The Rayfield River pluton, south-central British Columbia (NTS 92P/6): Geologic setting and copper mineralization

James M. Logan[1, a] and Paul Schiarizza[1]

[1] British Columbia Geological Survey, Ministry of Energy and Mines, Victoria, BC, V8W 9N3
[a] corresponding author: Jim.Logan@gov.bc.ca

Recommended citation: Logan, J.M. and Schiarizza, P., 2014. The Rayfield River pluton, south-central British Columbia (NTS 92P/6): Geologic setting and copper mineralization. In: Geological Fieldwork 2013, British Columbia Ministry of Energy, and Mines, British Columbia Geological Survey Paper 2014-1, pp. 15-27.

Abstract
The Rayfield River syenite pluton (Late Triassic, > 201 Ma) is exposed along the lower reaches of the Rayfield River, 20 km east of 70 Mile House. On its southern margin, the pluton intrudes volcaniclastic rocks of the Nicola Group (Upper Triassic). On its southeastern flank, it is apparently cut by granites of the Thuya batholith, and is otherwise overlapped by Neogene and younger basalts. The pluton consists primarily of nepheline-normative hornblende syenite, but also includes a leucosyenite phase, and dikes of quartz-normative monzonite, pegmatite, and quartz-feldspar porphyry. Copper mineralization is widespread but low grade, and is accompanied by weak potassic, albitic and sericite alteration. The composition, age, and location of the Rayfield River pluton suggest that it is part of the highly prospective Late Triassic (205-200 Ma) Copper Mountain magmatic belt.

Keywords: Alkalic, nepheline syenite, Copper Mountain suite, bornite, chalcopyrite, potassic, albitic, sericite alteration and copper-gold mineralization

1. Introduction

British Columbia porphyry copper-gold-molybdenum deposits formed by calc-alkaline and alkaline arc magmatism in two subduction episodes during which the paleo-Pacific ocean plate slid beneath ancestral North America (McMillan et al., 1995). Each episode lasted ~ 50 m.y.; the first was in the Late Triassic to Early Jurassic (beginning ~ 220 Ma), the second in the Late Cretaceous to Eocene. Early Mesozoic, pre-accretionary zoned alkalic intrusions are well documented in Quesnel and Stikine terranes (Fig. 1; Barr et al., 1976; Lueck and Russell, 1994; Lang et al., 1995; Logan and Mihalynuk, in press). Some are highly mineralized (Fig. 1; Galore Creek, Mount Polley, New Afton and Copper Mountain) with Cu-Au-Ag ± Pd-Pt deposits, whereas others are barren (Zippa Mountain, Rugged Mountain, Kamloops syenite).

A syenite pluton, with low-grade copper mineralization, was identified along the lower reaches of the Rayfield River in the 1960s, and has since received intermittent attention from exploration geologists. Although commonly considered an example of a Quesnel terrane alkaline porphyry Cu-Au system, little information about the pluton is available. This report summarizes a two-week field investigation directed at establishing the composition and distribution of intrusive phases, the nature and distribution of mineralization and alteration assemblages, and the external contact relationships of the pluton. U-Pb dates of ~ 202 Ma or as young as 198 Ma (Anderson et al., 2010) suggest a Late Triassic to early Jurassic age for the pluton, which places it at the young end of the highly mineralized 205-200 Ma Copper Mountain suite (Breitsprecher, 2010; Logan et al., 2007). Preliminary results from our geochronological studies confirm the > 200 Ma age.

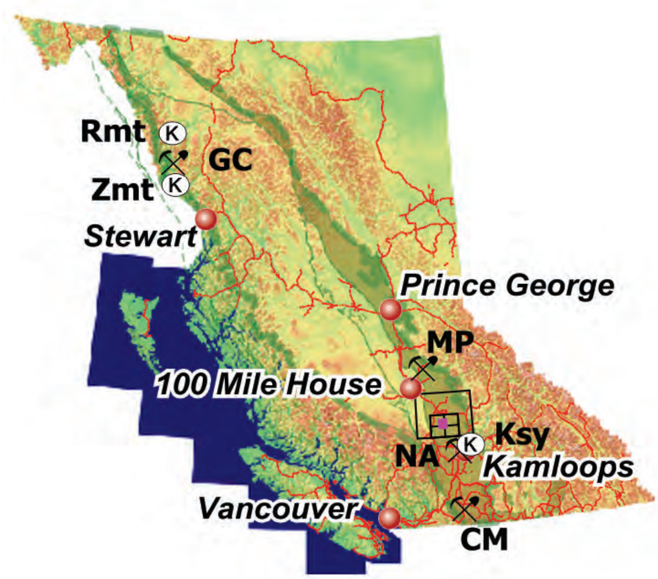


Fig. 1. Location of the Rayfield River area straddling the boundary between 92P/2, 3, 6 and 7 map sheets (black), near the eastern edge of Quesnel terrane (transparent green overlay). Mineralized alkalic centres (crossed picks) = CM, Copper Mountain; NA, New Afton; MP, Mount Polley; GC, Galore Creek; unmineralized alkalic centres (K) = Ksy, Kamloops syenite; Zmt, Zippa Mountain; Rmt, Rugged Mountain.

2. Location and previous work

The Rayfield River pluton is approximately 20 km east of 70 Mile House, B.C., in map sheet 92P/6, at about 51° 18' N and 121° 06' W (Fig. 1). It straddles both sides of Rayfield River

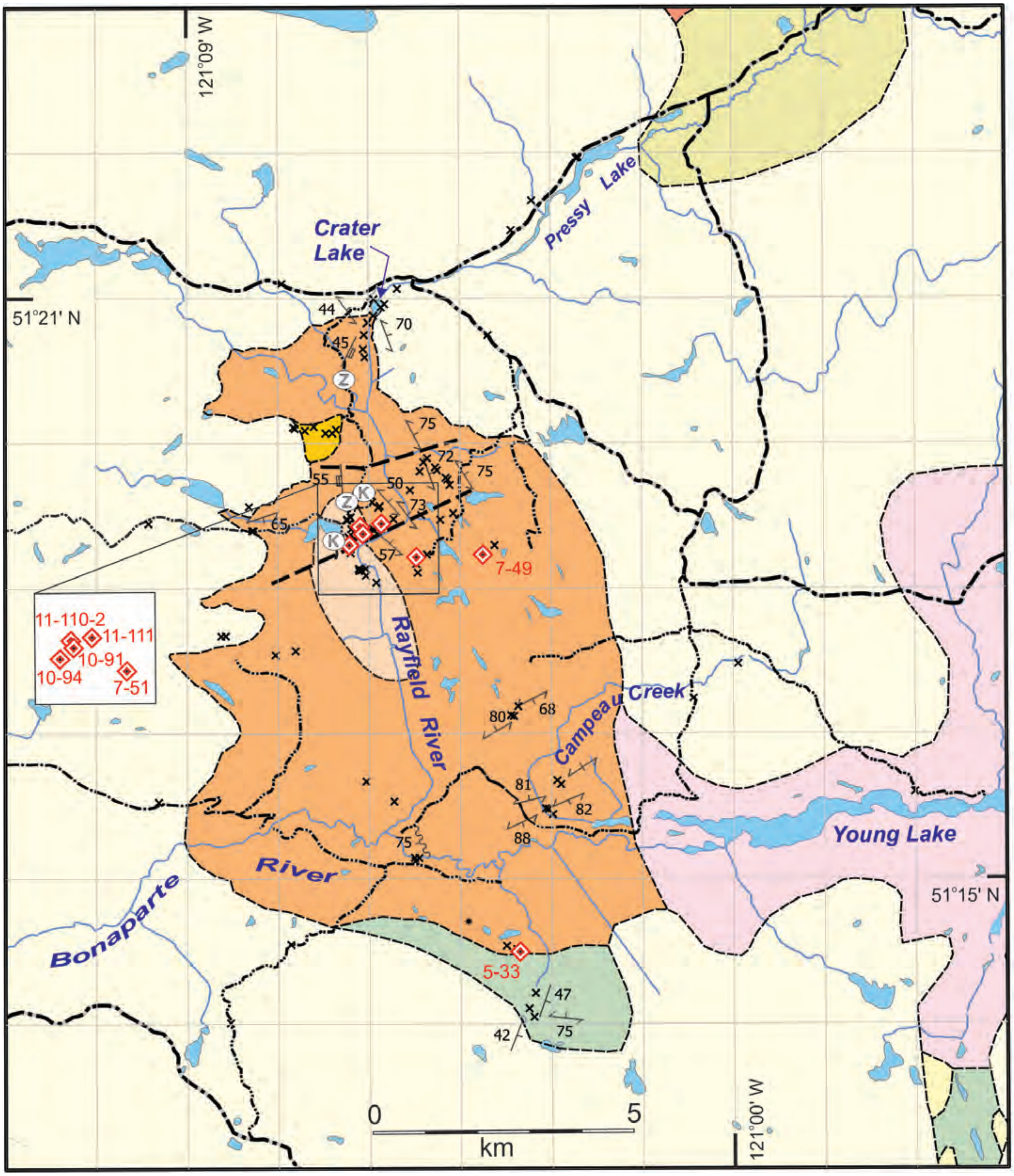
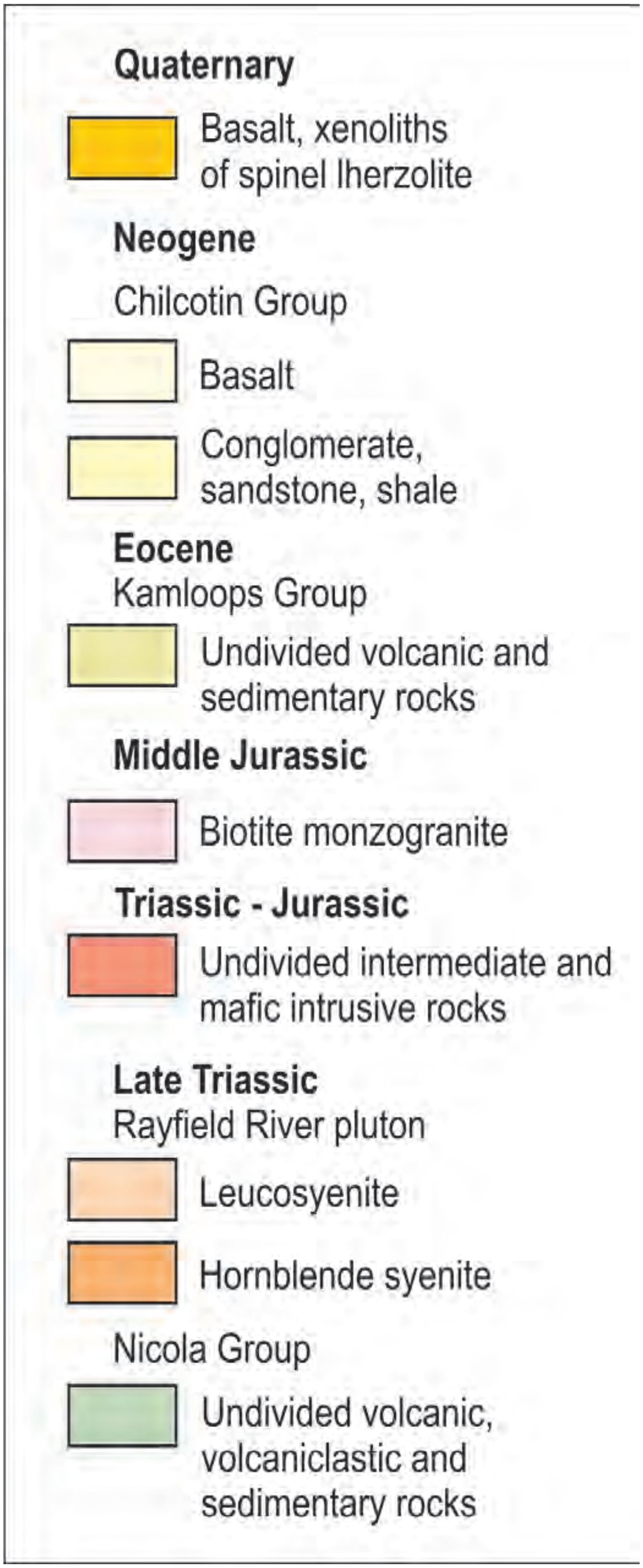


