Preliminary results of a petrological study of ultramafic rocks of the Northern Cordillera

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ABSTRACT

The Cache Creek (CCT) and Slide Mountain terranes (SMT, including the Seventymile Terrane in Alaska) of the Northern Cordillera consist of oceanic assemblages that have been tectonically emplaced. The CCT has been enclosed by a series of arc terranes, whereas the SMT has been thrust onto pericratonic North America. Detailed studies of ultramafic rocks in CCT, SMT, Livengood Terrane and the Kluane metamorphic assemblage across Yukon, Alaska and British Columbia were conducted at nine site locations. The most common type of ultramafic rock present at these localities is serpentinized harzburgite. The ultramafic rocks from the CCT and SMT have been interpreted as the lower layers from dismembered ophiolite complexes. Samples collected from the CCT are consistently harzburgite, whereas samples from the SMT are both mantle-derived harzburgite and lherzolite. The variety of ultramafic rock present in the SMT suggests they were generated within contrasting geological settings.

RÉSUMÉ

Les terranes de Cache Creek (TCC) et de Slide Mountain (TSM, y compris le terrane de Seventymile, en Alaska) de la Cordillère septentrionale sont constitués d'assemblages océaniques mis en place par tectonisation. Le TCC est encaissé dans une série de terranes d'arc, alors que le TSM a été poussé sur l'Amérique du Nord péricratonique. On a effectué des études détaillées des roches ultramafiques provenant de neuf sites représentant les terranes de TCC, TSM, Livengood, et de l'assemblage métamorphique de Kluane, au Yukon, en Alaska et en Colombie-Britannique. La variété de péridotite préservée la plus répandue dans ces sites est l'harzburgite serpentinisée. Les roches ultramafiques du TCC et du TSM constitueraient les couches inférieures de complexes ophiolitiques démembrés. Les échantillons provenant du TCC sont uniformément du même type de roche (harzburgite), alors que ceux extraits du TSM proviennent d'un plus vaste éventail de types de roche (harzburgite et lherzolite mantelliques). Les divers types de roche ultramafique (péridotites mantelliques et intrusions ultramafiques) du TSM suggèrent que ces roches se sont formées dans différents cadres géologiques (p. ex., tectonique et magmatique).

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INTRODUCTION

Ultramafic rocks characterize all orogenic belts, and include structurally interleaved mantle and metasedimentary rocks (orogenic peridotite massifs), oceanic mantle and crust (ophiolites), and concentrically zoned intrusions (Alaskan-type intrusions). Numerous ultramafic occurrences are known in the Northern Cordillera, and many of these have been interpreted as ophiolite, in some cases, despite the absence of other ophiolite components (Terry, 1977; Tempelman-Kluit, 1979; Keith et al., 1981; Leaming, 1982; Patton et al., 1994; Mihalynuk et al., 1994). The purpose of this study is to assess, through mapping, petrological and geochemical studies, the tectonic affinity of ultramafic occurrences between the Tintina and Denali faults in Yukon and adjacent portions of Alaska and British Columbia. This paper is an initial summary of petrographic and field observations of ultramafic rocks from the Northern Cordillera.

