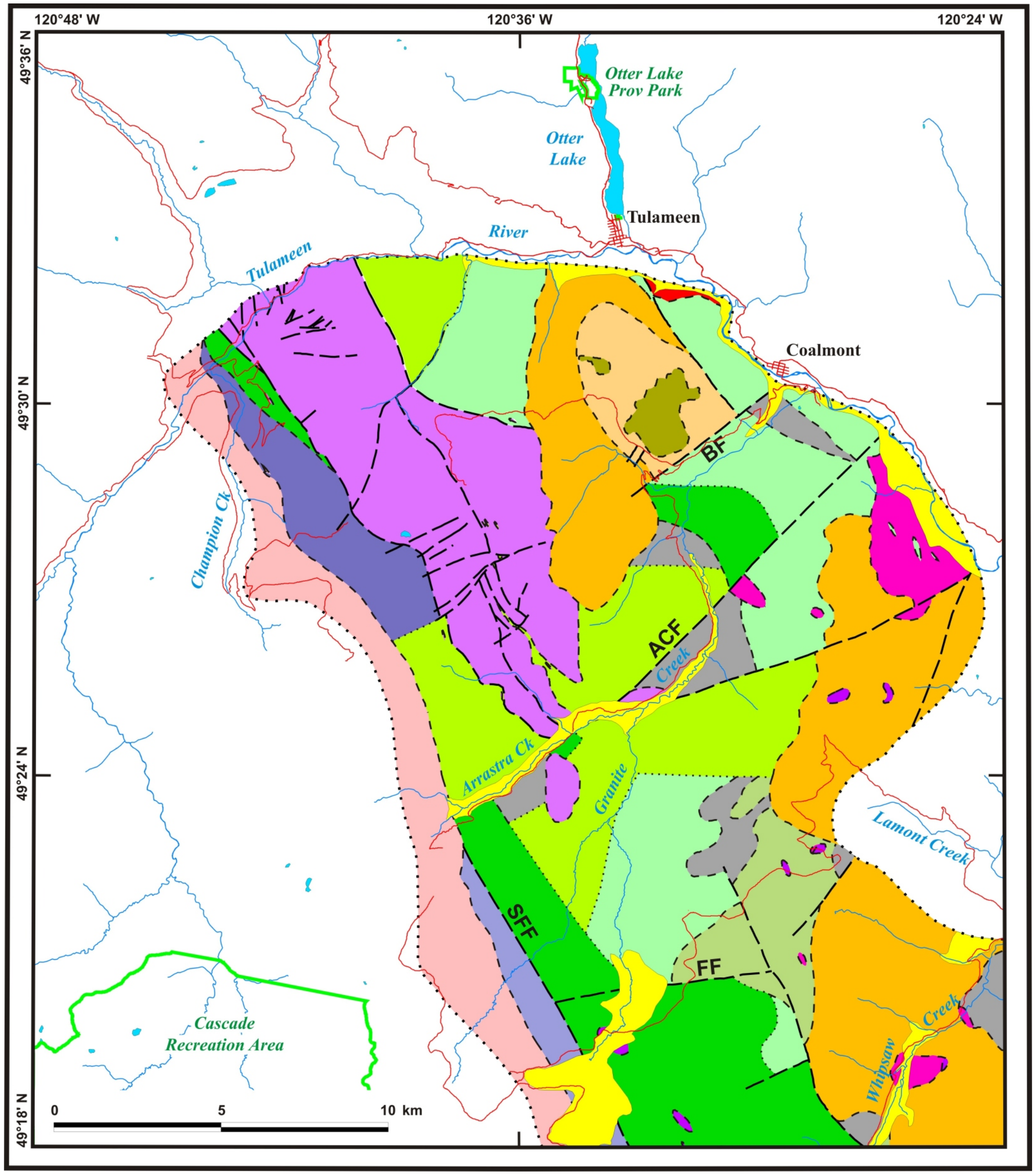


**Figure 2.** Geology of the Granite Creek area, southern British Columbia, from mapping done in 2009. See Figure 3 for key to geological units. Faults are shown with thick dashed lines; geological contacts with thinner dashed lines, or dotted lines where transitional or uncertain. Abbreviations: ACF, Arrastra Creek fault; BF, Blakeburn fault; FF, Frenchy Creek fault; SFF, Similkameen Falls fault.

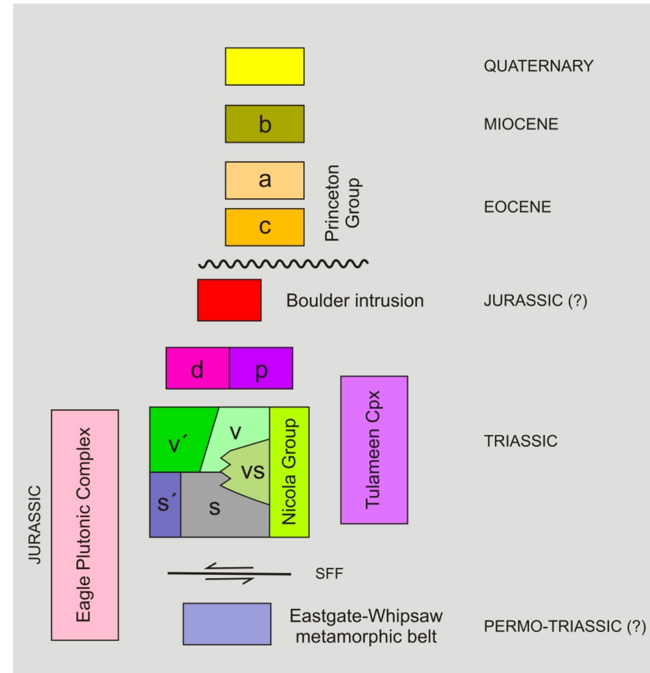


**Figure 3.** Geological units in the Granite Creek map area, southern British Columbia. Abbreviations: b, columnar basalt; SFF, Similkameen Falls fault; Cpx, complex. Princeton Group abbreviations: c, Cedar Formation; a, Allenby Formation. Nicola Group abbreviations: s, clastic sedimentary rocks; s´, schistose metasedimentary rocks; v, volcanic rocks; vs, volcaniclastic sedimentary rocks; v´, schistose volcanic rocks. Intrusive units abbreviations: d, diorite; p, pyroxenite.

cur interbedded with the amphibolite, which is presumably of volcanic protolith.

## LATE TRIASSIC NICOLA GROUP

Rocks of the Nicola Group west of Princeton are divided into two informal lithological units, a clastic sedimentary unit and a volcanic unit. Correlation between individual outcrop areas of the two units is uncertain and they may combine several distinct stratigraphic units. Feldspathic tuff and tuffaceous sedimentary rocks, found interbedded with the clastic sedimentary unit in the Lamont main road area to the south (Massey et al., 2009), were not seen in the present map area.

