Geology and Mineral Occurrences of the Mid-Cretaceous Spences Bridge Group near Merritt, Southern British Columbia (Parts of NTS 092H/14, 15, 092I/02, 03)

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INTRODUCTION

The Spences Bridge Project is a bedrock mapping program with objectives to refine stratigraphy of the Cretaceous Spences Bridge Group, determine the geological setting and characteristics of gold-bearing epithermal vein systems, and assess the regional economic potential of Cretaceous volcanic stratigraphy in southern British Columbia. The program focuses on two major rock successions: island-arc rocks of the Late Triassic Nicola Group, specifically the western belt (facies) mapped locally around Merritt in 2007 (Diakow, 2008); and a superimposed Early Cretaceous continent-margin arc succession, the Spences Bridge Group. The paper describes a new exhalite and sinter discovered in Late Triassic felsic stratigraphy, as well as low-sulphidation epithermal veins in the Cretaceous Spences Bridge Group.

PREVIOUS WORK AND CURRENT STUDY

Early Cretaceous volcanic rocks of the Spences Bridge Group form a narrow, northwest-trending belt regionally covering nearly 3200 km^2 east of the Fraser fault in southern British Columbia (Figure 1). They unconformably overlie both the oceanic Cache Creek terrane and, at the latitude of the study area, the more broadly distributed magmatic arc making up the Quesnel terrane. The Quesnel terrane in the study area consists primarily of mafic volcanic and interstratified sedimentary rocks of the Late Triassic Nicola Group and contemporaneous intrusive rocks of the Mount Lytton Plutonic Complex (Monger and McMillan, 1989; Monger, 1989). Together with the Late Jurassic Eagle Plutonic Complex (Greig, 1991), these tectonic elements define part of the southwestern margin of the Quesnel terrane.

Thorkelson (1986) studied a segment of the mid-Cretaceous belt south of Merritt and, after integrating relationships documented in previous regional mapping studies, proposed revisions to the confusing stratigraphic nomenclature for mid-Cretaceous rocks in southwestern BC. Consequently, Thorkelson and Rouse (1989) proposed that the Spences Bridge Group, with further subdivision into two formations, be formally adopted. The lower of these, the Pimainus Formation, is a lithologically diverse subaerial volcanic sequence composed largely of flows and fragmental deposits of andesitic and rhyolitic compositions, interspersed with terrestrial sedimentary rocks. The overlying Spius Formation differs significantly and is composed mainly of brownish-weathering amygdaloidal andesite flows. Palynomorphs from sedimentary rocks and K-Ar dates from volcanic rocks aided in assigning a somewhat broad, Early to Late Cretaceous time of deposition for these two formations (Thorkelson and Rouse, 1989).

Epithermal gold-bearing veins of the low sulphidation type were discovered within subaerial volcanic rocks of the Spences Bridge Group in 2002, and a bedrock–mineral deposit study was initiated in 2007 by the BC Geological Survey in order to evaluate the economic mineral potential of this succession. In the first year, 1:20 000 scale bedrock mapping focused on older, Triassic 'basement' rocks between Iron and Selish mountains, and a study of the Spences Bridge Group stratigraphy was started at a reference section exposed in the vicinity of Gillis Lake (Thorkelson, 1986; Diakow, 2008). During 2008, the mapping program extended beyond the Gillis Lake area, expanding the study of Spences Bridge stratigraphy laterally, northwest towards Prospect Creek and south to the Shovelnose Mountain area. This bedrock mapping has been published at 1:50 000 scale (Diakow and Barrios, 2008).

LITHOLOGICAL UNITS

The study area (Figure 2) lies near the western margin of the Quesnel terrane, which is dominated by Late Triassic volcanic and sedimentary rocks of the Nicola Group and associated intrusions of diorite to granodiorite composition, which have been divided into four regional facies belts (Preto, 1979). In the study area, the Nicola Group consists mainly of mafic volcanic rocks, although a unique felsic volcano-sedimentary facies is mapped between Iron and Selish mountains (McMillan, 1981; Diakow and Barrios, 2008). Triassic stratigraphy at this locality has been described in Diakow (2008), and several U-Pb isotopic dates obtained from felsic volcanic rocks are reported in this paper. The Nicola Group is unconformably overlain by Cretaceous sedimentary and volcanic units. The sedimentary rocks, characterized by chert-bearing conglomerate, are thought to be older and constitute a poorly exposed, recessive unit upon which volcanic and lesser sedimentary rocks of the mid-Cretaceous Spences Bridge Group were depos-

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ited. Throughout most of the study area, however, the chert-rich clastic unit is missing, and Spences Bridge rocks apparently rest nonconformably on intrusive rocks of the Late Triassic Coldwater pluton, the Triassic–Jurassic Mount Lytton Plutonic Complex and the Late Jurassic–Cretaceous Eagle Plutonic Complex (Monger, 1989; Monger and McMillan, 1989; Greig, 1991). The Eocene Princeton Group is the youngest succession mapped. Composed largely of hornblende-phyric dacite flows, it is a relatively flat-lying succession unconformably overlying Cretaceous strata. Thick deposits of conglomerate, marking a period of Eocene tectonic instability, are confined to the Fig Lake graben. Unconsolidated glacial deposits are relatively thin throughout most of the study area but have been reworked and redeposited in broad fluviatile terraces that completely conceal bedrock in several major valleys, such as that occupied by the Coldwater River.

Geochronology and Paleontology Results from Iron and Selish Mountains

Stratigraphy on Iron Mountain and the lower west slope of Selish Mountain were remapped in 2007 (Diakow, 2008; Diakow and Barrios, 2008). Significant felsic volcanic strata in these areas overlie a mafic succession resembling rocks more typical of the Late Triassic Nicola Group. Previous workers collected fossils from the Iron Mountain section, but none provided definitive age constraints. Two new U-Pb dates have been obtained from stratified felsic volcano-sedimentary sequences at Iron Mountain and Selish Mountain.

Stratigraphy mapped between Iron Mountain and Selish Mountain, south-southwest of Merritt, consists generally of a thick basaltic sequence conformably overlain by intervals characterized by felsic volcanic rocks interlayered with shallow marine limestone and sandstone (Diakow, 2008). With the exception of the Ashcroft map area, significant felsic volcanic accumulations are absent from within Late Triassic magmatic-arc successions elsewhere in BC. Two samples for U-Pb isotopic dating were collected from felsic rocks at widely spaced localities in order to determine their temporal relationship with the Nicola Group: one at Iron Mountain and the other from a Coquihalla Highway exposure at Castillion Creek (*see* 'Castillion Creek Exhalite-Sinter' section). Sample preparation and analytical work for U-Pb isotopic ages was conducted by R. Friedman at the Pacific Centre for Isotopic and Geochemical Research at the Department of Earth and Ocean Sciences, University of British Columbia.

On Iron Mountain, sample 08LDi 7.4 was collected from dacitic crystal-ash tuff that is conformably overlain by a relatively thin interval of interlayered limestone and calcareous sandstone containing an assemblage of bivalves and ammonoids that were collected for identification. At Castillion Creek, sample 08LDi 32.1 was taken from the base of a stratified section with siliceous sinter, the sample originating from a rare, rhyolite ash tuff that occurs as a 20–60 cm thick layer within a black limestone-mudstone bed.

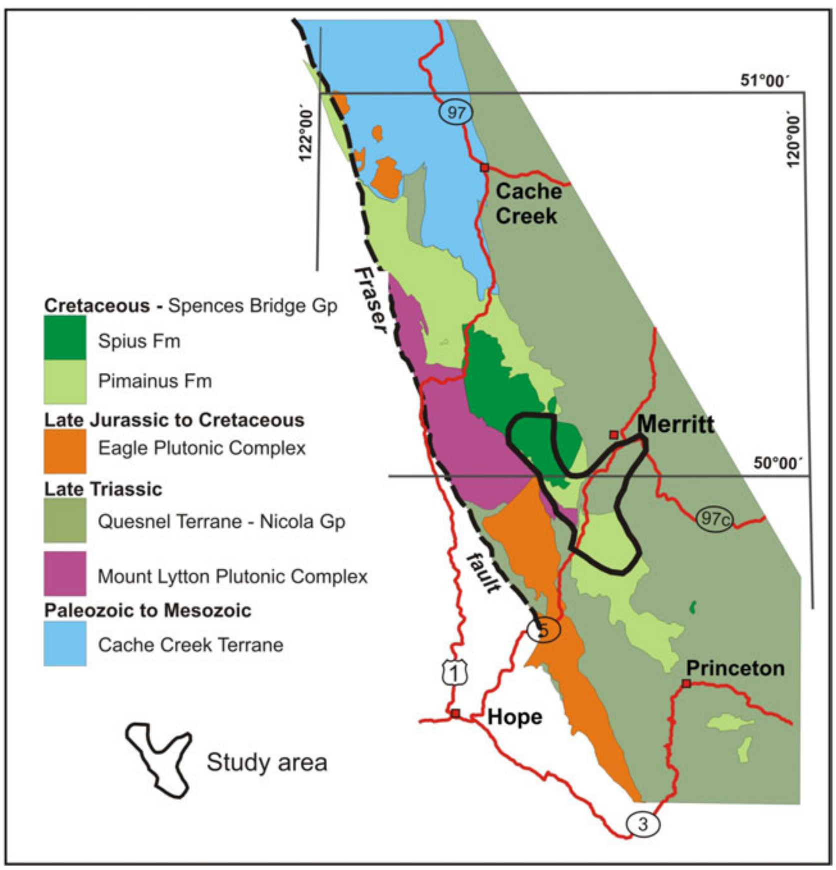

Figure 1. Regional geological setting of the Spences Bridge Group and location of the project area in southwestern British Columbia.

A solitary bivalve was recovered from these calcareous rocks and sent for paleontological identification.

The felsic volcanic rocks from both localities yielded identical Late Triassic (Carnian) U-Pb zircon ages of 224.6 ±0.9 Ma at Iron Mountain and 224.5 ±0.3 Ma at the Castillion Creek sinter. Fossil identifications corroborate these isotopic ages. The Iron Mountain macrofossil collections are considered to be Late Triassic, with a possible Norian to Rhaetian age suggested (Haggart, 2008). At Castillion Creek, the Triassic bivalve *Halobia*, species indeterminate, was identified from the black limestone-mudstone unit (M. Orchard, Geological Survey of Canada, pers comm, 2008). The western felsic facies (belt) of the Nicola Group has also been dated north of Merritt, where it gives a similar U-Pb zircon age of 222.5 ±1.4 Ma (Moore et al., 2000). Isotopic ages for the felsic rocks suggest that they, and accompanying sedimentary stratigraphy at Iron Mountain and Castillion Creek, are time-stratigraphic equivalents.

Early and Late Cretaceous Spences Bridge Group

Thorkelson (1986) mapped the Spences Bridge Group within a 250 km^2 area from Shovelnose Mountain northwest to the confluence of Prospect and Spius creeks. This area straddles the Coquihalla Highway, about 25 km south of Merritt. Near Gillis Lake, stratified mid-Cretaceous rocks are particularly well exposed, and they figured prominently in formal definition and subdivision of the Spences Bridge Group in southwestern BC (Thorkelson and Rouse, 1989).