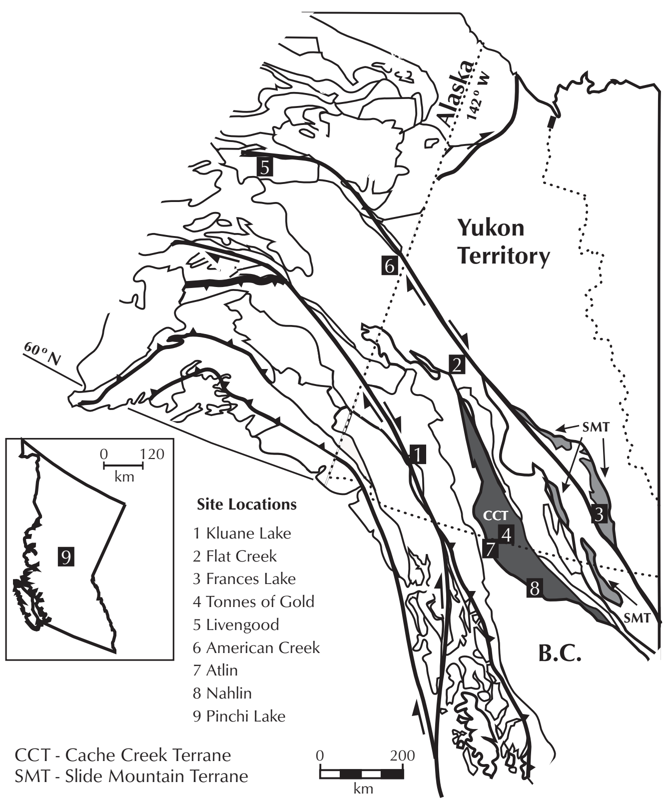

Figure 1. *Regional map of the Northern Cordillera showing site locations of ultramafic rocks, and the extent of the Cache Creek and Slide Moutain terranes.*

SITE LOCATIONS

During the summer of 2001, nine ultramafic rock occurrences were chosen for detailed geological investigation: four sites in Yukon, two in Alaska and three in British Columbia (Fig. 1). The nomenclature for peridotites of Harte (1977) is adopted for the petrographic textures. All samples are serpentinized, however the extent of serpentinization varies. Petrographic interpretation of these rocks is based on the recognition of relict minerals and their associated characteristic pseudomorph textures. Serpentine is primarily found along fractures and grain boundaries and locally as large veins (≤ 2 mm). Serpentinized olivine is recognized by crystal shape, fractures and remnant outline. Pyroxenes are identified by relict crystal shape, distinct cleavage and appearance of former exsolution lamellae. Orthopyroxene and clinopyroxene pseudomorphs can be distinguished by their extinction angle provided both crystals have preserved cleavage planes. Other common features include magnetite derived from serpentinized olivine and primary red-brown spinel.

YUKON

Kluane Lake

Mezger (2000) mapped a series of southeast-trending ultramafic lenses within the 150-km-long Kluane metamorphic assemblage, a southeast-trending belt of graphitic mica schist and gneiss located between Yukon-Tanana Terrane and Wrangellia in western Yukon. An ultramafic body along the Talbot Arm of Kluane Lake was selected for geological reconnaissance (Fig. 2). The outcrop is 500 m long, and is a continuation of a larger body that extends 5 km to the west (Fig. 2). The ultramafic body is in contact with the Ruby Range batholith to the north and muscovite-chlorite schist to the south. The contact relationships were not visible in the study area and have been inferred from aeromagnetic data (Mezger, 2000).

The ultramafic rocks weather red-brown with 1-3 mm orthopyroxene, irregular, blocky, 1-10 mm olivine and acicular, 2-4 cm long talc. The rocks consist of 40-90%, coarse (≤ 10 mm), anhedral olivine that has altered to serpentine and talc. Talc (0-35%; 0.5 to 2 mm) has a radiating fibrous texture. Orthopyroxene (~5%) grains (≤ 2 mm) have exsolution lamellae of clinopyroxene and commonly enclose talc. The remainder of the rock is made up of secondary magnetite, tremolite, and chlorite, however the textures of olivine and orthopyroxene suggest the protolith was a mantle harzburgite.

Flat Creek

The ultramafic rocks of Flat Creek were collected along a northwest-trending, semi-continous ridge located less than 1 km southwest of the Klondike-Dempster highway junction (Fig. 3). Mortensen (1996) assigned the ultramafic rocks to the SMT and interpreted thrust fault contact relationships with surrounding Yukon-Tanana Terrane rocks (Nasina Assemblage). Other ultramafic rocks of the SMT in this region are found along the Klondike River (west of the Tintina Trench) and continue northwest into Alaska.

The weathered surface of the ultramafic rock is bluish-grey with white to light beige talc and carbonate alteration. The fresh surface is greasy with black serpentine, olivine porphyroclasts, clear crystalline green lenses, and thin (≤ 1 mm) veins of secondary magnetite. The rock is generally brittle and fractured with asbestos-bearing slickensides.

Samples from Flat Creek show (~10%) relict coarse, equant olivine (≤ 0.1 mm). Carbonate is found as an aggregate alteration texture of either olivine or pyroxene within serpentine veins. Spinel is the only other primary mineral that has remained and is typically bright red, (rarely exceeds 0.5 mm) with corroded irregular grain boundaries. The protolith is not easily ascertained because the remaining primary textures cannot be differentiated between a mantle tectonite and a cumulate igneous rock.