The clastic sedimentary unit is dominated by black argillite interbedded with grey to green-grey siltstone and sandstone, and polymictic conglomerate. Finer grained beds are massive to laminated (Figure 5a) and may have a limy or siliceous matrix. Coarser beds can be massive, graded or laminated, and vary in thickness from millimetres to several centimetres. Layers of matrix-supported, polymictic granule to pebble conglomerate are intercalated with the finer sedimentary rocks. The clasts are dominantly clastic sedimentary, but locally include limestone (Figure 5b) and volcanic material.

In the Champion Creek area, in the northwest of the mapped area, the sedimentary rocks are strongly metamorphosed in the aureole of the Eagle Plutonic complex to produce a sequence of quartz±feldspar–rich schist with variable proportions of biotite, actinolite, garnet, muscovite and magnetite (Figure 6). Chlorite and epidote may occur as secondary alteration minerals. The schist shows marked colour banding with dark and pale layers up to several centimetres thick, although some quartzite beds can reach up to 2 m in thickness. Calcareous beds are recrystallized to buff-weathering, medium- to coarse-grained white marble. The marbles are usually massive, but can display a weak foliation delineated by quartz, chlorite or minor calcsilicate minerals.

**Figure 4.** Foliated amphibolite of the Eastgate–Whipsaw metamorphic belt, Granite Creek area, southern British Columbia (field station 09NMA04-03; UTM Zone 10, 5470528N, 658385E, NAD 83).

The volcanic unit includes the interbedded pyroxene-feldspar tuff, lapilli tuff, breccia, agglomerate and tuffaceous sedimentary rocks that are characteristic of the Nicola Group in other areas (Figure 7). The rocks of this unit are light grey, weathering to green-grey with orange-stained fracture surfaces and contain lithic clasts, which vary from angular to subrounded and are typically 3–5 cm across, ranging up to 20–25 cm in breccia and agglomerate. The clasts are dominantly pyroxene-feldspar porphyritic basalt and basaltic andesite, characterized by a wide variation in proportions and sizes of phenocrysts, although aphyric basalt can also be seen. They are usually supported in a medium- to coarse-sand–sized matrix containing feldspar and pyroxene crystals, and small lithic clasts. Epidote, chlorite and calcite occur as alteration minerals in clasts and matrix, and also in veins. Quartz veins are also common.

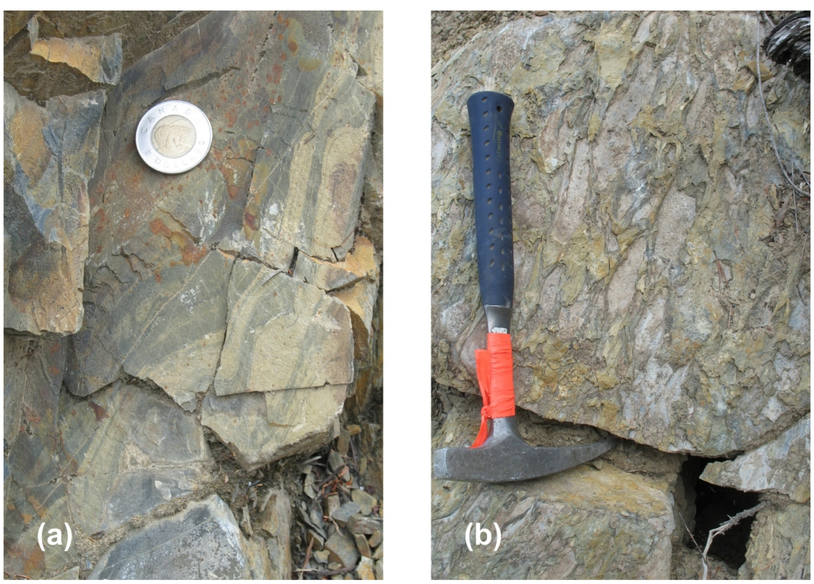


**Figure 5.** Clastic sedimentary rocks of the Nicola Group, Granite Creek area, southern British Columbia: **a)** slump structures in argillite-siltstone interbeds (field station 09NMA14-07; UTM Zone 10, 5484990N, 667162E, NAD 83); **b)** pebble conglomerate with negatively weathering limestone clasts (09NMA14-06; UTM Zone 10, 5484877N, 667157E, NAD 83).

A sequence of massive, medium grey to green, fine-grained feldspar basalt and greenstone flows occurs in the area southeast of the Granite Creek campsite. Lath-


**Figure 6.** Schistose metasedimentary rocks of the Nicola Group, Granite Creek area, British Columbia: **a)** thinly laminated biotite-actinolite schist (field station 09NMA01-03; UTM Zone 10, 5484828N, 650771E, NAD 83); **b)** interbedded quartzite and biotite-actinolite schist (09SOL01-10; UTM Zone 10, 5484054 N, 651703E, NAD 83); **c)** coarse actinolite needles and sheaves along a foliation plane in actinolite quartzite (09SOL02-03; UTM Zone 10, 5484382N, 651692E, NAD 83).

shaped feldspar phenocrysts 1–3 mm in size make up 5–10% of the rock. One flow also contained subhedral pyroxene phenocrysts 2–3 mm in size, with distinct blue-green feldspar in a bluish grey groundmass. Epidote and chlorite alteration is common both in the matrix and in veins.

The volcanic rocks become progressively schistose from east to west in the Fitzgerald mountain area, south of Coalmont. The tuff and lapilli tuff look massive in outcrop but display a weak foliation on broken surfaces. This foliation becomes progressively more penetrative to the west. Finer grained tuff produces bluish green-grey chlorite schist. Relict pyroxene is chloritized and varies from euhedral shapes to smeared blebs along the schistosity. Clasts in lapilli tuff and breccia are undeformed to slightly flattened. Chloritic rims may develop around the clasts, with feathering of their terminations occurring along the foliation. Similar schistose metavolcanic rocks also are found south of Arrastra Creek and in the Champion Creek area, where actinolite and biotite are developed in metavolcanic rocks in the aureole of the Eagle Plutonic complex.

## PRINCETON GROUP

Eocene rocks of the Princeton Group occur in the northern (Tulameen coal basin) and eastern (Princeton basin) parts of the map area (Figure 2). They lie unconformably on the Nicola Group and related intrusive rocks. Moderate paleorelief is evident on the unconformity and was estimated at more than 300 m in the Princeton area by McMechan (1983).

