Geology of the Cache Creek Terrane in the Peridotite Peak–Menatatuline Range Area, Northwestern British Columbia (Parts of NTS 104K/15, /16)

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Introduction

Ophiolites are ubiquitous features of Phanerozoic orogens around the world, where they are bounded by major suture zones, along which oceanic basins were consumed. The Canadian Cordillera hosts several belts of structurally dismembered Upper Paleozoic–Lower Mesozoic ophiolites, including the Nahlin ultramafic body exposed within the oceanic Cache Creek terrane (Figure 1). Nahlin represents the largest and best preserved of the Cordilleran ophiolites, and provides a glimpse into magmatic processes occurring in suprasubduction-zone–spreading environments and into subduction processes in the Panthalassa Ocean. Establishing clear relationships between mantellic, lower crustal and supracrustal rocks is paramount to understanding the tectonic setting and emplacement of the Nahlin ultramafic body. This in turn has implications for models of terrane accretion and continental growth in the Cordillera. Despite their importance in the Cordillera, detailed studies of the ophiolitic rocks in the Cache Creek terrane in northern British Columbia (BC) and Yukon have been limited in number.

A collaborative Geomapping for Energy and Minerals (GEM-2) project led by the Geological Survey of Canada aims to update the geological framework of the northern Cache Creek terrane through detailed mapping and regional map compilation. This paper presents preliminary results from 1:20 000 scale mapping and sampling of the Cache Creek terrane in 2015. The two study areas for this project are located in northwestern BC, approximately 115 km south of the Yukon border (Figure 1), and are accessed by helicopter from Atlin, BC. Bedrock mapping focused on the Menatatuline Range (TRIM sheet 104K/099) and Peridotite Peak (TRIM sheet 104K/097) areas, located 80 km and 110 km southeast of Atlin, respectively (Fig-

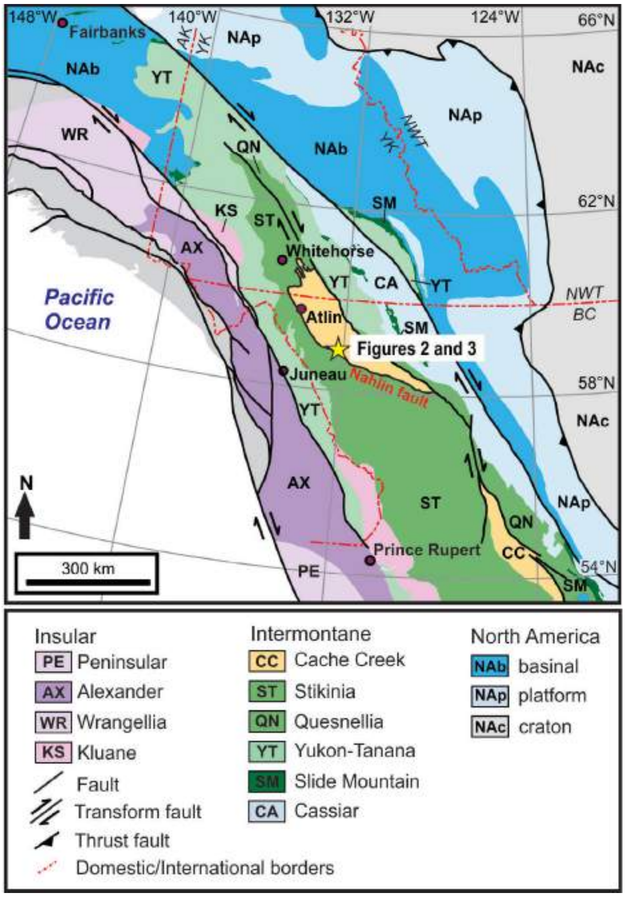

Figure 1: Terranes of the northern Cordillera, in northwestern British Columbia (from Colpron and Nelson, 2011). Star denotes location of Figures 2 and 3 on 1:20 000 TRIM map sheets 104K/097 and /099.

Keywords: *Cache Creek terrane, field relations, TRIM map sheet 104K/097, TRIM map sheet 104K/099, ophiolite*

ures 2, 3). The mapping evaluated the regional distribution and relationships between the mantle, intrusive and supracrustal rocks exposed in a northwest-trending series of mountains up to 1960 m in elevation. Low-lying areas are commonly vegetated and marshy, and covered by glaciofluvial sediments, whereas higher elevations yield excellent bedrock exposures with limited vegetation cover. Samples collected from all units mapped will be the focus of several ongoing projects related to the GEM-2 project. This paper summarizes field descriptions and outlines the results of bedrock mapping, as well as some preliminary interpretations.