Frances Lake

Ultramafic rocks occur west of Frances Lake on the King Arctic jade mine (Yukon MINFILE, 2001, 105H 014) road (west of the Robert Campbell Highway) in eastern Yukon (Murphy, 2001, 2000; Fig. 4). The ultramafic rock at this locality is interpreted by Murphy (2001) to represent a

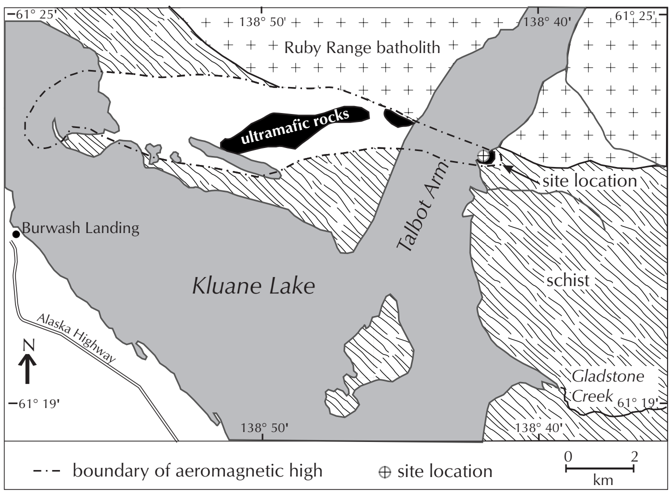

Figure 2. *Simplified geological map of Kluane Lake area with site location (modified from Mezger, 2000).*

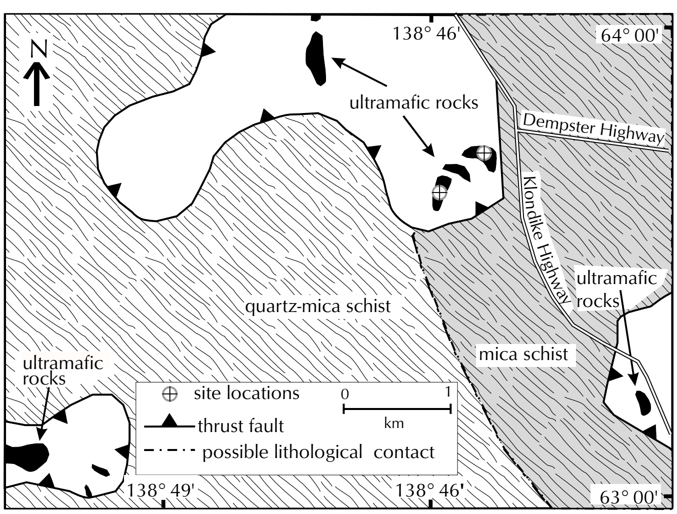

Figure 3. *Simplified geological map of Flat Creek area with site location (modified from Mortensen, 1996).*

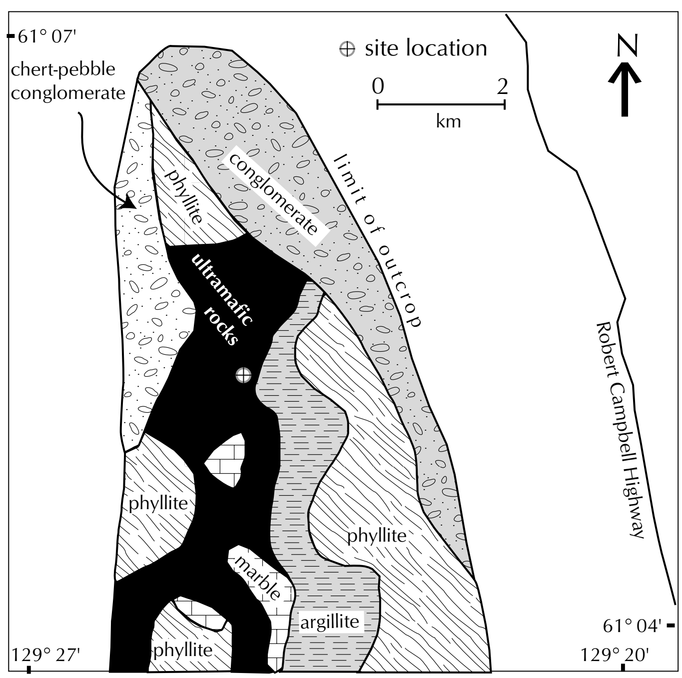

Figure 4. *Simplified geological map of Frances Lake area with site location (modified from Murphy, 2001).*

Pennsylvanian-Permian intrusion into carbonate rocks of Yukon-Tanana Terrane and may be correlative with similar age Campbell Range basalts (Murphy, 2000).

