Geology of the East Harrison Lake Belt, Southwestern British Columbia

By Chris Ash

KEYWORDS:*Cogburn ophiolitic assemblage, Giant Mascot Mine, ultramafic xenoliths, Cu-Ni-PGE, Late Triassic basinal clastic metasediments.*

INTRODUCTION

The East Harrison Lake belt (EHLB) refers to a northwest-trending belt of rocks occurring to the east of Harrison Lake in southwest British Columbia (Figure 1) which is currently the focus of exploration for ultramafic-related Cu-Ni (PGE). The geology of the EHLB will also be summarized as a 1: 50 000-scale compilation map (Ash *et al.*, in preparation) incorporating both published and unpublished data sets that include recent industry mapping.

This work is part of a multidisciplinary field study undertaken by the British Columbia Geological Survey in response to significant staking and grassroots exploration activity for PGEs within the EHLB. Since January 2000, over 2000 claims have been staked with four significant exploration projects conducted in 2001 (Houle, 2002). In addition to the geological mapping component described below, detailed aspects of PGE related Cu-Ni mineralization (Pinsent, this volume) and geochemical detection of PGEs in stream samples (Lett and Jackman, this volume) were also examined.

The author conducted intermittent fieldwork totaling six weeks between mid June and late October, 2001. The bulk of this time was focused on mapping two east-northeast trending areas across the EHLB. As well five days of mapping were completed in the area of the Giant Mascot Cu-Ni mine. One transect was mapped from the Bear Creek camp east along Cogburn Creek and beyond and a second from Silver Creek east along Hornet Creek and beyond. These are referred to as the Cogburn and Hornet transects in this report. Active logging roads which feed the Bear and Silver Creek log-sorting and mill areas on the eastern shore of Harrison Lake facilitated access in both these areas. As well, the North Fork and Settler Creek logging roads, branches to the north and south, off the main Cogburn logging road at roughly 4.5 and 12.5 kilometres respectively, were mapped to provide along strike continuity between the two transects.

Observations obtained through this study combined with a detailed assessment of the available data for the region enables recognition of a modified lithotectonic framework for the EHLB. They also help place constraints on the age and origin of ultramafic rocks that host Cu-Ni (PGE) mineralization at the Giant Mascot mine.

PREVIOUS WORK

This area was included in several earlier regional mapping studies by the Geological Survey of Canada (Daly, 1912; Cairnes, 1944). The earliest detailed mapping in the region was at the Giant Mascot Mine (Horwood, 1936; Aho, 1954, 1956). Thesis mapping by Lowes (1967, 1968, 1972), covering the southern three-quarters of the region under discussion, represents the only comprehensive mapping of the area and has been the geology used on most subsequent maps for this region.

In addition to these works the EHLB has been the subject of thesis mapping and related studies over the past three decades (Figure 2). Earlier studies were mainly by students with The University of British Columbia, Vancouver (Read, 1960; Richards, 1971; Richards and McTaggart; 1976; Vining, 1977; Reamsbottom, 1971, 1974; Pigage, 1973; 1976; Bartholemew, 1979 and Gabites, 1985). Most of this early work has been synthesized and augmented by

Figure 1. Location of the East Harrison Lake map area.

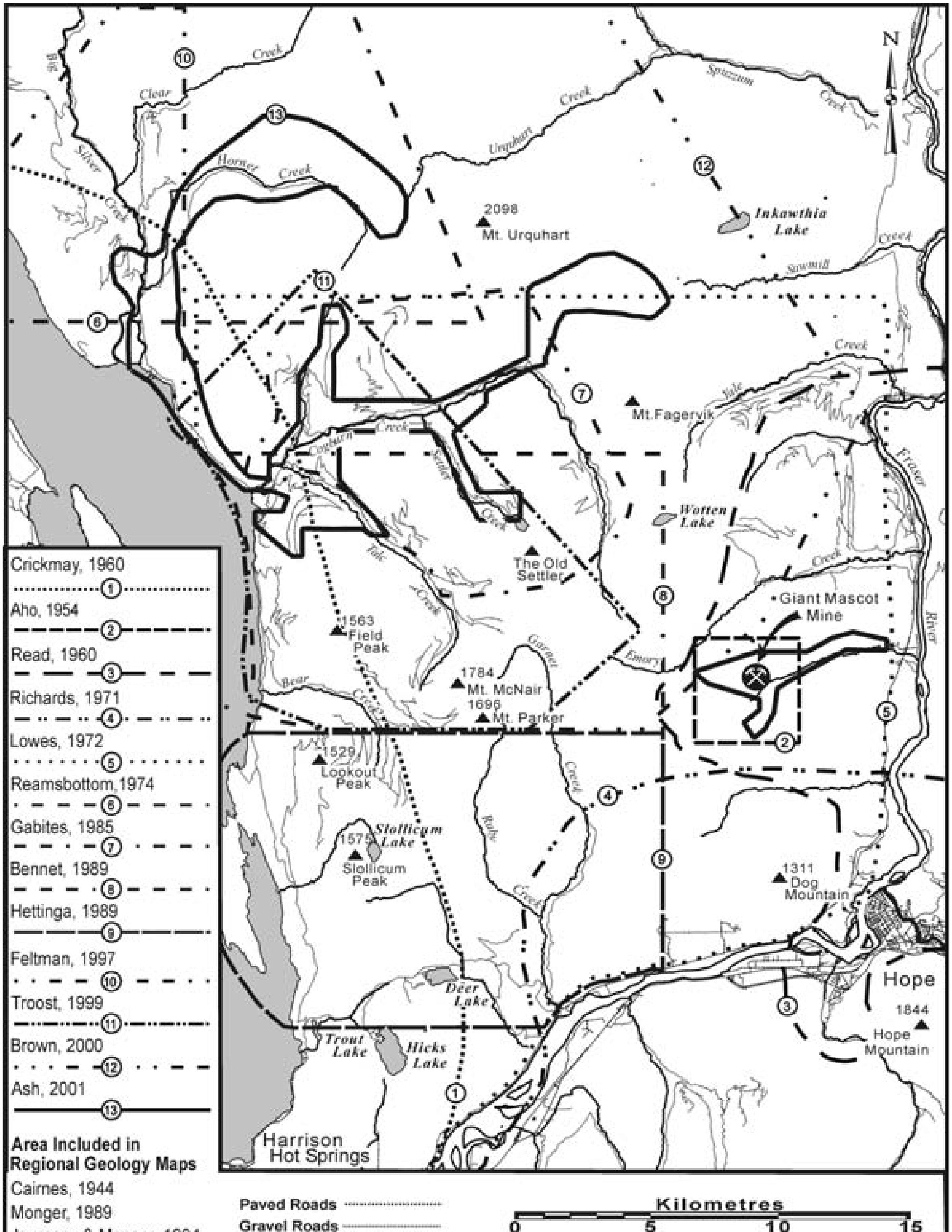

Figure 2. Areas examined during this study and mapping coverage by previous workers.