Within the map area, the Princeton Group comprises a lower volcanic sequence correlated by Read (2000) with the Cedar Formation and formerly called the 'Lower Volcanic Formation' (Shaw 1952a, b; McMechan, 1983), and an overlying sedimentary succession referred to as the 'Allenby Formation'. A Middle Eocene age has been suggested for these rocks based on whole-rock K-Ar dating and paleontological determinations (Church and Brasnett, 1983; Read, 2000). Field observations were restricted to outcrops of the Cedar Formation in the southwestern part of the Tulameen basin, in the Blakeburn Creek area, and on the eastern edge of the map area, from the old Rice millsite south to Bromley Creek.

In the Blakeburn Creek area, the basal unit is a distinctive fine-grained, aphyric, amygdaloidal to vuggy, massive mafic flow. It is medium grey, weathers brown to orange-brown and contains vesicles, vugs and thin veinlets infilled with milky white to clear chalcedony. This unit is overlain by a sequence of coarse-grained, grey-brown to pale brown-weathering clastic sedimentary rocks, ranging from sandstone and gritstone to pebble conglomerate. Sandstone is medium to coarse grained and includes dark lithic fragments as well as quartz and feldspar. Some beds fine upward into silty laminated tops. Conglomerate is polymictic and includes subangular to subrounded clasts of various volcanic rocks, fine-grained volcanic detritus and quartz. Clast-clast contacts are common. Carbonized plant debris was observed in one gritstone outcrop. The sedimentary sequence is overlain, in turn, by mafic to intermediate flows, which may contain some vesicles, although they are generally massive. The flows range from black to grey to buff and vary from aphyric to porphyritic. Phenocrysts include white feldspar, pink to toffee-coloured K-feldspar, pyroxene and biotite.

At the eastern edge of the map area, clastic sedimentary rocks are absent from the Cedar Formation. The volcanic rocks vary widely in type and composition, from mafic to felsic, aphyric to porphyritic, and massive to volcaniclastic. Volcanic units of intermediate composition are most common and generally display porphyritic textures. These include varieties of feldspar, feldspar-pyroxene, feldspar-

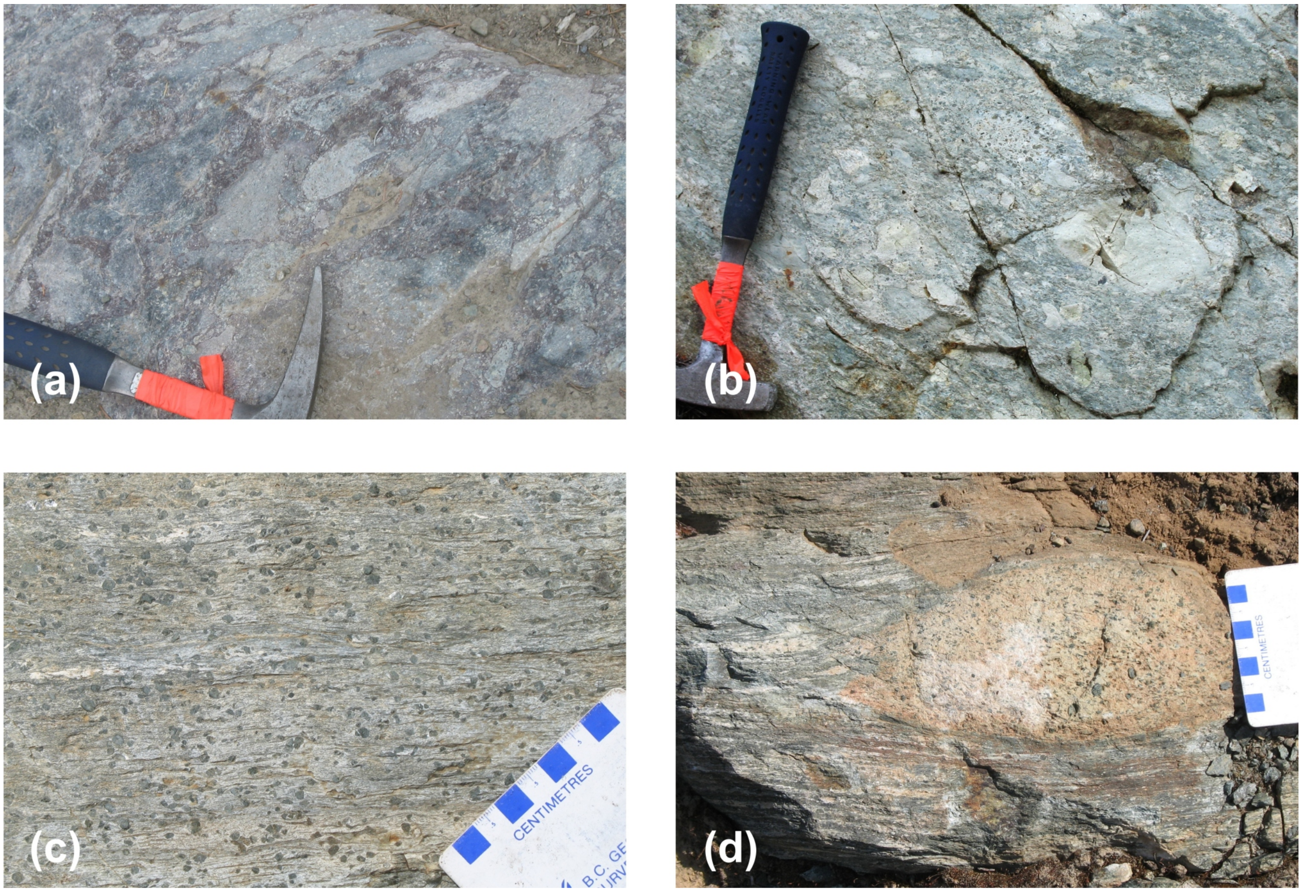


**Figure 7.** Volcanic and metavolcanic rocks of the Nicola Group, Granite Creek area, southern British Columbia: **a)** purple monolithic feldspar basalt breccia (field station 09NMA15-02; UTM Zone 10, 5484259N, 668284E, NAD 83); **b)** heterolithic tuff breccia (09NMA13-07; UTM Zone 10, 5483105N, 665739E, NAD 83); **c)** relict pyroxene crystals in chlorite schist (metatuff) (09NMA02-06; UTM Zone 10, 5471753N, 659170E, NAD 83); **d)** boudinaged clast in lapilli metatuff, showing notable feathering of end of clast into the schistosity (09NMA03-02; UTM Zone 10, 5472126N, 658555E, NAD 83).

hornblende and hornblende–K-feldspar andesites, megacrystic feldspar andesite and feldspar-hornblende dacite, as well as monolithic and heterolithic andesitic breccias, lapilli tuff, and pyroxene and feldspar crystal tuffs. Mafic units consist of dark grey or brown, vesicular, massive or monolithic breccia. Epidote alteration is found in the matrix of breccia, replacing feldspar phenocrysts and along fractures and veins. Chlorite infills vesicles and minor veinlets, and may be accompanied by minor calcite, quartz and zeolite.