Fig. 2. Geology of the Rayfield River pluton. Geology northeast of Pressy Lake and south of Young Lake from Massey et al. (2005). Outcrops = x; geochronology samples, K = K-Ar and Z = zircon; geochemistry samples = diamonds. Inset map: geochemistry samples (Table 1).

and extends from Crater Lake in the north to the Bonaparte River in the south. Physiographically the area occupies the Cariboo Plateau (Mathews, 1989).

Campbell and Tipper (1971) included plutonic rocks along the Rayfield River as a leuco-quartz monzonite phase of the Thuya batholith, although they noted that syenite had been identified



in the area after their mapping. The syenite unit (Rayfield River pluton) was outlined by exploration geologists in the mid- to late-1960s (e.g. Hodgson et al., 1969), and briefly described by Preto (1970). The TGI-3 program of the Geological Survey of Canada included work on Thuya batholith and adjacent plutonic suites, including geochronologic studies of Rayfield River pluton (Anderson et al., 2010). A high-definition airborne gamma-ray spectrometric and magnetic survey was completed over the Bonaparte-west map area (Coyle et al., 2007a, b). It was flown at an average 400-metre line spacing (reduced to 200-metres over the Rayfield River pluton) oriented N52°E at 125-metre terrain clearance. Exploration targets generated from the survey were tested by soil and rock geochemical surveys (Koffyberg, 2007a) and diamond drilling (Koffyberg, 2007b).

3. Regional setting

The Rayfield River map area is in Quesnellia, a volcanic arc terrane that developed in response to east-dipping subduction of the Cache Creek ocean beneath the western margin of ancestral North America beginning in the Late Devonian and continuing sporadically until the Middle Jurassic. Cache Creek terrane rocks are preserved ~ 30 km southwest of the map area, near Clinton, but the contact with Quesnellia is masked by Eocene volcanic and sedimentary rocks of the Kamloops Group and flat-lying Neogene basalts of the Chilcotin Group.

Calc-alkaline to alkaline arc magmatism in Quesnellia included emplacement of three Cordilleran-wide plutonic suites: the Late Triassic Guichon batholith (212-208 Ma), latest Triassic Copper Mountain (206-201 Ma) and Early Jurassic Takomkane/Wildhorse (197-193 Ma) suites (Fig. 2 in Friedman et al., this volume; Woodsworth et al. 1991; Breitsprecher et al. 2010; Logan and Mihalynuk, in press). Three porphyry copper mineralization events are directly linked to each of these calc-alkaline/alkaline magmatic episodes. The latest Triassic, central belt of alkalic plutons (Copper Mountain suite) defines a 400 km long arcuate belt that is prospective for Cu-Au mineralization (Fox, 1975; Lang et al. 1995) and hosts porphyry copper-gold deposits such as the currently producing Copper Mountain, New Afton and Mount Polley Cu-Au mines, and Cu-Au skarn and porphyry mineralization near Peach Lake. The Rayfield River pluton is projected to lie in the central part of this belt, between the New Afton and Mount Polley deposits (Fig. 2 in Friedman et al., this volume).

The Rayfield River pluton forms the western and oldest exposures of the composite Thuya batholith (Campbell and Tipper, 1971; Anderson et al., 2010), which includes Late Triassic (~ 202-200 Ma; Rayfield River pluton), Early Jurassic (195-193 Ma; Eakin Creek suite) and Middle Jurassic (164-161 Ma; Bonaparte Lake) phases. The Rayfield River pluton intrudes hornfelsed volcaniclastic rocks of the Nicola Group to the south, and is in contact with Middle Jurassic granite of the Bonaparte Lake phase to the southeast, at Young Lake (Fig. 2). The latter contact was not observed but the younger granite (Anderson et al., 2010; this study) is inferred to intrude the syenite.

4. Geology of the Rayfield River area

The Rayfield River area is underlain by (from oldest to youngest), the Nicola Group, the Rayfield River pluton, the Bonaparte Lake granite, and Neogene basalts (Fig. 2).

4.1. Nicola Group

Volcaniclastic rocks of the Nicola Group, hosts to the Rayfield River pluton, outcrop south of the Bonaparte River (Fig. 2).

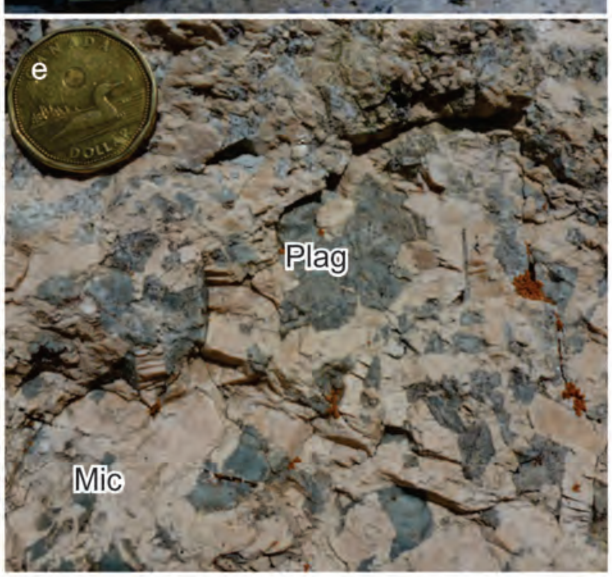


Fig. 3. Field photographs of lithologic units from the Rayfield River pluton. UTMs Zone 10, NAD 83. **a)** Float sample (633304 E, 5680835 N) showing contact between hornblende monzodiorite and hornblende syenite, xenolith of monzodiorite implies the hornblende syenite is younger. **b)** Xenolith of hornblende syenite in quartz-feldspar porphyry monzonite. **c)** Poikilitic melanitic garnet in coarse hornblende syenite (632129 E, 5685792 N). **d)** Hornblende syenite and mm-wide grey syenite dikelets defining a primary north northwest-trending igneous foliation that is cut by a younger sparsely porphyritic monzonite dike (632580 E, 5686059 N). **e)** Pegmatitic segregation consisting primarily of microcline- and sericite-altered plagioclase, blebs of bornite occur at this locale (632027 E, 5685856 N). Mnzdrt, monzodiorite; HbSyn, hornblende syenite; QFP, quartz feldspar porphyry; Grnt, garnet; Mnzn, monzonite; Plag, plagioclase; Mic, microcline.