Samples from Frances Lake area are composed of olivine (80-95%), orthopyroxene (10-15%), secondary magnetite (5%) and a minor amount of clinopyroxene (≤ 2%). Orthopyroxene is curviplanar, displays exsolution lamellae of clinopyroxene and is ≤ 4 mm long, subhedral and porphyroclastic. Clinopyroxene is equant, subhedral, typically ≤ 2 mm and has corroded boundaries. The clinopyroxene crystals form rims around a mineral with clay-like (dirty brown) edges and red-brown centres (remnant olivine or orthopyroxene). The textures of clinopyroxene were not observed in any other mantle harzburgite in this study and suggest these samples are lherzolite. Spinel (bright red) is a minor phase, has an irregular shape, and is less than 0.5 mm long. The corona-like rims of clinopyroxene around relict olivine/ orthopyroxene (?) are not indicative of tectonized peridotites and suggest these samples did not originate from the mantle.

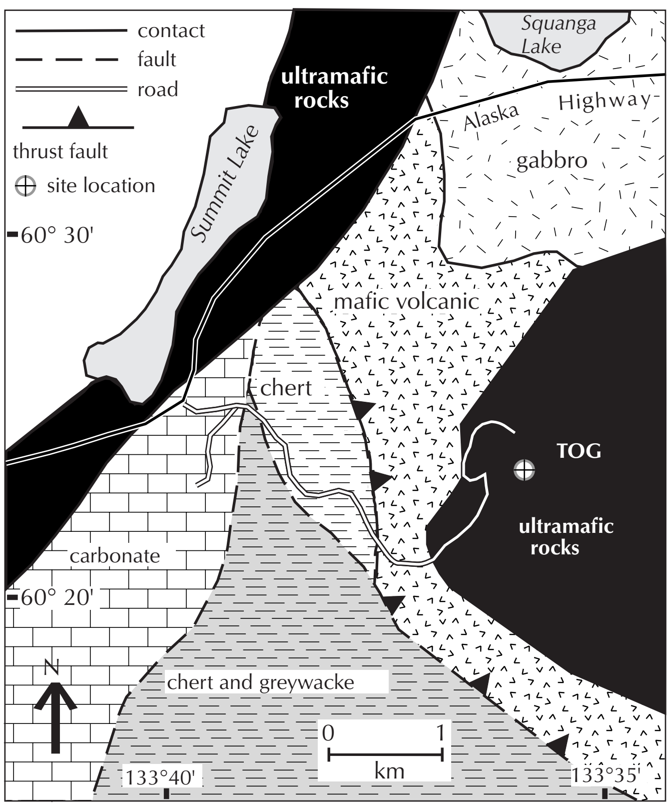

Figure 5. *Simplified geological map of Tonnes of Gold area with site location (modified from Hart, 1996).*

Tonnes of Gold

The Tonnes of Gold (TOG) site is located 20 km east of Jakes Corner and is one of many ultramafic outcrops within a 10 km radius of Squanga Lake (Gordey and Stevens, 1994; Hart, 1996; Fig. 5). The TOG ultramafic occurrence is in contact with mafic volcanic rocks to the west and gabbro to the north. The site has been the focus of gold-vein exploration and is located within the northern CCT (Hart, 1996).

The ultramafic rock collected at the TOG site consists of carbonate (30-40%) and serpentine (40-50%) with secondary magnetite (10%) and chlorite veins. The carbonate is likely an alteration of clinopyroxene, is typically ≤ 4 mm, and forms euhedral rhombs. Magnetite forms small (< 0.1 mm) euhedral cubes (locally rounded) distributed throughout the carbonate and serpentine veins, and is related to the breakdown of an unknown predecessor (olivine or orthopyroxene?). Serpentine is found between carbonate crystals, and has completely replaced any interstitial mineral that was present. The mineralogy and textures are not consistent with mantle rocks and may indicate the TOG ultramafic has an intrusive origin.