## MIOCENE COLUMNAR BASALT

Flat-lying, massive to columnar-jointed, olivine basalt flows unconformably overlie the Princeton Group in the Blakeburn area (Rice, 1947). Based on a whole-rock K-Ar determination of 9 ±0.9 Ma (Evans, 1978; Church and Brasnett, 1983; Mathews, 1989; Breitspecher and Mortensen, 2004), these basalt flows are Miocene and therefore correlative with the Chilcotin Group. Isolated, up to room-sized blocks are also observed in the Blakeburn Creek–Newton Creek area to the west of the main outcrop areas (Figure 8). The basalt is fine- to medium-grained, black on the fresh surface, but lighter grey with orange spots on the weathered surfaces. Sparse vesicles are infilled with white quartz and zeolite. Columnar joints are well developed, although often subhorizontal due to tilting of the blocks. Blocks up to 30 m across have also been reported in Granite Creek (Evans, 1985), which suggests that the flows were originally more extensive.

**Figure 8.** Large isolated block of Miocene columnar olivine basalt, Granite Creek area, British Columbia; block is approximately 2.5 m high (field station 09NMA09-14; UTM Zone 10, 5484605N, 660440E, NAD 83).

## Intrusive Rocks

Several phases of intrusions occur in the map area, including: the Late Triassic ultramafic-mafic Tulameen complex, the Jurassic–Cretaceous Eagle Plutonic complex, the Jurassic (?) Boulder intrusion and minor Tertiary intrusions coeval with the Princeton Group.

### LATE TRIASSIC INTRUSIONS

#### *Tulameen ultramafic-mafic complex*

The Tulameen complex is the largest Alaskan-type intrusion in British Columbia (Nixon et al., 1997). It occurs in the northwestern part of the map area, extending from Arrastra Creek to the Tulameen River (Figure 2) and north to Grasshopper Mountain. It has been described in detail by Findlay (1963, 1969), Rublee (1994) and Nixon et al. (1997). No new mapping was undertaken as part of the present study. The principal units of the complex comprise dunite, olivine clinopyroxenite, hornblende clinopyroxenite and gabbroic to dioritic and monzonitic rocks. Contacts with the surrounding Nicola Group rocks are rarely exposed and are generally faulted. However, Nixon et al. (1997) reported rafts of Nicola metasedimentary rocks intruded by gabbro and hornblendite south of Blakeburn Creek. A U-Pb zircon date in the range of 204–212 Ma from a syenodiorite phase was reported by Rublee and Parrish (1990) and Rublee (1994), in agreement with older K-Ar and $^{40}$Ar/$^{39}$Ar dates from hornblendes (Roddick and Farrar, 1971, 1972; McDougall, 1974), which indicates that the complex is Late Triassic, probably coeval with the surrounding Nicola Group.

#### *Other Diorite and Pyroxenite Stocks*

The Rice stock and several smaller stocks of diorite-gabbro and pyroxenite are found in the eastern part of the map area, where they intrude Nicola Group rocks or are unconformably overlain by the Princeton Group. They may be related to the Tulameen complex or to the Late Triassic Copper Mountain intrusions, further to the east.

The Rice stock is medium grey to green, coarse-grained and equigranular to slightly porphyritic gabbro to diorite. Feldspar laths are white to apple green; minor pink K-feldspar forms small interstitial crystals. Quartz is generally absent, but may be present as a minor constituent in more dioritic phases. Mafic minerals are interstitial to subhedral and include both square to lath-shaped pyroxene and tabular to needle-like hornblende, with colour indices varying from 25 to 50. Pyroxene phenocrysts up to 3–5 mm in size can impart a distinctly spotted appearance to the outcrop (Figure 9a).

An outcrop at the GD showing (Table 1), about 5 km to the west of the Rice stock, is similarly coarse-grained diorite with white to pale green plagioclase feldspar and minor pink K-feldspar. Hornblende needles range up to 1 cm in size. The diorite is notable for the presence of abundant xenoliths, including rounded, cognate pyroxenite (Figure 9b). Very coarse pegmatitic diorite, with hornblende up to 2–3 cm long, occurs in float, but was not observed in outcrop.

Coarse-grained, layered pyroxenite-gabbro-diorite occurs in an isolated outcrop 2 km south of the main Rice stock. Pyroxenite is dark green to black on fresh surfaces, weathers dark grey and contains crystals ranging up to 1 cm in size; minor white feldspar and magnetite occur interstitially. Pyroxene-rich gabbro and melanodiorite are generally finer grained. The diorite also contains elongate hornblende.

### JURASSIC-CRETACEOUS EAGLE PLUTONIC COMPLEX

The Eagle Plutonic complex lies along the western margin of the map area (Figure 2), intruding the Eastgate–Whipsaw metamorphic belt and Nicola Group. Greig (1989, 1992) described the complex immediately to the north. Within the map area, most outcrops belong to Grieg's 'Eagle tonalite', although, in the absence of petrographic data, these were called 'biotite-granodiorite' in the field, which terminology is retained here. Greig et al. (1992) reported Middle to Late Jurassic U-Pb zircon ages for the Eagle tonalite.

The biotite-granodiorite is a syntectonic intrusion with varying texture and fabrics. A range of foliate fabrics from massive to gneissic are seen in the granodiorite. Massive phases are equigranular to seriate, varying in grain size from 3–5 mm to 5–6 mm. White feldspar forms subhedral laths. Translucent grey quartz is irregular, often interstitial to feldspar and biotite and may be smaller in grain size. Biotite is typically black and makes up 10–25% of the rock. Minor epidote, magnetite and red garnet are common. Finer grained microgranodiorite (1–2 mm grain size) is of similar