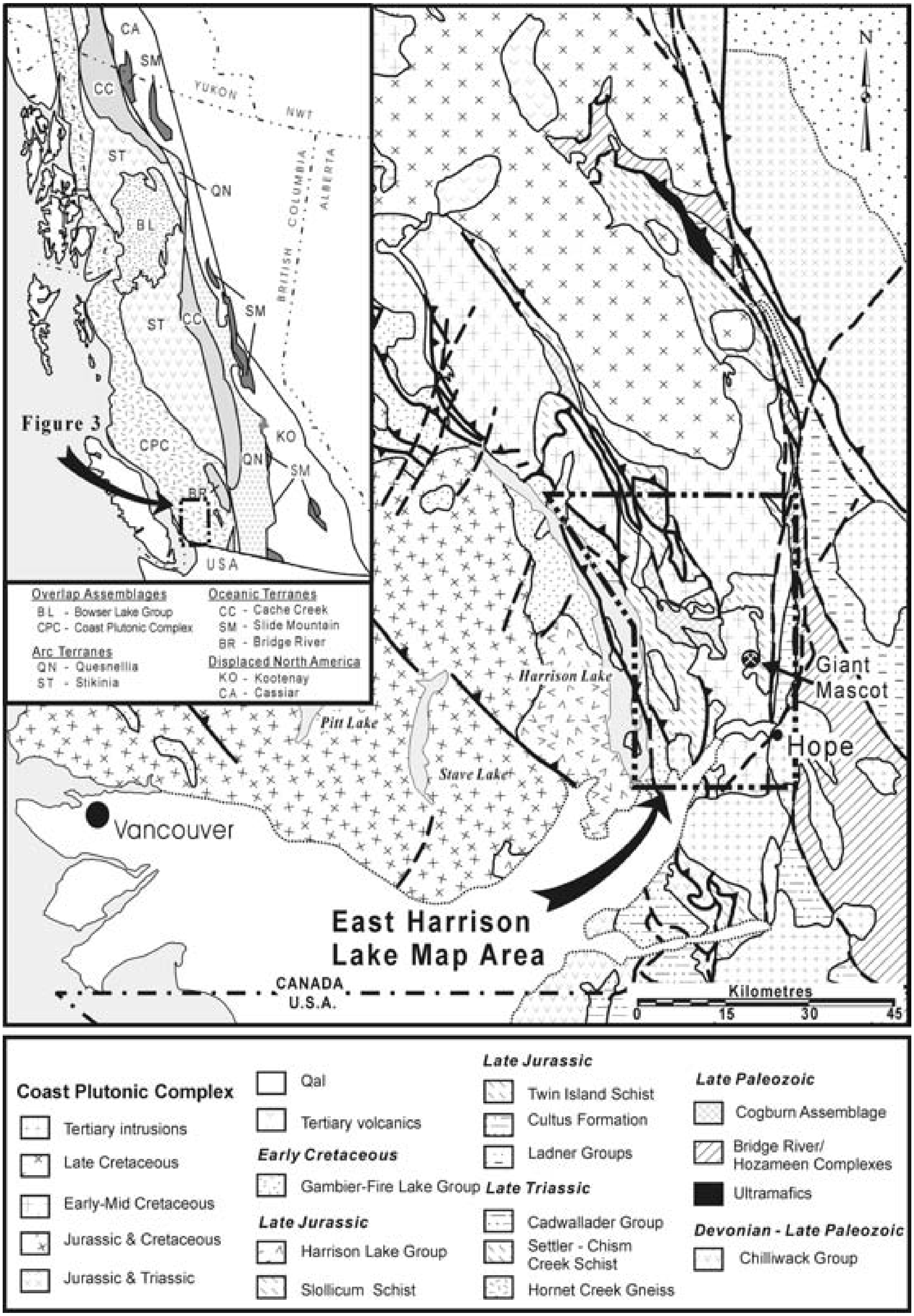

Figure 3. Regional geological setting of the East Harrison Lake map area (after Journeay and Friedman, 1993, with modified legend).

geologists with the Geological Survey of Canada (Monger, 1970; 1986; 1989; Journeay and Friedman, 1993; Journeay and Monger, 1994).

More recent thesis-related studies in the area have been the focus of students from Western Washington University, Bellingham and include works by Bennett (1989), Hettinga (1989), Feltman (1997), Lapen (1998) and Troost (1999). These studies are summarized and augmented with additional data by Brown and Walker (1993), Brown *et al.* (2000) and Brown and McClelland (2000).

The extent of research in this area has resulted in a range of individual approaches to combining lithologic units into packages or terranes, and intrusive rocks into suites. Therefore some discussion of the history of evolution of lithological classification and nomenclature is necessary before introducing a revised lithotectonic framework.

GEOLOGICAL SETTING

The EHLB is the eastern half of a broader belt of supracrustal rocks which crops out on both sides of Harrison Lake (Figures 3 and 4). This broad area of supracrustal rocks is largely surrounded by middle to late Mesozoic intrusions of the Coast Plutonic complex. Within the supracrustal rocks there has been consistent recognition of a general progressive increase in metamorphic grade from subgreenschist to amphibolite from west to east across the belt.

The rocks underlying a large area west of Harrison Lake, and forming the islands within it, are mainly sub greenschist grade, Jura-Cretaceous, calcalkaline, intermediate to felsic, arc volcanic-sedimentary sequences (Authur, 1986; Monger, 1989; Journeay and Monger, 1994) assigned to the Harrison Lake Terrane (Monger, 1991) (Figure 4). The oldest rocks are Middle Triassic (Ladinian), Camp Cove Formation clastic sediments and intermediate volcanic flows (Authur *et al*., 1993). These represent only a minor component of the Mesozoic stratigraphy and are limited to a relatively isolated area along the western shore of Harrison Lake, due east from Echo Island. These early Mesozoic rocks are unconformably overlain by the Middle (Toarcian) and Late Jurassic intermediate to felsic volcanic and related sedimentary rocks of the Harrison Lake Group (Authur, 1986; Authur *et al.,* 1993). Plutons related to the Harrison Lake Group formed during several distinct episodes of magmatism over a 15 Ma period with U-Pb dates indicating magmatic events at 148-145, 158-153 and 162-160 Ma (Journeay and Friedman, 1993). Harrison Lake Group rocks are unconformably overlain by the late Early Cretaceous (Albian) Fire Lake Group or its regional correlative, the Gambier Group.

Harrison Lake and Fire Lake Group rocks are also dominant in the lower half of the west-facing slopes along the eastern shore of Harrison Lake. Lowes (1972) identified vestiges of sheared Buchia shells in metasedimentary rocks at the 460 metre elevation above the eastern shore of Harrison Lake, east of Cascade Bay, indicating Early Cretaceous strata to at least that level.

EAST HARRISON LAKE BELT

The EHLB is underlain by a northwest-trending belt of variably deformed and metamorphosed, greenschist to amphibolite grade, sedimentary, volcanic and lesser plutonic rocks (Figure 5). These rocks extend east from Harrison Lake for several tens of kilometres where they are bounded by younger, mid to Late Cretaceous (84-92 Ma) diorite to tonalite intrusions of the Coast Plutonic Complex. Within the belt there are two lithotectonic packages. The term package is applied as an informal designation referring to a number of lithologically distinctive rock types, which share a spatial and interpreted genetic association. In the EHLB a package of remnant abyssal oceanic (ophiolitic) rocks termed the Cogburn assemblage rests structurally above a succession of basinal, marine, clastic sedimentary rocks.