ALASKA

Livengood

The Livengood ultramafic body is located approximately 100 km north of Fairbanks along the Elliot Highway (Fig. 6) and has been assigned to the Livengood Terrane of east-central Alaska (Loney and Himmelberg, 1988;

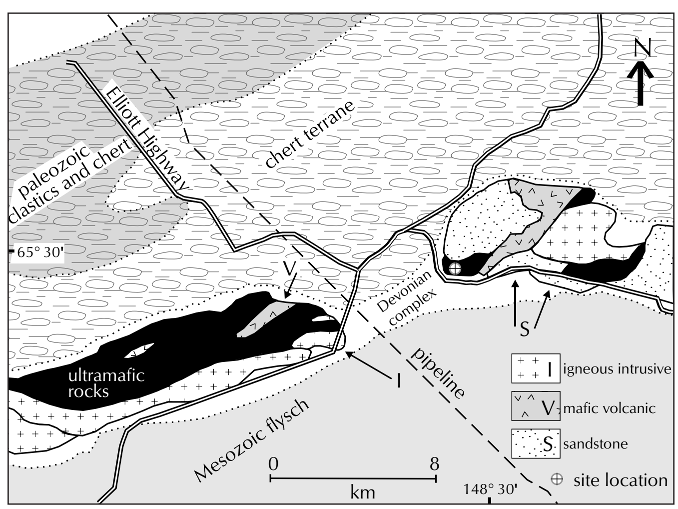

Figure 6. *Simplified geological map of Livengood area with site location (modified from Albanese et al., 1986).*

Patton et al., 1994). Two elongate ultramafic occurrences that strike east-northeast have been mapped as members of a Devonian ultramafic-mafic-clastic complex (Weber et al., 1992; Albanese et al., 1986; Fig. 6). The ultramafic bodies form areas of higher topography or ridges (Amy Dome and Cascaden Ridge) and are bound to the north by a thrust fault and to the south by Mesozoic flysch. The ultramafic rocks have been intruded by gabbro and diorite dykes with K-Ar hornblende dates of 633 Ma to 518 Ma (Patton et al., 1994).

Samples collected from Cascaden Ridge are brittle, fractured, greasy, black to dark green serpentinites. The rocks are nearly 100% serpentine with minor amounts of relict orthopyroxene, olivine and spinel. The rocks of the Livengood area are interpreted as serpentinized harzburgite (Loney and Himmelberg, 1988), however the amount of alteration of the samples makes classification difficult.

American Creek

The American Creek peridotite is located 4 km south of Eagle along the Taylor Highway (Fig. 7). The peridotite is one member of a group of tectonically emplaced ultramafic complexes known as the Salcha-Seventymile Terrane (70MT) that extends west-southwest for 350 km from the Yukon-Alaska border to Fairbanks and is considered to be correlative to the SMT in Canada (Foster and Keith, 1994; Mortensen, 1992). The American Creek peridotite is fault bounded by quartz-mica schist and greenstone, and is mapped as an orogenic (tectonite) peridotite (harzburgite and dunite) with olivine (Fo_{95-85}), enstatite, minor clinopyroxene and accessory chromite (Foster, 1976).