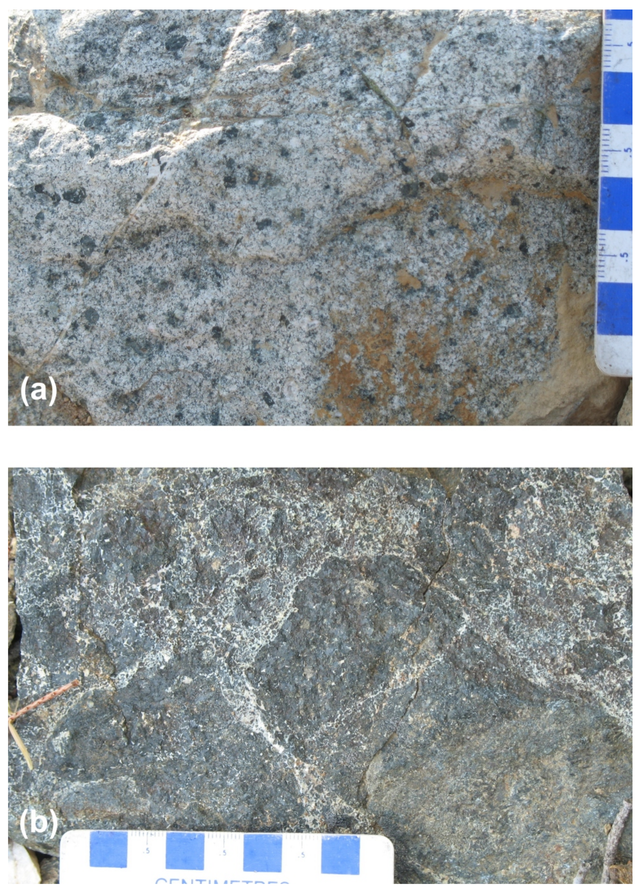

**Figure 9.** Triassic diorite from the Granite Creek area, southern British Columbia: **a)** pyroxene phenocrysts in diorite (field station 09NMA17-03; UTM Zone 10, 5479310N, 671135E, NAD 83); **b)** cognate pyroxenite xenoliths in diorite (09NMA18-07; UTM Zone 10, 5479715N, 666731E, NAD 83).

**Table 1.** Mineral occurrences in the map area (from MINFILE, 2009). Note that only the principal name is shown for each occurrence for brevity. Deposit type codes: A03, sub-bituminous coal; A04, bituminous coal; B07, bog Fe, Mn, U, Cu, Au; C01, surficial placer; D01, open-system zeolite; E06, bentonite; G06, Noranda/Kuroko massive sulphide; I01, Au-quartz vein; I02, intrusion-related Au pyrrhotite veins; I05, Ag-Pb-Zn±Au polymetallic veins; K01, Cu skarn; K04, Au skarn; K07, Mo skarn; L01, subvolcanic Cu-Ag-Au (As-Sb); L03, alkalic porphyry Cu-Au; L04, porphyry Cu±Mo±Au; M04, magmatic Fe-Ti±V oxide deposit; M05, Alaskan-type Pt±Os±Rh±Ir.

| MINFILE Number | Name | Status | Commodities |
|---|---|---|---|
| **Tulameen Coal Basin: Coal and industrial minerals** | | | |
| 092HNE094 | Collin's Gulch | Past Producer | Cl, Cy |
| 092HNE188 | Fraser Gulch | Prospect | Ze |
| 092HSE157 | Basin Coal | Past Producer | Cl, Bn |
| 092HSE228 | Hayes and Vittoni | Prospect | Cl |
| **Tulameen Complex: Cu-Pt-Cr, magnetite, olivine** | | | |
| 092HNE008 | Jenson's | Showing | Cu |
| 092HNE009 | Sootheran | Showing | Pb, Cu, Zn, Ag |
| 092HNE010 | Britton | Showing | Cu, Ag |
| 092HNE038 | Cathy | Showing | Cu, Pt, Pd, Cr |
| 092HNE128 | D | Prospect | Cr, Pt, Cu, Ni, Ab |
| 092HNE184 | Olivine Mountain | Prospect | Pt, Cr |
| 092HNE189 | Grasshopper Mountain Olivir | Prospect | Ol |
| 092HNE201 | Asp 14 | Showing | Cu |
| 092HNE202 | Copper Queen | Showing | Cu |
| 092HNE205 | H & H | Showing | Cu, Ag, Pd, Pt, Au |
| 092HNE206 | West Side | Showing | Cu, Ag, Au, Pt |
| 092HSE034 | Lodestone Mountain | Developed Prospect | Ma, Fe, Va, Pt, Ti |
| 092HSE035 | Tanglewood Hill | Developed Prospect | Ma, Fe, Ti |
| 092HSE039 | Hop | Showing | Cu, Au, Ag |
| 092HSE095 | Asp | Showing | Cu, Ag |
| 092HSE117 | Polaris 16 | Showing | Cu |
| 092HSE120 | FRM 52 | Showing | Cu, Pt, Pd |
| 092HSE128 | FRM 73 (99) | Showing | Cu |
| 092HSE129 | FRM 92 | Showing | Cu |
| 092HSE141 | RC | Showing | Cu |
| 092HSE142 | Lode 1 | Showing | Cu, Fe |
| 092HSE159 | Newton Creek Platinum | Showing | Pt, Cu |
| **Polymetallic veins and skarn** | | | |
| 092HNE022 | El Alamein | Past Producer | Au, Ag, Cu |
| 092HNE097 | Red Gold | Prospect | Mo, Cu, Zn, Ag, Au |
| 092HNE209 | White Gold | Showing | Zn, Ag |
| 092HSE042 | Wilmac | Showing | Cu |
| 092HSE076 | Newton Creek | Showing | Cu, Au |
| 092HSE077 | Riv | Showing | Au, Ag |
| 092HSE105 | Ski | Showing | Cu |
| 092HSE115 | Polaris | Showing | Cu |
| 092HSE124 | Goldrop | Past Producer | Zn, Cu, Pb, Au, Ag |
| 092HSE134 | GD | Prospect | Au, Cu, Ag |
| 092HSE135 | Lam | Showing | Cu |
| **Placers** | | | |
| 092HNE194 | Cedar Creek Placer | Past Producer | Au, Pt |
| 092HNE195 | Collins Gulch Placer | Past Producer | Au |
| 092HNE197 | Hines Creek Placer | Past Producer | Pt, Au |
| 092HNE198 | Slate Creek Placer | Past Producer | Au, Pt |
| 092HNE199 | Tulameen River Placer | Past Producer | Au, Pt, Cu |
| 092HSE230 | Granite Creek Placer | Past Producer | Au, Pt, Os, Ir, Rh, Pd, Cr, Cu |
| 092HSE232 | Newton Creek Placer | Past Producer | Au, Pt |
| 092HSE235 | Tulameen River | Past Producer | Au, Pt, Ir, Pd, Rh, Os, Ru |
| 092HSE236 | Whipsaw Creek Placer | Past Producer | Au, Pt |
| **Other Industrial Minerals** | | | |
| 092HSE103 | Granite Creek Gypsum | Prospect | Gy |
| 092HSE170 | Roany Creek | Past Producer | Mr |