This twofold subdivision of the EHLB deviates from the threefold subdivision of units as established by Monger (1986) and adopted by all subsequent workers which recognized three lithologically distinctive belts of rocks (Figure 6b). From west to east these three units have been designated as the Slollicum, Cogburn and Settler packages (Monger, 1986) schist belts (Monger, 1989; Journeay and Monger, 1994) or terranes (Brown, *et al*., 2000; Brown and McCelland, 2000). These individual belts have been interpreted to be juxtaposed along west-verging thrust faults. These faults are marked by ultramafic rocks and are interpreted to become more deeply rooted towards the east (Figure 6b).

The revised tectonostratigraphic framework introduced here (Figure 6c) is a significant modification from that presented by previous workers. The first major modification is the inclusion of the upper mafic volcanic component of the previously defined Slollicum as part of the Cogburn ophiolitic assemblage. Reassignment of this unit is based on its 1) structural position in faulted contact above the clastic metasedimentary unit, 2) basaltic composition and local pillowed character (Lowes, 1972), and 3) MORB petrochemical signature (Bennett, 1989; Hettinga, 1989). These rocks are comparable to those that comprise the basaltic volcanic component of the Cogburn assemblage to the east (Figure 6b). This modification reestablishes a correlation between these rocks as suggested by earlier mappers (Lowes, 1972, Figure 6a; Gabities, 1985) based on lithological similarities between the two areas.

A second implication of the revised tectonic framework involves recognition of continuity of the metasedimentary clastic unit across the EHLB. Lithological similarity and a comparable structural setting show that the metasedimentary component of the previously designated Slollicum and Settler (Figure 6b) are part of the same stratigraphic unit (Figure 6c). Previous designation into two separate units has been founded largely on interpreting the belts of ultramafic rocks as delineating deeply-rooted fault zones.

Variations in the macroscopic character of these previously separated clastic metasedimentary units are not particularly evident where examined throughout the map area. Clastic sedimentary rocks along Silver and Hornet Creeks,

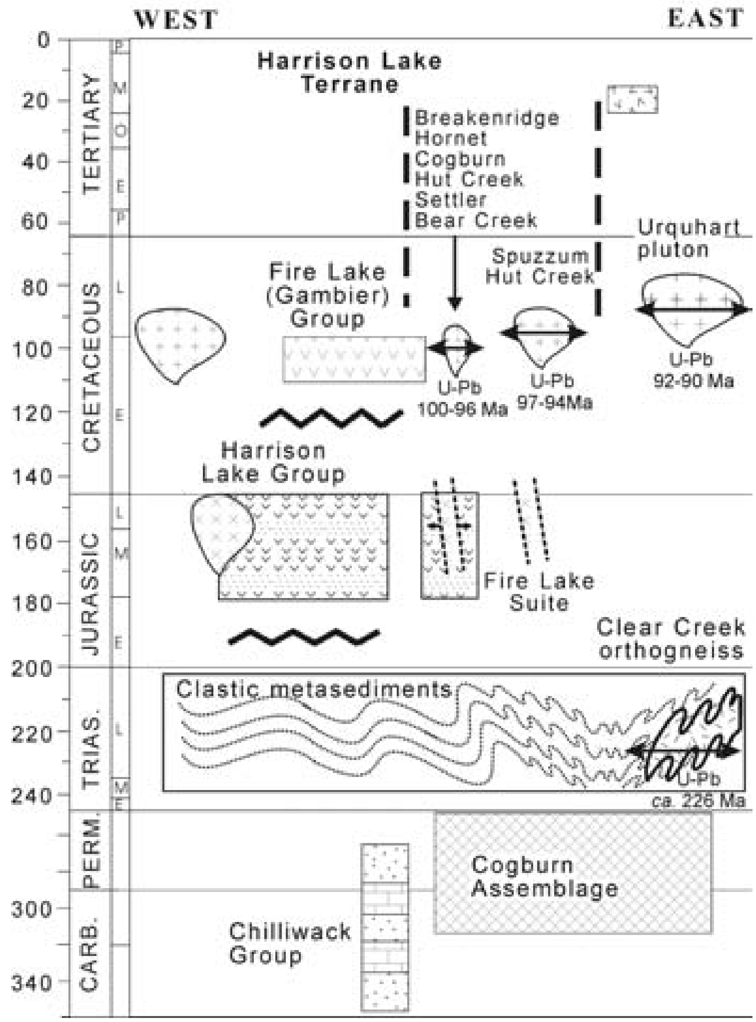

Figure 4. Time correlation chart for lithologies in the East Harrison Lake belt. Age constraints and unit designations are from sources discussed in the text.

the north-trending belt centered on the 6 km point of the Cogburn logging road, those to the north of The Old Settler Mountain and clastic rocks east of Giant Mascot are relatively consistent. These are variably metamorphosed and deformed clastic sedimentary rocks comprising interbedded mudstone, siltstone and fine to medium-grained volcanic wackes (Lowes, 1972). They are generally well bedded at the outcrop scale with individual beds from centimetres to metres in thickness. The most notable variation in the clastic metasedimentary unit is the higher degrees of metamorphism and increase in complexity in styles of ductile deformation towards the east. However, this is considered more likely the result of secondary processes, unrelated to its primary depositional environment.

The age of this unit is poorly constrained, at least in part, due to the metamorphism and recrystallization, which has destroyed any fossils. Two U-Pb monzonite ages of metasedimentary rocks near the southeast portion of the Urquhart Pluton at 90±1 and 89±1 Ma are consistent with metamorphism related to intrusion of the pluton, which is dated by U-Pb zircon methods at 92-91 Ma (Brown *et al.*, 2000).

Bennett (1989) reported a 146 Ma, U-Pb zircon age (attributed to Nick Walker, University of Texas at Austin) for a felsic rock described as being interbedded with the Slollicum metasedimentary unit northeast of Field Peak, roughly 220 meters above the Harrison Lake shore. This reported date has been often invoked to constrain the age of the previously defined Slollicum (Hettinga, 1989; Journeay and Friedman, 1993; Troust, 1999; Brown *et al*., 2000). Felsic volcanic rocks, however, were not recognized as a lithologic component of the clastic medisementary unit in the region previously designated as Slolicum, where examined to the north and east. These Late Jurassic felsic volcaniclastic rocks are largely constrained to the east Harrison Lake shore in the southern half of the map area. The transition from the intermediate to felsic volcaniclastic succession eastward into the calstic metasedimentary unit is interpreted involves a primary stratigraphic contact relationship in which the Late Jurassic rocks overlie the older clastic metasedimentary unit.