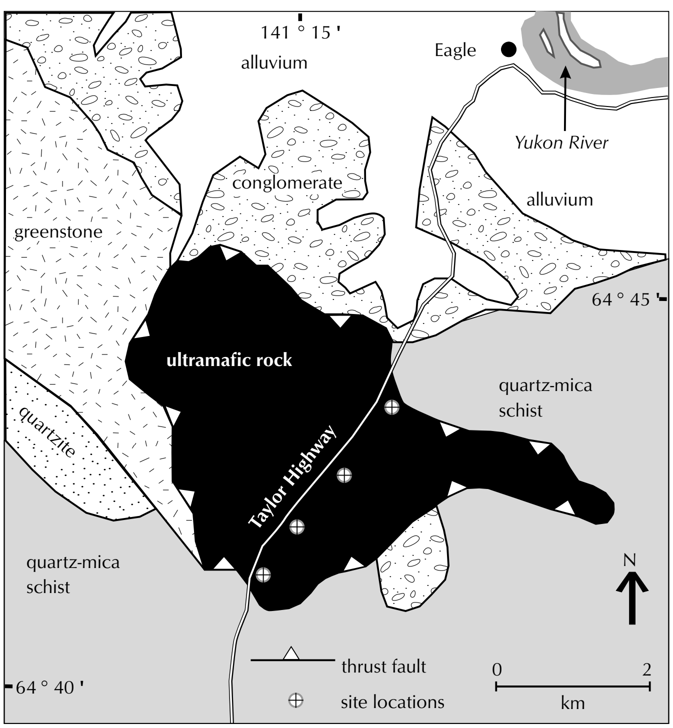

Figure 7. *Simplified geological map of American Creek area with site locations (modified from Foster, 1976).*

The American Creek peridotite is bluish-grey to black with abundant beige carbonate and light green asbestos; it has a greasy feel and is fractured in outcrop. The fresh surface shows serpentinized olivine, relict grey orthopyroxene crystals and thin (1 mm) black magnetite veins. The samples collected from the centre of the peridotite body tend to be less altered (i.e., less serpentinization and carbonatization).

Olivine (50%) is coarse and less than 6 mm in diameter. Orthopyroxene (up to 15%) is typically smaller (≤ 3 mm), more altered, and contains exsolution lamellae of clinopyroxene. Some orthopyroxene grains have feathery grain boundaries that grade into amphibole. Amphibole (< 2%) forms tabular radiating laths approximately 0.5 mm long. Clinopyroxene (0-5%) is typically less altered. Spinel is intergrown with orthopyroxene to form a symplectic texture. The American Creek peridotite displays classic textures and mineralogy of a mantle tectonite (Harte, 1977; Ross, 1977; Tardy et al., 2001).

BRITISH COLUMBIA

Pinchi Lake

Harzburgite with dunite and pyroxenite veins at the Pinchi Lake locality is located in central British Columbia (Fig. 8) and forms part of the Cache Creek Terrane. These rocks are fault-bounded to the west by Upper Paleozoic to Jurassic Stikine Terrane and to the east by the Triassic Takla Group and Early Jurassic Quesnel Terrane (Tardy et al., 2001; Ross, 1977).

Samples were collected from a quarry located 8 km north of Fort St. James. A series of linear, northwest-striking outcrops, a few hundred metres apart, are exposed along a seasonal logging road. The rock is characteristic dun brown to dark bluish-grey (serpentine alteration) with (~5 mm) bronze coloured orthopyroxene porphyroclasts, thin magnetite veins and slickensides.

Petrographically, the rock consists of olivine (80%), orthopyroxene (10%) and spinel (2%). Olivine forms equant, anhedral to subhedral neoblasts and in some

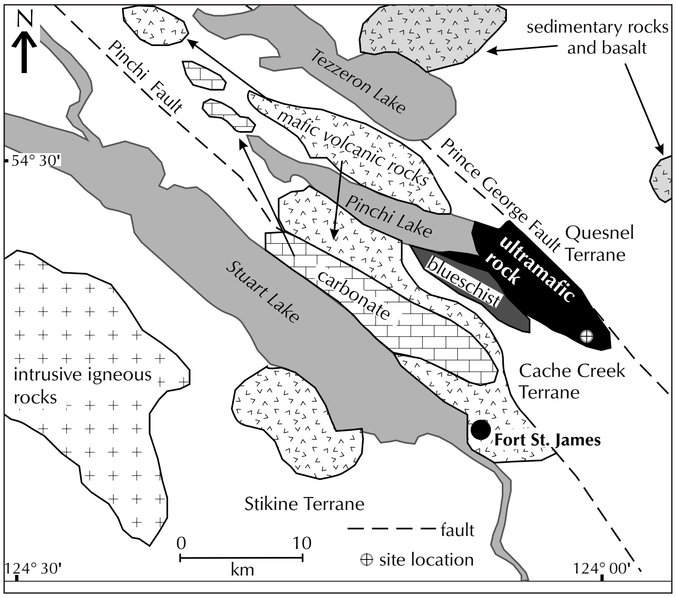

Figure 8. Simplified geological map of Pinchi Lake area with site location (modified from Tardy et al., 2001).

instances is fluidal. Other olivine grains are 1 cm in size. Curviplanar orthopyroxene porphyroclasts (≤ 3.5 mm) show exsolution lamellae of clinopyroxene. Spinel is a bright red colour and forms ≤ 0.5 mm euhedral cubes. The ultramafic rocks of the Pinchi Lake area are tectonized mantle harzburgite.