**Table 1.** (continued)

| MINFILE Number | Latitude | Longitude | Deposit type | Zone | Easting | Northing |
|---|---|---|---|---|---|---|
| **Tulameen Coal Basin: Coal and industrial minerals** | | | | | | |
| 092HNE094 | 49.513890 | -120.734700 | A04 | 10 | 663970 | 5487051 |
| 092HNE188 | 49.513050 | -120.745000 | D01 | 10 | 663229 | 5486936 |
| 092HSE157 | 49.489170 | -120.754200 | A04, E06 | 10 | 662645 | 5484260 |
| 092HSE228 | 49.499720 | -120.717200 | A03 | 10 | 665285 | 5485514 |
| **Tulameen Complex: Cu-Pt-Cr, magnetite, olivine** | | | | | | |
| 092HNE008 | 49.509450 | -120.881700 | L01, M05 | 10 | 653348 | 5486247 |
| 092HNE009 | 49.528890 | -120.895000 | I05, M05 | 10 | 652323 | 5488382 |
| 092HNE010 | 49.521670 | -120.917500 | M05 | 10 | 650717 | 5487533 |
| 092HNE038 | 49.518610 | -120.906100 | M05 | 10 | 651551 | 5487217 |
| 092HNE128 | 49.527220 | -120.902800 | M05 | 10 | 651765 | 5488181 |
| 092HNE184 | 49.519170 | -120.882200 | M05 | 10 | 653278 | 5487327 |
| 092HNE189 | 49.526390 | -120.904200 | M04 | 10 | 651667 | 5488085 |
| 092HNE201 | 49.503330 | -120.854400 | M05 | 10 | 655338 | 5485624 |
| 092HNE202 | 49.511110 | -120.890000 | M05 | 10 | 652740 | 5486416 |
| 092HNE205 | 49.530280 | -120.861900 | M05 | 10 | 654710 | 5488603 |
| 092HNE206 | 49.533050 | -120.887200 | M05 | 10 | 652873 | 5488861 |
| 092HSE034 | 49.463050 | -120.836900 | M05 | 10 | 656734 | 5481182 |
| 092HSE035 | 49.492220 | -120.820800 | M05 | 10 | 657807 | 5484458 |
| 092HSE039 | 49.455830 | -120.810300 | L03 | 10 | 658689 | 5480435 |
| 092HSE095 | 49.491110 | -120.841100 | L04 | 10 | 656342 | 5484293 |
| 092HSE117 | 49.410560 | -120.789700 | L04, M05 | 10 | 660326 | 5475446 |
| 092HSE120 | 49.497500 | -120.891100 | | 10 | 652702 | 5484900 |
| 092HSE128 | 49.433890 | -120.819400 | L04, M05 | 10 | 658096 | 5477977 |
| 092HSE129 | 49.434720 | -120.800800 | L04, M05 | 10 | 659442 | 5478109 |
| 092HSE141 | 49.489440 | -120.855000 | M05, L04 | 10 | 655342 | 5484079 |
| 092HSE142 | 49.486110 | -120.883900 | M05 | 10 | 653260 | 5483649 |
| 092HSE159 | 49.439720 | -120.802200 | M05 | 10 | 659325 | 5478662 |
| **Polymetallic veins and skarn** | | | | | | |
| 092HNE022 | 49.539440 | -120.839700 | I02 | 10 | 656289 | 5489668 |
| 092HNE097 | 49.509720 | -120.930800 | K01, K04, K07, I05 | 10 | 649789 | 5486179 |
| 092HNE209 | 49.501390 | -120.933100 | I05 | 10 | 649653 | 5485248 |
| 092HSE042 | 49.375550 | -120.679700 | | 10 | 668424 | 5471795 |
| 092HSE076 | 49.462220 | -120.736400 | I05, L01 | 10 | 664022 | 5481304 |
| 092HSE077 | 49.355000 | -120.601400 | I01, L01 | 10 | 674183 | 5469688 |
| 092HSE105 | 49.348610 | -120.604700 | | 10 | 673963 | 5468970 |
| 092HSE115 | 49.405560 | -120.799700 | | 10 | 659617 | 5474869 |
| 092HSE124 | 49.335560 | -120.626900 | G06, I05 | 10 | 672395 | 5467468 |
| 092HSE134 | 49.447780 | -120.699400 | M05, L01, L04 | 10 | 666748 | 5479779 |
| 092HSE135 | 49.401670 | -120.678100 | L04 | 10 | 668456 | 5474701 |
| **Placers** | | | | | | |
| 092HNE194 | 49.521670 | -120.787800 | C01 | 10 | 660105 | 5487801 |
| 092HNE195 | 49.532500 | -120.740600 | C01 | 10 | 663486 | 5489107 |
| 092HNE197 | 49.536950 | -120.864700 | C01 | 10 | 654488 | 5489339 |
| 092HNE198 | 49.534440 | -120.822500 | C01 | 10 | 657551 | 5489148 |
| 092HNE199 | 49.533610 | -120.889200 | C01 | 10 | 652730 | 5488918 |
| 092HSE230 | 49.456670 | -120.725800 | C01 | 10 | 664806 | 5480709 |
| 092HSE232 | 49.447500 | -120.780000 | C01 | 10 | 660911 | 5479573 |
| 092HSE235 | 49.476940 | -120.629400 | C01 | 10 | 671719 | 5483179 |
| 092HSE236 | 49.306390 | -120.649700 | C01 | 10 | 670841 | 5464174 |
| **Other Industrial Minerals** | | | | | | |
| 092HSE103 | 49.481670 | -120.708300 | B07 | 10 | 665989 | 5483527 |
| 092HSE170 | 49.479170 | -120.663300 | B07 | 10 | 669257 | 5483349 |

mineral composition, although more melanocratic with up to 50% biotite.

Weakly foliated granodiorite is similar to the massive phase, except that biotite shows a marked alignment, may cluster and may also be coarser grained. In foliated phases, biotite forms penetrative sheets, or folia, that break the granodiorite into layers 1–10 cm thick. Within the layers between folia, biotite is aligned parallel to the folia. White feldspar megacrysts up to 1–2 cm can be associated with the biotite folia, giving a very distinctive spotted look to surfaces.

Massive muscovite granite, probably related to muscovite granite in the mid-Cretaceous Fallslake Plutonic suite (Grieg, 1992; Greig et al., 1992), occurs in the upper Arrastra Creek area. The granite is pinkish white to pale grey, medium to coarse grained (1–3 mm grain size) and leucocratic. It contains both pink and white subhedral feldspar laths, rounded to interstitial quartz, silvery micaceous muscovite and black biotite. Contacts between the granite and the biotite granodiorite were not observed.

#### JURASSIC (?) BOULDER INTRUSION

Granite of the Boulder intrusion occurs in the very northeast of the map area near Tulameen. This intrusion of still uncertain age was not visited during this present study, but has been described by Camsell (1913) and Rice (1947) as pink, coarse-grained, hornblende granite. It intrudes rocks of the Nicola Group and is, in turn, intruded by the Cretaceous Otter Lake stock.

#### MINOR TERTIARY INTRUSIONS

Dikes of mafic to felsic composition, coeval with the Princeton Group, occur throughout the map area. They include feldspar basalt; pyroxene, pyroxene-feldspar and hornblende±feldspar andesite porphyries; hornblende-feldspar, feldspar and aphyric dacite; and rare rhyolite.