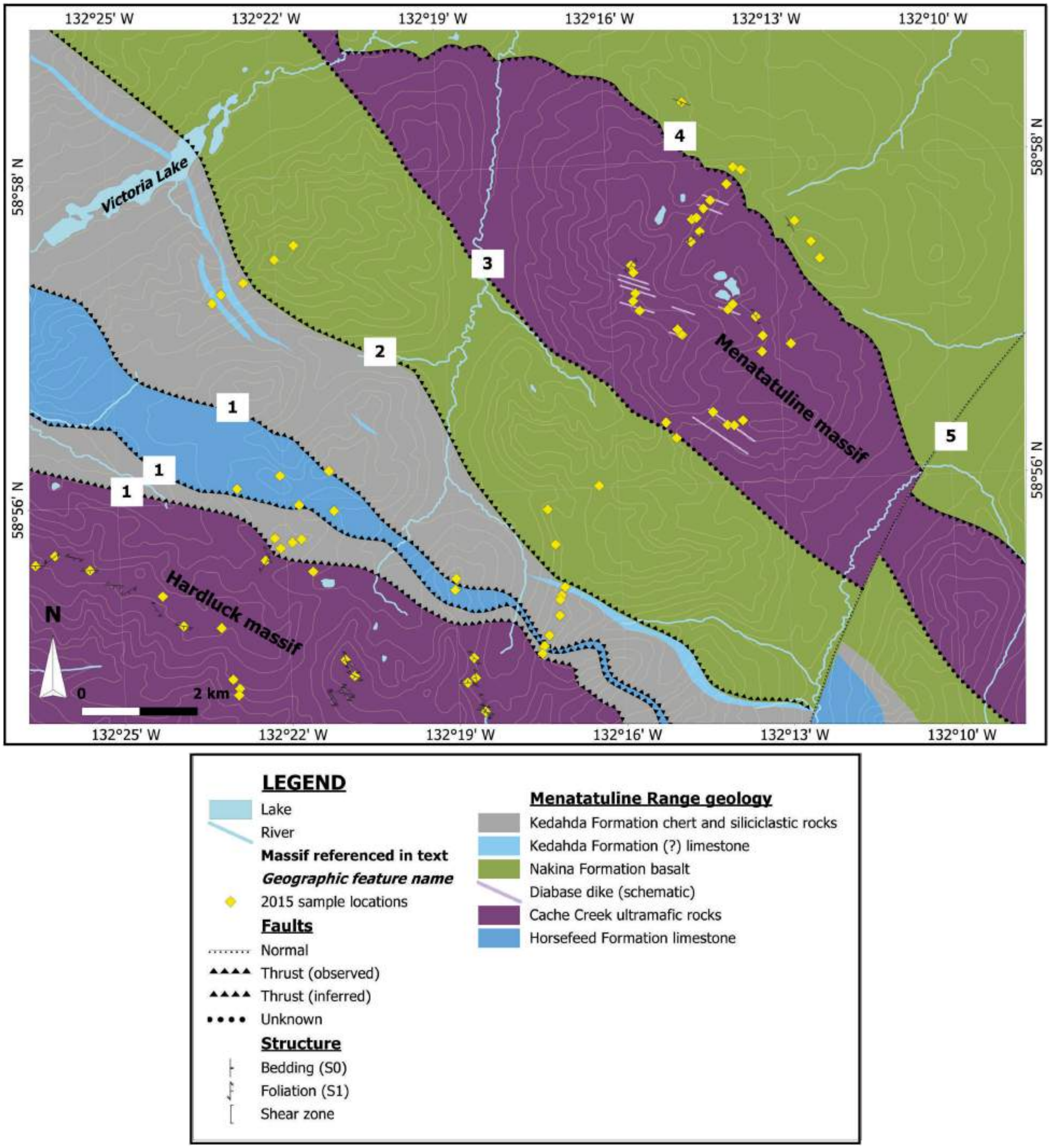

Figure 2: Preliminary bedrock geology of the Menatatuline Range area, based on 2015 mapping and compiled British Columbia Geological Survey data (Mihalynuk et al., 1996). Diabase dikes are shown schematically. Faults, labelled by numbers in white boxes, are discussed under 'Structure' in this paper (background topographic raster image from Natural Resources Canada, 1990a).

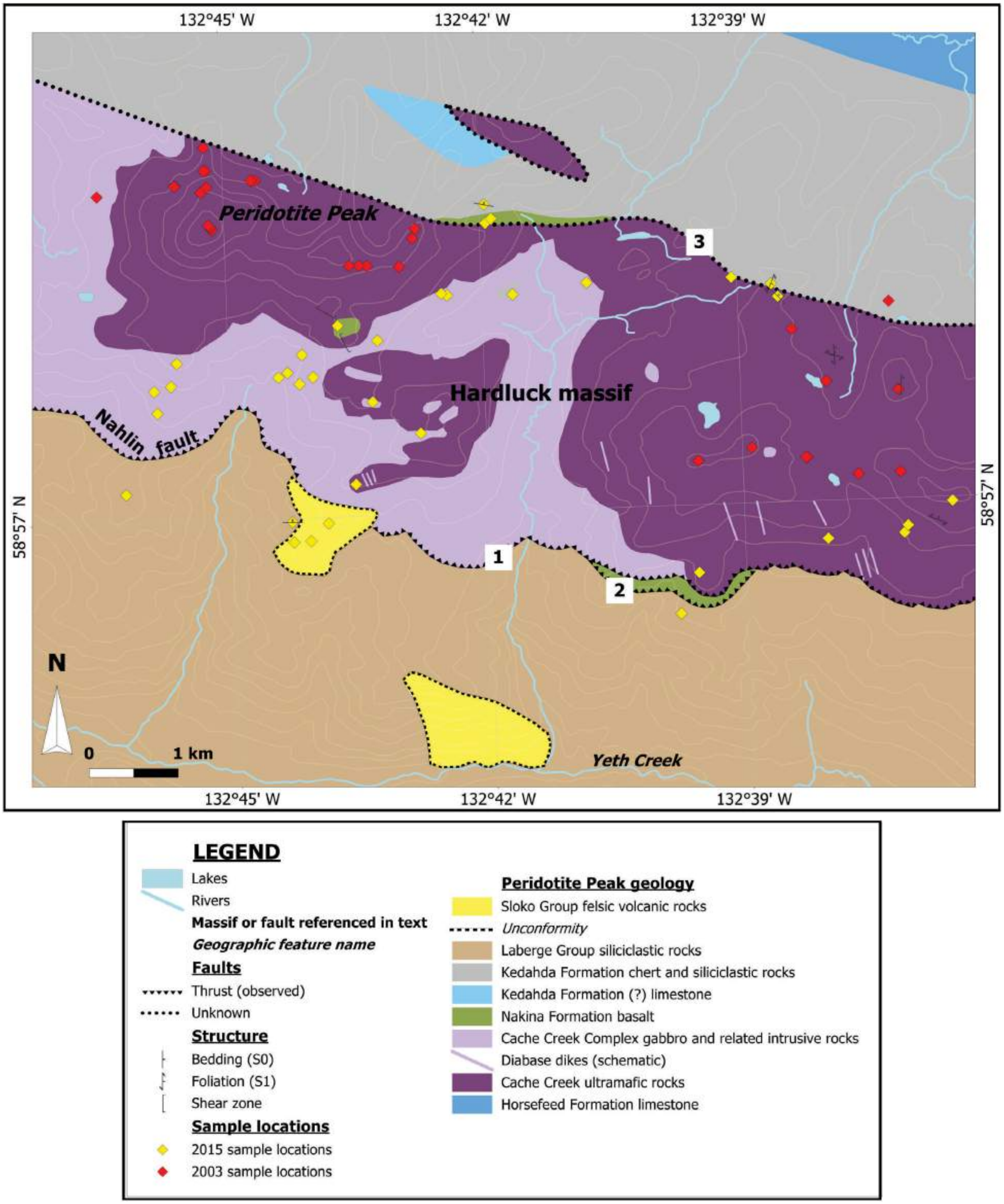

Figure 3: Preliminary bedrock geology of the Peridotite Peak area, based on 2015 mapping and compiled British Columbia Geological Survey data (Mihalynuk et al., 1996). Diabase dikes are shown schematically. Faults, labelled by numbers in white boxes, are discussed under 'Structure' in this paper (background topographic raster image from Natural Resources Canada, 1990b).

Regional Geology

The Mississippian to Lower Jurassic Cache Creek terrane is located within the Intermontane Belt adjacent to the Yukon-Tanana, Quesnel and Stikine terranes (Figure 1). The northern Cache Creek terrane near Atlin, BC has been the focus of a number of studies, ranging from regional to thematic in scope (e.g., Aitken, 1959; Souther, 1971; Monger, 1975; Terry, 1977; Bloodgood and Bellefontaine, 1990; Ash, 1994; Mihalynuk et al., 1994).