They include: thickly bedded tuffite; cm-scale sandstone (with grains of pyroxene and plagioclase) and siltstone interlayers, and granulestone with aphyric mafic volcanic clasts. Adjacent to, and up to 1 km south of, the contact with the pluton, Nicola Group rocks are cut by irregular dikes and veinlets of hornblende diorite and, in a wide zone of contact metamorphism, contain oval clots of epidote, garnet, hematite, calcite, and pyrite. Local graded sandstone beds indicate that the east-southeast-dipping succession is right-way-up (Fig. 2). Campbell and Tipper (1971) also show Nicola Group rocks in an area west of the confluence of Rayfield and Bonaparte rivers that coincide with an isolated magnetic high (Coyle et al., 2007a, b), but the three outcrops in this area comprise hornblende syenites of the Rayfield River pluton.

4.2. Rayfield River pluton

The Rayfield River pluton occupies a 65 km^2 erosional window bounded on three sides by Neogene basalts (Fig. 2). We recognize two subunits, a hornblende syenite phase and a leucocratic syenite phase. Both phases are cut by late-stage comagmatic pegmatite, syenite, monzonite, and quartz-feldspar porphyry dikes, and by mafic dikes that are probably related to the Neogene basalt. Most of the pluton is hornblende syenite; leucosyenite comprises less than 20% and is confined to the centre of the pluton (Fig. 2). The hornblende syenite and leucosyenite phases display gradational and locally crosscutting contacts (Preto, 1970). Minor components of the pluton include a monzonite to monzodiorite phase; diorite to quartz diorite was reported from drilling near the southern margin of the pluton (Koffyberg, 2008).

Early work considered that the pluton is concentrically zoned, grading inwards from mafic to more felsic compositions (Hodgson et al., 1969). This interpretation hinged largely on outcrops of diorite to monzonite mapped by Preto (1970) at the northern (Crater Lake) and southern (close to the confluence of Rayfield and Bonaparte rivers) limits of the pluton. However, rocks at Crater Lake are coarse-grained syenite to monzonite, with 40-50% alkali feldspar, 20-30% plagioclase, 10-12% hornblende and 5-8% biotite. Cliff exposures west of Young Lake, near the confluence of Campeau Creek and Bonaparte River, contain marginally more mafic minerals and plagioclase, but normative plots indicate that they are nepheline-bearing monzonites (Fig. 3; see below). Furthermore, the southern margin of the pluton, south of the Bonaparte River, comprises holocrystalline hornblende syenite. Hence our mapping failed to confirm a concentric zonation.

4.2.1. Hornblende syenite

Hornblende syenite is the predominant component of the Rayfield River pluton. It forms cliffs along the length of the river and extends several kilometres east and west before it is lost beneath the Neogene basalt cover. The rock is light grey, generally massive to well jointed, and holocrystalline, with mainly 5-10 mm laths of microcline microperthite (65%) and interstitial stubby sodic plagioclase, hornblende, and biotite (25-30% ± corroded pyroxene, poikilitic melanite garnet, titanite, magnetite, and apatite; Figs. 3 a-d).

The hornblende syenite contains a well to weakly developed igneous foliation defined by alignment of feldspar phenocrysts and/or hornblende and biotite. Grey to pink, millimetre to metre wide fine-grained syenite dikes commonly parallel this foliation (Fig. 3d).

4.2.2. Leucosyenite

Leucosyenite is restricted to a narrow (1250 m wide) north-northwest-trending zone in the centre of the pluton. It varies from coarse to medium grained, displays a primary igneous foliation parallel to that found in the hornblende syenite, and is characteristically sericite-altered. It consists mainly of coarse laths of orthoclase > microcline microperthite, together with ~ 10-20% sodic plagioclase and less than 5% mafic minerals (green hornblende and green biotite). It also contains trace garnet, titanite, and magnetite. Hornblende crystals are mantled by biotite, which is commonly altered to chlorite. In places orthoclase rims the larger (~ 3 x 6 mm) perthitic microcline or is intimately intergrown with plagioclase. The feldspars are turbid, and plagioclase is dusted by fine sericite or entirely replaced by fine sericite and patchy mm-sized muscovite grains. Low-magnetic and low-resistivity signatures of the leucosyenite are useful for distinguishing it from the hornblende syenite (Hodgson et al., 1969).

4.2.3. Dikes

The hornblende syenite and leucosyenite units are cut by north-northwest-trending dikes that include, in decreasing order of abundance, pegmatite, syenite, orthoclase porphyritic quartz monzonite, and quartz-feldspar porphyry (Figs. 3b, d, e). Pegmatite is common as irregular pods and dike-like masses concentrated around the leucosyenite, but is also in the hornblende syenite throughout the pluton. The mineralogy is identical to the host, and contacts are gradational, suggesting these coarser grained segregations evolved from pockets of similar magmas. Pegmatites in the hornblende syenite contain coarse (up to 5 cm) tabular microcline (65-80%), interstitial (1-2 cm) equant plagioclase (15-30%), and minor nepheline, cancrinite, corroded pyroxene and/or hornblende, biotite, titanite, calcite and sericite. Pegmatites in the leucosyenite are similarly coarse grained, comprising interlocking tabular pinkish white microcline (55-70%), interstitial waxey green sericite-altered plagioclase (25-40%), and minor muscovite (Fig. 3e). Isolated mm-blebs of bornite were recognized in trench outcrops west of the river.

Lavender to grey, fine-grained, equigranular and porphyritic syenite is the most abundant phase crosscutting the hornblende syenite. It occupies centimetre to metre-wide dikes, and sheeted millimetre-wide veins, which often parallel the primary northwesterly trending foliation, and stockwork zones. The syenite consists of interlocking perthitic microcline>>sodic plagioclase, and green hornblende, biotite, garnet, titanite and apatite.

A distinctive dike of K-feldspar "rhomb" porphyry monzonite to quartz monzonite outcrops north of the dogleg in Rayfield River. About 4 m wide, the dike (321°/39°), cuts the predominant magmatic foliation of the hornblende syenite (310°/57°). The rhomb porphyry consists of 10-20 mm stubby euhedral microcline phenocrysts (10-20%) and 1-2 mm tabular oscillatory zoned sodic plagioclase phenocrysts (20-30%) in a groundmass of 0.1-0.2 mm orthoclase>>plagioclase, green hornblende, biotite, titanite, magnetite, and apatite. Weak copper mineralization is evident.

A northwest-trending dike of quartz - feldspar - hornblende porphyry monzogranite crosscuts the north end of leucosyenite (Fig. 3b) and similar monzogranite is reported at the centre of the rhomb porphyry dike north of the dogleg in Rayfield River (Hodgson et al., 1969). Hodgson et al. (1969) correlated these quartz-bearing intrusions with granite of the Thuya batholith, but the common orientation, mineralogy, and evolved composition suggests that they are probably quartz saturated end members of the Rayfield River alkaline suite. Preliminary U-Pb zircon age determinations (see below) are consistent with this hypothesis.

4.2.4. Geochronology

K-Ar cooling ages for hornblende from the hornblende syenite (193 ± 14 Ma) and biotite from the leucosyenite (186 ± 12 Ma) provide minimum ages for the Rayfield River pluton (Breitsprecher and Mortensen, 2004). Anderson et al. (2010) reported a U-Pb zircon age of ~ 202 Ma for the syenite, allowing that it could be as young as 198 Ma. We collected two samples for U-Pb zircon geochronologic work at the Pacific Centre for Isotopic and Geochemical Research of the Department of Earth, Ocean and Atmospheric Sciences, The University of British Columbia. The first is from unaltered and unmineralized hornblende syenite (13-JLO-12-129), collected 1.5 km southwest of Crater Lake (Zone 10, NAD83; 631885 E, 5688894 N). Preliminary results indicate the zircons have high uranium contents, and only 2 of 5 grains analysed generated data. The two analyses are concordant but do not overlap. The $^{206}Pb/^{208}U$ ages are: 198.6 ± 0.4 Ma and 200 ± 0.4 Ma. Given the high uranium contents we assume some Pb loss and therefore the latter to be a minimum age (R. Friedman, pers. comm. 2013).The second sample is from a weakly altered quartz-feldspar porphyry monzogranite dike (13-JLO-13-133) collected ~ 1 km north of the dogleg in Rayfield River (631992 E, 5686557 N). Preliminary results indicate an age of 199.7-199.9 Ma (R. Friedman, pers. comm., 2013). Because the dike intrudes the hornblende syenite, this age demonstrates that the syenite is older than 200 Ma. It also demonstrates that these quartz-bearing dikes are late, quartz-saturated phases of the Rayfield River syenite complex and unrelated to the adjacent Bonaparte Lake granite (164-161 Ma; Anderson et al., 2010).

4.3. Bonaparte Lake granite

Monzogranite of the Bonaparte Lake phase of the Tuya Batholith underlies the eastern portion of the area. It is a medium-grained, equigranular to weakly K-feldspar porphyritic biotite-hornblende granite, comprising pinkish-white orthoclase (35%), greyish-white plagioclase (30%), vitreous subhedral quartz (25%), and chloritized hornblende and biotite (10%), with minor disseminated magnetite. In thin section quartz and orthoclase exhibit 120° annealed crystal boundaries, titanite is fractured, and myrmekitic intergrowths of quartz and K-feldspar replace rims of plagioclase (Fig. 4) suggesting recrystallization, brittle strain, and K-metasomatism. Anderson et al. (2010) reported a Middle Jurassic U-Pb crystallization age of 161.2 ± 0.1 Ma for monzogranite samples collected ~ 2 km northwest of the west end of Bonaparte Lake. The granite is inferred to intrude the Rayfield River pluton, but contacts are not exposed.