## STRUCTURE

### *Folds*

Problematic correlation within different lithological units, the lack of regional markers and suspected facies changes within the volcanic and volcaniclastic rocks of the Nicola Group render the identification of major folds difficult. Although few bedding attitudes were observed, even in the sedimentary rocks, they generally strike northwesterly. Dips are often steep, 60–80° to both the northeast and the southwest. Bedding attitudes in the sedimentary unit immediately northeast of Roany Creek suggest that they lie in the core of a syncline. However, the volcanic rocks in the two limbs show significant lithological differences and the effects of faulting cannot be discounted.

Schistosity or cleavage in the Nicola Group rocks is subparallel to bedding, where both are observed. They strike northwesterly with variable (40–80°) southwesterly dips. Dips are more consistent, with steep inclinations (50–75°) closer to the contact with the Eagle Plutonic complex. Amphibolite of the Eastgate–Whipsaw metamorphic belt and syntectonic granodiorite of the Eagle Plutonic complex have similarly inclined schistosities.

Two schistosities are discernible in some outcrops in the Whipsaw area to the south (Massey et al., 2009). These intersect at an acute angle and it is often difficult to determine their relative order of formation; similar fabrics were rarely observed in the Granite Creek area. Occasionally observed outcrop-scale S- and Z-folds of both bedding and schistosity (Figure 10) usually show shallow plunges of 10–20° to the southeast. The age of deformation of rocks within the Nicola Group and Eastgate–Whipsaw metamorphic belt is unknown, although it is at least, in part, contemporaneous with the intrusion of the Middle to Late Jurassic Eagle tonalite.

The Tertiary Tulameen basin preserves a portion of a southeasterly plunging syncline, which has been truncated on the southeast by the Blakeburn fault (Church and Brasnett, 1983; Read, 1987). Beds are generally gently dipping (up to 35°), although they may steepen up to 63° on the western limb (Read, 1987). Princeton Group rocks in the east of the map area lie on the western limb of the Tailings syncline of the Princeton basin (Read, 1987); however, the predominantly massive volcanic rocks yield a scarcity of structural information.

### *Major Faults*

Contacts between the Tulameen complex and the Nicola Group are reported to be ductile shears or faults (Nixon et al., 1997). The attitudes of contact faults and re-

**Figure 10.** S-fold in actinolite-chlorite schist of the Nicola Group metavolcanic unit, Granite Creek area, southern British Columbia (field station 09NMA03-03-01; UTM Zone 10, 5472062N, 658522E, NAD 83).

lated planar fabrics in adjacent rocks along the western margin of the Tulameen complex are parallel to the regional northwesterly trending foliations in the Nicola Group and Eagle Plutonic complex. Northeast- to easterly trending high-angle faults crosscut the Tulameen complex and may be contemporaneous with other northeasterly trending faults cutting the Nicola Group, such as the Arrastra Creek fault (Figure 2). The age of this faulting is unknown, but truncation of the Tulameen coal basin by the Blakeburn fault suggests that some of the faulting may be Tertiary.

The Eastgate–Whipsaw metamorphic belt is separated from Nicola Group volcanic rocks by the northwest-trending Similkameen Falls fault of unknown age. Though not exposed in the present field area, it is seen along Highway 3 about 1 km south of Similkameen Falls (Massey et al., 2009). The fault trace appears to be linear and is interpreted to be steep. It terminates easterly trending faults in the Nicola Group and also appears to acutely crosscut the three lithological assemblages of the Eastgate–Whipsaw metamorphic belt, which suggests that it postdates the Middle–Late Jurassic deformation. Both the metamorphic belt and the fault trace are terminated by muscovite granite of the Eagle Plutonic complex, which may correlate with the mid-Cretaceous Fallslake Plutonic suite, suggesting that the fault predates the mid-Cretaceous.

## MINERALIZATION

Some 48 mineral occurrences are reported for the map area in the MINFILE database (Table 1; MINFILE, 2009). The most important of these are the deposits of the Late Tri-