Atlin

The ultramafic rocks near Atlin are located within the Cache Creek Terrane and have been the focus of other studies (e.g., Ash and Arksey, 1990; Ash, 1994; Mihalynuk et al., 1999; Fig. 9). Harzburgite and associated dunite and pyroxenite have been interpreted to represent the base of an ophiolite sequence that includes the Nahlin ultramafic suite (Aitken, 1959; Souther, 1971; Terry, 1977; Ash and Arksey, 1990) and may be correlative with samples collected from Pinchi Lake.

Harzburgite contains lenses of dunite (Fig. 10) and 2- to 6-cm-wide pyroxenite dykes. The weathered surface of the harzburgite is rough, red-brown, with protruding porphyroclasts of pink-red orthopyroxene (1-5 mm in diameter) and 1- to 2-mm-thick black veins of magnetite. The fresh surface is bluish-grey, showing conspicuous grey orthopyroxene porphyroclasts. Serpentinization of these rocks ranges from 50 to 60%. Dunite pods are a few centimetres to tens of metres in length and have characteristic smooth dun-brown weathered surface.

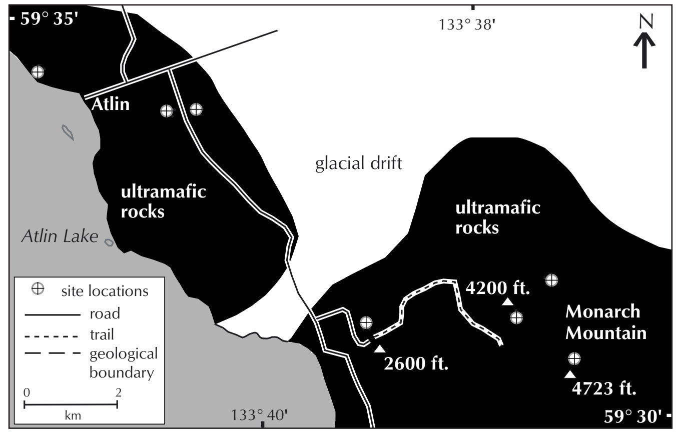

Figure 9. Simplified geological map of Atlin area with site locations (modified from Aitken, 1959).

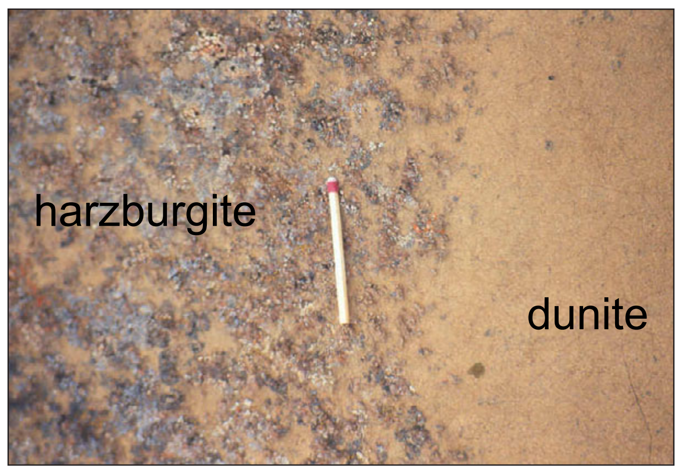

Figure 10. Coarse harzburgite with dunite lense from Atlin. Match is six centimetres.

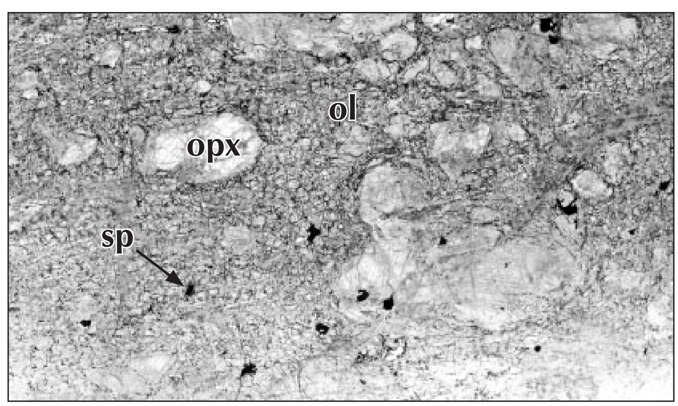

Figure 11. Plane-polarized light image of coarse harzburgite with olivine (ol), orthopyroxene (opx) and spinel (sp). Thin section is about 3.6 cm long by 2.1 cm wide.