The Cache Creek and Stikine terranes were accreted to North America by the Middle Jurassic, as constrained by biostratigraphy, ca.172 Ma crystallization age of crosscutting plutons and timing of peak blueschist-facies metamorphism at 173 Ma (Gabrielse, 1991; Mihalynuk et al., 1992; Mihalynuk et al., 1999). Presence of Tethyan fauna in pre-ophiolitic, Permian–Mississippian carbonate rocks of the Cache Creek terrane contrasts strongly with that of McLeod fauna found in the adjacent Stikine and Quesnel terranes (Monger and Ross, 1971; Orchard et al., 2001), suggesting that parts of the Cache Creek terrane are exotic with respect to Laurentia. The presence of these contrasting faunal assemblages between the accreted terranes and the Jurassic emplacement age have strongly influenced the tectonic models for the northern Cordillera. For example, it has been proposed that the far-travelled Cache Creek terrane and other accreting terranes, including the Stikine and Quesnel, were amalgamated during intra-oceanic collisional events in Panthalassa prior to docking onto the North American plate (Johnston and Borel, 2007). Alternatively, the closure of the Cache Creek ocean may have resulted in Late Triassic to Early Jurassic oroclinal bending of a once continuous Stikine–Quesnel arc system prior to accretion of the terranes with the Laurentian margin (Mihalynuk et al., 1994).

The northern Cache Creek terrane was first recognized to contain a disrupted ophiolite sequence by Monger (1975), an interpretation that was later confirmed by Terry (1977) and Ash (1994); however, several distinct and possibly unrelated subterranes (Monger, 1975) have also been identified including an ophiolite and/or rifted arc (e.g., Childe and Thompson, 1997; English et al., 2010; Schiarizza, 2012; Bickerton et al., 2013), seamounts and/or oceanic plateaus (e.g., English et al., 2010), and a subduction-related accretionary complex (Monger, 1975; Terry, 1977; Ash, 1994; Mihalynuk, 1999; English and Johnston, 2005). The age of the ophiolitic rocks is most reliably constrained by a pyroxenite sample from the Teslin area in southern Yukon that yielded a weighted-average zircon U-Pb age of 245.4 ±0.8 Ma (Gordey et al., 1998). In the Peridotite Peak–Menatatuline Range area, the Cache Creek terrane comprises the dismembered remnants of oceanic lithospheric mantle, mafic intrusions, mafic volcanic rocks and sedimentary basins (e.g., carbonate rocks, chert and siliciclastic rocks).

Geology of the Menatatuline Range Area

Cache Creek Ultramafic Massifs

Aitken (1959) recognized two belts of ultramafic rocks in the Menatatuline Range area, which were subsequently investigated by Terry (1977). Together, these two belts form the Nahlin ultramafic body. The northern belt trends northwest and underlies Nahlin Mountain and the Menatatuline Range (Menatatuline massif; Figure 2). The west-northwest-trending southern belt continues through Peridotite Peak to the Hardluck Peaks (Hardluck massif; Figure 3). Ultramafic rocks in the Menatatuline and Hardluck massifs comprise variably serpentinized harzburgite with pyroxenite dikes, and replacive dunite pods. The harzburgite massifs are fairly homogeneous, with the exception of some across-strike compositional variations observed in the Hardluck massif. Locally, a primary-mantle tectonic fabric (S_1) defined by orthopyroxene elongation and variably developed pyroxene-defined layering is preserved in both massifs.

Harzburgite Tectonite

Menatatuline Massif

The Menatatuline massif consists of massive harzburgite, pyroxenite dikes and replacive dunite. The harzburgite weathers dun brown, with protruding brown to green-brown orthopyroxene and rare emerald-green clinopyroxene. The protruding appearance of the pyroxene crystals is a result of their resistance to serpentinization and alteration, relative to the surrounding olivine crystals. There is little variation in modal mineralogy throughout the massif, with ~25–40% orthopyroxene, lesser clinopyroxene (2%) and rare spinel (<5%). Orthopyroxene, clinopyroxene and olivine grain size varies between 2 and 10 mm, and orthopyroxene grains are commonly subhedral. Anhedral spinel ranges in size from <1 mm to 5 mm. Discrete zones of ophicalcite (<1 m in width) are found throughout the massif and comprise brecciated harzburgite in a carbonate±quartz matrix.

Hardluck Massif

Hardluck massif consists predominantly of layered harzburgite, with lesser amounts of massive harzburgite. The layered harzburgite consists of layers 5–20 cm thick defined by variable proportions of pyroxene. There is an abrupt shift from layered to massive harzburgite along a westerly-trending zone of serpentinite that may define a steeply dipping fault in the northernmost part of the Hardluck massif. Overall, the harzburgite is largely similar to that in the Menatatuline massif; however, in the Hardluck massif, an across-strike increase in modal orthopyroxene toward the north was observed.

Pyroxenite

Pyroxenite dikes, rarely exceeding 5–10 cm in width, although locally reaching up to 20 cm, crosscut both the Menatatuline and Hardluck massifs. In both massifs, northwest- to north-northwest-striking and steeply dipping pyroxenite dikes can be layer-discordant or concordant with respect to the locally layered harzburgite (Figure 4 a, b) and are locally deformed into metre-scale folds. Small-scale folds and regionally variable dip direction of the pyroxenite dikes likely document regional-scale folding within the Hardluck massif.

Dunite

Discrete, dun-weathering dunite pods comprise as much as 20% of the Menatatuline and Hardluck massifs. These replacive bodies represent melt channels formed as a result of melt-rock interaction in the host harzburgite (Kelemen and Dick, 1995). The size of individual pods is variable, ranging from sub-metre scale up to 100 m across. Dunite bodies have sharp contacts against harzburgite, are locally folded and locally crosscut pyroxenite, indicating that there are likely multiple generations of replacive dunite and pyroxenite dikes (Figure 4c). Establishing temporal relationships between the pyroxenite dikes and dunite pods is not everywhere straightforward; in the Hardluck massif, dunite also appears as centimetre-scale envelopes surrounding the pyroxenite dikes or as orthopyroxene-poor horizons in the layered harzburgite. In both massifs, dunite is mostly homogeneous, consisting of ~95% olivine, with accessory euhedral spinel. Olivine macroscopically appears to be equigranular and fine grained; however, this may be a result of disaggregation of larger crystals along serpentine-veinlet boundaries. The dunite is commonly enriched in spinel relative to the host harzburgite, with modal abundance locally reaching up to 8% and grain size, up to 4 mm.