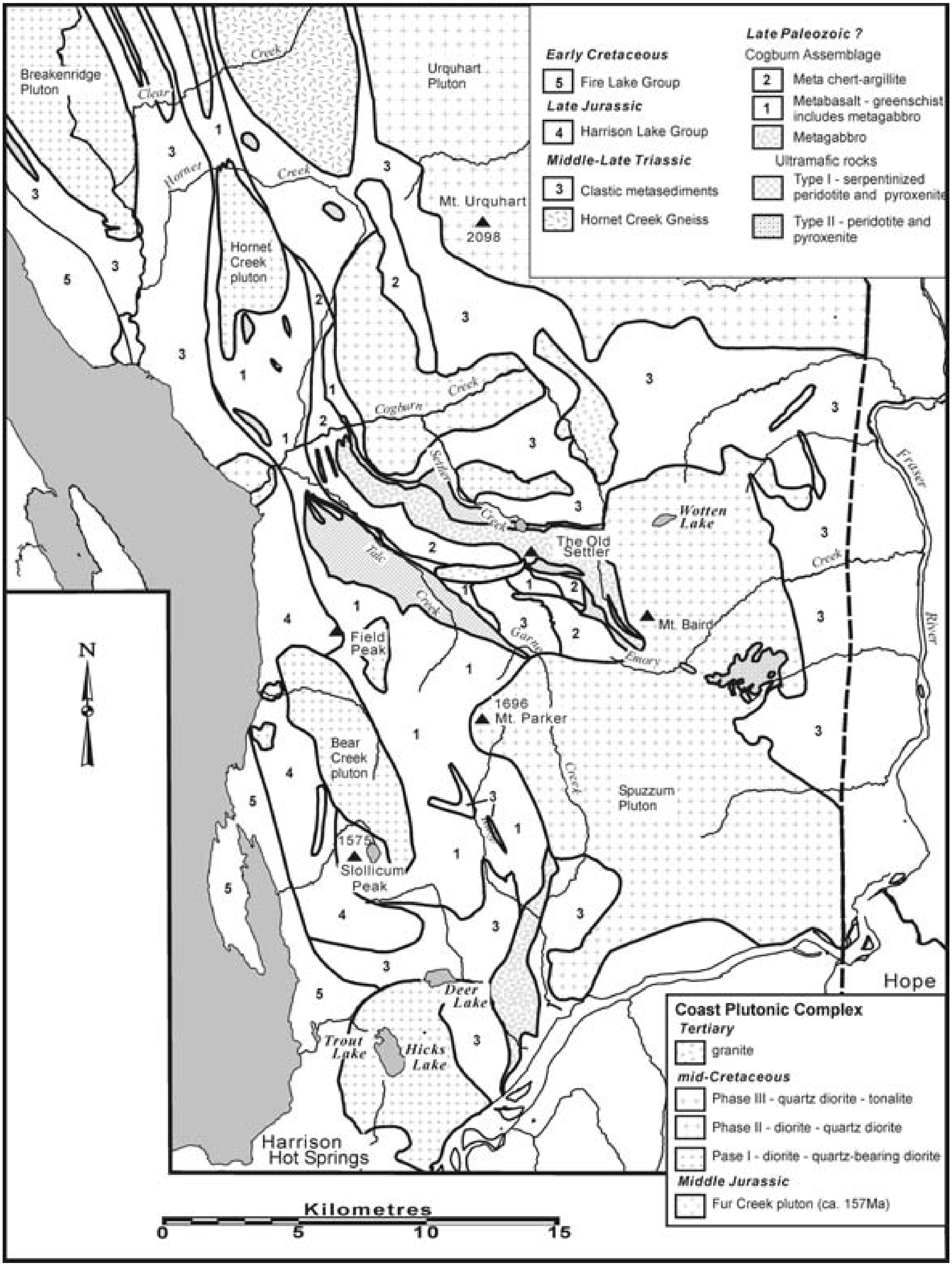

Figure 5. Geology of the East Harrison Lake area, based on preliminary compilation by Ash and Brown (in preparation).

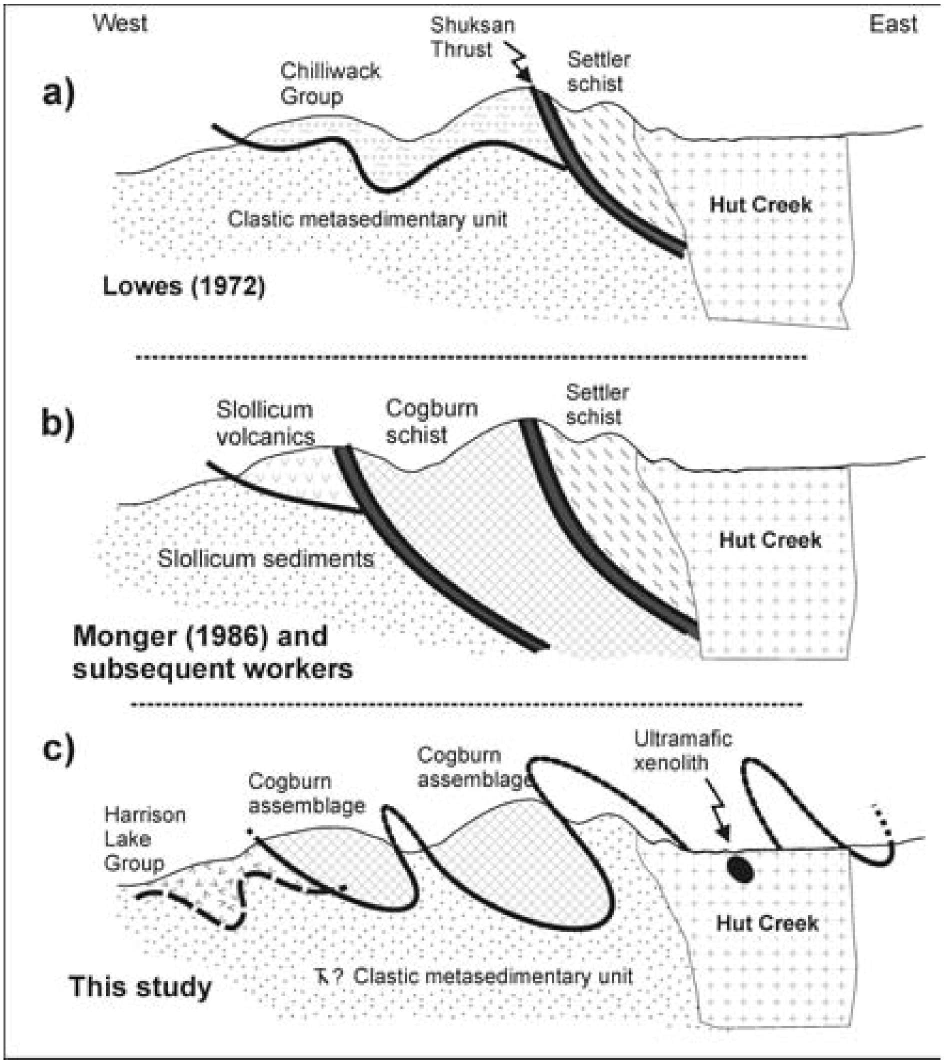

Figure 6. Schematic cross-sections through the central portion of the EHLB illustrating the evolving lithotectonic interpretations. a) Lowes (1972), b) Monger (1986) and subsequent workers, c) this study.