Our geological mapping overlaps Thorkelson's original work and maintains usage of his stratigraphic divisions, Pimainus and Spius formations, for the Spences Bridge Group. This study consists of 1:20 000 scale mapping and presently extends for about 50 km, from Shovelnose Mountain in the south, north-northwest through the Gillis Lake area to the Prospect Creek area in the northwest (Diakow and Barrios, 2008). Generalized stratigraphic sections, approximate thicknesses and contacts for stratigraphic units of the Spences Bridge Group between Shovelnose Mountain and Prospect Creek are shown in Figure 3, and the locations of these sections given in Figure 2.

This mapping provides stratigraphic refinements and a new U-Pb isotopic date for the Spences Bridge Group. Additional rocks were collected for U-Pb isotopic dating in 2008, but age determinations were not available for this report. These new dates will aid internal division and correlation within the Pimainus Formation and also constrain the age of the upper contact with the overlying Spius Formation.

PIMAINUS FORMATION

The Pimainus Formation exhibits significant lithological diversity, in both its vertical stratigraphy and lateral facies variations, within the northwest-trending corridor mapped between Shovelnose Mountain and Prospect Creek. A somewhat continuous lateral view of the Pimainus Formation is evident in the transect from Prospect Creek southeast to the Gillis Lake area (i.e., Gillis Lake–Prospect Creek transect). At Gillis Lake, the Pimainus Formation is well stratified, inclined northeast and estimated to be about 1200 m thick. Immediately east-southeast of Gillis Lake, stratigraphic continuity of the Pimainus Formation is severed by the north-striking Fig Lake and Coldwater faults, which demarcate the Eocene Fig Lake graben. Within the graben, crossfaults separate blocks that progressively step down northward, generally resulting in Pimainus stratigraphy being exposed mainly in the south and Eocene rocks becoming progressively more extensive farther north. The Pimainus Formation continues southeast of the graben, apparently thickening to more than 2200 m at Shovelnose Mountain (i.e., Shovelnose Mountain transect). At Shovelnose Mountain, however, orientation of stratigraphy is difficult to ascertain because of the general lack of bedding attitudes and poorer exposure; therefore, comparative thickness estimates for the Pimainus Formation are more speculative. Furthermore, internal stratigraphic correlations of Pimainus rock units between transects is difficult. However, one particularly distinctive volcaniclastic unit can be correlated with relative certainty, and correlation is corroborated by U-Pb geochronology.

Gillis Lake–Prospect Creek Transect

The most lithologically diverse Pimainus stratigraphy is found in a northeast-dipping section that underlies a northwest-trending ridge near Gillis Lake (Figure 4). These rocks represent a stratigraphic reference section utilized by Thorkelson (1986) in his redefinition of the Spences Bridge Group. Remapping the geology during this study reveals mainly subaerial flows and pyroclastic volcanic units (90%), interlayered with minor sedimentary intervals containing conglomerate and sandstone. In this area, the lower contact of the Pimainus Formation is probably a nonconformity with dioritic rocks of the Late Triassic to Early Jurassic Mount Lytton Plutonic Complex, although the contact was not observed.

Pimainus stratigraphy at Gillis Lake is subdivided into ten map units. Collectively, they are at least 1200 m thick in a continuous conformable section lacking faults. Along strike, these map units are juxtaposed by high-angle faults striking northeast. Farther northwest, they diminish to only three map units adjacent to Prospect Creek, where they are poorly exposed within a section estimated to be less than 600 m thick (Diakow and Barrios, 2008). The change laterally to a simplified stratigraphy is thought to reflect primary deposition, perhaps controlled by an irregular sub-Pimainus topography. In the Gillis area, the thicker and more varied rock succession probably accumulated within a topographic low that persisted throughout active volcanism. This is indicated by tuffs and lava flows that are separated by intervals of epiclastic rocks, including four distinctive conglomerate units and other locally derived, finer sandstone units containing plant debris.

Lava Flows and Ash-Flow Tuffs

Initial deposits (unit G1) of the Pimainus Formation in the Gillis Lake–Prospect Creek transect consist of grey-green andesite, of which medium-grained flows containing pyroxene (1–3%) and plagioclase (25–30%) phenocrysts are most common. Amygdaloidal flows with small chlorite- and chalcedony-filled amygdules occur but are not common. Nearly identical andesite flows recur up-section above the basal andesite in unit G7. The basal andesite is sharply overlain by a rhyolitic pyroclastic unit (unit G4), averaging 100–150 m thick. This is an important stratigraphic marker within the Pimainus Formation, as it crops out throughout the Gillis Lake–Prospect Creek transect. It correlates, on the basis of consistent lithological

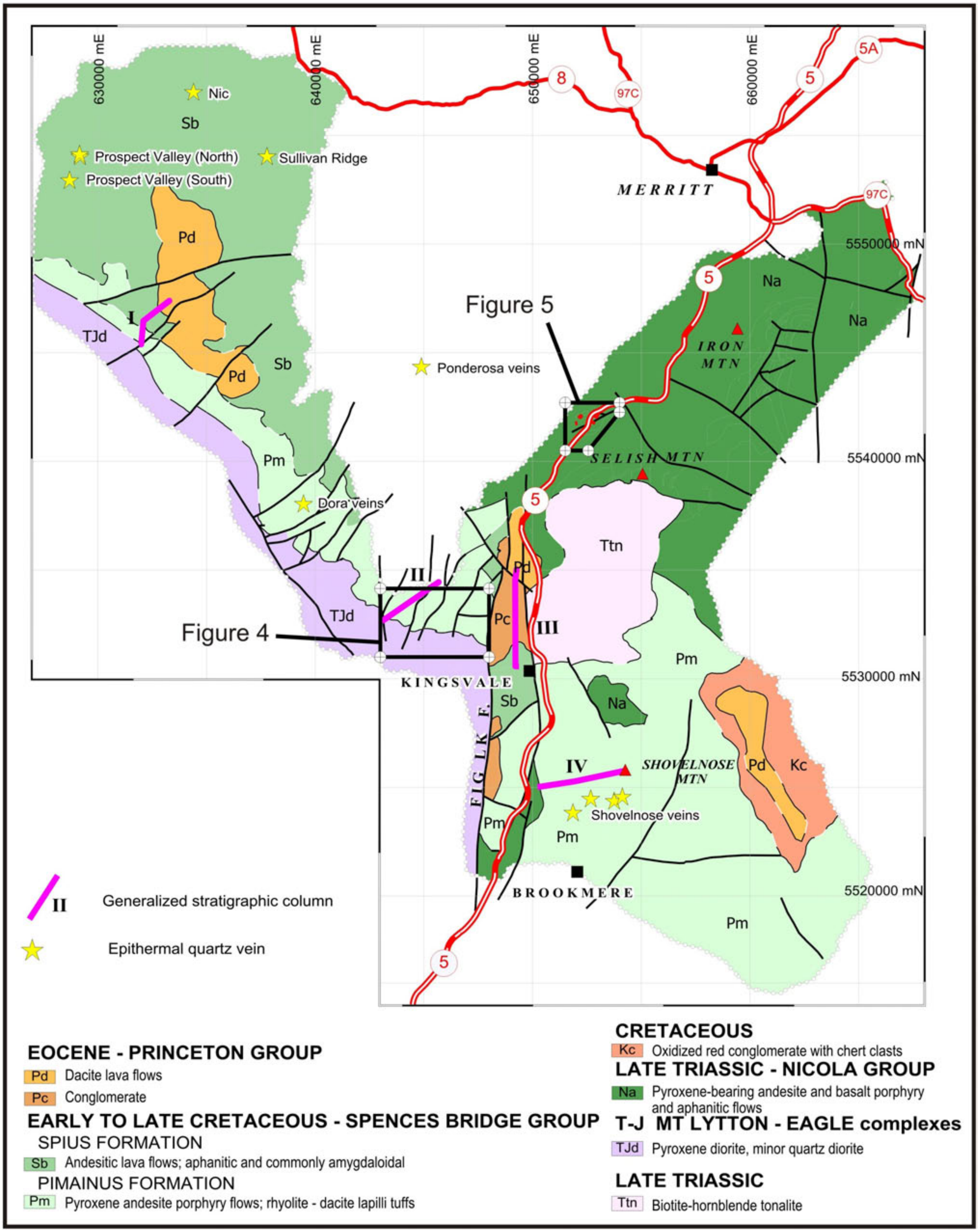

Figure 2. Generalized geology near Merritt, British Columbia, based on bedrock mapping in 2007 and 2008. Locations of epithermal gold-quartz vein prospects discovered since 2002 are shown.

characteristics and U-Pb isotopic age, with the large volume of rhyolitic tuffs and associated rhyolite flows underlying the lower slopes of Shovelnose Mountain (Diakow and Barrios, 2008, units PS3 and PS4). The appearance of this unit varies considerably from incompetent and rubbly weathered to indurated, massive structureless deposits that form a series of competent benches. It is distinguished by lithic pyroclasts that include light-coloured (generally whitish), clay-altered, aphanitic rhyolite; some flow-laminated rhyolite; and pink, medium-grained granitoid of quartz monzonite to granodiorite composition. Quartz (1–2 mm in diameter) and scarcer biotite crystal fragments are widespread but can be easily overlooked owing to their small size and trace abundances. Fragments within the tuff are generally sorted and less than 2 cm in diameter, although tuff breccia sometimes alternates with lapilli tuff with or without sparse blocks. Rare charred logs, several metres long, have been observed in the unit near Prospect Creek. Tuffs from unit G4 are interpreted as a nonwelded rhyolite ash flow or ignimbrite.