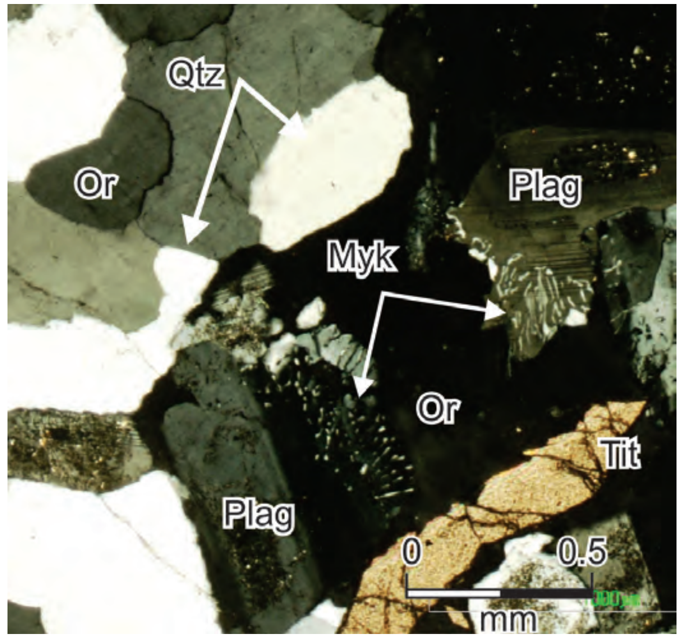


Fig. 4. Photomicrograph of Bonaparte Lake hornblende-biotite monzogranite (Middle Jurassic) in crossed-polarized light. Note the 120° annealed crystal boundaries (Or and Qtz) and the myrmekitic (myk) intergrowths of quartz and K-feldspar replacing the rims of plagioclase. Qtz, quartz; Or, orthoclase; Plag, plagioclase; Tit, titanite.

4.4. Chilcotin Group

Flat-lying basaltic flows and pyroclastic rocks of the Chilcotin Group (Early Miocene to Early Pleistocene) cover much of the Interior Plateau of south-central British Columbia (Mathews, 1989). Recent studies indicate that unit is not as continuous as was previously thought, and that regional compilations overestimate its areal extent by up to 50% (Dohaney, 2009). Furthermore, the thickness of the unit is controlled by paleotopography; thick (> 30 m) accumulations in paleochannels thin to less than 10 m in paleointerfleuve uplands (Andrews and Russell, 2010). Hence geologically and economically important Mesozoic rocks, such as Rayfield River commonly appear as windows through the basalt.

In the Rayfield River map area, the Chilcotin Group includes aphyric basalt, basalt with sparse olivine and pyroxene phenocrysts, and local subophitic gabbro. The basalt forms 5 to 12 metre thick, flat-lying benches (Fig. 5). It is black, brown weathering and massive to locally scoriaceous and red weathering. Vesicles, locally filled with calcite and/or zeolite minerals, are near the tops and bottoms of the flows, which are locally separated by breccias and interflow red and orange paleosols. The Chilcotin Group is best exposed at Crater Lake, where the Rayfield River has eroded through more than 50 metres of basalt. At this locale it consists of at least 3 coherent massive flow units that lie directly on hornblende syenite of the Rayfield River pluton (Fig. 5).

4.5. Quaternary basalt

Mantle xenoliths, mainly spinel lherzolite, have long been known from the Rayfield River area, but the host basalt, of hawaiite (Canil et al., 1987) or basanitic (Greenfield et al., 2013) composition, had been included in the Chilcotin Group. Here, we map the xenolith-bearing basalt separately, and assign

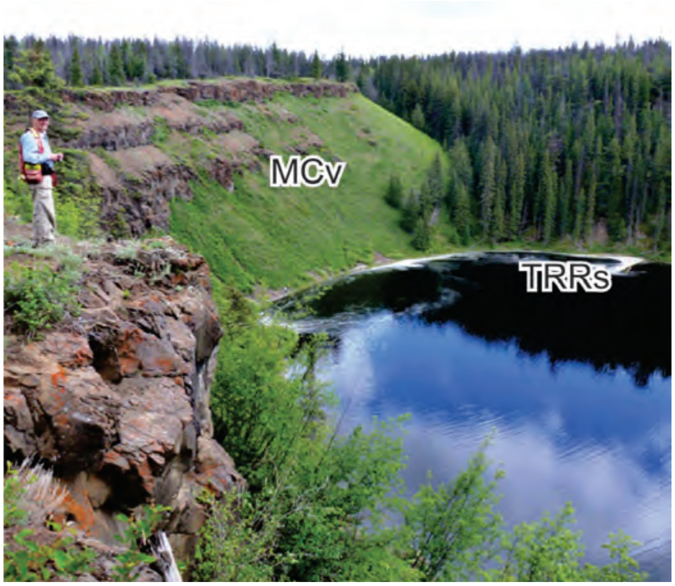


Fig. 5. Brown-weathering, 50 metre-high benched Miocene basalt flows comprise the northern shore of Crater Lake. Hornblende syenite and leucosyenite are exposed along the heavily wooded shore below the basalt (viewed easterly). MCv, Miocene Chilcotin volcanic rocks; TRRs, Triassic Rayfield River syenite.

Fig. 6. Basalt with lherzolite xenoliths, comprising olivine (75%), bright green clinopyroxene (10%), orthopyroxene (10%) and lesser dark spinel, ~ 2.4 km southwest of Crater Lake.

it a Quaternary age based on correlation with similar xenolith-bearing basalt outliers above Quesnel terrane in the Thuya Creek – Woodjam Creek area to the north (Schiarizza et al., 2013).

The Quaternary basalt occurs in two areas, approximately 2.4 km southwest of Crater Lake and 3.6 km due south of Crater Lake. The best exposure is southwest of Crater Lake, where flat-lying aphyric xenolith-rich basalt and welded basalt flow breccia cover a 0.4 km^2 area. The basalt is light grey, fine grained and includes abundant (up to 20%) angular to rounded peridotite xenoliths that range from a few mm to more than 10 cm (Fig. 6). Xenoliths as large as 15 x 9 cm occur over the entire exposed thickness of about 60 m. The xenoliths contain yellowish green olivine (75%), bright green clinopyroxene (10%), orthopyroxene (10%) and lesser dark spinel.

A xenolith-bearing basalt unit on Takomkane Mountain (approximately 100 km north of Rayfield River) rests on a glaciated surface (Sutherland Brown, 1958) and has yielded a K-Ar whole rock date of 0.40 ± 0.04 Ma (Sun et al., 1991). Another, from Mount Timothy (approximately 70 km north), has yielded an Ar-Ar whole rock date of 0.465 ± 0.023 Ma (Schiarizza et al., 2013). We assume that similar basalts at Rayfield River are also Pleistocene.

5. Structure

The Rayfield River pluton contains a primary igneous foliation that is defined by the planar alignment of tabular K-feldspar and hornblende ± biotite crystals. The foliation is variably developed throughout the intrusion and generally strikes northwest and dips between 50 and 75° northeast. In the southeast part of the intrusion however, foliation strikes northeast and dips steeply to either the northwest or southeast (Fig. 2). Sheeted veins, several mm to several cm wide, follow the northeast dipping foliation in many parts of the pluton.

Brittle fault zones occur throughout the pluton, with two main orientations. One set strikes northwest (335°) with variable steep dips, and a later set strikes northeast (055°) with moderate northwest dips. The fault zones are characterised by anastamosing slip planes coated with chlorite, epidote, hematite and/or calcite, and commonly minor malachite. Bleached, weak argillic alteration assemblages overprint the brittle structures and are probably related to surface weathering.

North of the Rayfield River dogleg, a north-northwest trending lineament marks the contact between pervasively sericite-altered leucosyenite and hornblende syenite that displays weak fracture-controlled pink K-spar alteration. Cataclastic fault rocks can be traced for more than 1 km along the course of the river. Samples of altered leucosyenite(?) from this fault zone (13JLO10-91-2, and R07-34538 from Le Couteur in Koffyberg, 2007b) have strong cataclastic textures that include brecciated orthoclase and plagioclase crystals, kinked and broken plagioclase twin planes, and biotite crystals (Fig. 7). In detail the breccias are cut by late calcite veinlets that have albite selvages.

Two east-northeast-striking faults, one coinciding with the dogleg bend in the Rayfield River, are shown on the geologic map (Fig. 2). These structures are traceable by resistivity surveys (Hodgson et al., 1969), and appear to post date mineralization. Mineral fibers on the northeast-striking fault planes plunge gently and indicate a sinistral sense for latest motion. Hodgson et al. (1969) reported that a north-trending rhomb porphyry dike extends across one of the structures with no apparent displacement.