A relative age for the unit is suggested by its association with the Late Triassic Clear Creek orthogneiss, a banded to strongly foliated tonalite situated at the eastern end of the Hornet transect. This deformed pluton is dated by U-Pb zircon methods at ca. 226 Ma. (Monger, 1991). Primary contact relationships between the orthogneiss and clastic metasedimentary rocks are obscured by deformation and metamorphism. Similar styles of deformation suggesting comparable structural histories imply that the clastic metasedimentary rocks are at least as old as the intrusion.

These rocks are clearly typical of Late Triassic basinal sedimentary sequences that are a dominant component of Mesozoic volcanic arc terranes along the Cordillera. The Slollicum metasedimentary-volcanic unit was initially correlated by Monger (1986) with the little metamorphosed Late Triassic Cadwallader Group along regional trend to the north-northwest. Similarities with the Late Triassic Stuhini Group, with which the author is familiar, are particularly evident.

Supporting evidence for the lithotectonic framework presented is provided by regional variations in the geology along the trend of the EHLB. There is significant difference in the structural style of the terrane-bounding faults between the Cogburn and Hornet transects. Along the Hornet transect the terrane bounding structure forms a broad open upright fold (Figure 7), in which ophiolitic assemblage rocks comprise the hangingwall. At its central portion the Cogburn assemblage forms the core of a large-scale synform (Monger, 1986; Brown *et al*., 2000). In detail however, this regional folding produces a crenulation at the scale of several to tens of metres that causes infolding of contrasting units at terrane boundary contacts. The structural complexity of this relationship is demonstrated between the 14 and 15 kilometre point of the Hornet Creek logging road where steeply dipping, bedded clastic metasediments alternate over 5 to 10 m intervals with ribboned chert-argillite of the Cogburn assemblage.

To the south rocks along the Cogburn transect rocks are characterized by tight, west-verging isoclinal folds. The

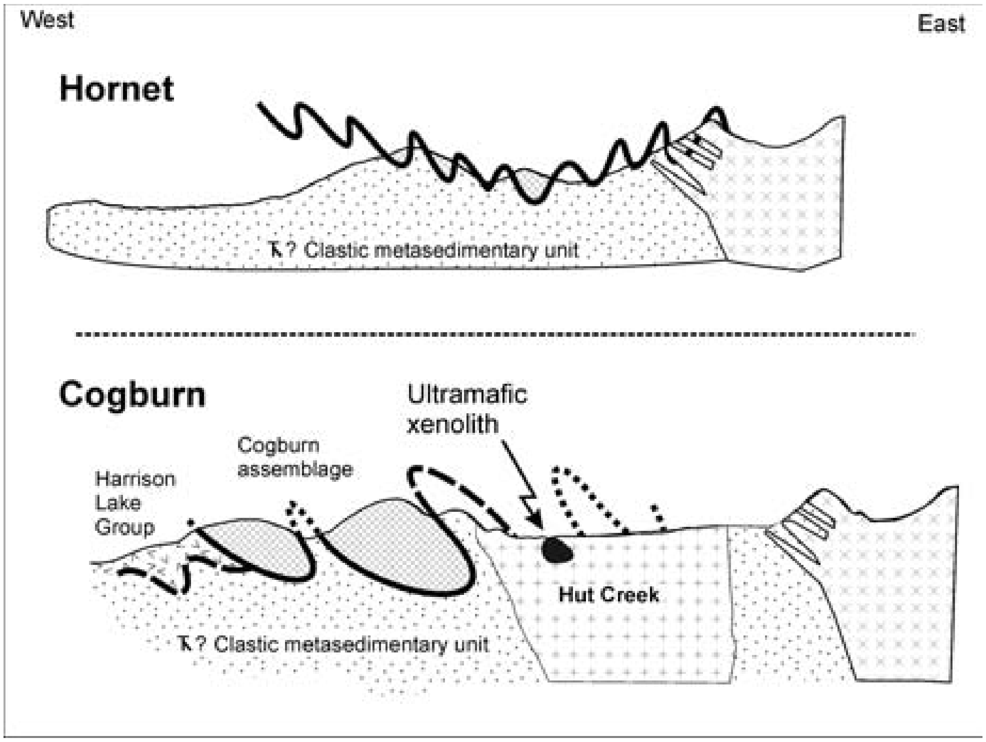

Figure 7. Schematic cross-section through the Hornet and Cogburn transects contrasting their lithotectonic character.

There are also regional lithological variations along the belt that involve a general reduction in the amount of ophiolitic assemblage rocks towards the north. Cogburn assemblage rocks become much more abundant southwards as they form the core of an arcuate, south to southeast plunging anticline. This relationship is consistent with the shallow southeasterly dip of the crust in this region as constrained by increased metamorphic grade of the rocks to the north (Journeay and Friedman 1993).

At the southern extent of the map sheet in lower Garnet Creek area, Lowes (1972) describes clastic sediments underlying volcanics in the core of an antiform indicating continuity of this structural style in that direction (Figure 5).

Isoclinal folding of the terrane bounding structure in the central Cogburn region is attributed to the structural heterogeneity introduced by the Hut Creek pluton during crustal shortening.

Most notable is the loss, or dissipation of the previously interpreted west-verging, terrane-bounding thrust faults, so well delineated by ultramafic belts south of Cogburn Creek. This variation is explained by the combined effects of the changing structural styles and reductions in the relative amount of ophiolitic rocks towards the north. In either case, a preexisting scenario in which the clastic metasedimentary unit is overlain by ophiolitic assemblage rocks that have been modified by subsequent inhomogeneous deformation accounts for the observed lithotectonic relationships.

COGBURN ASSEMBLAGE

The term ‘Cogburn assemblage’ is introduced to refer to an ophiolitic (oceanic crustal) package of variably deformed and metamorphosed chert-argillite, mafic volcanics, gabbros and ultramafic rocks. These units occur as tabular, folded and attenuated bodies that parallel the local and regional foliation. They are most prevalent within the central portion of the map sheet where they are thickened within the core of a large scale synform.

The term Cogburn Creek Group was initially introduced by Gabaites (1985) to include only the sedimentary and volcanic component of the currently defined Cogburn assemblage. The gabbroic and ultramafic units were interpreted as part of a separate and older package of rocks, representing the root zone and northern extension of the ‘Shuksan Thrust’ of the North Cascades in Washington State where similar rocks of the Yellow Aster Complex were considered as being possibly analogous (Lowes, 1972; Gabities, 1985).