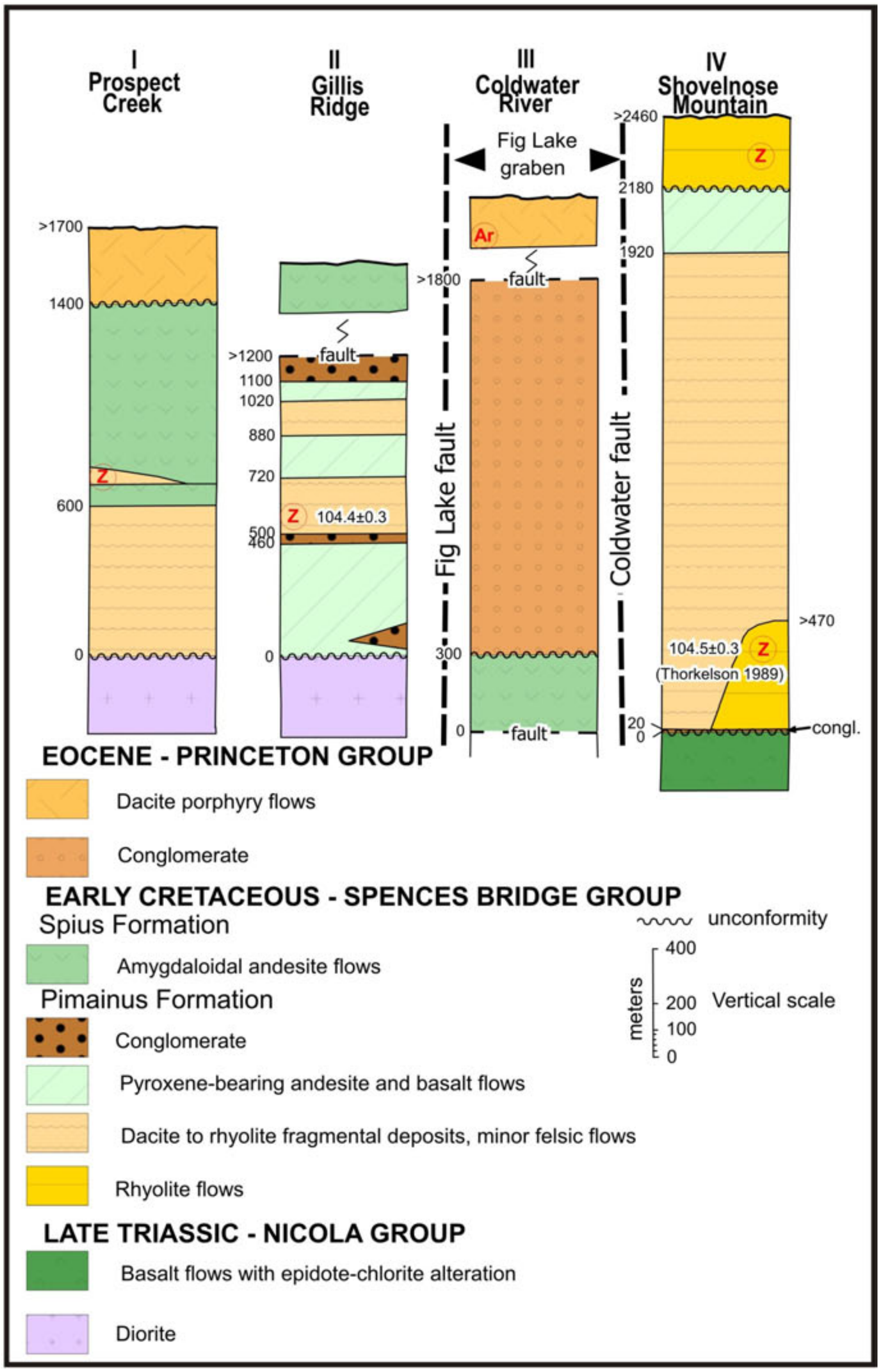

Figure 3. Generalized stratigraphic sections for rocks of the Spences Bridge Group between Shovelnose Mountain and Prospect Creek. Column locations are shown in Figure 2.

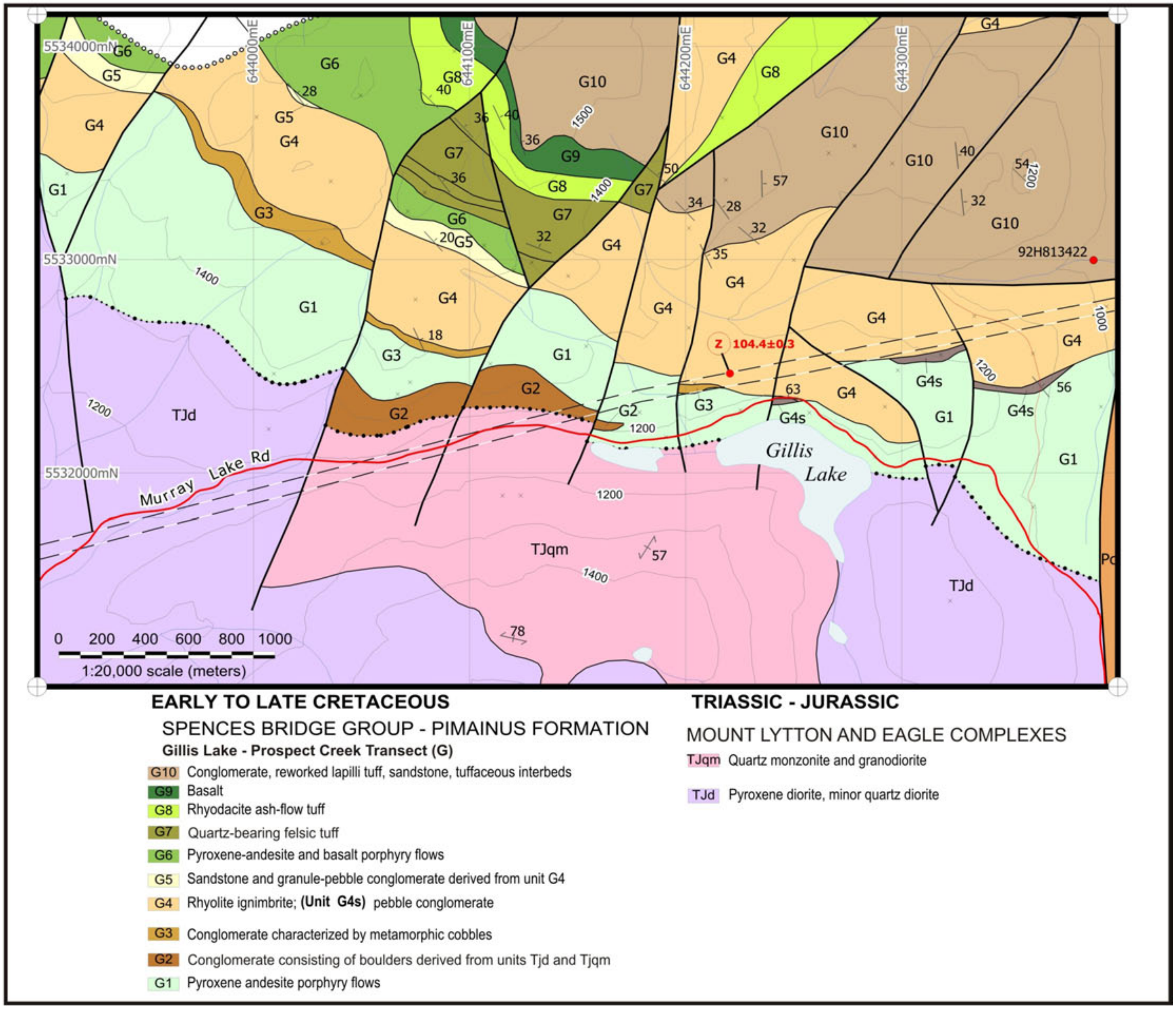

Figure 4. Detailed geology of the Pimainus Formation, Spences Bridge Group, at a reference area near Gillis Lake, south of Merritt. Location of Gillis Lake area is shown in Figure 2.

Minor bedded tuffs containing crystals, ash and small lithic fragments form thin-layered deposits within the otherwise massive ash flows. Cuspate vitric shards, which attest to the presence of pumice, compressed pumice and resorbed quartz phenocrysts have been observed in thin section. Other layered rocks associated with the ash-flow tuffs consist of tuffaceous sandstone made up of crystal fragments, mainly plagioclase, quartz±biotite and small volcanic lithic clasts and carbonaceous plant debris. Discrete, fine lapilli tuffs may form subordinate layers within the volcanic-derived sandstone.

A second ash-flow tuff unit (unit G8) occurs near the top of the Gillis Lake section. It occurs above pyroxene-phyric andesite (unit G7) and, in turn, is overlain by columnar-jointed basalt (unit G8) that displays a distinctive orange-brown spheroidal weathered surface. This tuff unit is distinguished from those lower in the section by monomictic juvenile lapilli and blocks composed of reddish, sparsely plagioclase-porphyritic and flow-laminated rhyodacite. Rhyolite lava flows, presumed to represent small domes or facies related to this pyroclastic flow, occur at two localities in the transect, one of which has been examined for gold mineralization (*see* 'Dora Prospect' section).

Conglomerate and Sandstone

Differentiating sequentially younger and lithologically similar andesite lavas and felsic ash-flow tuff units in the Gillis Lake–Prospect Creek transect is facilitated by four distinctive conglomeratic beds dispersed at successively higher levels in the stratigraphy. The stratigraphically lowest conglomerate (unit G2) is best exposed in resistant bluffs west of Gillis Lake, where it is about 150 m thick and apparently overlies intrusive rocks concealed by colluvium in the valley. This lenticular body is partly enclosed laterally by andesite lavas from unit G1. One additional isolated exposure of the same conglomerate was found to the northwest near the upper contact of diorite with andesite, suggesting that the unit is laterally discontinuous, its distribution controlled by surface irregularities in the underlying plutonic basement. Conglomerate from unit G2 is crudely layered and composed of poorly sorted angular and subrounded boulders up to 2.2 m in diameter. The clasts have local provenance, derived from diorite and quartz monzonite phases of the Mount Lytton Plutonic Complex and underlying pyroxene-phyric andesite flows of unit G1.

The next highest conglomerate (unit G3) occurs at the contact between unit G1 andesite and overlying ash-flow tuff of unit G4. Unit G3 is a maximum of 60 m thick, pinching out over a distance of 4 km along strike. It is a polymictic cobble and boulder conglomerate composed mainly of well-rounded metamorphic clasts, dominated by foliated, intermediate composition granitoid; lesser greenschist, metasandstone and quartzite; rare schist; and locally abundant vein quartz. Evidently, the provenance of this conglomerate is an exhumed metamorphic terrain. A potential source area might be the Nicola horst, 50 km northwest, where a marginal belt, composed of metamorphic rocks broadly similar to those found in the conglomerate, has been reported (Erdmer, et al., 2002, 'Bob Lake assemblage').

Upsection, epiclastic rocks reappear as relatively thin but widespread sandstone and interbedded conglomerate (unit G5) occurring at the top of unit G4 ash-flow tuffs. A marked change in clast types occurs in unit G5 along strike between Gillis Lake and Prospect Creek. Closer to Gillis Lake, it exhibits planar, locally crosslaminated beds of feldspar-rich sandstone and pebble-granule and local boulder conglomerate containing detrital grains of quartz, traces of biotite and rhyolitic clasts, which are indicative of erosion of the underlying ash-flow tuffs. Farther northwest, however, these rocks are supplanted by sandstone and conglomerate (Diakow and Barrios, 2008, unit G5c) dominated by granitoid clasts. In order of abundance, the clasts include diorite, quartz diorite, granodiorite and mylonitic quartz monzonite that resemble intrusive phases mapped immediately to the southwest in the Mount Lytton Plutonic Complex. Rare pebbles of vein quartz and biotite schist have also been found. Unit G5c is particularly well exposed along part of Prospect Creek, where drab olive-green sandstone forms lenses and thick beds interlayered with conglomerate in a cliff section rising about 80 m above creek level. Bedding is thick, with parallel and internal crossbedding sometimes observed. Wood and plant debris is common everywhere within sandy layers in units G5 and G5c.