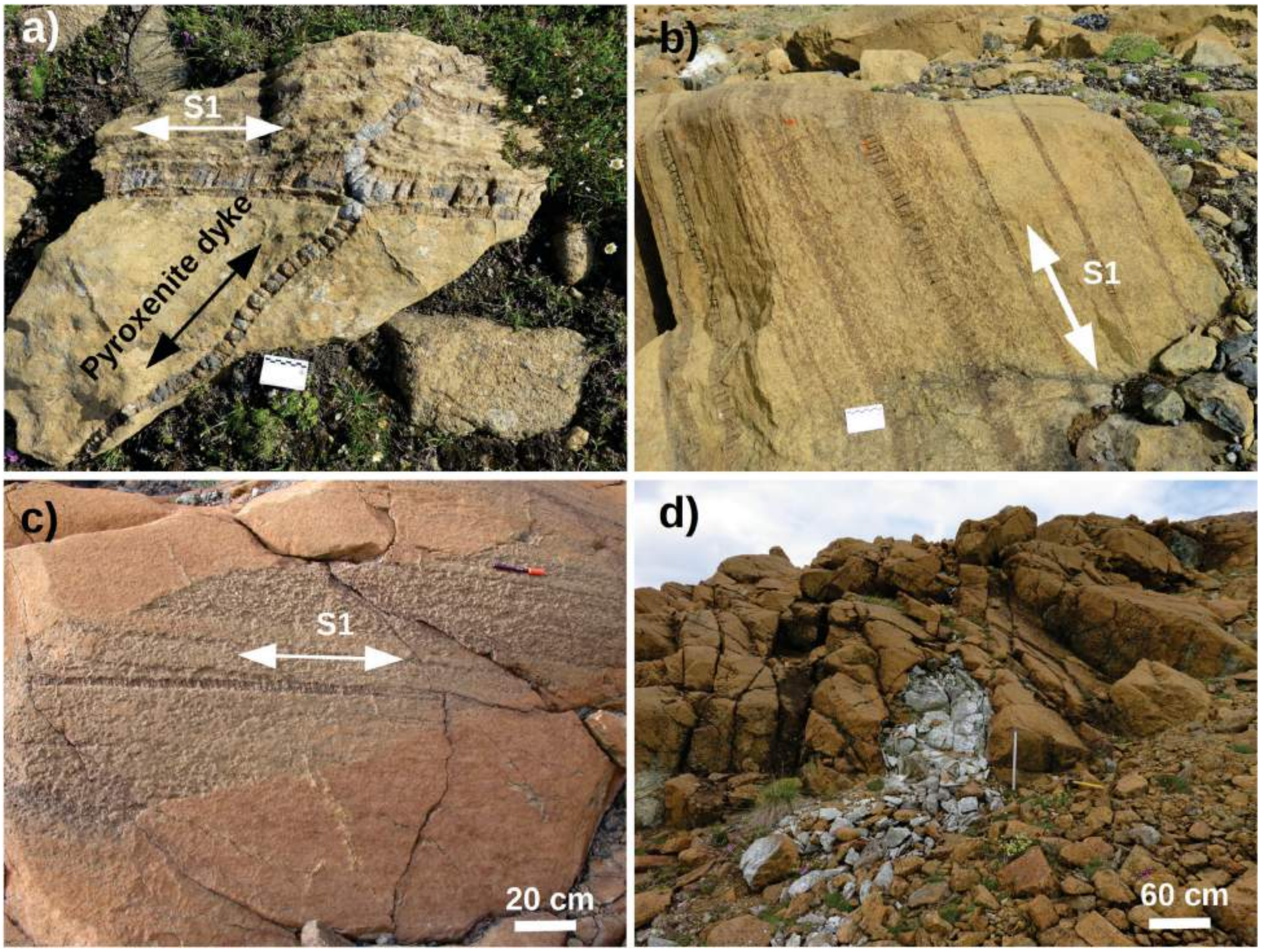

Figure 4: Field photographs of harzburgite of the Hardluck massif: **a)** a boulder of typical layered harzburgite, crosscut by a pyroxenite dike; dikes are locally deformed into metre-scale folds and can be layer concordant or discordant with respect to locally layered harzburgite; **b)** layered harzburgite defined by variable proportions of orthopyroxene and layer-concordant pyroxenite dikes; **c)** dunite pod replacing layer-concordant pyroxenite dikes in layered harzburgite near Peridotite Peak; **d)** white-weathering listwaenite zone in massive harzburgite of the Hardluck massif in the Menatatuline Range area.

Alteration Assemblages

In both the Menatatuline and Hardluck massifs, the alteration and serpentinization of harzburgite varies from thin millimetre-scale serpentine veinlets to complete replacement of primary olivine by serpentine and talc±carbonate. Serpentinization generally results in darkening of the peridotite from green-grey to black on fresh surfaces, making it easy to identify highly altered samples. Metasomatized and pervasively altered sections (e.g., listwaenite, Figure 4d) are typically associated with faults, gabbro intrusions and diabase dikes; however, irregular and relatively cryptic alteration zones also occur irrespective of faulting and intrusions, implying that the massifs have likely experienced multiple episodes of alteration.

Cache Creek Gabbro

Gabbroic rocks consisting of plagioclase and pyroxene±amphibole are present along the southern margin of the Hardluck massif. Gabbroic dikes and pods with distinctive chill margins commonly intrude serpentinite, especially in proximity to the Nahlin fault. Gabbro is varitextured and ranges from fine grained to pegmatitic (Figure 5a). Foliated amphibolite- and trondhjemite-rich zones are locally present. Gabbroic rocks are clearly visible as light-weathering streaks in scree slopes along gullies. Gabbro becomes less abundant toward the north, where it typically forms thin dikes and reticulated dike and vein swarms within variably serpentinized peridotite. Northernmost exposures of gabbro comprise boudinaged rodingite pods completely enveloped within fresh peridotite. Rodingite locally preserves the primary gabbroic texture, including apparent igneous layering in the gabbro.

Diabase Dikes

West- to northwest-trending and steeply dipping diabase dikes ranging in width from <2 to 20 m occur as a swarm crosscutting the Menatatuline massif. The dikes have chilled margins against the host harzburgite, and core zones typically comprise fine- to medium-grained equigranular plagioclase (40–50%) and pyroxene (1–3 mm). Many of these dikes display ophitic to subophitic textures (Figure 5b) and wider dikes also contain rare (<1%), black, 3-4 mm phenocrysts of pyroxene. Dikes are commonly bordered by serpentinite and/or listwaenite alteration zones.

Nakina Formation

Mafic volcanic rocks, previously mapped as part of the Triassic Nakina Formation (Mihalynuk et al., 1996; English et al., 2002; Mihalynuk et al., 2002), are exposed to the northeast of the Menatatuline massif, and between the Menatatuline and Hardluck massifs. To the northeast of the Menatatuline massif, a ~150 m zone of phacoidal serpentinized harzburgite defines a southwest-dipping contact against the mafic volcanic rocks. This contact is interpreted as a thrust fault with volcanic rocks in the footwall. Dark grey-weathering basaltic volcanic rocks crop out sporadically on low hills to the northeast of the Menatatuline massif. The flows are pillowed (Figure 6a) and massive but it is difficult to determine younging direction or contact relations as outcrop quality and exposure are poor. The basaltic rocks are dark green-grey on fresh surfaces and predominantly aphanitic, with the exception of one outcrop of plagioclase- and pyroxene-phyric basalt. The Nakina Formation basalt in this area is chloritized and commonly contains thin quartz veinlets.

