An alpine peridotite in the Dawson Range, Yukon-Tanana Terrane: Preliminary results and interpretations

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ABSTRACT

This report summarizes the results of geological mapping and preliminary petrological studies of an exposure of ultramafic rocks, the Buffalo Pitts Peridotite (BPP), in the eastern Dawson Range, central Yukon. The BPP is characterized by fresh spinel peridotite. Plagioclase mantles on spinel grains are interpreted to have developed during decompressive metamorphism during exhumation from sub-crustal depths to mid- to upper-crustal depths. The peridotite body forms a foliaform lens 580 m by 100 m that is enclosed in and intruded by leucocratic, biotite-garnet-corundum blue orthogneiss. The peridotite and blue corundum orthogneiss are in turn hosted in a north-dipping panel of amphibolite-grade metamorphic rocks that are included in the pericratonic Devono-Mississippian Wolverine Creek metamorphic suite, part of the Yukon-Tanana Terrane. Quartzite, quartz-mica schist and amphibolite with minor marble and calc-silicate units occur largely south of, and structurally beneath the peridotite body. Leucocratic tonalite gneiss, part of the ~357 Ma Selwyn Gneiss, occurs north of, and structurally above the BPP. Tonalite veins intrude the blue corundum orthogneiss and are interpreted as marginal intrusions of the Selwyn orthogneiss. Intrusion of dykes derived from the Selwyn Gneiss requires exhumation and emplacement of the BPP and the enclosing blue corundum orthogneiss in or prior to the earliest Mississippian.

RÉSUMÉ

Le présent sommaire décrit les résultats de cartographie géologique et d'études pétrographiques préliminaires d'un affleurement de roches ultramafiques, la Péridotite de Buffalo Pitts (PBP), dans l'est du chaînon Dawson, du centre du Yukon. La PBP est caractérisée par une péridotite à spinelle non altérée. L'examen des manteaux de plagioclases sur les grains de spinelle indique qu'ils se sont formés en cours d'un métamorphisme de décompression associé à l'exhumation de la pérodite depuis des profondeurs subcrustales jusqu'à des niveaux moyens à supérieurs de la croute. Le corps de péridotite forme une lentille foliacée de 350 m sur 40 m dans une gangue d'orthogneiss à biotite-grenat-corindon leucocrate bleu intrusif. La péridotite et l'orthogneiss à corindon bleu sont à leur tour logés dans un panneau de roches métamorphiques du faciès des amphibolites, de pendage nord, qui fait partie de la série métamorphique péricratonique de Wolverine Creek, d'âge Dévono-Mississippien, du terrane de Yukon-Tanana. Un quartzite, un schiste à quartz-mica et une amphibolite, ainsi que quelques unités de marbre et silicate calcique, se retrouvent essentiellement au sud et structuralement en-dessous du corps de péridotite. Un gneiss tonalitique leucocrate, faisant partie du gneiss de Selwyn âgé de ~357 Ma, se trouve au nord et structuralement au-dessus de la PBP. Des filons de tonalite qui pénètrent dans l'orthogneiss à corindon bleu sont considérés commes des intrusions marginales de l'orthogneiss de Selwyn. Cette relation suppose que la PBP et sa gangue d'orthogneiss à corindon bleu ont été exhumées et mises en place pendant ou avant le Mississippien précoce.

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INTRODUCTION

This paper reports on the preliminary results of 1:5000-scale geological mapping of a peridotite body and its wall rocks within the Dawson Range, central Yukon (115I/12; Fig. 1), conducted during the summer of 2000.

The ultramafic body, hereafter referred to as the Buffalo Pitts Peridotite (BPP), occurs within subdued topography in a saddle between hilltops. It forms an elongate, east-trending lens and is hosted within a distinctive, blue, corundum-bearing orthogneiss. Exposures consist of low relief surfaces that were stripped of vegetation during a 1995 forest fire, and outcrops occur atop small local rises in elevation.

Previous work in the area includes reconnaissance mapping by Cairnes (1916); local 1:15 000-scale mapping by Bostock (1936) and Johnston (1963); 1:250 000-scale mapping by Tempelman-Kluit (1984); and 1:50 000-scale mapping by Johnston and Hachey (1993a). Johnston (1995) published a 1:100 000-scale geologic compilation map of the Dawson Range. Johnston and Hachey (1993a,b) first documented the existence of the BPP; however, they interpreted the ultramafic body as an intrusion.