The stratigraphically highest conglomerate (unit G10) forms the top of the Gillis section. It contains numerous mauve, sparsely plagioclase-phyric rhyodacite cobbles that resemble underlying pyroclastic flow unit G8. It also contains significant interbedded sandstone, some displaying large-scale planar crossbeds. It is estimated the this unit might be several hundred metres thick, although faults are suspected. The conglomerate appears to pass imperceptibly into a thick, mixed unit composed of reworked and primary lapilli tuff beds at the top of the ridge north of Gillis Lake.

Shovelnose Mountain Transect

The Shovelnose Mountain transect covers the general region extending east from the Coldwater fault to Voght valley road and south from Kane valley road to Brookmere road. In this region, stratigraphy of the Pimainus Formation is generally equivalent to that mapped in the Gillis Lake–Prospect Creek transect (for map units cited here for the Shovelnose transect, *see* Diakow and Barrios, 2008). In the Shovelnose area, however, Pimainus stratigraphy does not exhibit the diversity and sequential stratified order observed in the Gillis Lake–Prospect Creek transect. The most notable general stratigraphic difference between these transects is the considerable increase in thickness of the Pimainus Formation, due mainly to substantially greater volume of felsic fragmental rocks, particularly rhyolite lava flows, and greatly reduced epiclastic deposits in the Shovelnose section. Furthermore, stratigraphic contacts in the area are poorly defined and irregular, commonly exemplified by rhyolitic rocks that are bulbous in outline.

The base of the Pimainus Formation is believed to be an unconformity, based on contact relationships near Seymour Lake, just north of Kane valley road. Previous mapping placed a fault between the Late Triassic Coldwater pluton and the Spences Bridge succession in this locality (Thorkelson, 1986; Monger, 1989). Although a direct contact with the pluton was not observed, a small isolated exposure of conglomerate with rounded clasts of the pluton and a consistent curved contact between the pluton and overlying andesite flows (unit PS1) are adopted as indirect evidence for an unconformity. In addition, several outliers composed of similar andesite rest on the Coldwater pluton. The southern pluton margin can be placed as far south as

Voght Creek and, although it is largely concealed by overburden, the pluton crops out at creek level immediately east of the Coquihalla Highway. Between this granitic outcrop and a stratified section containing coal seams exposed along the highway, a distance of about 400 m to the south, scant evidence for a fault contact exists and the preferred interpretation is that of a nonconformity.

A stratified section along the Coquihalla Highway south of the Coldwater pluton is unique in the study area. It is distinguished by two intervals, each about 40 m thick, composed of interlayered coal beds, up to 0.5 m thick, alternating with sandstone and minor pebble conglomerate (unit PS1c). The lowest coal bed rests on pyroxene andesite flows and the uppermost coal is depositionally overlain by dacitic lapilli tuffs containing aphanitic andesite fragments and trace amounts of quartz. The area between the coal intervals is occupied by a coarse epiclastic deposit about 75 m thick. It is composed of boulder-size clasts of sandstone and lesser amygdaloidal andesite that protrude from a more recessive matrix made up of friable sandstone, coal chips and pebbles. The stratigraphic position of this unusual section within Pimainus stratigraphy is uncertain; however, because of its character and bounding volcanic rocks, it is interpreted as a lenticular deposit that has limited extent within the pyroxene andesite lava sequence of unit PS1.

Andesite flows of undetermined thickness, assigned to unit PS1, are widespread adjacent to Kane valley road and are believed to occur at the bottom of mid-Cretaceous stratigraphy at Shovelnose Mountain. Their lithological characteristics and speculated low stratigraphic position are perceived to be comparable to those of unit G1 in the Gillis Lake–Prospect Creek transect. These flows have grey-green colouration and typically exhibit porphyritic textures imparted by 25–30% medium-grained plagioclase and several percent or less pyroxene phenocrysts that often have a dull appearance due to partial replacement by chlorite. Rare amygdaloidal flow members have been observed. Celadonite is widespread along with chalcedonic silica, filling fractures in the andesite.

Up section, andesite of unit PS1 is apparently overlain by sedimentary rocks of unit PS2. Outcrops are scattered at low elevation east of the Coldwater River and generally concealed by overburden, whereas exposure improves on a hill north of Shouz Creek. An isolated occurrence of conglomerate farther south along the old CP rail bed, underlying rhyolite, may mark the southern extent of this sedimentary unit. The conglomerate contains numerous dark andesite clasts resembling the Nicola Group, and quartz-rich sandstone. An exposure along the Coquihalla Highway, about 750 m north of Coldwater Exit 256, is typical of the finer conglomerate and sandstone belonging to unit PS2. Conglomerate and sandstone of this unit are dominated by rounded cobbles and pebbles composed mainly of porphyritic andesite and sparsely plagioclase-phyric dacite. Pink granodiorite and biotite-tonalite pebbles and small cobbles are a minor component but are a characteristic and widely distributed feature of the unit. Sandstone contains abundant angular plagioclase and locally diagnostic quartz and biotite. Plant debris is widespread in most of the finer grained beds. In spite of very different lithic components, unit PS2 is believed to correlate in terms of stratigraphic position with unit G2 in the Gillis Lake–Prospect Creek transect.

Rhyolitic crystal-lithic tuff with associated sandstone and granule conglomerate containing felsic volcanic detritus occupy a relatively thin outlier depositionally above unit PS2 north of Shouz Creek. This felsic tuff, designated unit PS4, and minor sedimentary rocks of unit PS4s apparently extend southward at low elevation through Shovelnose Mountain, the former unit thickening dramatically where it underlies much of the lower, southerly-facing slope. Internally, this tuff changes character over short distances, although the general dacite to rhyolite composition of the unit is maintained. Exceptions are where less voluminous volcanic rocks are interspersed and clearly contrast with the surrounding lapilli tuffs. For example, rhyolite flows (unit PS3) and pyroxene andesite (unit PS4a) sometimes display highly discordant contacts with the tuffs. Due to the relatively poor exposure and lithological variability in unit PS4, there was no representative section recognized during this study.

Unit PS4 is composed primarily of tuffs containing a variety of different fragment compositions. Felsic lapilli, typically in shades of off-white with aphanitic textures and less commonly flow laminated, are widespread and diagnostic; however, they are not necessarily the most abundant fragments. They are usually accompanied by varying proportions of green aphanitic and porphyritic andesite and mauve dacite, and sparse but widespread pink quartz monzonite fragments. Generally the tuffs are sorted and composed mainly of subangular to subrounded lapilli and few blocks. The tuff matrix is composed of crystal fragments dominated by plagioclase, quartz and commonly trace quantities of biotite. Commonly, the tuffs form resistant, massive, indurated beds where the fragments protrude from a recessive matrix. Welded fabrics were rarely observed.

Rhyolite lava flows rise from the level of the Coldwater River more that 400 m up the west-facing slope of Shovelnose Mountain (units PS3 and PS3r). They conformably overlie subhorizontal conglomerate and sandstone from unit PS2, and the apparent contact with adjacent unit PS4 tuffs is steep, giving the rhyolite the appearance of a flow dome. The rhyolite rises in a series of cliffs made up of dense, laminated flows. Vertical standing columns 60 m high occupy a zone locally at the base of the unit. Typically, the rhyolite is mauve, finely flow laminated and plagioclase porphyritic. Original glass in the rocks is replaced by small ovoid spherulites that are scattered and coalescing as they overprint flow laminations in specific layers. The mineralogy changes in rhyolite higher in the pile with the addition of minute quartz, biotite and possible slender hornblende prisms, none of which exceed 1% of the rock. Surprising is the absence of flow breccia and talus breccia. Only in a similar rhyolite unit southeast of Shovelnose Mountain is monolithic breccia associated with these lavas.

A second, homogeneous rhyolite flow unit (PS6) is found at the top of Shovelnose Mountain. It extends as a continuous sheet from the summit partway down the north slope, then turns southeast, tapering as it loses elevation to its present terminal position astride the Brookmere road. The original distribution of the unit might have been more extensive, possibly extending over much of the southern slope of the mountain where similar rocks presently crop out in a cluster of prominent knolls. These scattered exposures of rhyolite are speculated to represent remnants of a continuous rhyolite capping that existed above 1300 m elevation on the mountain. Thickness estimates for rhyolite vary from 150 to 250 m, inferred from sections at the summit.

The lower contact of the rhyolite might be an unconformity. The most compelling field evidence in support of an unconformable relationship is from a knoll approximately 4 km southeast of the Shovelnose summit. Here, rhyolite flows have a subhorizontal base, overlying a gentle northeast-inclined succession made up of older Pimainus rocks (units PS1, PS3 and PS4). Moreover, a window through the rhyolite northeast of the summit reveals boulder conglomerate directly beneath the rhyolite. This conglomerate contains well-rounded clasts up to boulder size that are composed of porphyritic andesite and dacite. Nearby, another isolated conglomerate exposure has rounded cobbles admixed with angular flow-laminated rhyolite blocks in a breccia, suggesting that flows apparently overrode loosely consolidated conglomerate.

Rhyolite from unit PS6 is best viewed along the access road to the summit of Shovelnose Mountain. Columns form a cliff a short distance southeast of the summit. Typical exposures of the rhyolite are mauve with fine, reddish flow laminations and 10–15% medium-grained plagioclase phenocrysts. The laminations vary significantly in attitude within individual outcrops and commonly outline internal flow folds. The characteristic mauve colour of the rocks is modified by incipient supergene alteration, evident as irregular patches and streaks composed of whitish clay minerals. Weathering and alteration are accompanied by the development of a narrow-spaced parting that is oriented parallel to flow laminae.

SPIUS FORMATION

The Spius Formation is characterized by a thick, monotonous, andesite flow succession. In the study area, these lava flows crop out from within the Fig Lake graben, and also to the northwest where they overlie the Pimainus Formation in the Gillis Lake–Prospect Creek transect. This transect marks the southeastern limit of these flows, which extend regionally towards the northwest, blanketing an area nearly 10–15 km wide by 70 km long (Monger and McMillan, 1989). This region corresponds to the Nicoamen Plateau, a highland situated between the Nicola River to the east and, in part, the Fraser River to the west, and the hamlet of Spences Bridge to the north.

Thorkelson (1986) recognized the gradational nature of the contact between the Pimainus and Spius formations as being indicated by pyroxene andesite porphyry lavas or welded and crystal tuff, common in the Pimainus, interleaved with aphanitic and amygdaloidal andesite lavas diagnostic of the overlying Spius. Alternation of the pyroxene andesite porphyry and thinner amygdaloidal flow members can take place over hundreds of metres in elevation, as observed during this study in semicontinuous lava exposures west of Spius Creek. In this transitional contact zone, we mapped the bottom of the Spius Formation, where multiple, aphanitic or amygdaloidal flows produce brownish-weathered, rounded, low-relief exposures of fine rubble and soil. An unambiguous gradational contact is located along Prospect Creek. The lowest flows of the Spius Formation sharply bound an interbed, 30 m thick, composed of lithic-crystal tuff. Microscopically, the tuff is dominated by pumiceous lithic fragments, cuspate vitric shards and 1–3% resorbed quartz-crystal fragments. It is undoubtedly related to rhyolite pyroclastic flows assigned to unit G4 of the Pimainus Formation that crop out downslope, beneath the lowest Spius flows. The tuff was sampled in 2008 for U-Pb isotopic dating to determine timing for the onset of Spius lava eruptions.