A broadly northwest-trending valley separates the Menatatuline massif from the volcanic/volcaniclastic rocks that

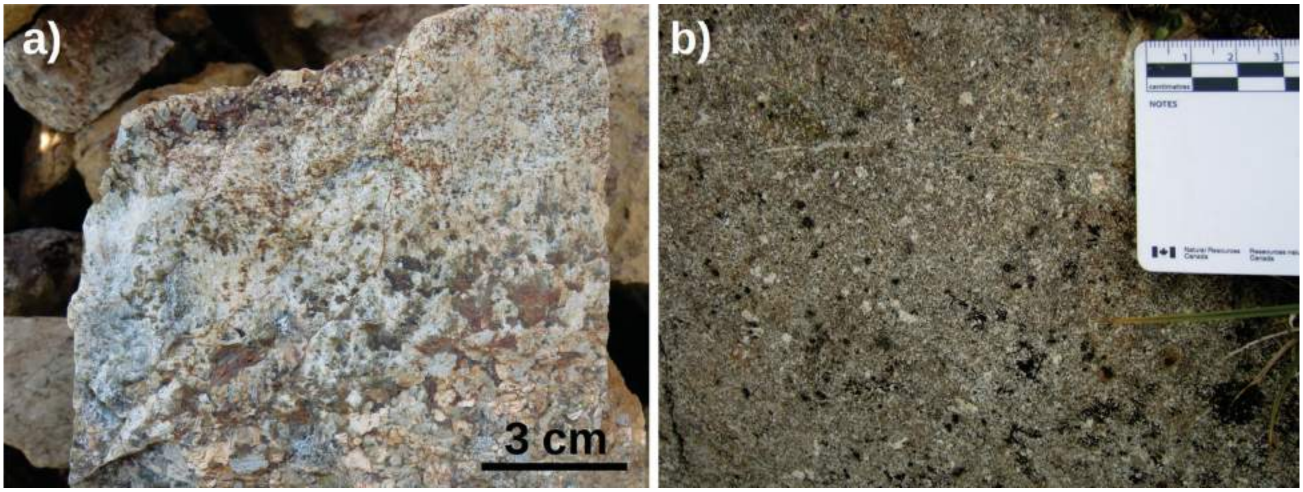

Figure 5: a) Varitextured gabbro intrusion in the Hardluck massif, in the Menatatuline Range area. Grain size within the gabbroic intrusions varies from fine grained to pegmatitic. **b)** Ophitic texture in the medium-grained centre of a ~5 m wide diabase dike crosscutting massive harzburgite in the Menatatuline massif, in the Menatatuline Range area.

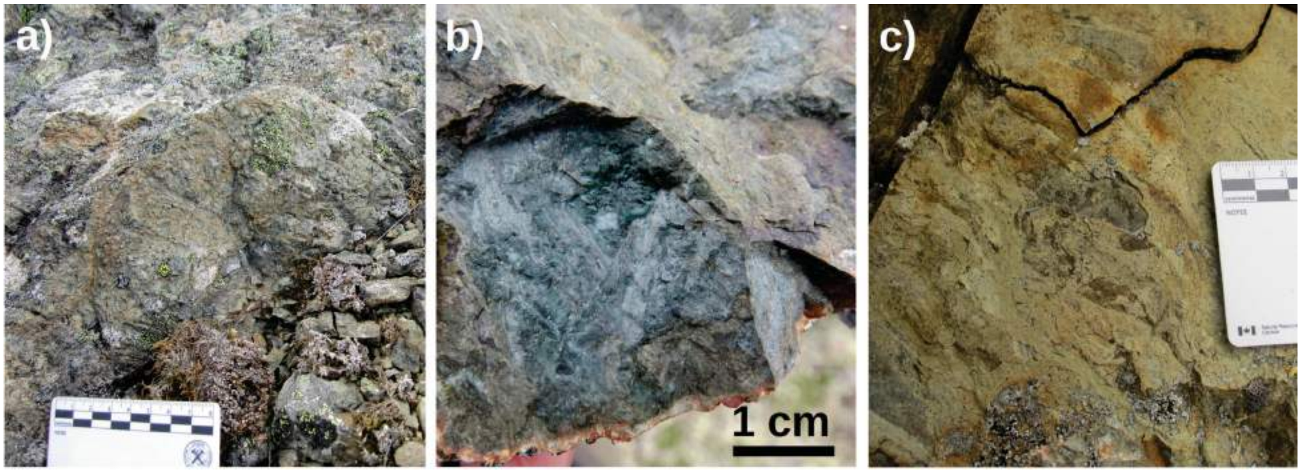

Figure 6: Mafic volcanic rocks of the Nakina Formation, in northwestern British Columbia: **a)** dark grey, pillowed, mafic volcanic rocks to the northeast of the mantle section; **b)** light grey-green, pervasively hematite-altered volcanic or volcaniclastic rocks to the southeast of the Menatatuline massif; **c)** locally fragmental texture in the volcaniclastic rocks between the Menatatuline and Hardluck massifs.

form steep cliffs and jagged ridges to the south. A saddle of highly serpentinized and fissile-weathering rock is interpreted as a fault trace that follows this valley. The dip direction and sense of displacement of this fault were not observed, although it is thought to dip steeply because of its apparent interaction with topography (Figure 2). Here, the Nakina Formation volcanic rocks have light grey-green to mint-green fresh surfaces, and locally show signs of pervasive hematite alteration (Figure 6b). These volcanic rocks are fine grained, aphanitic, locally vesicular and flow banded, and commonly fragmental. Fragments are variable in shape, from rounded to elongate or shard-like (Figure 6c), suggesting a proximal volcanic origin. Thin veins and thick zones of chlorite and/or quartz alteration, as well as inclusions of red to green chert, are common.

Horsefeed Formation

A wide belt of fault-bounded limestone extends through the area, thinning significantly to the southeast and widening toward the northwest, where it appears to be continuous with Mississippian–Permian Horsefeed Formation limestone (Monger, 1975; Mihalynuk et al., 2002.). In general, this limestone is massive although it is locally thinly bedded (Figure 7), fetid and oolitic.

Kedahda Formation

Sedimentary rocks, previously mapped as the Kedahda Formation (Monger, 1975; Mihalynuk et al., 1996; Mihalynuk et al., 2002), occur as two belts that are separated by the Mississippian–Permian Horsefeed Formation limestone (Monger, 1975; Mihalynuk et al., 2002). Sedimentary rocks are folded and comprise abundant massive to ribbon chert and argillite that are interbedded with fine-grained sandstone to pebble conglomerate. Siliciclastic rocks contain abundant free quartz, suggesting a source region that contains felsic volcanic and/or plutonic rocks. Lateral extent of the siliciclastic rocks is difficult to determine due to folding and lack of exposures between ridges. Thin lenses of massive limestone are present within the siliciclastic sequence; in the absence of age constraints, these lenses may be part of the Horsefeed Formation or Kedahda Formation limestone (see Mihalynuk et al., 2003).