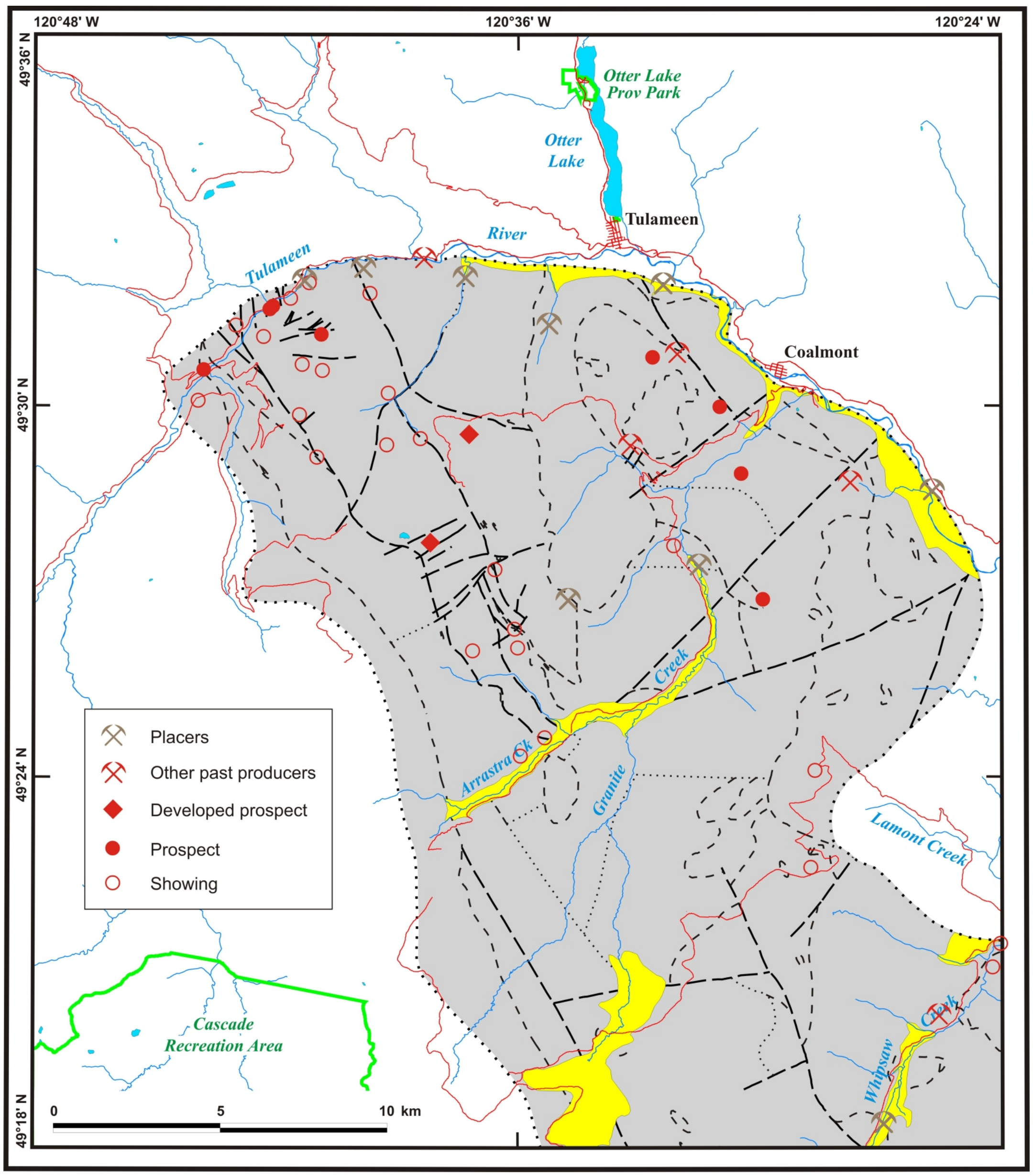


**Figure 11.** Locations of mineral occurrences in the map area, Granite Creek area, southern British Columbia. Geological contacts and faults in the grey map area are as in Figure 2.

assic Tulameen complex, the Tertiary Tulameen coal basin and the various gold-platinum placers.

### Tulameen Complex

Twenty-two of the MINFILE occurrences lie in the northwestern corner of the map area (Figure 11) and are hosted in the Tulameen complex. Aspects of the geology and mineralization have been described by Camsell (1913), Rice (1947), Findlay (1969) and Nixon et al. (1997); four main types of deposit have been found. Chromitite in the dunite core of the complex, in the Olivine Mountain area, forms bulbous or irregular masses or thin discontinuous schlieren up to 4 m in length (Nixon et al., 1990). The chromitite can be rich in platinum group metals, although the proportion of platinum group minerals is highly variable. Minor quantities of base-metal sulphide and arsenide minerals also occur.

Magnetite forms semi-massive to massive lenses or vein-like bodies in hornblende pyroxenite in the Lodestone Mountain and Tanglewood Hill areas. The lenses vary from a few centimetres to 5.5 m thick, although they usually are less than 1 m thick. Ilmenite, minor leucoxene and sphene are intimately associated with the magnetite.

Copper mineralization is associated with a variety of hostrocks, commonly gabbro to diorite or hornblende-rich pegmatite. Mineralization is primarily chalcopyrite, pyrite and bornite, but may include minor sphalerite and galena. Whereas some silver and platinum have been reported in assays, only trace quantities of gold have been found. The mineralization occurs in lenticular or discontinuous zones within faults, fractures and quartz veins. Some hostrocks exhibit epidote-chlorite alteration, and malachite and azurite staining is also found.

Olivine from unserpentinized dunite in the Olivine Mountain–Grasshopper Mountain area may be suitable for the production of foundry sand and other refractory products (White, 1987; Hora and White, 1988).

### Tulameen Coal Basin

Exploration for, and production of, coal in the Tulameen basin has proceeded sporadically since prior to 1900, when coal was first discovered near Blakeburn Creek and Collins Gulch. Summaries and details of the coal deposits and their exploration have been provided by Camsell (1913), Rice (1947), Shaw (1952), Donaldson (1973), Church and Brasnett (1983), Evans (1985) and Read (2000). From 1919 to 1940, underground coal mines extracted about 2 million tonnes from the Tulameen basin, and in the 1950s, surface mining extracted about 0.15 million tonnes (Ryan, 2004). There was renewed exploration in the Tulameen basin in the 1970s and 1980s, and a major exploration program in 1998. Small-scale production has proceeded sporadically into the 2000s.

The coal deposits are hosted in the Allenby Formation of the Princeton Group. Several coal seams are found in a shale-rich member approximately 130 to 200 m thick (the Vermilion Bluffs shale of Read, 1987), underlain by up to 120 m of sandstone, siltstone and andesitic volcanic rocks (‘Hardwicke sandstone’ of Read, 1987), and overlain by 580 to 700 m of sandstone and pebble conglomerate, with interbeds of shale, ash and coal in the lower sections (‘Summers Creek sandstone’ of Read, 1987). The coal consists of up to 30 m of coal interbedded with mudstone, bentonite shale and sandstone. It occurs in the lower 80 m of the coal-shale member in a zone of mostly brown to grey to black fissile shale and mudstone with lesser coal and white to buff bentonite. Individual seams vary in thickness from a few centimetres to over 10 m and strike lengths, up to 2–3 km; however, correlation of seams between the two limbs of the basin is not possible. Coal rank is generally high-volatile C to B bituminous (Ryan, 2002).

Zeolite and bentonite are also known from intermediate to felsic ash-rich sedimentary units in the Allenby Formation of the Tulameen basin (Read, 2000).

### Gold-Platinum Placers

Placer deposits were discovered along the Tulameen and Similkameen rivers in the 1860s, with major production starting up in the 1880s. Within the map area, the richest deposits were on Granite Creek and the Tulameen River; however, several other creeks have also attracted interest (Table 1; Figure 10). Although production at most deposits continued intermittently only into the 1930s, exploration and production along the Tulameen River continued well into the 1970s. Interest is now limited to small-scale seasonal operations.

Gold has been the main focus of interest, but significant platinum has also been extracted (Rice, 1947). Metals found along the Tulameen River tend to occur in old sinuous channels buried deep below glacial gravel, which yields only spotty values. At Granite Creek, gold- and platinum-bearing sections are generally found to occur on bedrock. These pay gravels are well indurated and cemented by a stiff clay. The gold in the placers occurs in rough, angular or slightly flattened, rarely well-flattened nuggets, some of which contain abundant white quartz. Platinum forms small rounded grains of uniform size, which are smaller than the gold nuggets and are commonly pitted. The gravel worked along the upper Tulameen River also yielded black sand consisting of magnetite and chromite as well as significant gold and platinum values. The origin of the gold and platinum in the placers is believed to be from gold veins of the Grasshopper Mountain area and the chromitite, in the dunite of the Tulameen complex in the Olivine Mountain region (Rice, 1947; Nixon et al., 1990; Levson et al., 2002).

### Other Occurrences

Copper mineralization similar to that observed in the Tulameen complex is found associated with the Rice stock at the GD (MINFILE 092HSE134; MINFILE, 2009) and Lam (MINFILE 092HSE135) occurrences and in pyroxenite at the Wilmac (MINFILE 092SHE042) showing. Other mineral showings mainly consist of a variety of quartz veins with gold and sulphide minerals, and a polymetallic skarn; gypsum and marl are found in Quaternary sediments in the Granite Creek area.

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