East of the confluence of Prospect and Spius creeks, the lower contact of the Spius Formation, exposed in a roadcut, is sharp and identified by 6 m of conglomerate. Flows underlying the conglomerate, consisting of moderately to coarsely plagioclase-pyroxene–phyric andesite, have been assigned to the Pimainus Formation. Those above the conglomerate consist of aphanitic and amygdaloidal andesites and have been assigned to the Spius Formation.

From a distance, sections of the Spius Formation exhibit individual lava flows tens of metres thick stacked in parallel succession. Good exposures of this massive layered nature can be viewed from vantages along the Patchett road, looking west towards the intersection of Prospect and Spius creeks. Similar, thickly layered, gently inclined lava flows occur throughout the more remote northwestern part of the study area. The Edgar Creek and Hooshum logging roads provide access into this area. The Spius Formation is overlain above a subhorizontal unconformity by volcanic rocks of the Eocene Princeton Group.

Spius flows that usually appear well layered and gently inclined from a distance are massive with bedding difficult to discern at outcrop scale. Within any individual flow member there are, however, noticeable colour and small-scale textural variations. Brown shades are common for weathered surfaces and red-maroon shades when the surface is oxidized. Fresh rocks are typically drab grey-green. The texture of flows varies greatly, ranging from aphanitic, with and without sparse pyroxene phenocrysts, to finely to moderately pyroxene-plagioclase phyric, to amygdaloidal, in which the concentration, shape, size and composition of amygdules vary. Amygdules range from round to elongate and are filled most frequently with white quartz, chlorite and, less commonly, zeolite. The aphanitic flows display a honey yellow colour and granular texture. Interflow breccia forms irregular lenticular layers, generally oxidized and just a few metres thick. Geodes ranging up to 10 cm, and rarely to 60 cm, lined with quartz-calcite druse or completely filled with laminated greyish white agate or radiating zeolite, were found in the flows.

Age of the Spences Bridge Group

Thorkelson and Rouse (1989) reported a number of K-Ar ages on whole-rock samples collected from the Spences Bridge Group near Merritt. Seven overlapping dates for the two formations range from about 94 to 79 Ma with errors of 3 Ma (1). Based on identified palynomorph assemblages, Thorkelson and Rouse (1989) favoured a "late Albian assignment for the Pimainus Formation as well as the Spius Formation." Thorkelson sampled rhyolite of the Pimainus Formation at Shovelnose Mountain for a U-Pb zircon date, appending the date of 104.5 ±0.3 Ma in Thorkelson and Rouse (1989). Although the geological context for the dated rhyolite was not presented in their paper, we suspect it is derived from the rhyolite dome mapped on the lower west side of the mountain, a body designated as either unit PS3 or unit PS3r in Diakow and Barrios (2008). In our mapping, this rhyolite is found stratigraphically low within the Pimainus Formation, and it represents a coherent flow facies associated with a more extensive felsic fragmental facies assigned to unit PS4.

Farther northwest near Gillis Lake, a fragmental unit (unit G4) containing felsic lithic and crystal pyroclasts similar to those in unit PS4 is correlative. In the Gillis Lake–Prospect Creek transect, these felsic deposits were interpreted as a nonwelded, low-volume, lithic-rich ash-flow tuff mapped close to the bottom of Pimainus stratigraphy. A U-Pb zircon date of 104.4 ±0.3 Ma (Albian) from this unit confirms a time-stratigraphic relationship with the topographically low felsic flows and fragmental succession at Shovelnose Mountain.

A topographically higher succession of rhyolite flows (unit PS6) drapes the summit of Shovelnose Mountain, apparently in an unconformable contact with the underlying felsic succession that includes dated Albian rhyolite. A rhyolite flow at the summit of Shovelnose Mountain was sampled (sample 08LDi 59.1) for a U-Pb isotopic age to determine if these extensive flows are part of the Pimainus Formation and, if so, to establish the duration of rhyolitic eruptions.

The gradational contact relationship observed between the Pimainus and Spius formations, manifested as coalescing felsic tuffs and amygdaloidal andesite flows, suggests that these distinctive rock units erupted in rapid succession. Onset of the massive effusive flow event that characterizes the Spius Formation will be established by U-Pb dating of sample 08LDi 14.3, which was collected from rhyolite vitric tuff of the Pimainus that occurs as an interbed, 30 m thick, between amygdaloidal flows at the base of the Spius Formation. Direct dating of the Spius Formation is difficult because of alteration and lack of suitable minerals. A black andesite glass with conchoidal fracture, the freshest lava encountered in the Spius Formation, was sampled for a whole rock $^{40}Ar/^{39}Ar$ date (sample 08LDi 57.1). This flow is just one of many very thick planar flows comprising a homoclinal, northeast-dipping succession dissected by Teepee Creek in the northwestern part of the map area, where they host gold-bearing quartz veins at the Prospect Valley showings.

Early Cretaceous (?) Conglomerate (Unit Kc)

A subhorizontal conglomerate unit is exposed intermittently in an area of at least 21 km^2 east of Shovelnose Mountain, where it is estimated at between 60 and 180 m thick. This conglomerate crops out consistently adjacent to rhyolitic rocks that are tentatively assigned to the Early Cretaceous Spences Bridge Group; however, because these rock successions have not been observed in direct contact, the exact nature of the lower contact is uncertain. The top of the conglomerate unit is defined by a sharp depositional contact with the remnants of a flat-lying Eocene hornblende-dacite flow unit. The conglomerate weathers recessively and its presence in areas of poor exposure or subcrop is indicated by distinctive reddish brown soil.

The conglomerate is polymictic, generally dominated by cobble-size clasts that are supported by a matrix composed of sand and granules. The clasts are typically well rounded, oxidized red and composed of a variety of volcanic porphyries, some quartz bearing, fewer granitoid and locally abundant greyish, off-white and black chert. Sandstone containing subordinate pebbles and fewer cobbles forms interbeds within the coarser conglomerate, imparting a diffusely layered appearance in some exposures.

Preto (1979) described similar conglomeratic rocks (his unit 9) and showed their distribution northeast of the present study area, where they are either localized adjacent to major faults or occupy a medial stratigraphic position between Late Triassic Nicola Group and rocks presumed to be equivalent in age to the Early Cretaceous Spences Bridge Group.

Eocene Princeton Group

Eocene volcanic rocks in the vicinity of Merritt have been mapped as part of the Princeton Group, distinguished by the presence of slender hornblende phenocrysts (Monger and MacMillan, 1989). Eocene rocks in the study area consist mainly of lava flows with a thick, subhorizontal, hornblende dacite porphyry flow sequence, more than 300 m thick, occupying a ridge north of Prospect Creek (unit Pd). The lower contact of this sequence with underlying andesitic lavas of the Spius Formation is a disconformity along which there is no evidence of erosion. A similar dacite flow unit crops out 24 km farther southeast, forming a series of isolated dome-like mounds scattered over 10 km. These isolated outcrops are interpreted to represent resistant remnants of a solitary lava flow that was deposited above oxidized red conglomerate of unit Kc.

The dacite forms thick homogeneous sections in which columns and autoclastic breccia locally contrast with typical massive, diffusely layered exposures. Platy parting in these lavas produces flaggy weathered debris. They are light grey to greyish green and exhibit porphyritic texture, dominated by 10–15% medium-grained plagioclase and up to 5% slender hornblende. In dacite flows north of Prospect Creek, pyroxene is abundant as microscopic grains in addition to hornblende.

Eocene volcanic rocks, associated with significant sedimentary rocks, occupy part of the Fig Lake graben, where they unconformably rest on rocks of the Spences Bridge Group (Thorkelson, 1989). As in adjacent regions, hornblende-phyric dacite flows dominate with subordinate, underlying, black, glassy aphanitic andesite. These dacite flows are distinguished by local flow lamination and ubiquitous, albeit sparse, quantities of biotite and quartz, in addition to prominent hornblende phenocrysts.

Sedimentary rocks of unit Pc form a significant proportion of graben fill north of Kingsvale. They are believed to underlie nearby dacitic flows; however, a stratigraphic contact has not been found and several fault strands appear to juxtapose the units. The sedimentary rocks are mainly conglomerate, with scarce finer clastic interbeds, that are estimated at more than 1800 m thick in a gently northward-dipping section exposed, in part, along the Coldwater River. Crude, thick layering within the conglomerate is sometimes accentuated by sandstone to fine conglomerate interbeds. Clasts display grading and local imbrication, suggesting fluvial transport and deposition.

The conglomerate is polylithic and poorly sorted, containing well-rounded clasts up to 30 cm in diameter that are supported by a friable matrix composed of abundant quartz and potassium-feldspar grains. The clasts include abundant white vein quartz and granitoid, a variety of porphyritic andesite and rhyolite, and scarce jasper and schist. Some granitic clasts are distinctive, recognized as phases that form the Mount Lytton Plutonic Complex, located just a few kilometres southwest. These include chlorite-altered granodiorite–quartz monzonite with bluish translucent quartz, foliated diorite and sparsely porphyritic rhyolite, which is a late dike phase.

INTRUSIVE ROCKS

Late Triassic Diorite (Unit Td)

Small, isolated dioritic bodies enclosed by Nicola Group strata are thought to be Late Triassic in age. The pluton near the top of Iron Mountain consists of medium- to coarse-grained gabbro and diorite, whereas a cluster of plugs southeast of Selish Mountain consists of fine-grained diorite, one of them displaying a sill-like relationship with volcanic rocks.

Late Triassic Coldwater Pluton (Unit Ttn)

The Coldwater pluton crops out in an area of approximately 40 km^2 east of the Coldwater fault, between Selish Mountain in the north and Voght Creek in the south. The intrusion passively invades and causes minor bleaching in adjacent rocks of the Late Triassic Nicola Group, particularly along its subhorizontal northern contact. Similar thermal alteration is also evident in a screen of Nicola volcanic rocks mapped farther south. The southern and southeastern contact of the pluton is thought to be a nonconformity with overlying volcanic rocks assigned to the Early Cretaceous Spences Bridge Group. There are mainly pyroxene-phyric andesite flows, but a solitary exposure of polymictic conglomerate at the base of the succession near Seymour Lake contains tonalite clasts derived from the pluton. The pluton projects through thick gravel overburden in a few localities along Voght Creek and, at the westernmost outcrop, a strong shear fabric is developed adjacent to the Coldwater fault. Upstream, beside the Coquihalla Highway, outcrop of the intrusion at creek level marks the southernmost extent of the pluton. Immediately to the south of this locality, strata of the Spences Bridge Group are thought to drape the intrusion above a nonconformable contact. Here, exposed in steep cuts along the highway, the Spences Bridge consists of interbedded volcanic and sedimentary rocks, the latter containing intervals of coal.