Geology of the Peridotite Peak Area

Cache Creek Ultramafic Rocks

Ultramafic rocks in the Peridotite Peak area and along-strike continuation of the Hardluck massif are largely similar to those in the Menatatuline Range area, comprising variably serpentinized harzburgite and lherzolite, with pyroxenite dikes, websterite and replacive dunite pods (Mihalynuk et al., 2004). Harzburgite and lherzolite are mostly massive and are locally foliated in the centre of the

Figure 7: Bedded limestone of the Mississippian–Permian Horsefeed Formation, in northwestern British Columbia (Monger, 1975; Mihalynuk et al., 2002).

mapped area, where west-striking, steeply dipping layering was observed.

On the northern side of Peridotite Peak, layers of lherzolite contain up to 25% emerald-green clinopyroxene (Mihalynuk et al., 2004). Exposures of harzburgite in the southern sections of the Hardluck massif at Peridotite Peak contain variable amounts of clinopyroxene (5–7%, 2–3 mm across) and orthopyroxene (up to 20%, 4–5 mm across). Disseminated 1–3 mm spinel grains make up 1% of the lherzolite. In one outcrop, a dunite pod is cut by a 1 m wide, anastomosing pegmatitic websterite dike. In the eastern part of the map area, sparse orthopyroxenite dikes 3–10 cm wide are both concordant and locally crosscutting with respect to layering, where present, in the harzburgite and lherzolite. As in the Menatatuline Range area, the ultramafic rocks are cut by abundant thin serpentine veinlets and are locally highly serpentinized. The latter is particularly apparent in proximity to gabbro bodies on the western side of the Peridotite Peak area, where phacoidal serpentinite is often present as metre-scale outcrops.

Cache Creek Gabbro to Quartz Diorite

Intrusive rocks underlie much of the map area, and range in composition from gabbro to quartz diorite. In the eastern part of the map area, they are found exclusively as isolated knobs within the ultramafic rocks or as metre-scale, north-striking and steeply dipping diabase dikes. The texture and modal mineralogy of these diabase dikes are identical to those in the Menatatuline massif at hand-sample scale. In contrast, in the central and western parts of the mapping area, the intrusive rocks are more voluminous and the ultramafic-intrusive contacts closely follow topographic contours. Similar contacts were observed on the northern side of Peridotite Peak, suggesting that the gabbro to quartz diorite may form a shallowly northeast-dipping intrusive sheet underlying the ultramafic rocks, which are exposed only at higher elevations. Alternatively, the ultramafic rocks may be structurally emplaced upon the gabbro intrusions by a shallowly northeast-dipping thrust fault.

The gabbroic rocks are grey weathering, very fine to medium grained, and are locally varitextured on a scale of tens of metres. Fresh surfaces are medium blue to greenish grey, and mafic minerals are variably chloritized. Where the composition is more dioritic, the texture is generally coarser grained than in the gabbro (i.e., mostly medium grained). Modal proportions for the gabbroic rocks are generally 60% plagioclase and 40% pyroxene. Quartz diorite proportions of plagioclase to pyroxene and/or amphibole are similar, although with the addition of 1–5% quartz and local biotite.

Nakina Formation

Mafic volcanic rocks, previously mapped as part of the Triassic Nakina Formation (Mihalynuk et al., 1996; English et al., 2002; Mihalynuk et al., 2002), are observed in faulted contact against the Hardluck massif to the north and south of Peridotite Peak. To the north of the ultramafic body, pyroxene-phyric amygdaloidal basalt underlies a sedimentary package. This green-grey weathering porphyritic basalt contains approximately 8% pyroxene phenocrysts, ranging in size from 1 to 3 mm, and up to 20% calcite-filled amygdules that are typically2 mm in diameter. Sparsely plagioclase-phyric basalt occurs as isolated sheets within a gabbro-dominated drainage south of Peridotite Peak. The basalt is grey to green-grey weathering, variably chloritized, locally foliated, and is commonly crosscut by thin quartz veins. Both the pyroxene-phyric amygdaloidal basalt and the sparsely plagioclase-phyric basalt include centimetre-scale, irregular-shaped inclusions of grey limestone (Figure 8).

South of the Hardluck massif, mafic volcanic rocks are in faulted contact along a portion of the Nahlin fault separating the Cache Creek terrane from the Jurassic Laberge Group. At this locality, the volcanic rocks comprise aphanitic massive basalt with sparse amygdules and twinned, needle-like pyroxene phenocrysts.

Kedahda Formation

North of the ultramafic body, clastic sedimentary rocks previously mapped as the Kedahda Formation (Mihalynuk et al., 1996; Mihalynuk et al., 2002) include chert, cherty siltstone and fine sandstone. Dark grey chert occurs along portions of the northern contact with the ultramafic rocks, and typically contains abundant crosscutting quartz and/or calcite veins. The Kedahda Formation chert locally preserves radiolarians that yield Late Carboniferous to pre-

Figure 8: Irregular-shaped inclusions of grey, fine-grained limestone in highly amygdaloidal pyroxene-phyric basalt near the contact between mantle and supracrustal rocks in the northern part of the Peridotite Peak area.

dominantly Middle Triassic ages (Mihalynuk et al., 2002). Sedimentary rocks overlying a sliver of pyroxene-phyric amygdaloidal basalt to the north of the Hardluck massif ultramafic rocks include cherty siltstone to fine sandstone in thin, west-striking, steeply dipping beds. Outcrops of these fine-grained sedimentary rocks are fissile and rusty orange weathering, although fresh surfaces are dark grey. No graded bedding or other way-up indicators were observed in these rock units.

Laberge Group

A west-striking sedimentary package of siltstone, mudstone, fine to very coarse lithic sandstone, and lithic-rich biotite-bearing granule conglomerate is exposed along drainage channels to the south of the Hardluck massif. These have been previously mapped as part of the Jurassic Laberge Group (Mihalynuk et al., 1996; Mihalynuk et al., 2003). Graded bedding, flame structures, rip-up clasts and channels indicate upright stratigraphy (S_0 ~270°/60°), in which interbedded mudstone and siltstone overlying fissile mudstone are incised and overlain by interbedded fine to very coarse lithic sandstone (Figure 9). Interbedded siltstone and mudstone overlie the lithic sandstone, and are in turn overlain by lithic granule conglomerate.

The interbedded grey to black siltstone and mudstone is finely laminated on a millimetre scale and locally contains veins of pyrite. Fine to very coarse sandstone comprises quartz, feldspar, mafic minerals, including biotite, and clasts of dark grey to black fine-grained siltstone to mudstone. Sandstone beds vary in thickness from subcentimetre scale to ~20 cm. The coarsest grained rock unit is a lithic-rich and biotite-bearing granule conglomerate, which is clast supported and crudely bedded. The locally red-stained outcrop is crosscut by abundant thin, rusty veins, which contain pyrite and chalcopyrite along broken surfaces.