6. Chemistry

Major oxide, trace, and rare earth element chemistry was determined for hornblende syenite, leucosyenite, a pegmatite dike, and a late stage quartz-feldspar porphyry dike from the Rayfield River pluton, and for granite from the Bonaparte phase of the Thuya batholith (Fig. 8). Complete analytical

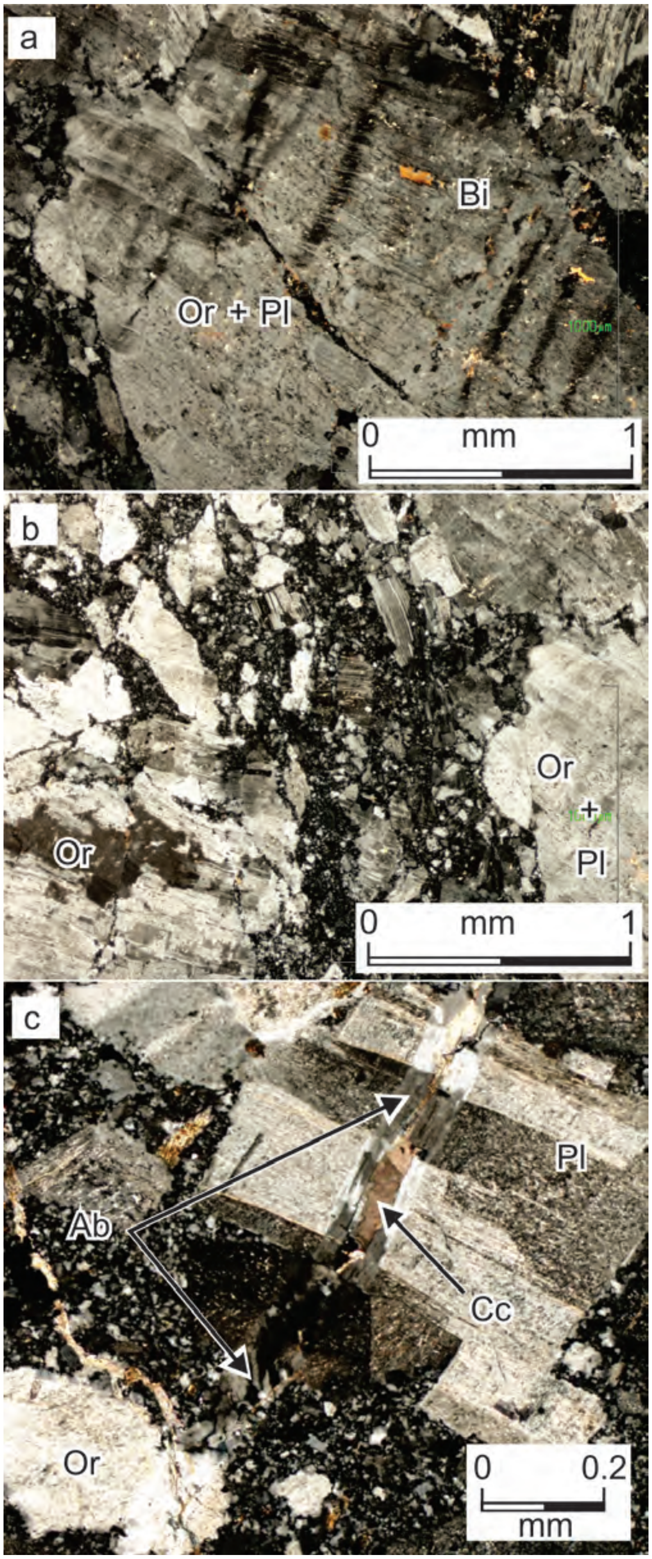


Fig. 7. Cross-polarized light photomicrograph of cataclastic leucosyenite (Zone 10, NAD 83, 632219 E, 5685884 N). **a, b)** Plagioclase/perthite crystals show kinked, broken, and sheared twin planes, and finely milled fragments of feldspar, plagioclase, and biotite. **c)** The cataclasite is cut by late calcite veinlets that have albite selvages. Abbreviations: Pl, plagioclase; Ab, albite; Bi, biotite; Cc, calcite; Ser, sericite.

data tables, classifications, tectonic discrimination diagrams, and regional comparisons with selected Late Triassic alkalic intrusions from south-central British Columbia (Mount Polley stock, Shiko Lake and Bootjack Lake stock) are in Logan and Schiarizza (2014).

Hornblende syenite samples contain 55 to 59 wt% SiO_2 and occupy the intermediate, alkaline field on the total alkali versus SiO_2 (TAS) plot of Cox et al. (1979) where they are classified as nepheline syenite to syenite (Fig. 8a). The leucosyenite sample (65 wt% SiO_2) and a pegmatite dike, (64 wt% SiO_2,) are classified as syenites, in the acid, alkaline field. A quartz-feldspar porphyry dike (67 wt% SiO_2) and a sample of the Middle Jurassic Bonaparte granite (70 wt% SiO_2) plot in the acid, subalkaline granite classification field (Fig. 8a).

CIPW normative calculations were determined and plotted on a Streckeisen diagram (Fig. 8b). The hornblende syenite is nepheline normative and occupies the transition between foid-monzosyenite to foid-bearing syenite fields, with one sample from the southern margin of the body plotting in the foid-bearing monzonite field (Fig. 8b). The pegmatite and leucosyenite are silica saturated and plot in the syenite field. The Late Triassic quartz-feldspar porphyry dike that crosscuts the leucosyenite in the core of the pluton plots with the Bonaparte intrusion in the granite field (Fig. 8b). The intrusions are metaluminous (magnetite series), plot in the volcanic arc granite field (Pearce et al., 1984) on trace element tectonic discrimination diagrams (Logan and Schiarizza, 2014) and lack Eu anomalies on chondrite-normalized REE plots (not shown).

High grain counts of thorianite (ThO_2) are reported in till samples collected from the Raft batholith and the western margin of the Thuya over the Rayfield River pluton (Plouffe et al., 2010). In addition, the airborne gamma-ray Th (ppm) equivalent measurement plots (Coyle et al., 2007a, b) show elevated Th values (between 5.00 and 8.35) extending from Crater Lake south to the dog-leg bend and within a 3.5 x 1km northwest-trending area extending west of the confluence of Rayfield and Bonaparte rivers. The pattern of thorianite grain distribution was attributed to southwestward glacial transport, which led Plouffe et al. (2010) to suggest derivation from the Rayfield River syenite. To test this hypothesis, we examined the trace geochemistry of Rayfield River complex samples. Hornblende syenite (n=10) and late stage pegmatite and quartz feldspar porphyry monzonite dike rocks (n=4) analysed by inductively coupled plasma mass spectrometry (ICP-MS) after a lithium metaborate/tetraborate fusion at Activation Laboratories Ltd., or by ICP-MS following a 4-acid digestion at ACME Labs. The detection limit for thorium is 0.05 ppm using the fusion technique and 0.1 ppm with the acid digestion. The complete geochemical data set is in Logan and Schiarizza (2014); here we focus on thorium concentrations, which range from 1.4 - 5.9 ppm with an arithmetic mean value of 3.2 ppm. Th and U-enriched syenite bodies in the literature typically have concentrations at least an order of magnitude higher than 3.2 ppm (Labhart and Rybach, 1971; Van Gosen et al., 2009; Martins et al., 2011), thus we consider that if the Rayfield River pluton is the source of the thorianite grains found by Plouffe et al. (2010) the grains must be very localized or contained in a phase not sampled during our study.

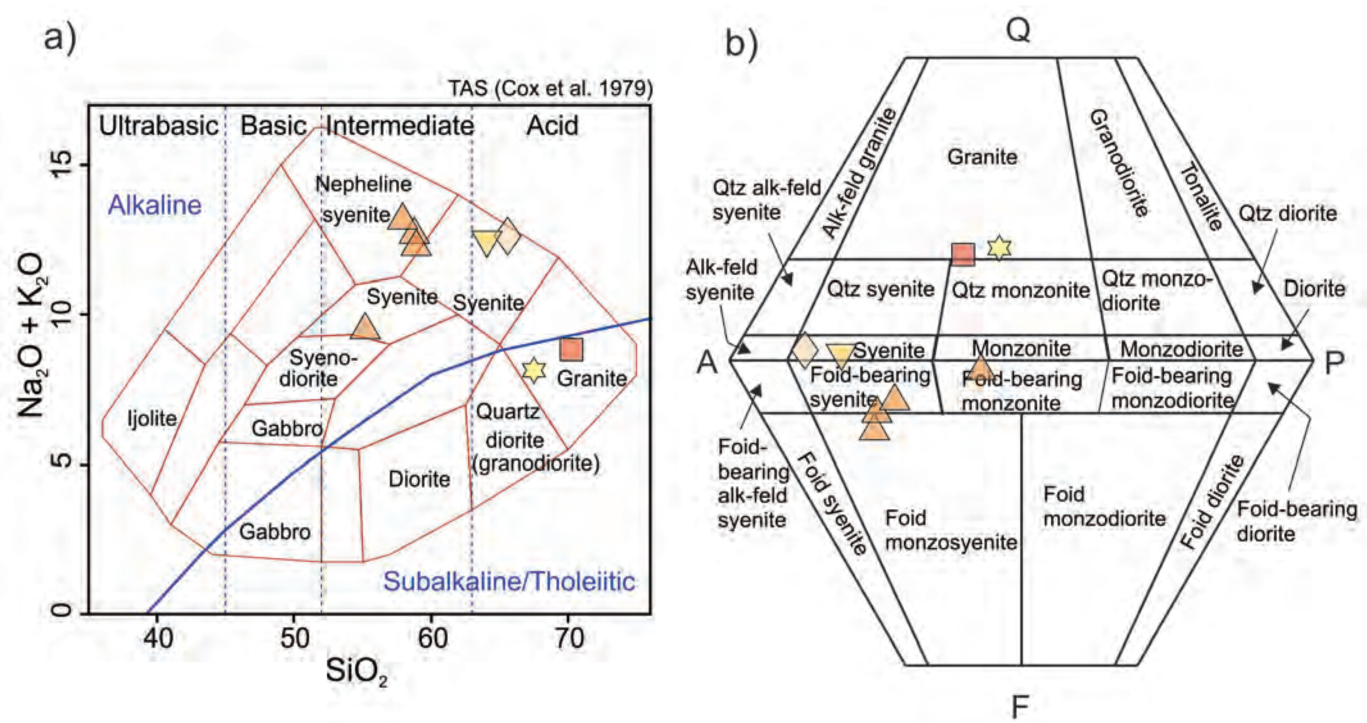


Fig. 8. Hornblende syenite (orange triangles), leucosyenite (pink diamond), pegmatite (gold inverted triangle) and quartz feldspar porphyry (yellow star) units from the Rayfield River complex and Bonaparte Lake monzogranite (red square) of the Thuya batholith plotted on **a)** total alkali versus silica (TAS) diagram (Cox et al., 1979) and **b)** an IUGS classification diagram using CIPW normative values (after Streckeisen, 1976).