The pluton is composed primarily of tonalite with a transition to quartz diorite in the north. Generally, the tonalite is light greyish white with a medium to coarse equigranular texture. The mafic minerals are dominated by fresh hornblende (20–30%) and biotite (2–5%). Biotite increases to 25% locally along the pluton margin.

Dikes crosscutting the tonalite are uncommon and typically narrow. They consist of pink, orange-weathered, fine-grained granite and rare diabase. At one locality along the pluton margin, pink aplite dikelets project from the intrusion into bordering country rocks.

The pluton has produced several Late Triassic K-Ar dates (Preto et al., 1979). An unaltered tonalite collected during this study near the centre of the stock yielded an $^{40}Ar/^{39}Ar$ cooling age on biotite of 212.7 ±1.1 Ma, confirming emplacement of the Coldwater pluton in Late Triassic time.

Cretaceous (?) Plutons (Unit Kqm)

Two quartz monzonite–granite bodies crop out near the top of Shovelnose Mountain. Despite being isolated bodies 2 km apart, they have similar appearance and mineralogy, suggesting they might be apophyses of a larger pluton at depth. They are pink, coarse grained and equigranular, and contain chlorite-altered biotite as the primary mafic mineral. Pyroxene-bearing andesite of the Pimainus Formation is nearest the intrusions and lacks alteration. Because they are isolated plugs located well within Spences Bridge stratigraphy and in close proximity with rhyolite flows capping the Pimainus Formation on Shovelnose Mountain, a genetic connection is suspected.

Triassic–Jurassic Diorite and Quartz Monzonite (Units TJd, TJqm)

Granitic rocks form a continuous border along the southwestern margin of the study area; based on regional mapping by Monger (1989), they apparently belong to two intrusive complexes that interface near the juncture of Maka and Spius creeks. These complexes are composed of broadly similar rocks but have differing emplacement ages and histories. The Mount Lytton Plutonic Complex comprises Late Triassic and Early Jurassic plutons, gneiss, amphibolite and mylonite that may represent deeper parts of the Late Triassic Nicola arc in Quesnellia (Monger, 1989). In contrast, the Eagle Plutonic Complex comprises predominantly deformed plutonic rocks that range in age from Middle Jurassic to mid-Cretaceous and maintain a record of contractional deformation at the western margin of the Intermontane Belt (Greig, 1991).

Diorite and lesser quartz diorite prevail on the ridge south of Gillis Lake and continue uninterrupted towards the northwest, underlying lower slopes adjacent to Maka and Prospect creeks. A less voluminous phase of quartz monzonite–granodiorite crosscuts the diorite and, in turn, they are both intruded by felsic dikes. Collectively, these granitoid bodies form an older base upon which rocks of the Spences Bridge Group locally lie.

Diorite to quartz diorite is the oldest intrusive phase recognized. It is grey-green and contains equigranular plagioclase, pyroxene (20–40%) and quartz in a medium-grained rock. Rare enclaves, several metres across, composed mainly of coarse pyroxene intergrown with less than 15% plagioclase, occur in the diorite. Epidote lining veinlets and chlorite replacing mafic minerals constitute weak alteration common throughout diorite. Quartz monzonite or granodiorite forms small plugs and narrow dikes intruding diorite. They are typically pinkish with a subtle green colouration due to secondary chlorite, and are coarse grained, inequigranular and weakly foliated. Bluish translucent quartz (20–25%) is diagnostic and occurs with up to 20% chlorite-altered mafic minerals. A foliation striking northwest and generally inclined southwest is prominent in both intrusive phases south of Gillis Lake; however, foliation is weak or absent elsewhere in the diorite. An intense penetrative foliation and mylonitic fabric are confined to a narrow, northwest-trending band of quartz monzonite that crops out intermittently adjacent to the fault along Maka Creek.

Nondeformed dikes, generally 1 m or less in width and rarely up to 60 m, crosscut foliated diorite and quartz monzonite phases. The dikes are pinkish to white, light orange weathered and of felsic composition. They exhibit textures varying from aphanitic aplite porphyry with up to 10% medium-grained potassium feldspar and biotite to quartz-feldspar pegmatite.

MINERALIZATION

Two contrasting types of mineralized silica deposits are found in the study area. A new occurrence, characterized by stratiform and stratabound silica-carbonate horizons, has been discovered within shallow-marine stratified volcanic and sedimentary rocks of the Late Triassic Nicola Group. Named the 'Castillion Creek Exhalite-Sinter', they have a weakly anomalous signature for the epithermal suite of elements. No associated discordant epithermal quartz veins have been discovered. Narrow veins and veinlets with epithermal features are associated with Late Triassic subvolcanic (?) dacite, and tonalite of the Coldwater pluton (Diakow and Barrios, 2008, Table 2, samples c, d, aa, bb and cc). This suggests that high-level epithermal mineralization is possible in compositionally evolved rocks of Late Triassic age in areas where the western felsic belt of the Nicola Group crops out.

Currently, mining exploration in the Merritt region focuses on low sulphidation, epithermal gold-bearing quartz vein systems that are hosted in subaerial volcanic rocks of the Early Cretaceous Spences Bridge Group. The veins occur in differing host stratigraphies, those on Shovelnose Mountain in rhyolitic rocks of the Pimainus Formation and others, including Prospect Valley, Ponderosa, Sullivan Ridge and Nic, in the thick, andesitic flow sequence of the Spius Formation.

Late Triassic Castillion Creek Exhalite-Sinter Occurrence

A Late Triassic hydrothermal system represented by stratiform silica-carbonate exhalites and sinter was discovered during the BC Geological Survey mapping survey in late 2007. This hydrothermal system and associated products are located along the Coquihalla Highway, near Castillion Creek, approximately 14 km south of Exit 286 at Merritt (Figure 2). Named the 'Castillion Creek Exhalite-Sinter', three subhorizontal siliceous zones, interlayered with Nicola Group volcanic and sedimentary rocks, are vertically stacked, with approximately 100 m elevation separating lower and upper exhalites. Sinter, superbly exposed in a roadcut, occupies a medial position relative to the exhalites. The local geology, with relative locations of siliceous horizons, is shown in Figure 5.

EXHALITE-SINTER CHARACTERISTICS

Two silica exhalite horizons have sharp, conformable lower and upper contacts with both subaerial (?) mafic volcanic rocks and shallow-marine sedimentary rocks, and strike north-northeast and dip moderately southeast (~20–30). The lower exhalite comprises two segments thought to be connected but separated by a vegetated gap. Each is composed of stratiform and stratabound silica. The southern segment is a series of resistant mounds composed of siliceous blocks, aligned along a low-lying ridge. Internally, finely laminated white and light grey silica, forming beds up to 11 cm thick, alternate with recessive carbonate layers several centimetres thick. Angular blocks of red jasperoid silica occur on the surfaces but they have not been observed *in situ*. A very old blast pit revealed chalcopyrite in fractures cutting across laminated silica, and vuggy silica in which irregular cavities are cored by sparry calcite surrounded by prismatic quartz. The northern segment is defined by semicontinuous silica subcrops traceable for 120 m and widest in a coherent layer 4 m thick. It displays lithological features resembling those in the southern segment.

The upper exhalite is a silica horizon expressed as a series of resistive mounds distributed for 500 m along a stratigraphic contact between fossiliferous black carbonate and overlying sandstone. A 200 m gap, caused by crossfaulting, breaks the continuity of the horizon. The silica layer is 1.5–3 m thick and composed of white and dark grey, internally laminated and massive silica. Finely disseminated pyrite is the only sulphide visible.

Sinter contrasts with the exhalites in dimension and appearance, attaining a strike length close to 300 m and a maximum thickness of 30 m at its northern limit, and thinning southward across a series of steep faults to around 1 m at the southern limit of cliff exposure along the Coquihalla Highway. Characteristically, the deposit is distinctly bedded, with silica beds being up to 0.5 m thick but typically thinner, and interlayered with orange-weathered, laminated siltstone and sandstone. The silica, a clear translucent variety, typically displays interlayer cavities, most of them irregular and some elongate parallel to layering. Finely disseminated pyrite is found in fine clastic interbeds. No discordant quartz veins have been found in the vicinity of the exhalites or sinter.

Chip samples collected from the exhalites and sinter were analyzed for a suite of elements by aqua regia digestion–ICP-MS at ACME Analytical Laboratories Ltd (Vancouver, BC). Table 1 is a summary of results extracted from original data given in Diakow and Barrios (2008). These data show that the epithermal suite of elements is weakly anomalous in Au, Ag, As and Hg. Sinter has significantly higher concentrations of Au, Mo, Mn, Hg and Ba than either of the exhalite zones. Silver is higher in the exhalites, the lower of which has higher average concentrations for all elements with the exception of Pb and Zn.

LOCAL GEOLOGICAL SETTING

Nicola Group stratigraphy at Castillion Creek has a basal section dominated by mafic pyroxene-phyric lava flows that are abruptly overlain locally by flow-laminated rhyolite. The lowest exhalite horizon occurs within these flows. This flow unit persists upslope to the elevation of the sinter, where it forms the base for an overlying stratified volcano-sedimentary sequence, within which both sinter and the highest exhalite horizons occur.

The section of stratified rocks hosting sinter is about 30 m thick and lies directly on the underlying mafic volcanic unit. At the bottom of the section is 1.5 m of thinly bedded, grey-black limestone and mudstone that contains a 20–60 cm thick rhyolite ash-tuff interbed. A collection of bivalves was obtained from the limestone for identification, and a sample was collected from the rhyolitic tuff interbed for U-Pb zircon geochronology.