Sloko Group

Hypabyssal felsic rocks, previously mapped as part of the Eocene Sloko Group (Mihalynuk, 1999), were observed to the north of Yeth Creek. Sparsely quartz-phyric, flow-banded rhyolite is pale grey to chalky white and fissile weathering, and is locally clay altered, with disseminated pyrite. Rhyolite locally hosts metre-scale, matrix-supported breccia zones, which contain angular to subrounded 3 mm to 3 cm clasts of dark siltstone, chert and rhyolite in a dark grey, fine-grained matrix. The genesis of this breccia and its relation to the host rhyolite are still unclear, although it may represent a hydrothermal breccia zone or a volcaniclastic deposit. Field observations of the Sloko Group suggest that it crosscuts the Laberge Group sedimentary rocks and that this contact represents an unconformity (Figure 10).

Structure

Certain primary features are preserved throughout both map areas, including bedding and way-up indicators in sedimentary rocks, pillow structures, crosscutting relationships, and mantle tectonite fabrics. The diabase dikes show primary crosscutting relationships with straight boundaries, suggesting that they have been essentially unstrained. The variably developed layering and orthopyroxene-defined fabric (S_1) in the harzburgite tectonites are interpreted as primary features related to high-temperature ductile flow in the mantle (Dick and Sinton, 1979; Nicolas and Violette, 1982; Nicolas, 1995). Some pyroxenite dikes in the harzburgite bodies define locally isoclinal metre-scale folds that are also suggestive of shearing and ductile flow, which would have occurred shortly after the hot lithosphere

Figure 9: Rip-up clasts of dark grey mudstone at the base of a coarse sandstone bed, and graded bedding (white arrow indicating direction of fining) indicating that bedding is right way up (S_0 ~270°/60°) in the Laberge Group sedimentary rocks south of the Hardluck massif, in the Peridotite Peak area.

Figure 10: White-weathering Eocene Sloko Group hypabyssal felsic rocks intruding rusty orange-weathering, Jurassic Laberge Group sedimentary rocks in the southern part of the Peridotite Peak area. Dashed line traces intrusive contact.

was formed. In the Menatatuline Range area, orientations of pyroxenite dikes in the Hardluck massif indicate the possible presence of a large-scale, west-trending antiformal fold, likely of similar origin.

The harzburgite bodies in both map areas are structurally juxtaposed with the mafic volcanic rocks, and carbonate and siliciclastic sedimentary rocks. The most conspicuous structure affecting the Peridotite Peak–Menatatuline Range area is the Nahlin fault (Figure 3), a southwest-vergent thrust fault separating the Cache Creek terrane from the Laberge Group sediments to the south (Monger, 1975; Terry, 1977; Mihalynuk et al., 2003; English et al., 2010).

Menatatuline Range Area

The Menatatuline Range area is transected by several northwest-trending faults. The Hardluck massif ultramafic rocks and gabbro are thrust over the Triassic (?) Yeth Creek volcanic rocks (informal; Mihalynuk et al., 2004; English et al., 2010) and Jurassic Laberge Group sedimentary rocks along the Nahlin fault (see fault labelled in Figure 1; Monger, 1975; Terry, 1977; Mihalynuk et al., 2003). The Nahlin fault (see Figure 1) appears to be a brittle structure that corresponds to regions of low topography. Evidence of deformation along the Nahlin fault is marked by the development of a moderately intense foliation in the Yeth Creek volcanic rocks, and by the formation of scaly serpentinite shear zones in the Hardluck massif (Figure 2).

The Hardluck massif is in fault contact (fault 1 on Figure 2) with the Kedahda Formation and Horsefeed Formation limestone to the north. Although the contact dips steeply to the northeast, reliable kinematic indicators were not observed. It is possible that this fault is related to the similarly-oriented southwest-directed Nahlin fault, in which case it has thrust supracrustal rocks over the mantle, and presumably represents a second or later generation thrust. Sedimentary rocks of the Kedahda and Horsefeed formations are internally folded and are likely imbricated. Complex internal structure is apparent in outcrops, where fine-scale, commonly chaotic folding is present in chert units, and in map view, where the Horsefeed Formation limestone drastically thins to the southeast and Triassic Kedahda (?) limestone is repeated.

The southern belt of the Nakina Formation is fault bounded. The southern boundary is a moderately to steeply dipping fault similarly oriented to the Nahlin fault, and may represent a southwest-directed thrust, placing Nakina Formation basalt over the Kedahda Formation (fault 2 on Figure 2). The northern boundary is a late, brittle, northwest-striking fault separating the Nakina volcanic rocks from the Menatatuline massif ultramafic rocks to the north (fault 3 on Figure 2). The dip magnitude and direction of this fault were not observed, although based on its interaction with topography, it is interpreted to be steeply dipping.

The Menatatuline massif ultramafic rocks are thrust to the northeast over the northern belt of the Nakina Formation mafic volcanic rocks (fault 4 on Figure 2). This fault is moderately southwest dipping, and a zone of phacoidal serpentinite separates the hanging wall harzburgite from the footwall volcanic rocks (Figure 11a). A late normal fault (fault 5 on Figure 2) is suspected, based on map-pattern offsets, to run along the major south-southwest-trending drainage channel separating the Menatatuline Range on the hanging wall from Nahlin Mountain.

Peridotite Peak Area

South of Peridotite Peak, ultramafic, intrusive and volcanic rocks of the Cache Creek terrane are thrust over the Laberge Group sedimentary rocks along the Nahlin fault (fault 1 on Figure 3; Monger, 1975; Terry, 1977; Mihalynuk et al., 2003). A sliver of mafic volcanic rocks is also thrust over the Laberge Group (fault 2 on Figure 3), and is truncated by the Nahlin fault. The ultramafic rocks are interpreted to be either intruded by a subhorizontal sheet of the lower crustal intrusions, or structurally emplaced over the gabbro to quartz diorite intrusive rocks by a shallowly dipping thrust fault (Figure 11b).

North of Peridotite Peak, a sharp contact juxtaposes Nakina Formation mafic volcanic rocks and Kedahda Formation sedimentary rocks against the harzburgites of the Hardluck massif. This contact crosses topography at a high angle, suggesting a steeply dipping faulted contact (fault 3 on Figure 3). The nature of the displacement along this approximately west-trending fault is unresolved, although, as with the similar contact between the Hardluck massif ultramafic rocks and overlying Kedahda Formation in the Menatatuline Range area, it may be related to the southwest-vergent Nahlin fault and may represent a later generation thrust fault.