Subsequently, Monger (1986) using, ‘Cogburn package’ or Monger (1989) and Journeay and Monger (1994) using ‘Cogburn schist’, unlike Gabites (1985), included the ultramafic rocks with the chert-argillite, and mafic volcanics. They retained the assignment of the metagabbro rocks to the Proterozoic-Paleozoic Yellow Aster Complex. This correlation was maintained in part because of a whole rock Rb-Sr isochron age of 3.2±2.3 Ga obtained by Gabities (1985) for these retrograde metamorphosed gabbroic rocks (Baird metadiorite of Gabities, 1985). This age is not considered reliable due to the sample's exceptionally large error combined with the generally low abundance of these large ion lithophile elements which are known to be easily remobalized. The combined effects of hydrothermal activity during its life as ocean crust as well as the effects of a complex tectonic history involving related metamorphic, magmatic and associated hydrothermal activity suggest ample opportunity for modification of the primary isotopic signature.

Both the mafic and ultramafic igneous bodies display features characterizing their tectonic mode of emplacement. Their are typically completely converted to retrograde schistose rocks while internally they are relatively massive and locally preserve remnant primary texture and mineralogy. A genetic association between these mafic and ultramafic rocks is supported by local variations in the gabbro that range from more mafic melanocratic phases to pyroxene dominant ultramafic phases suggesting the two are compositionally transitional.

Traditionally, this unit has been directly correlated with the Bridge River Terrane (Gabites, 1985; Monger, 1986; Journeay, 1990; Journeay and Monger, 1994). The Bridge River Terrane to the north is dominated by chert-argillite deposits with local remnants of ophiolitic assemblage rocks (Ash, 2000). Although now largely attenuated and converted to schists, the individual units display a well-defined ophiolitic tectonostratigraphy with no indication of internal tectonic disruption and mixing of lithologies to suggest melange development. The term assemblage is applied as outlined by Ash (2000) to help characterize the association of chert-argillite, basalts gabbros and ultramafic rocks as remnants of oceanic crust and distinct from the tectonically disrupted, chaotic chert-argillite dominant complexes.

Chert and Argillite

Chert and argillite beds of the Cogburn assemblage are best represented along the Cogburn transect. They are well exposed in near continuous sections between 6 and 7.5 kilometres along the Cogburn logging road and intermittently from roughly 1 to 5 kilometres along the North Fork logging road. The unit is relatively conspicuous due to the typically ribboned nature with fine grained, 0.5 to 1 cm, light-grey to buff-white chert layers alternating with medium to dark grey argillite that is largely converted to schists. Locally within the unit, either chert or argillite may dominate within intervals of several meters.

Further north at the eastern end of the Hornet transect the appearance of the chert – argillite unit is significantly different due to the amphibolite metamorphic grade. The unit alternates between intervals of black biotite schist (metamorphosed argillite) and fine to medium-grained polygonized quartz bands (recrystallized chert).

Metabasalt Unit

The metabasalt unit is light to dark green in colour and distinctively homogeneous in appearance. It occurs most often as a fine-grained, schistose rock consisting mainly of chlorite and could be adequately referred to as greenschist. It usually displays a well-developed 1-2 cm scale schistosity-parallel, planar cleavage. Locally the chlorite schist contains thin, discontinuous intervals of light-gray to off-white, thinly banded chert. White quartz veinlets and stringers are a commonly developed within and proximal to these cherty intervals. Several localities of less schistose mafic volcanic rock preserve relict pillow structures similar to those first noted by Lowes (1972, his Figure 16) on Slollicum Peak. During this study pillow structures were identified in greenschist-grade metabasalt at roughly the 6 kilometre point along the North Fork logging road. This unit is prominent within the central zone of the Cogburn assemblage, where it is intimately associated with the chert-argillite, metagabbroic and ultramafic units.

Barid Metagabbro

The gabbroic component of the Cogburn ophiolitic assemblage is best represented by a belt of mafic igneous rocks exposed along the eastern slopes of Talc Creek valley (Figure 4). Minor amounts of similar gabbro are also found associated with ultramafic and volcanic rocks in the high ground west of Talc Creek. It is a light grey-green, medium-grained equigranular rock with a weak to moderate foliation defined by alignment of secondary amphibole and chlorite. Near its tectonized contact margins the metagabbro is converted to medium-grained chlorite-sericite schist. Lowes (1972) initially designated the unit as metagabbro and interpreted it to be related to the adjacent belt of ultramafic rocks. He reported that plagioclase contained relict cores in the range of An^{65}, in contrast to the An^{37} content for albitic rims attributed to regional metamorphism. In addition, he recognized relict clinopyroxene cores in hornblende.

The large northwest trending body was later termed the 'Baird metadiorite' by Gabities (1985) with geographic reference to Mount Baird, which is just beyond the eastern limit of the unit and separated from it by a sliver of ultramafic rocks. In light of the relict composition of this mafic igneous rock as gabbro, it is referred to as the 'Baird metagabbro'. This rock name also adequately distinguishes between this older unit and the younger mid-Cretaceous intrusions which are in part dioritic.

Ultramafic Rocks

Ultramafic rocks are recognized along the length of the EHLB. The largest and most continuous exposures form two prominent ridges along opposite sides of the northwest-trending segment of Talc Creek in the central portion of the map area. Starting near Cogburn Creek these ultramafic belts continue to the southeast to where they become disrupted by the Spuzzum pluton near Mount Baird. North of Cogburn Creek exposures of ultramafic rocks are discontinuous and sporadic. These cumulate ultramafic rocks range from dunite to peridotite and pyroxenite. The belt of ultramafic rocks to the southeast appears to be the most olivine rich, consisting mainly of dunite with local intervals of chromite-bearing dunite. Though locally dunitic, the belt east of Talc Creek shows more compositional variation with peridotite and pyroxenite more prevalent. In the peridotites and pyroxenites both ortho and clinopyroxene have been identified as relict primary phases (Lowes, 1972; Gabities, 1985; Pinsent, this volume). Massive dunite is dark-green and weathers a characteristic dun brown. Where serpentinized, ultramafic rocks display characteristic light and dark grey mottled surface with a distinctive purple tinge. Orange rusty-brown exposures typify talc-carbonate altered zones.

On the basis of level of preservation of primary texture and mineralogy, as well as spatial association with younger mid-Cretaceous quartz dioritic intrusions, two distinctive styles of ultramafic rocks are identified. In the first and most prominent type, ultramafic rocks occur as attenuated tabular bodies and lenses that parallel the local foliation fabric. These are consistently found in association with all or some of the ophiolitic assemblage rocks. They are everywhere variably serpentinized (mainly antigorite, Troost, 1999). Intense serpentinization is often associated with talc and local carbonate alteration proximal to tectonic contacts and later crosscutting faults. Relict primary textures and mineralogies show only moderate preservation locally and it is often restricted to the core of these ultramafic bodies. No Cu or Ni sulphides have been found in these ultramafic rocks.