Situated between the Minto-Battle Fault to the south (formerly the Hootchekoo fault, Johnston, 1999) and the Yukon River to the north, the study area is underlain by predominantly Devono-Mississippian rocks of the

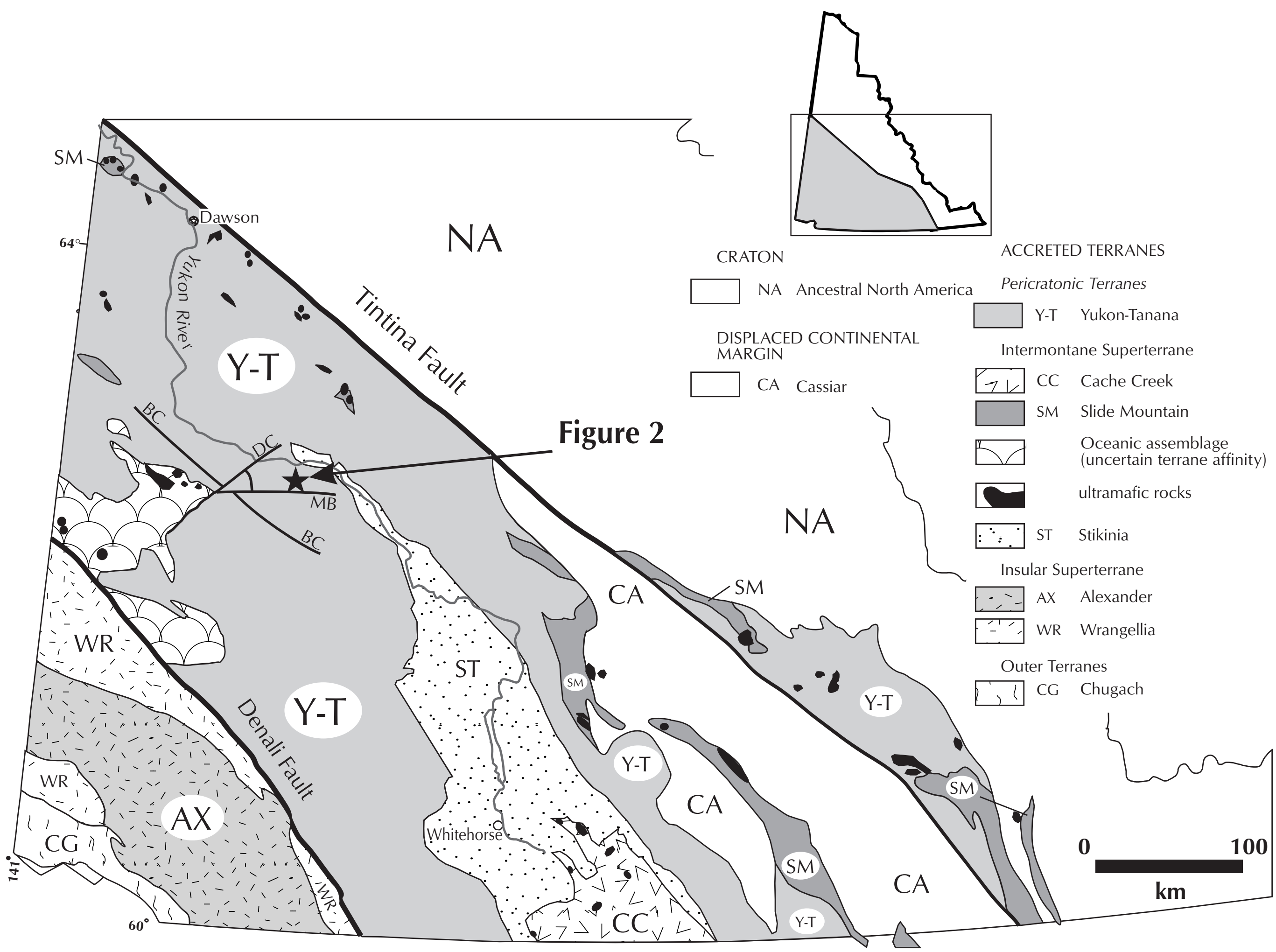

Figure 1. *Terrane map of southwestern Yukon modified from Wheeler and McFeely (1991). Ultramafic rocks indicated in black. The star marks the Buffalo Pitts Peridotite. Accreted terranes are shown in grey on a location map at upper right. Faults include the Dip Creek (DC), Big Creek (BC) and Minto-Battle (MB; after Johnston, 1999).*