7. Alteration and mineralization

Historically, exploration at Rayfield has focused on disseminated copper associated with the Rayfield River pluton. Geological, geochemical, and geophysical programs were conducted by Kennco Exploration Ltd., Cominco Ltd. and Amax Exploration Inc. between 1960 and 1970. Percussion drilling in 1970 by Amax Exploration Inc. totalled 1748 m in 31 holes and delineated a north-trending area 450 m by 2130 m of copper mineralization grading between 0.05% and 0.1% Cu on the west side of the Rayfield River (Wynne, 1990). The best copper intersection was 0.42% over 6.1 m at the north end of the zone. In 1989, Discovery Consultants carried out geological mapping, an I.P. geophysical survey and 1140.9 m of diamond drilling in eight holes (Wynne, 1990). Three of these holes ended in > 0.1% Cu at depths of < 150 m below surface. More recently, exploration targets generated from a high-definition airborne gamma-ray spectrometric and magnetic survey were tested by soil and rock geochemical surveys (Koffyberg, 2007a) and diamond drilling to depths of between 250 and 300 metres (Koffyberg, 2007b). The results confirmed low-grade porphyry Cu-Au mineralization in the upper 150 metres that did not extend to greater depths.

Our observations during 2013 fieldwork suggest that alteration of the Rayfield River pluton is relatively minor. The northern portion of the pluton is cut by abundant veins of syenite, but mineralized veins are sparse. They are generally sheeted structures, but stockworks of grey to lavender syenite veins are also common (Fig. 9). Along fractures and margins of grey syenite dikelets, alteration assemblages include: patchy intergrowths of biotite, magnetite, and hematite; epidote; and locally, chlorite or sericite. Alteration does not extend beyond the immediate contact zone. K-feldspar "pinking" and chalcopyrite are common but restricted to narrow (mm-scale) zones.

In thin section alteration is limited to weak epidote and sericite replacement of plagioclase, local orthoclase overgrowths on perthitic microcline, and replacement of primary hornblende by biotite and later chlorite. Late stage mm-thick veinlets of albite and calcite crosscut leucosyenite and feldspar porphyry dikes in the core of the pluton.

Most alteration is restricted to narrow late northerly- and northeast-trending structures that appear to postdate mineralization. Bleached, sericite - clay alteration zones are confined to these structures. Pale buff to yellow bleaching accompanies sericite and late albite-carbonate alteration of leucosyenite west of the dogleg bend in the river. K-spar pinking and pervasive sericite alteration overprinted the primary north northwest-trending magmatic foliation in leucosyenite, with the development of disseminated mm-scale muscovite crystals. A sample with secondary muscovite has been submitted for $^{40}Ar/^{39}Ar$ isotopic analysis to determine its cooling age.

Hypogene copper minerals include chalcopyrite and bornite as interstitial blebs in the syenite and pegmatite or localized along the margins of narrow (mm- to cm-wide) grey syenite dikelets, veins and tight fractures. Secondary supergene chalcocite, malachite, and rare native copper are associated with altered fault zones and surface weathering. Hematite occurs throughout the syenite, and pyrite is conspicuous by its

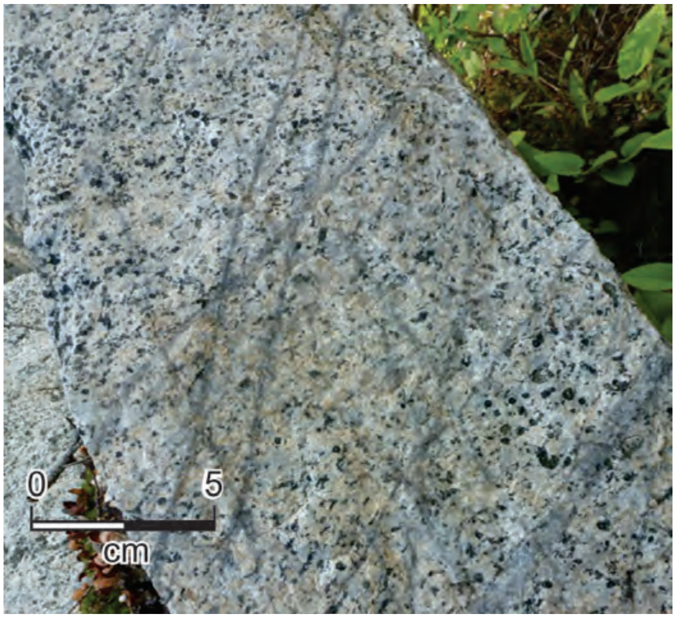


Fig. 9. Massive, coarse-grained and little altered hornblende biotite syenite intruded by at least two sets of sheeted fine-grained grey syenite dikelets. Minor malachite colours weathering fractures and attests to trace amounts of copper mineralization (Zone 10, NAD 83, 633552 E, 5685580 N). Copper mineralization is widespread and low grade.

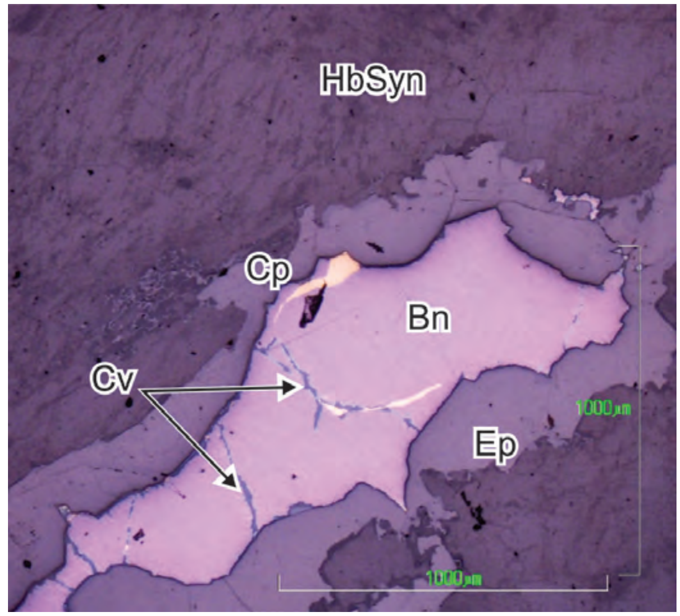


Fig. 10. Plane polarized reflected light photomicrograph of mineralized vein cutting hornblende syenite at 13JLO7-49 (Zone 10, NAD 83, 634620 E, 5685605 N). Bornite vein is enveloped by pale green epidote and contains chalcopyrite exsolution lamella. It is replaced along curved fractures by chalcopyrite and covellite. Abbreviations: HbSyn, hornblende syenite; Ep, epidote; Bn, bornite; Cp, chalcopyrite; cv, covellite.

absence. Copper grades reported from historical work (surface trenching and diamond drilling programs) average between 0.05 - 0.1% Cu and < 50 ppb Au (Selmer et al., 1968; Hodgson et al., 1969; Preto, 1970; Wynne, 1990; Koffyberg, 2008). Gold values are typically less than 10 ppb, and although elevated gold values accompany higher grades of copper, the Cu:Au ratios are several orders of magnitude below the 1:1 (1 g/t Au to 1% Cu) suggested for gold-rich porphyries (Kirkham and Sinclair, 1995) and the ranges for British Columbia alkaline deposits (Panteleyev, 1995).