In contrast to the attenuated and altered character of the ultramafic rocks described above, the second type of ultramafic rocks are usually devoid of penetrative fabrics and maintain exceptionally well preserved primary igneous mineralogy and textures. These occur, almost exclusively, as xenoliths or inclusions within the younger mid-Cretaceous Coast Plutonic Complex diorite and quartz diorite intrusions. The largest of these ultramafic xenoliths occurs along the east side of the Spuzzum pluton and is host to Cu-Ni sulpide mineralization at the Giant Mascot mine (Horwood, 1930, Aho, 1956, Pinsent, this volume). The body covers an area of roughly four kilometres. It is very irregular in shape, with lobate tongues of the ultramafics and the quartz diorite protruding into one another. Smaller inclusions tend be subrounded in outline. Irrespective of shape all the ultramafic inclusions display distinctive, black, coarse-grained hornblende-rich metasomatic reaction rims at the intrusive contacts.

The largest exposures of this type are ultramafic rocks that host Cu-Ni (PGE) mineralization at the Giant Mascot mine (Pinsent, this volume). This ultramafic body consists of cumulate pyroxenites and lesser peridotites and is contained largely within the Spuzzum pluton.

Ultramafic xenoliths are also present in the Hut Creek pluton along its western margin where it intrudes the northern extent of the prominent eastern ultramafic belt where it extends north across Cogburn and along Hut Creek Valley. Examples of these ultramafic inclusions are present along the Cogburn logging road and in the high ground near the end of the North Fork logging road. These ultramafic bodies range in size from several centimetres to hundreds of metres. Like the larger ultramafic body at Giant Mascot, these are usually pyroxene-rich ultramafic rocks, often containing interstitial sulphides with elevated concentrations of Cu and Ni. Significantly, the ultramafic xenoliths associated with the younger mid-Cretaceous plutons always contained some sulphides.

The marked contrast in style of preservation between the two types of ultramafic rocks led previous workers to suggest that both types were genetically distinct. Most previous workers interpreted the well-preserved ultramafic rocks as a phase the Spuzzum pluton (Aho, 1954; McLeod, 1975; Vinning, 1977; Gabities, 1985) or as distinct ultramafic intusions, younger than the Spuzzum pluton. Lowes, (1972) interpreted the ultramafic rocks at the Giant Mascot mine to be part of a younger, composite zoned intrusion including peridotite, pyroxenite, hornblendite and diorite.

The relative age of these ultramafic inclusions can be constrained by intrusive contact relationships in the area of the Giant Mascot mine. In this area the Spuzzum pluton displays a characteristic hornblende-rich, banded margin in contact with metasomatically altered country rock. These features are developed along the margin of the quartz-diorite where in contact with both the clastic metasedimentary unit and the ultramafic body hosting the Giant Mascot mine. In addition, small plugs of diorite intrude this ultramafic body and show identical contact features to those developed around its external margin. These contact relationships indicates that the Spuzzum pluton is younger than both the ultramafic and adjacent sedimentary rocks. This relationship eliminates the possibility that the ultramafic rocks are younger than the mid-Cretaceous intrusions as suggested by Lowes (1972). One could still possibly argue that the ultramafic rocks are earlier phases of the pluton. However, the observed contact reaction argues against a co-genetic relationship between the ultramafic rocks and the Spuzzum pluton. Additionally, ultramafic inclusions of this type do not occur elsewhere in the vast expanse of the Cosat Plutonic Complex, except locally in the Harrison Lake area where they interact with older ultramafic rocks. This isolated occurrence of ultramafic rocks suggests that they are not a primary phase of the mid-Cretaceos plutons.

Interestingly, Lowes (1972) also interpreted a narrow zone of ultramafic rocks along the western side of the Spuzzum pluton just east of Mount Baird as being genitically similar to those at Giant Mascot. This zone occurs right at the southeastern extent of the northern ultramafic belt where terminated by the Spuzzum pluton. In light of the relative constraints on the age of ultramafic rocks at the Giant Mascot, and the isolated position of the zone along the contact between the ultramafic belt and the Spuzzum intrusion, it is reasonable to infer that this zone resulted from interaction of the two. Additionally, ultramafic rocks are present in the Emory Creek Valley midway between the Giant Mascot mine and the northwest trending belt of Cogburn assemblage rocks to the northwest. This relationship lends further support to disruption of a once contiguous belt of ultramafic rocks that has been engulfed by a younger intrusion with local preservation of older ultramafic rocks due to the high melting point of the primary silicate minerals. The texture of the ultramafic rocks have survived because of being sheltered by the plutonic competent mass from post intrusion alteration and tectonism.

INTRUSIVE ROCKS

The bulk of intrusive rocks recognized in the EHLB are mainly mid-Cretaceous diorites to tonalites of the Coast Plutonic Complex (Gabities, 1985; Monger, 1989; Parrish and Monger, 1992; Brown and Walker, 1993; Journeay and Friedman, 1993; Brown and McClelland, 2000; Brown *et al*, 2000). Several younger tabular feldspar porphyric intrusions of interpreted Miocene age and a number of older deformed felsic dikes of possible Late Jurassic age are also present.

Mid-Cretaceous intrusions in the EHLB appear to be part of a single evolving suite of intrusion that formed between 103 and 90 Ma. These intrusions show a progressive variation in age, scale, composition, grain size and contact margin relationships from west to east across the belt. Plutons become progressively younger and larger, with an accompanying increase in grain size, quartz content and an increase in the width and complexity of their contact aureoles. Three identifiable phases of this evolving suite are present within the EHLB. A fourth and younger phase is present to the northeast beyond the EHLB map area.

Phase I

The most westerly phase includes a number of smaller, isolated intrusions with their long axis paralleling the dominant structural grain. These are medium-grained diorites and quartz-bearing diorites that range in age from 103 to 96 Ma. Lowes (1972) recognized that the westerly belt of linear plutons and their smaller related stocks were compositionally similar to the larger easterly mid-Cretaceous intrusions. He also recognized that the westerly belt of intrusions were distinctive, being in general finer-grained, lacking foliation fabrics, and displaying relatively narrow static hornfels zones, unlike the broader and complex migmatized zones characteristic of the larger plutons to the east.

Intrusions belonging to the phase include from north to south; the Hornet Creek (at 98.3±2 Ma, Brown and McClellan, 2000), Cogburn (at 97±1 Ma, Parrish and Monger, 1992) and Settler (at 96.7±1Ma, Brown and McClellan, 2000) plutons. The southern portion of Breakenridge plutonic complex extends into the northwestern corner of the EHLB. This intrusion has been designated as a plutonic complex (Journeay and Friedman, 1993) to include a number of larger sheeted bodies that are separated from the main intrusive body. This complex also occurs along the western margin of the belt and its long axis parallels the regional structural grain. It is also of similar magmatic age as the Phase I plutons (at 103.8±0.5 and 96±0.5 Ma, Brown and McClellan, 2000), being the oldest dated among the mid-Cretaceous suite.

The unnamed, northwest-trending body in the south central portion of the map area that is underlain largely by Bear Creek is informally designated the 'Bear Creek pluton'. It is also tentatively included with this suite due to its comparable size, composition, texture, contact margin features and linear nature which parallels the regional structural grain. The Bear Creek pluton has been previously assigned a Tertiary age on the basis of a hornblende K-Ar age 53±1.7 Ma (Monger, 1989). Notably, the physically similar Phase I Hornet Creek pluton to the north, was also designated as Tertiary due to an Eocene hornblende K-Ar age (Monger, 1989). Subsequent U-Pb zircon dating established that the Hornet pluton is mid-Cretaceous. This Tertiary K-Ar isotopic age date is considered unreliable due to potential and likelihood of re-setting of K-Ar systematics of hornblende during younger magmatic or tectonic activity. U-Pb dating is required to verify this interpretation.