Economic Potential

There are several rock units within the Cache Creek terrane that are potential hosts of awaruite, gold and other base metals. The highly serpentinized ultramafic rocks throughout the Nahlin ultramafic body are prospective hosts for awaruite, a naturally occurring nickel-iron alloy. These same ultramafic rocks are the target of several ongoing projects by First Point Minerals Corporation in central and northwestern BC and southern Yukon (e.g., Rabb and Britten, 2012; Britten et al., 2014). Listwaenite, observed near diabase dikes in the harzburgite bodies throughout the Nahlin ultramafic body, has been associated with lode gold occurrences (Ash et al., 1992; Hansen et al., 2004), which have historically played a major role in the economy of the Atlin–Cassiar region. Near Peridotite Peak, the contact

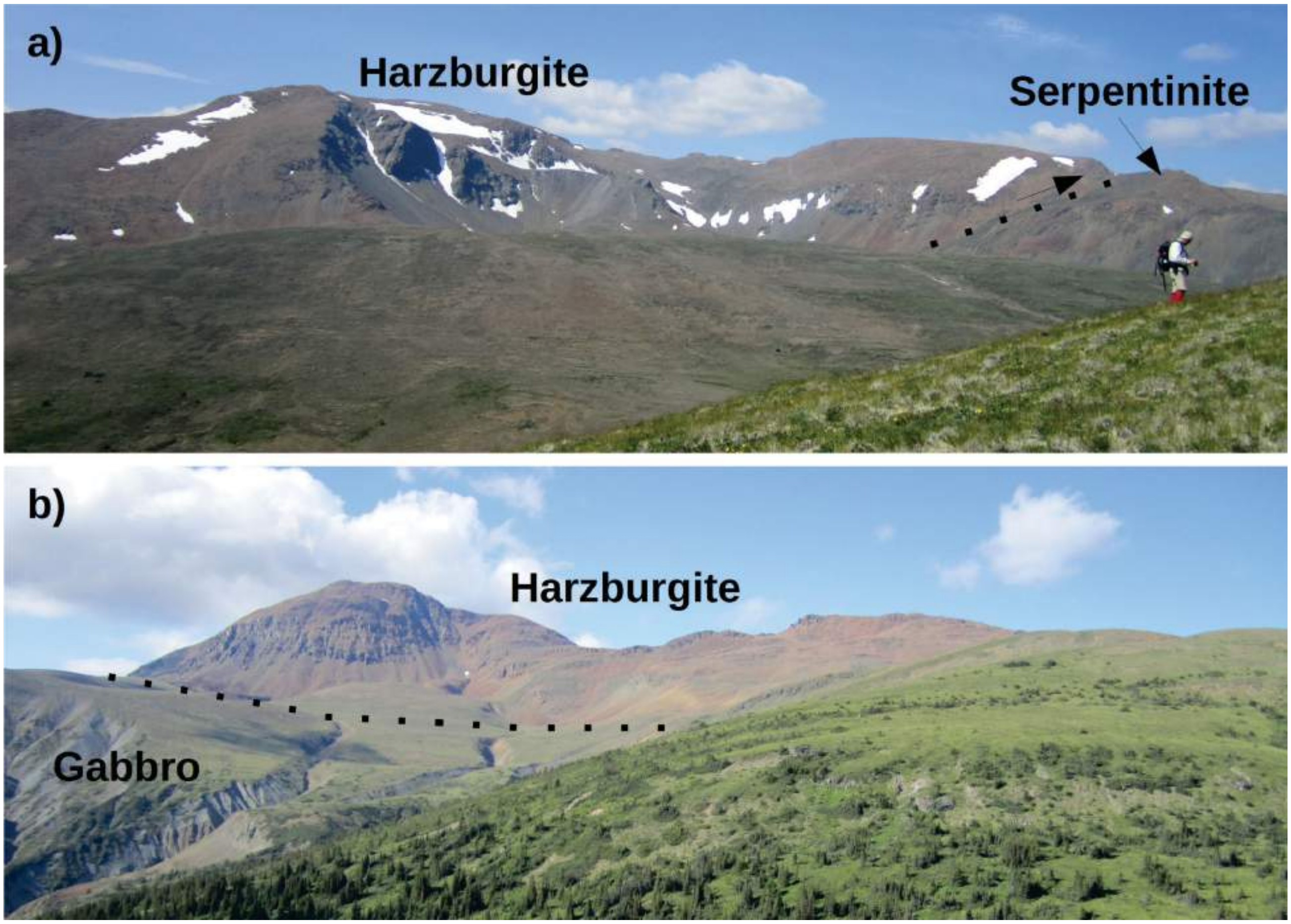

Figure 11: a) Ultramafic rocks of the Menatatuline massif thrust to the northeast over the Nakina Formation mafic volcanic rocks in the northern part of the Menatatuline Range area (fault 4 on Figure 2). View looking west-southwest. **b)** Shallow contact between ultramafic rocks on Peridotite Peak and underlying gabbroic intrusion exposed at lower elevations and along a drainage channel. The exact nature of this contact relationship is unresolved at present. View looking northwest toward Peridotite Peak.

area between the Hardluck massif and Kedahda Formation, the southern Laberge Group sedimentary rocks, and the crosscutting Sloko Group felsic volcanic rocks have been examined as potential hosts of base metals. Samples from this area yielded elevated, but not significant, concentrations of Au, Ag, Pb, Zn and Cu (Brown and Shannon, 1982; Mawer, 1988; Dynes, 1989; Mann and Newton, 2006).

Summary and Future Work

The Nahlin ultramafic body in the northern section of the Cache Creek terrane appears to conspicuously lack components of the classic Penrose-model ophiolite (Anonymous, 1972), most notably the sheeted-dike complex and significant lower crustal cumulates. However, the mantle, lower crustal and hypabyssal intrusions, and volcano-sedimentary sequences are all present, albeit structurally disrupted, within the Cache Creek terrane. The features of the Nahlin ultramafic body, including the absent sheeted-dike complex and significant supracrustal sequences, are similar to other Tethyan ophiolites that are now interpreted as oceanic-core complexes exhumed along low-angle detachments on the ocean floor (e.g., Lagabrielle et al., 2015). Future work on this project will aim to determine if this interpretation can be applied to the Nahlin ultramafic body.

Preliminary interpretations from the 2015 fieldwork indicate that although some primary contact relations may be obscured by faulting, it is still possible to work toward constraining the tectonostratigraphy of the Cache Creek terrane in this area. For example, existing biostratigraphic data can constrain ages in some chert units within the Kedahda Formation and within various carbonate units in the Cache Creek terrane (Cordey et al., 1991; Orchard et al., 2001). Radiolarian chert and fossiliferous carbonate samples collected during 2015 will provide further constraints on the ages and distribution of these units, and may elucidate the nature of some faults throughout the map areas. Results from planned geochemical analyses will provide the data necessary to test the homogeneity of the various mantle, intrusive and volcanic rocks. The geochemical relations between these, or lack thereof, will be used to re-evaluate the existing maps and interpreted tectonostratigraphy. Geochemical data will also be used in inversion modelling to yield compositions of melts in the mantle, which will be compared to compositional data from Cache Creek volcanic rocks. Uranium-lead geochronology of pegmatitic and coarse-grained gabbro and diorite samples will constrain the timing of magmatism. Additionally, mineral chemistry and the application of several geothermometers to the ultramafic rocks will aim to quantify the thermal history of the ophiolite, and interpret this in light of a possible oceanic-core complex hypothesis.

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