Depositionally overlying the thin carbonate is thickly bedded siltstone and coarse sandstone containing several percent disseminated pyrite grains. A massive pyroxene flow with a distinct lenticular geometry overlies these clastic rocks. Sinter immediately follows upsection, sharply overlying both the mafic flow and underlying clastic beds. The sinter is composed of silica and carbonate, forming thin beds and laminations that alternate with orange-oxidized calcareous siltstone, feldspathic sandstone and minor pebble conglomerate. Rare rhyolite ash tuff, up to 3 cm

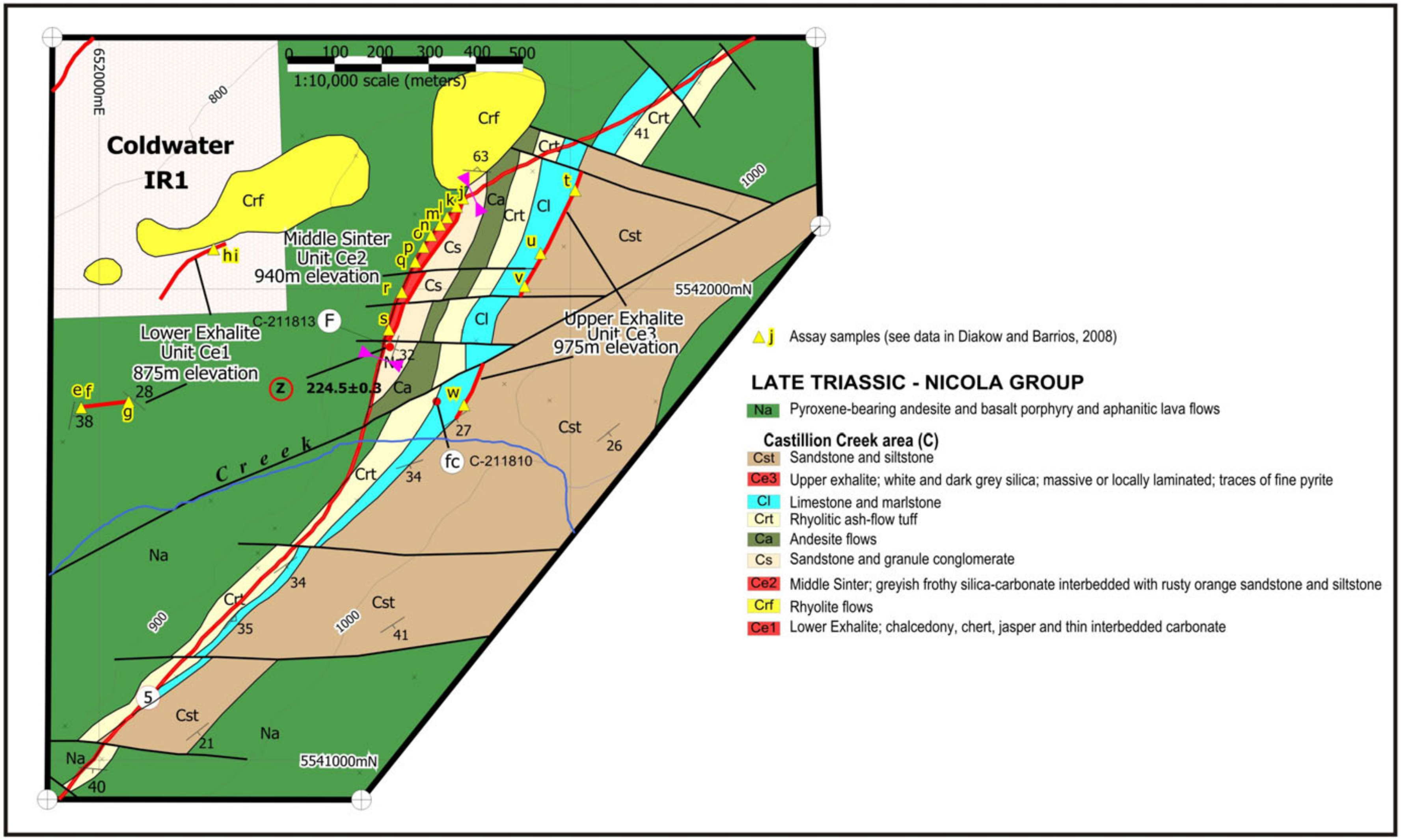

Figure 5. Detailed geology of the areas hosting exhalative zones near Castillion Creek. The exhalites are situated adjacent to the Coquihalla Highway within a stratified shallow-marine sequence composed of sedimentary and rhyolitic volcanic rocks of the Late Triassic Nicola Group. Location of Castillion Creek, south of Merritt, is shown in Figure 2.

thick, weathers off-white and occupies 0.5 m thick intervals within interlaminated silica and siltstone beds.

Above the sinter-sedimentary section are conformable volcanic rocks with pyroxene andesite overlain by rhyolite ash-flow tuff. The tuff contains angular white and greyish aphanitic and flow-laminated rhyolite fragments. The matrix is light green and contains an assortment of small lithic, feldspar and minor quartz fragments. Except for local thin zones that display moderate welded fabric, the deposit is generally nonwelded. Ash-flow tuff is succeeded by black limestone replete with recrystallized, thin-shelled bivalves. The highest siliceous exhalite sharply overlies limestone and is, in turn, followed upsection by a thick sedimentary unit. In the lower part of the section and sharply overlying the exhalite, parallel and crosslaminated sandstone and siltstone are interleaved with maroon lapilli tuff beds. Farther up the section, lapilli tuffs become more prevalent, and have thin accretionary lapilli interbeds. Still farther upsection, these volcaniclastic rocks pass into thick pyroxene-bearing flows occupying the mid-slope area of Selish Mountain.

Table 1. Summary of assays from exhalite-sinter zones near Castillion Creek.

Element (units)[1]		Zone		
		Upper Exhalite (N=4)	Sinter (N=10)	Lower Exhalite (N=5)
Au	(ppb)	0.7 (0.2–1.3)	15 (0.2–25)	1.8 (0.2–7)
Ag	(ppb)	133 (68–187)	89 (34–120)	300 (39–879)
Cu	(ppm)	10 (3–23)	13 (5–23)	296 (10–1124)
Pb	(ppm)	10 (8–11)	4 (0.8–7)	4 (3–17)
Zn	(ppm)	100 (26–168)	31 (10–53)	42 (3–102)
Mo	(ppm)	10 (4–15)	148 (3–48)	17 (3–47)
Mn	(ppm)	316 (97–458)	1567 (827–1612)	1037 (178–2294)
As	(ppm)	6 (3–9)	27 (7–32)	62 (5–13)
Hg	(ppm)	5 (5–6)	38 (5–58)	26 (6–48)
Sb	(ppm)	0.4 (0.24–0.5)	1.3 (0.24–1.7)	1.4 (0.25–2.4)
Ba	(ppm)	51 (12–160)	65 (20–151)	54 (24–71)
Tl	(ppm)	1 (0.02–3.6)	0.5 (0.02–0.9)	0.07 (0.06–0.08)
Te	(ppm)	0.02 (0.02–0.04)	0.03 (0.02–0.05)	0.03 (0.02–0.05)

[1] concentrations reported as mean (range)

The stratified section in the interval at and above the level of the sinter to the upper exhalite comprises distinctive rock types that can be traced for at least 2 km adjacent to the Coquihalla Highway. Throughout, bedding consistently strikes northeast and dips southeast at 20–30°. A series of parallel high-angle faults, oriented east-west, cut obliquely across the northeast-striking stratigraphy. In the sinter section, south-verging thrusts locally thicken the sinter horizon and underlying carbonate unit.

East-trending faults cutting post-Nicola stratigraphy have not been recognized in the study area. Curiously, there is a concentration of such structures at Castillion Creek and they delimit the lateral extent and internally shuffle the diverse stratigraphy and associated exhalative horizons. This leads us to speculate that these faults might have been active at the time of deposition and focused the hydrothermal fluids within a depositional environment that changed several times from subaerial to shallow marine.

An isolated siliceous exhalite, found 5.5 km southwest of Castillion Creek, is speculated to have developed at the same time as those at Castillion Creek. Exhalites at this locality are poorly exposed due to a thin mantle of overburden. Trenches were excavated at this locality many decades ago but are presently slumped and overgrown. Three samples collected for assays returned results comparable to those obtained from the Castillion Creek exhalites. These data are tabulated in Diakow and Barrios (2008).

ENVIRONMENT AND AGE

Because no obvious depositional breaks were recognized in stratified rocks hosting the exhalite and sinter occurrences, it is assumed that deposition of the sequence was relatively continuous. Pre-sinter stratigraphy is dominated by massive pyroxene andesite flows, probably subaerial and periodically interrupted by submarine silica-carbonate exhalations. Unequivocal evidence for marine conditions begins at the bottom of the well-stratified sequence hosting sinter and continues upward to the upper exhalite. At the bottom of this succession, a thin black carbonate-mudstone contains the common Late Triassic marine bivalve *Halobia* (M. Orchard, Geological Survey of Canada, pers comm, 2008). A thin layer of rhyolite ash tuff within this carbonate yields a U-Pb isotopic date of 224.5 ±0.3 Ma. Rhyolite flows nearby may be temporally associated with this ash, erupted before the limy mud was consolidated. The sinter itself is interstratified, typically with finely laminated siltstone and sandstone that display parallel layering and rarely crosslaminations and small channels. Up section, evidence of deposition above sea level or alternatively in very shallow water is provided by the build-up of pyroxene flows succeeded by thin rhyolite ash-flow tuff. The tuff is locally welded and, because of its meagre thickness (typically less than 40 m), is unlikely to have developed welded structure in deep water. The abrupt upper contact of the ash flow with limestone, capped by the upper exhalite and then crosslaminated sandstone, demonstrates the change back to marine deposition.

Epithermal Gold-Quartz Veins

PROSPECT VALLEY (MINFILE 092I/SW 107)

The Prospect Valley showing is located 29 km west of Merritt. Access to the property is via the Petit Creek Forest Service Road to Hooshum logging road, then north along a mining road under construction by Consolidated Spire Ventures Ltd in 2008.

Prospect Valley is a low-sulphidation, epithermal stockwork-vein system carrying gold that is hosted within a homoclinal succession composed of thick andesite flows belonging to the Spius Formation. The quartz-vein system is exposed sporadically for about 1.3 km towards the northeast, maintaining random widths with interleaved country rocks of 50–150 m. Internally, this quartz-vein corridor is made up of parallel veinlets and veins, 15–75 cm wide, separated by country rocks. The veins are commonly banded, with open cavities lined by drusy quartz crystals, and some quartz breccia. Alteration observed along some veins consists of cloudy pink selvages composed of fine adularia that is accompanied by variably intense sericite-illite (?), hematite and fine-grained pyrite (Thomson, 2008). Drilling shows veining and attendant alteration localized in the hangingwall of the Early fault zone, a structure apparently striking northeast and dipping shallowly towards the northwest (Thomson, 2008). Encouraging gold values from trench chip samples range from 0.48 to 1.58 g/t Au over 2.0 to 10.0 m.

The only historical work recorded on the property was small-scale placer mining activity along Prospect Creek, located at the south end of the property, and in the Shakan Creek drainage at the northwest corner (Thomson, 2007). Prospecting from 2001 to 2003 by Almaden Minerals Ltd, combined with follow-up on BC Regional Geochemical Stream Sediment Survey data (Jackaman and Matysek, 1994a, b), led to the discovery of chalcedonic quartz float and gold-bearing quartz-vein breccia. Early stages of exploration by the company focused on reconnaissance soil and silt sampling, and a 5 line-km IP-resistivity survey. Results from Almaden's initial exploration defined several mineralized epithermal gold zones. The main target areas were the RM-RMX zones, now called the Discovery North and South zones, respectively. In 2004, Almaden entered into a joint venture with Consolidated Spire Ventures Ltd until 2006, at which time Consolidated Spire acquired 100% ownership of the property. In 2005, Consolidated Spire collected 302 trench chip samples from 33 hand-dug trenches across the Discovery North and South zones. A 45 line-km ground magnetic and IP survey and 3734 m of diamond-drilling in 23 holes were completed in 2006. The highlight of this drill program was hole RM2006-04, which gave 2.17 g/t Au over 10.5 m, and hole RM2006-21, which showed a significant zone of stockwork veining and fault breccia between 37.2 m and 82 m. This section had a weighted average grade of 1.57 g/t Au over 45.7 m, including 14.07 g/t Ag over 11.8 m (Thomson, 2007). Work in 2007 consisted of a 1188 line-km airborne magnetic survey, followed by a 10-hole drill program totalling 1775 m. Diamond-drill hole DDH2007-02, located 85 m northwest of hole RM2006-21, returned 0.90 g/t Au and 5.86 g/t Ag over 66.82 m from similar looking stockwork quartz veinlets (Thomson, 2008).