Lithogeochemical analyses of mineralized samples collected during 2013 fieldwork are presented in Table 1. Sample 13JLO5-33 is from the pyritic hornfelsed southern contact zone between hornblende syenite and Nicola Group volcaniclastic rocks. The sample returned low copper, gold, and silver values and relatively elevated iron, magnesium, nickel, and vanadium. Hornblende syenite samples 13JLO7-49 and 7-51 were collected from outcrops east of Rayfield River in the central area of the pluton. The highest copper, gold and silver values came from a 5 mm-wide veinlet of bornite, malachite ± chalcopyrite and magnetite (Fig. 10) hosted in relatively unaltered hornblende syenite. The syenite here was also intruded by numerous malachite – stained pegmatites and fine-grained grey syenite dikes, as well as unmineralized quartz veins. Sample 13JLO7-51 was collected farther west from a road exposure of hornblende syenite cut by grey syenite dikes. At this location chalcopyrite and malachite mineralization and chlorite alteration are localized adjacent to dike and syenite contacts. The remaining four samples (13JLO10-91, 10-94, 11-110-2 and 11-111) originate from the cliffs north of the dog-leg bend in Rayfield River. Sample 13JLO10-94 is a sericite-altered, garnet-bearing pegmatitic leucosyenite that contains small blebs of bornite. The other three are grab samples of typically malachite-coated, weakly-altered grey syenite-veined leucosyenite or hornblende syenite, rarely with blebs of chalcopyrite replacing primary mafic mineral clots.

8. Summary and conclusions

The alkalic chemistry, crystallization age, and metal assemblages at Rayfield River are shared by porphyry deposits of the Late Triassic Copper Mountain magmatic belt (e.g. Copper Mountain porphyry Cu-Au, New Afton porphyry Cu-Au and the Mount Polley porphyry Cu-Au), inviting speculation that this intrusion is part of this highly prospective magmatic belt within Quesnellia. This hypothesis is being addressed through ongoing U-Pb zircon and Ar/Ar white mica isotopic age determinations aimed at testing the Late Triassic age of the Rayfield River intrusions and synchronicity of copper-gold mineralization.

Our preliminary study leads to the following conclusions.

1) The Rayfield River pluton consists primarily of silica-undersaturated nepheline syenite, with a minor component including late-stage silica-saturated leucosyenite, pegmatite, and quartz monzonite dikes.

2) The Rayfield River pluton is probably Late Triassic (> 201 Ma) and part of the Copper Mountain suite of alkaline intrusions.

3) The syenite contains amphibole and biotite (hydrous), poikilitic metablastic melanite garnet, coarse crystals of sphene, apatite, and magnetite, and rare blebs of bornite or chalcopyrite. Abundant hornblende and magnetite and accessory igneous melanite is a distinguishing feature of many of the alkaline plutons in Stikine and Quesnel terrane and is an important

Table 1. Selected geochemical results of mineralized samples collected during the 2013 property visit.

		Analyte	Ag	As	Au	Bi	Cd	Co	Cr	Cu	Fe	Mo	Ni	Pb	S	Sb	Sn	Th	U	W	Zn
		Unit	PPM	PPM	PPB	PPM	PPM	PPM	PPM	PPM	%	PPM	PPM	PPM	%	PPM	PPM	PPM	PPM	PPM	PPM
		MDL	2	0.1	0.2	0.02	0.01	0.1	0.5	0.01	0.01	0.01	0.1	0.01	0.02	0.02	0.1	0.1	0.1	0.1	0.1
Station Number	Easting	Northing																			
13JLO 5-33	635515	5678018	<0.1	33	8	0.3	<0.1	24.5	67	64.9	5.8	1.1	28.3	0.8	0.2	0.7	0.5	1.5	0.90	1.5	36
13JLO 7-49	634621	5685606	15.5	<1	352	3.8	0.9	6.7	9	>10000.0	2.52	0.7	1.5	23.4	0.3	0.1	0.6	3.2	1.70	0.4	85
13JLO 7-51	633347	5685526	2.2	1	50	0.7	<0.1	3.4	10	4166.2	2.1	0.2	0.8	8.9	<0.1	0.2	0.5	2.1	1.50	0.2	71
13JLO 10-91	632220	5685884	1.7	2	20	0.2	0.2	1.7	10	3926.6	1.25	2.6	0.9	11.7	0.3	1.3	0.2	3.5	1.6	1	10
13JLO 10-94	632130	5685793	1.4	3	17	0.9	0.2	1.8	9	1132.9	1.44	0.4	0.7	17	<0.1	0.3	0.4	3.4	2.3	0.3	31
13JLO 11-110-2	632624	5686092	1.9	2	37	0.2	<0.1	5.1	10	1010.5	2.31	0.3	0.6	15.5	<0.1	0.3	0.5	4.3	1.9	0.2	89
13JLO 11-111	632662	5686149	2.9	2	83	0.7	0.9	5.5	8	5646.5	2.16	0.2	1.2	13.1	<0.1	0.2	0.6	3.7	2	0.2	110
Pulp Duplicates																					
13JLO 11-111	632662	5686149	2.9	2	83	0.7	0.9	5.5	8	5646.5	2.16	0.2	1.2	13.1	<0.1	0.2	0.6	3.7	2	0.2	110
13JLO 11-111	632662	5686149	2.9	3	-	0.7	0.9	5.9	9	5866.4	2.29	0.2	1.1	13.3	<0.1	0.2	0.6	3.4	1.7	0.2	115

criteria for distinguishing mineralized from barren intrusions (Lueck and Russell, 1994).

4) Alteration and mineralization are limited to narrow (0.5-1.0 mm) envelopes of tight sheeted and stockwork grey syenite veins that crosscut the hornblende syenite and leucosyenite.

5) The complex contains low-grade Cu-Au mineralization on the order of 0.1% Cu and < 50 ppb Au.

6) Geochemistry did not indicate elevated thorium values, so the pluton is an unlikely source for anomalously abundant thorianite grains identified in nearby till samples (Plouffe et al., 2010).

References cited

Anderson, R.G., Schiarizza, P., Andrews, G., Breitsprecher, K., Davis, W., Dunne, C.E., Plouffe, A. and Thomas, M.D., 2010. Bedrock, surficial, geophysical and geochemical mapping reveals exploration targets in the Thuya batholith, southern Nicola arc. In: Geological Association of Canada, Targeted Geoscience Initiative 3 Workshop, March 2010, Vancouver, pp. 52-57. URL accessed November, 2012, http://www.gac-cs.ca/workshops/TGI3/abstracts/GAC_TGI3_workshop_abstracts.pdf

Andrews, G.D.M. and Russell, J.K., 2010. Distribution and thickness of Volcanic and glacial cover on the Interior Plateau: in Geological Association of Canada, Targeted Geoscience Initiative 3 Workshop, Vancouver, pp. 49-51. URL accessed November, 2012.

Barr, D.A., Fox, P.E., Northcote, K.E. and Preto, V.A., 1976. The Alkaline Suite Porphyry Deposits: a summary; in Porphyry Deposits of the Canadian Cordillera, Sutherland Brown, A., Editor, Canadian Institute of Mining and Metallurgy, Special Volume 15, pp. 359-367.

Bath, A.B. and Logan, J.M., 2006. Petrography and geochemistry of the Late Triassic Bootjack stock (NTS 093A/12), south-central British Columbia; in Geological Fieldwork 2005, BC Ministry of Energy, Mines and Petroleum Resources, Paper 2006-1 and Geoscience BC, Report 2006-1.

Breitsprecher, K., Mortensen, J.K., 2004. B.C. Age 2004A-1 (release 3, October 2004) - A database of isotopic age determinations for rock units from British Columbia: BC Ministry of Energy, Mines, and Petroleum Resources, British Columbia Geological Survey Open File 2004-03.

Breitsprecher, K., Weis, D., Scoates, J.S. and Anderson, R.G., 2010. Targeting mineralized Late Triassic to Early Jurassic plutons in the Nicola arc, southern Quesnel terrane, Canadian Cordillera. In: Geological Association of Canada, Targeted Geoscience Initiative 3 Workshop, Vancouver, pp. 49-51. URL accessed November, 2012, http://www.gac-cs.ca/workshops/TGI3/abstracts/GAC_TGI3_workshop_abstracts.pdf

Campbell, R.B. and Tipper, H.W., 1971. Bonaparte Lake map area, British Columba: Geological Survey of Canada, Memoir 363, pp. 100.

Canil, D., Brearley, M., and Scarfe, C.M., 1987. Petrology of ultramafic xenoliths from Rayfield River, south-central British Columbia: Canadian Journal of Earth Sciences, V. 24, 1679-1687.

Coyle, M., Dumont, R., Potvin, J., Carson, J.M., Buckle, J.L., Shives, R.B.K. and Harvey, B.J.A., 2007a. Geophysical Series – Green Lake 92P/6, British Columbia, Bonaparte Lake West geophysical survey, British Columbia: Geological Survey of Canada, Open File 5502, scale 1:50,000, 10 sheets.

Coyle, M., Dumont, R., Potvin, J., Carson, J.M., Buckle, J.L., Shives, R.B.K. and Harvey, B.J.A., 2007b. Geophysical Series – Loon Lake 92P/3, British Columbia, Bonaparte Lake West geophysical survey, British Columbia: Geological Survey of Canada, Open File 5502, scale 1:50,000, 10 sheets.

Cox, K.G., Bell, J.D. and Pankhurst, R.J., 1979. The interpretation of igneous rocks; George Allen & Unwin, London, 450 p.

Currie, K.L. (1976): The alkaline rocks of Canada: Geological Survey of Canada, Bulletin 239, 278 p.

Dohaney, J.A.M., 2009, Distribution of Chilcotin Group basalt, British Columbia: Unpublished M.Sc. thesis, Vancouver, Canada, The University of British Columbia, 123 p.

Fox, P.E. (1975): Alkaline rocks and related mineral deposits of the Quesnel Trough, British Columbia (abstract); Geological Association of Canada, Cordilleran Section, Symposium on Intrusive Rocks and Related Mineralization of the Canadian Cordillera, Program and Abstracts, 12.