The more rounded intrusive body in the southwest corner of the map area underlying Hicks Lake, informally referred to as the 'Hicks Lake pluton', has been previously interpreted as Miocene on the basis of a 24.6±0.8 Ma hornblende, K-Ar age (Richards and White, 1970). This plutons is also of similar composition and texture with comparable contact relationships to plutons characteristic of the Phase I plutons (Lowes, 1972) described above. Its shape however is not characteristic of the Phase I plutons and may be more texturally akin to the Chillawick to the south to which has been previously assigned (J. Monger, personal communication, 2001). An older, mid-Cretaceous age may be more consistent with the interpreted genetic relationship between the intrusion and a number of mesothermal gold-quartz veins at the Harrison Gold mineral occurrence (MINFILE No. 92H092) on Bear Mountain several kilometres northeast of Harrison Hot Springs. U-Pb dating is obviously required to resolve this uncertainty.

Phase II

The second or intermediate phase of the mid-Cretaceous suite in the EHLB includes the Spuzzum (at 96.3±0.5 Ma, Brown, *et al.,* 2000) and Hut Creek plutons (at 94.6±0.5 Ma, Brown, *et al.,* 2000). These are somewhat larger than, and situated mainly to the east of, the phase I plutons. They are medium to coarse-grained and range from diorites to quartz diorites. This plutonic phase of the mid-Cretaceous suite is economically most significant as these are the only plutons to host Cu-Ni mineralized ultramafic inclusions.

Metasomatic contact margins accompanied by ductilely deformed and often well-banded marginal zones, termed 'layered migmatic gneiss zones' by Lowes (1972) are a characteristic feature of the phase two plutons. The width of these metasomatic intrusive contact aureoles is generally on the order of several tens of metres, but may be locally greater than 100 metres. The transition from host rock into the intrusion involves several 10s of metres of migmatized banded country rock, often displaying contorted, complex folded patterns. This is followed inward by a brecciated zone in which black medium to coarse-grained to locally pegmatitic hornblendite forms the matrix to subrounded to angular clasts of both migmatized country rock and host intrusion. Adjacent to this brecciated zone the intrusion is typically well banded, over distances of several metres with alternating dark mafic and light felsic bands from 1 to 2 cm thick and generally steeply dipping. The banding quickly dissipates and gives way to a relatively massive, equigranular rock that is more typical of the intrusions away from the migimatized contact margins. Injection of black hornblendite dikes into both the intrusive diorite and adjoining migmatized host rocks is a common feature that may extend several hundred metres beyond the contact.

Phase III

Underlying most of the northeast portion of the EHLB is the southeastern part of the Urquhart pluton (at 91.3±0.3 and 91.2±0.3, Brown and McCelland, 2000). It consists mainly of coarse-grained quartz-diorite and tonalites and displays a pervasive magmatic foliation fabric. Contact relationships between the intrusion and country rocks were examined at eastern end of both the Hornet and Cogburn transects.

Within 1 to 2 kilometres of the of the pluton contact, medium-grained to more often pegmatitic, white, tonalite dikes and irregular bodies are a minor component. Towards the pluton both the frequency and thickness of these dikes increases. Within several 100 metres or more of the pluton these intrusions form sheeted zones with alternating intrusive sills and screen of country rock up to 10 metres in thickness that dip at moderate to shallow angles towards the core of the pluton. Beyond this sheeted zone the pluton becomes mainly continuous but large concordant country rock screens can occur for 2 to 3 kilometres beyond the pluton margin (Brown and McCelland, 2000, data repository note).

Phase IV

This spatial variation in pluton character also extends regionally to the northeast, beyond the current map area. To the immediate northeast of the Urquhart pluton is the younger (84-90 Ma, Brown and McClellan, 2000), larger and mainly coarse-grained, tonalitic Scuzzy Pluton. Brown and McClellan (2000) describe the margin of the Scuzzy pluton as a, ‘spectacular sheeted sill complex’. These marginal sheeted zones of the Scuzzy pluton are up to three kilometres wide, with sills from tens of centimetres to over a 100 meters thick separated by screens of country rock with of similar varied thickness. These contact margin features are obviously akin to that of the somewhat smaller and slightly younger Phase III Urquhart pluton.

CONCLUSIONS

The geology of the East Harrison Lake belt is interpreted to include only two, and not three, major lithotectonic belts of rocks. A lower clastic metasedimetary sequence of interpreted middle to Late Triassic age is structurally overlain by an ophiolitic assemblage of metamorphosed chert-argillite, mafic volcanics, gabbros and ultramafic rocks referred to as the ‘Cogburn assemblage’. This proposed twofold subdivision provides a structural framework that allows for continuity of lithologically similar rock types across the EHLB. It distinguishes two lithological distinctive rock packages that can be correlated with two contrasting paleotectonic environments of formation including both basinal-arc and abyssal ocean settings.

The ultramafic rocks hosting the Giant Mascot deposit are older than the mid-Cretaceous quartz-bearing diorites and quartz diorites that surround and locally intrude them. The Spuzzum pluton cross cuts the ultramafic-clastic metasediment contact with similar metasomatic contact aureoles affecting both.

Cu-Ni (PGE) mineralization is consistently found only in ultramafic rocks of the Cogburn assemblage where they occur as xenoliths within the mid-Cretaceous Spuzzum intrusions. Where not proximal to the younger intrusion, ultramafic rocks are devoid of Cu-Ni sulphide mineralization. The reasons for this spatial relationship between intrusion and ultramafic rocks remain uncertain.

This relationship lends itself to the possibility that Giant Mascot ore is not primary but related to metasomatic interaction where the older ultramafic is intruded by the younger felsic plutons.

ACKNOWLEDGMENTS

Enthusiastic and capable field assistance was provided by Mary Dubravcic during a portion of the field program. Ned Brown, (Western Washington University) and Jim Monger (GSC, Vancouver) are graciously acknowledged for enlightened discussions and sharing of their ideas and data.

Ongoing discussions, following field interaction with Robert Pinsent, Jacque Houle (BC Ministry of Energy and Mines), George Nicholson (Nicholson and Associates Natural Resources Development Inc.), Robert Krause (Starfield Resources Inc.), Murray McClaren (Crockite Resources Ltd.), Robert Macdonald and Craig Payne (Crest Geological Consultants Ltd.), Jazi Nikhanj and Mike MacLeod (Leader Mining International Inc.) are continually informative and greatly appreciated.

The paper has been improved by edits from Dave Lefebure and Brian Grant. Michael Green deserves many thanks for producing the illustrations.

Without the assistance, and often tolerance for ‘that rock guy’ by the staff of Lakeside Pacific Forest Products Ltd. in allowing ready access to gated logging roads, the scope of this work would not have been possible.

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