NIC (MINFILE 092I/SW 107)

Prospecting in 2001, followed by 38 line-km of soil sampling, uncovered veins in the Discovery zone, now called the Nic zone. The Nic zone is located in the northeast corner of the Prospect Valley claim block, 24 km west-northwest of Merritt. Road access is via the Petit Creek Forest Service Road, then west on the Edgar Creek logging road.

Nic is an epithermal, low-sulphidation quartz-vein target hosted by the Spius Formation, which on the property is a thick succession of variably red oxidized, pyroxene-phyric and amygdaloidal andesite lava flows. Vein segments, exposed in shallow trenches at Nic, strike northeast and dip steeply. The veins range up to 4 m long by 30 cm wide and display irregularities, such as branching veinlets and knots. They are composed of finely crystalline, white to translucent quartz accompanied by minor calcite with banding, comb, and breccia textures. Weak limonite stain occurs adjacent to the veins in the country rocks. Chip sampling across the vein returned up to 27.3 g/t Au and 209.1 g/t Ag, with an average for 40 chip samples of 1.63 g/t Au (Moore, 2005).

In 2004, Almaden optioned the Prospect Valley claims to Consolidated Spire Ventures Ltd. Between 2004 and 2005, Consolidated Spire enlarged the existing trenches, dug pits to test Au-in-soil anomalies and added a soil grid. In 2006, they drilled five holes, targeting a magnetic low that trends northeast and corresponds to the Nic zone. The program, consisting of 1344 m of drilling to test the Nic zone, returned 3.2 g/t Au over 1.3 m from hole NIC2006-01 and 0.95 g/t Au over 6.7 m from hole NIC2006-05 (Thomson, 2007).

SULLIVAN RIDGE (MINFILE 092I/SW 106)

Reconnaissance silt, soil and rock sampling in 2004 prompted staking of the Merit claims by Almaden Minerals Ltd. Further prospecting found the Sullivan Ridge prospect, located at UTM Zone 10, 637963E, 5554070N (NAD 83; Balon, 2006). The Sullivan Ridge prospect is located 20 km west of Merritt. Access to this prospect is via the Petit Creek Forest Service Road, then onto a series of old roads heading west and then north.

A north-northeast-trending vertical structure, traceable intermittently in orange iron-carbonate–altered fault breccia for 750 m, hosts the Sullivan Ridge low-sulphidation epithermal veins. The veins occur in altered amygdaloidal, vesicular and aphanitic andesites of the Spius Formation. Branching quartz veins and veinlets locally occupy a zone 7.5 m wide and consist of white silica with comb textures. Altered country rocks nearest the veins and along the presumed fault trace are replaced by orange-brown iron carbonate and accompanied by weak pervasive silicification that obliterates primary mineralogy and textures in volcanic hostrocks. Minor disseminated pyrite, typically less than 2%, occurs in altered rocks and quartz veins. Rare malachite, azurite and grey–steel blue metallic minerals were noted in white crystalline quartz in a trench near the south end of the prospect. Almaden's chip sampling of veins in trenches returned up to 14.94 g/t Au over 0.6 m and 4.28 g/t Au over 2.5 m (Balon, 2006). A bleached and silicified zone, encountered during regional mapping, is located approximately 2 km southwest of the Sullivan Ridge prospect; a chip sample assayed 48.2 ppb Au and 444 ppb Ag (*see* data in Diakow and Barrios, 2008).

PONDEROSA–AXEL RIDGE PROSPECT

The Ponderosa property is located 16 km southwest of Merritt. Access to the property is from an old secondary forestry road that branches off Patchett road.

The epithermal, low-sulphidation vein occurrences on the Ponderosa prospect are hosted by pyroxene-andesite porphyry flows of the Spius Formation. The Axel Ridge vein forms a short but distinctive low ridge trending north and covered by thin overburden. A series of trenches across the ridge exposes a series of parallel quartz veins over a width of 12 m. The quartz is grey and white chalcedony with crustiform and colloform banded textures, as well as microcrystalline quartz, with drusy cavities and layered comb quartz (Balon, 2007). Jasper and jasper breccia were found with white microcrystalline quartz in a trench north of the Axel Ridge vein. Sparsely disseminated pyrite is present in the quartz veins, along with greyish sulphide or sulphosalt minerals.

Early work on the property by Almaden Minerals Ltd, beginning in 2002, consisted of reconnaissance geochemical silt, soil and rock sampling. Later, a grid-based soil survey, conducted in 2005 and 2006, collected 1095 soil samples. Encouraging Au-in-soil results led to the discovery of Axel Ridge, a 2000 m long soil geochemical anomaly located approximately at UTM 645000E, 5540000N. Follow-up work included hand trenching and blast-pit work that collected 29 bulk channel samples. Significant gold and silver mineralization was found at three locations in trenches PT06-1, 2 and 3, and in numerous float samples along Axel Ridge. Channel samples from quartz-vein breccia at Axel Ridge returned values ranging from 0.11 to 6.57 g/t Au and averaging 2.22 g/t Au over 11.7 m, 1.50 g/t Au over 10 m and 2.83 g/t Au over 6.6 m (Balon, 2007).

In 2007, Almaden optioned the Ponderosa property to Strongbow Exploration Inc. Strongbow mapped the property, trenched, sampled and conducted a 6.78 line-km ground magnetic survey that culminated in a six-hole, 960 m drill program on the Axel Ridge occurrence. The magnetic survey showed a zone of subdued magnetic values trending north along Axel Ridge and an apparent dislocation of the magnetic anomaly by a fault. The geophysical survey was followed by a trenching program that included five trenches and 193 chip samples across extensions of the Almaden trenches and new prospective vein areas. Drilling tested the depth and lateral extent of the epithermal quartz veins and breccias. No significant veins were encountered at depth, although small zones of silicification and weak brecciation returned up to 68 ppb Au over a 1.15 m interval in hole PD07-03.

DORA PROSPECT

The Dora prospect is located 24 km southwest of Merritt. Access to the property from the north is via the Patchett road, then south along the North Maka road to a branch road heading northeast and uphill to the property. Dora is owned and operated by Appleton Exploration Inc and was discovered in 2006 by silt and soil geochemistry and rock assays. The silt survey recovered three samples with values of 105, 250 and 965 ppb Au (Henneberry, 2007). An extensive soil grid, from which 3196 samples were collected, aided in delineating the Dora south and north zones, which were subsequently trenched by backhoe in 2007 and 2008.

Dora south is underlain by layered, fine nodular rhyolite flows from the Pimainus Formation. Hair-thick microveinlets of translucent quartz cut the country rocks with no obvious alteration observed. About 650 m northwest is Dora north, a zone of bleached and clay-altered porphyritic andesite of the Pimainus Formation that hosts white massive and banded quartz veins. Chip samples across nodular rhyolite and quartz in the porphyritic andesite returned values of up to 0.919 g/t Au over 6 m, 0.512 g/t Au over 5 m and 0.622 g/t Au over 3 m (Appleton Exploration Inc, 2008).

QUARTZ VEIN PROSPECTS AT SHOVELNOSE MOUNTAIN

The Shovelnose Mountain prospect is located 30 km south-southwest of Merritt near the village of Brookmere. Access to the property is from a forestry road veering north off the Brookmere Road, west of the village. Strongbow Exploration Inc staked the Shovelnose property in 2005 and, in 2006, conducted an extensive silt sampling program followed by prospecting, mapping and soil sampling. This work lead to the discovery of the Tower showing (Stewart and Gale, 2006). Further work in 2007, including a 308 line-km airborne geophysical survey and grid soil surveys, identified two new showings: the Line-6 and MIK.

The Line-6 quartz veins are located at UTM 652500E, 5524400N. These veins are up to 0.75 m wide and consist of massive chalcedony hosted in rhyolitic lapilli tuff of the Pimainus Formation. Alteration consists of weak clay replacement of fragments and matrix in the hostrock. In 2007, Strongbow found Au values ranging from 0.49 to 4.89 g/t in 1–8 cm wide quartz veins. Trenching in 2008 uncovered wider veins and samples returned up to 1.4 g/t Au over 16.0 m in trench L6-XT-02 and 17 g/t Au over 2 m in trench L6-XT-01 (Strongbow Exploration Inc, 2008).

The MIK showing, located at UTM 653800E, 5524300N, is represented by narrow colloform-banded veins in weakly clay-altered rhyolitic lapilli tuff of the Pimainus Formation. Trenching in 2008 exposed a 30 cm wide vein, but no mineralization was observed. Quartz-vein float, sampled in 2007, returned up to 79.79 g/t Au and 94 g/t Ag; however, an *in situ* vein source was not uncovered in the 2008 trenches. Channel sampling in trench MK-XT-01 returned 1.4 g/t Au over 3 m and, in trench MK-XT-02, 1.45 g/t Au over 2 m.

The Tower showing (UTM 654150E, 5524550N) consists of rare banded chalcedony veinlets up to 1 cm wide and float pieces of chalcedony breccia up to 5 cm in size hosted in hydrothermally altered lapilli tuff of the Pimainus Formation. Fifteen pyrite-bearing quartz vein samples from the Tower showing averaged 0.22 g/t Au (Stewart and Gale, 2006).

The Brookmere quartz veinlets and stockwork at UTM 651890E, 5523745N are hosted in a sparsely plagioclase-phyric rhyolite flow. The veinlets range from several millimetres to 1.5 cm wide over a strike length of 1–2 m. They are characteristically comb textured and alteration consists only of slight bleaching of the rhyolite host. Trace amounts of crystalline disseminated pyrite was the only observed sulphide and assay samples returned no significant results (Stewart and Gale, 2006).

ISOTOPIC AGE OF HYDROTHERMAL GOLD-QUARTZ VEIN ALTERATION

Epithermal vein prospects throughout the belt of Spences Bridge Group rocks have been visited and specimens collected of altered rocks adjacent to gold-bearing quartz veins, the principal objective being to determine the timing of hydrothermal alteration. Only at Prospect Valley is there evidence of potassium alteration, as narrow, cloudy, pink adularia selvages adjacent to quartz veins. The adularia from sample 06LDi 10.3 originates from a vein envelope at 92 m in diamond-drill hole RM2006-4 in the Prospect Valley epithermal vein system. It yielded a $^{40}Ar/^{39}Ar$ age determination of 104.2 ±0.6 Ma. This date suggests that the hydrothermal system associated with the epithermal gold mineralization at Prospect Valley is penecontemporaneous with the Spences Bridge Group, a finding that has regional implications for the possibility for new discoveries elsewhere in the belt of Early Cretaceous rocks. On a local scale, this date also demonstrates the contemporaneity of the veins' hostrocks, the Spius Formation, and isotopically dated Pimainus Formation at Gillis Lake and Shovelnose Mountain.

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