The harzburgite contains (60-75%) coarse, equant olivine that is subhedral and less than 1 mm in diameter. Olivine is altered to both serpentine and carbonate. Orthopyroxene typically represents 20% of the bulk mineralogy and encloses small clinopyroxene crystals. Many orthopyroxene crystals are tabular to irregular shapes, are ≤ 5 mm in length, and show exsolution lamellae of clinopyroxene. Bright red spinel (≤ 2 mm) is irregular to euhedral and represents 2% of the modal mineralogy. Textures from the dunite are similar to harzburgite, except that olivine crystals are larger (≤ 5 mm; Fig. 11).

Nahlin

The Nahlin ultramafic suite is located along the western boundary of the Cache Creek Terrane south of Atlin (Fig. 12). It is the largest (260 km^2) ultramafic body in the Northern Cordillera and is fault-bounded in the west against Triassic-Jurassic Laberge Group and in the east by Upper Paleozoic sedimentary rocks of the Cache Creek Group (Aitken, 1959; Souther, 1971; Terry, 1977).

Souther (1971) and Terry (1977) described ultramafic rocks from the Nahlin suite to be very similar to ultramafic rocks found in the town of Atlin. However, rocks collected for this study from the Nahlin ultramafic body differ from those collected in the Atlin area. They are brittle, black to dark green, greasy, almost entirely serpentinized and are not associated with dunite or pyroxenite dykes.

The rocks are 80% to 100% serpentinized. Relict olivine, when present, forms groups of small (≤ 1 mm), equant, anhedral to subhedral neoblasts, which define a mosaic porphyroclastic texture. Coarse orthopyroxene (≤ 4 mm) shows exsolution lamellae and encloses small (< 0.5 mm) grains of clinopyroxene. Spinel is bright red with irregular boundaries (< 1 mm). Since most of the samples consist of serpentine, it is difficult to assign a rock name other than serpentinite. Based on the presence of remnant spinel and neoblastic olivine, it appears that these samples were mantle harzburgites and possibly represent tectonized equivalents found elsewhere in the Nahlin suite or in Atlin Group (Aitken, 1959; Souther, 1971; Terry, 1977).

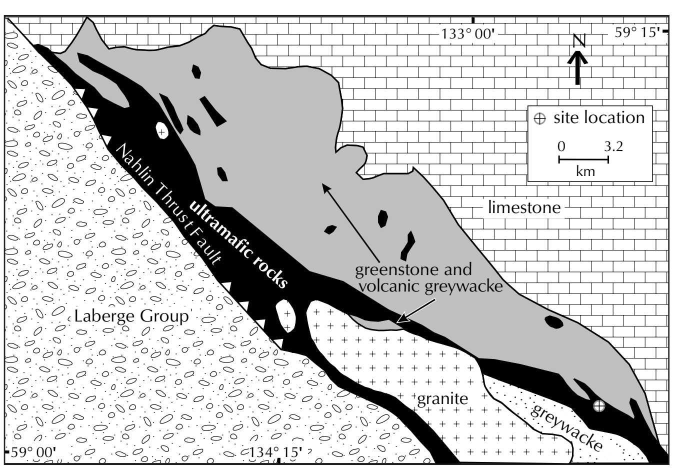

Figure 12. *Simplified geological map of Nahlin ultramafic suite with site location (modified from Aitken, 1959).*

SUMMARY

Future geochemical research will provide better constraints on the origin of ultramafic rocks from the Cache Creek (CCT), Slide Mountain (SMT) and Livengood terranes and the Kluane metamorphic assemblage. The results will lead to firmer conclusions regarding the geological history of each terrane. The ultramafic rock types from the CCT are homogeneous while those from SMT are heterogeneous .

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