Greenfield, A.M. R., Ghent, E.D., and Russell, J.K., 2013. Geothermobarometry of spinel peridotites from southern British Columbia: implications for the thermal conditions in the upper mantle. Canadian Journal of Earth Sciences, 50, 1019-1032.

Hodgson, C.J., McKnight, B.K., Horsnail, R.F., and Mustard, D.K., 1969. Geological, geochemical, geophysical report on the Dansey Rayfield River copper property. In: BC Ministry of Energy, Mines, and Petroleum Resources, Assessment report #2,135, 72 p.

International Commission on Stratigraphy, 2013, International stratigraphic chart (http://www.stratigraphy.org/)

Kirkham, R.V., and Sinclair, W.D., 1995. Porphyry copper, gold, molybdenum, tungsten, tin, silver, In Eckstrand, O.R., Sinclair, W.D., and Thorpe, R.I., eds., Geology of Canadian Mineral Deposit Types: Geological Survey of Canada, Geology of Canada, no. 8, 421-446.

Koffyberg, A., 2007a. Assessment report on the airborne gamma-ray spectrometric and magnetic surveys - Rayfield River property. In: BC Ministry of Energy, Mines, and Petroleum Resources, Assessment report #29,110, 121 p.

Koffyberg, A., 2007b. Assessment report on the geochemical soil survey and prospecting - rock sampling program - Rayfield River property. In: BC Ministry of Energy, Mines, and Petroleum Resources, Assessment report #29,538, 143 p.

Koffyberg, A., 2008. Assessment report on a diamond drill program - Rayfield River property. In: BC Ministry of Energy, Mines, and Petroleum Resources, Assessment report #30,271, 161 p.

Labhart, T.P., and Rybach, L., 1971. Abundance and distribution of uranium and thorium in the syenite of Piz Giuv (Aar-Massif, Switzerland): Chemical Geology 01 DOI:10.1016/0009-2541(71)90010-6

Lang, J.R., Lueck, B., Mortensen, J.K., Russell, J.K., Stanley, C.R. and Thompson, J.F.H., 1995. Triassic–Jurassic silica undersaturated and silica-saturated alkalic intrusions in the Cordillera of British Columbia: implications for arc magmatism; Geology, V. 23, 451–454.

Logan, J.M., and Mihalynuk, M.G., in press, Tectonic controls on Early Mesozoic paired alkaline porphyry deposit belts (Cu-Au ± Ag-Pt-Pd-Mo) within the Canadian Cordillera, in alkalic Special Volume, Economic Geology.

Logan, J.M., and Schiarizza, P., 2014. Rayfield River major oxide, trace and rare earth element geochemical data: British Columbia Ministry of Energy and Mines, GeoFile 2014-X.

Logan, J.M., Mihalynuk, M.G., Ullrich, T., and Friedman, R.M., 2007. U-Pb Ages of intrusive rocks and $^{40}Ar/^{39}Ar$ plateau ages of copper-gold-silver mineralization associated with alkaline intrusive centres at Mount Polley and the Iron Mask Batholith, southern and central British Columbia: British Columbia Ministry of Energy, Mines and Petroleum Resources, Geological Fieldwork 2006, Paper 2007-1, pp. 93-116.

Lueck, B.A. and Russell, J.K., 1994. Silica-undersaturated, zoned, alkaline intrusions within the British Columbia Cordillera: British Columbia Ministry of Energy, Mines, and Natural Resources, Geological Fieldwork 1993, Paper 1994-1, pp. 311-315.

Martins, T., Couëslan, C.G. and Böhm, C.O., 2011. The Burntwood Lake alkali-feldspar syenite revisited, west-central Manitoba (part of NTS 63N8); in Report of Activities 2011, Manitoba Innovation, Energy and Mines, Manitoba Geological Survey, 79–85.

Massey, N.W.D., MacIntyre, D.G., Desjardins, P.J. and Cooney, R.T., 2005. Digital geology map of British Columbia: whole Province; BC Ministry of Energy, Mines and Petroleum Resources, GeoFile 2005-1.

Mathews, W.H., 1989. Neogene Chilcotin basalts in south-central British Columbia: geology, ages, and geomorphic history; Canadian Journal of Earth Sciences, V. 26, 969–982.

McMillan, W.J., Thompson, J.F.H., Hart, C.J.R., and Johnston, S.T., 1995. Regional geological and tectonic setting of porphyry deposits in British Columbia and Yukon Territory, in Schroeter, T. G., ed., Porphyry Deposits of the north western Cordillera of North America: Canadian Institute of Mining, Metallurgy and Petroleum Special Volume 46, p. 40-76.

Miles, W.F., Shives, R.B.K., Carson, J., Buckle, J., Dumont, R. and Coyle, M., 2007. Airborne Gamma-Ray Spectrometric and Magnetic Surveys over the Bonaparte Lake Area (NTS 092P), South-Central British Columbia: In Geological Fieldwork 2006, British Columbia Ministry of Energy and Mines, pp. 375-376.

Panteleyev, A., 1995. Porphyry Cu-Au: Alkalic, in Selected British Columbia Mineral Deposit Profiles, Volume 1 - Metallics and Coal, Lefebure, D.V. and Ray, G.E., Editors, British Columbia Ministry of Employment and Investment, Open File 1995-20, 83-86.

Pearce, J.A., Harris, N.B.W. and Tindle, A.G., 1984. Trace element discrimination diagrams for the tectonic interpretation of granitic rocks: Journal of Petrology, V. 25, 956-983.

Plouffe, A., Bednarrski, J.M., Huscroft, C.A., Anderson, R.G. and McCuaig, S.J., 2010. Geochemistry of glacial sediments of the Bonaparte Lake map area (NTS 92P), south central British Columbia: Geological Survey of Canada, Open File 6440, CD-ROM.

Preto, V.A., 1970. BD, VB, WIN (Dansey-Rayfield River): British Columbia Department of Mines & Petroleum Resources, Geology, Exploration and Mining, 1970, pp. 218-221.

Rees, C., Gillstrom, G., Ferreira, L., Bjornson, L. and Taylor, C., 2013. Geology of the Mount Polley Intrusive Complex (Draft Version): Geoscience BC, Report 2013-21.

Schiarizza, P., Israel, S., Heffernan, S., Boulton, A., Bligh, J., Bell, K., Bayliss, S., Macauley, J., Bluemel, B., Zuber, J., Friedman, R.M., Orchard, M.J., and Poulton, T.P., 2013. Bedrock geology between Thuya and Woodjam creeks, south-central British Columbia, NTS 92P/7, 8, 9, 10, 14, 15, 16; 93A/2, 3, 6. British Columbia Ministry of Energy, Mines and Natural Gas, British Columbia Geological Survey Open File 2013-05; 4 sheets, 1:100 000 scale.

Schiarizza, P., Bell, K. and Bayliss, S., 2009. Geology of the Murphy Lake area, south-central British Columbia (93A/03); In Geological Fieldwork 2008, BC Ministry of Energy, Mines and Petroleum Resources, British Columbia Geological Survey Paper 2009-1, pp. 169-188.

Souther, J.G., 1970. Volcanism and its relationship to recent crustal movements in the Canadian Cordillera: Canadian Journal of Earth Sciences, V. 7, 553-568.

Sellmer, H.W., McKnight, B.K., Horsnail, R.F., and Allan, J.F., 1968. Dansey Rayfield River copper property. In: BC Ministry of Energy, Mines, and Petroleum Resources, Assessment report #1,723, 64.

Streckeisen, A., 1976. To each plutonic rock its proper name, Earth Science Reviews, 12: 1-33.

Sun, S.S., and McDonough, W.F., 1989. Chemical and isotopic systematics of oceanic basalts: implications for mantle composition and processes. In: Saunders, A.D., and Norry, M.J., (eds.) Magmatism in ocean basins. Geological Society of London Special Publication, 42: 313-345.

Sun, M., Armstrong, R.L., and Maxwell, R.J., 1991. Proterozoic mantle under Quesnellia: variably reset Rb-Sr mineral isochrons in ultramafic nodules carried up in Cenozoic volcanic vents in the southern Omineca Belt. Canadian Journal of Earth Sciences, 28, 1239-1253.

Sutherland Brown, A., 1958. Boss Mountain; In Annual Report of the Minister of Mines for 1957, BC Ministry of Energy, Mines and Petroleum Resources, 18–22.

Thomas, M.D. and Pilkington, M., 2008. New high resolution magnetic data: A new perspective on geology of the Bonaparte Lake map area, British Columbia. Geological Survey of Canada, Open File 5743.

Van Gosen, B.S., Gillerman, V.S., and Armbrustmacher, T.J., 2009. Thorium deposits of the United States—Energy resources for the future?: U.S. Geological Survey Circular 1336, 21 p. [http://pubs.usgs.gov/circ/1336].

Woodsworth, G.J., Anderson, R.G., and Armstrong, R.L., 1991. Plutonic Regimes, in Gabrielse, H., and Yorath, C. J., eds., Geology of the Cordilleran Orogen in Canada: Geological Survey of Canada, Geology of Canada, no.4, pp. 491-531.

Wynne, F.L., 1990. Assessment report on exploration on the Rayfield 1 and 3 claims, In: BC Ministry of Energy, Mines, and Petroleum Resources, Assessment report #19, 927, 118 p.