Wolverine Creek metamorphic suite (Fig. 2a), part of the Yukon-Tanana Terrane. This assemblage dips regionally to the north and consists of an undifferentiated quartzite and quartz mica-schist unit, and a structurally overlying amphibolite unit. These two units locally include minor amounts of marble and calc-silicate rock, and are structurally overlain to the north by leucocratic orthogneiss, thought to be part of the Selwyn orthogneiss. The Selwyn orthogneiss forms an elongate (> 100 km long) northwest-trending body that has been interpreted as being allochthonous relative to the underlying amphibolite and quartz-mica schist (Wheeler and McFeeley, 1991). The BPP and the spatially associated corundum-bearing orthogneiss occur along the contact between the Selwyn orthogneiss and the underlying amphibolite and quartz-mica schist units. Local occurrences of gabbro and a garnetiferous greenstone are also present within this contact zone.

The following is a description of the rock units that constitute the BPP and its wall rocks, and an explanation of the relations between these units. These data are consistent with emplacement of the BPP as an alpine peridotite prior to intrusion by the plutonic protolith of the Selwyn Gneiss, and points to significant Paleozoic tectonism in the Yukon-Tanana Terrane; however much work remains to be done to confirm this interpretation.

UNIT DESCRIPTIONS

QUARTZITE / QUARTZ-MICA SCHIST

This unit consists largely of fine- to medium-grained micaceous quartzite, and subordinate quartz-mica schist, marble and calc-silicate. Quartzite is black to tan, weathers brown, orange or grey, and consists of 90% translucent quartz grains. Colour banding is common, consisting of alternating black and tan brown bands 1 to 3 cm wide, and is thought to represent primary compositional layering (Johnston and Hachey, 1993b). The black colour is thought to result from the presence of graphite. Small amounts (1 to 10 %) of fine-grained biotite, muscovite and feldspar are commonly present. Foliaform lenses of milky white quartz ranging from 1 cm to 3 m in length are common.

Buff- to brown-weathering, grey, medium- to coarse-grained, quartzofeldspathic muscovite-biotite schist occurs as layers one to tens of metres thick. The rock consists of up to 50% mica with lesser amounts of quartz and feldspar. White, medium- to coarse-grained marble occurs in the southeastern corner of the study area. The weathered surface is orange and the rock consists of 90% calcite. Other mineral constituents include quartz, feldspar, phlogopite, diopside, epidote, and garnet. Pale-green-weathering, white to green, garnet-diopside-epidote calc-silicate rock, with minor calcite occurs as lenses within marble and as isolated lenses enclosed in micaceous quartzite.

The quartzite unit is inferred to be metamorphosed clastic rocks. This is consistent with the quartzose nature of the unit, and the presence of metapelitic rocks. The quartzite and quartz-mica schist unit is intruded by blue, corundum-bearing orthogneiss, which in turn hosts rare xenoliths of quartzite.

AMPHIBOLITE

Green- to brown-weathering, black to dark green, medium- to coarse-grained amphibolite occurs as continuous and discontinuous horizons, one centimetre to tens of metres thick. Garnet and diopside are locally present. Additional components include biotite, feldspar, quartz, titanite and epidote. Chloritic alteration of hornblende and biotite is common, as is sericitic alteration of feldspar. Amphibolite occurs along contacts between orthogneiss and quartzite (Johnston and Hachey, 1993a,b). A hilltop outcrop 700 m west of the BPP constitutes a layer of amphibolite that is enclosed by quartzite. This amphibolite layer is along strike from, and is thought to be continuous with, a westward thickening layer of amphibolite found to the west of the study area which is thought to separate the quartzite and quartz-mica schist from the more northerly Selwyn orthogneiss. Amphibolite may represent metamorphosed mafic flows and dykes either the same age as, or younger than, the quartzite (Johnston and Hachey, 1993b).

SELWYN ORTHOGNEISS

Grey-weathering, grey, medium- to coarse-grained, leucocratic, equigranular hornblende-biotite quartz diorite to granodiorite gneiss is the structurally shallowest unit, and underlies the northern part of the study area. Mafic minerals commonly comprise less than 5% of the rock. Hornblende is the dominant mafic mineral. Significant amounts of biotite are locally present, imparting a schistose texture to the rock. Feldspars occur as milky white subhedral grains. Streaky grey quartz occurs interstitial to other grains.

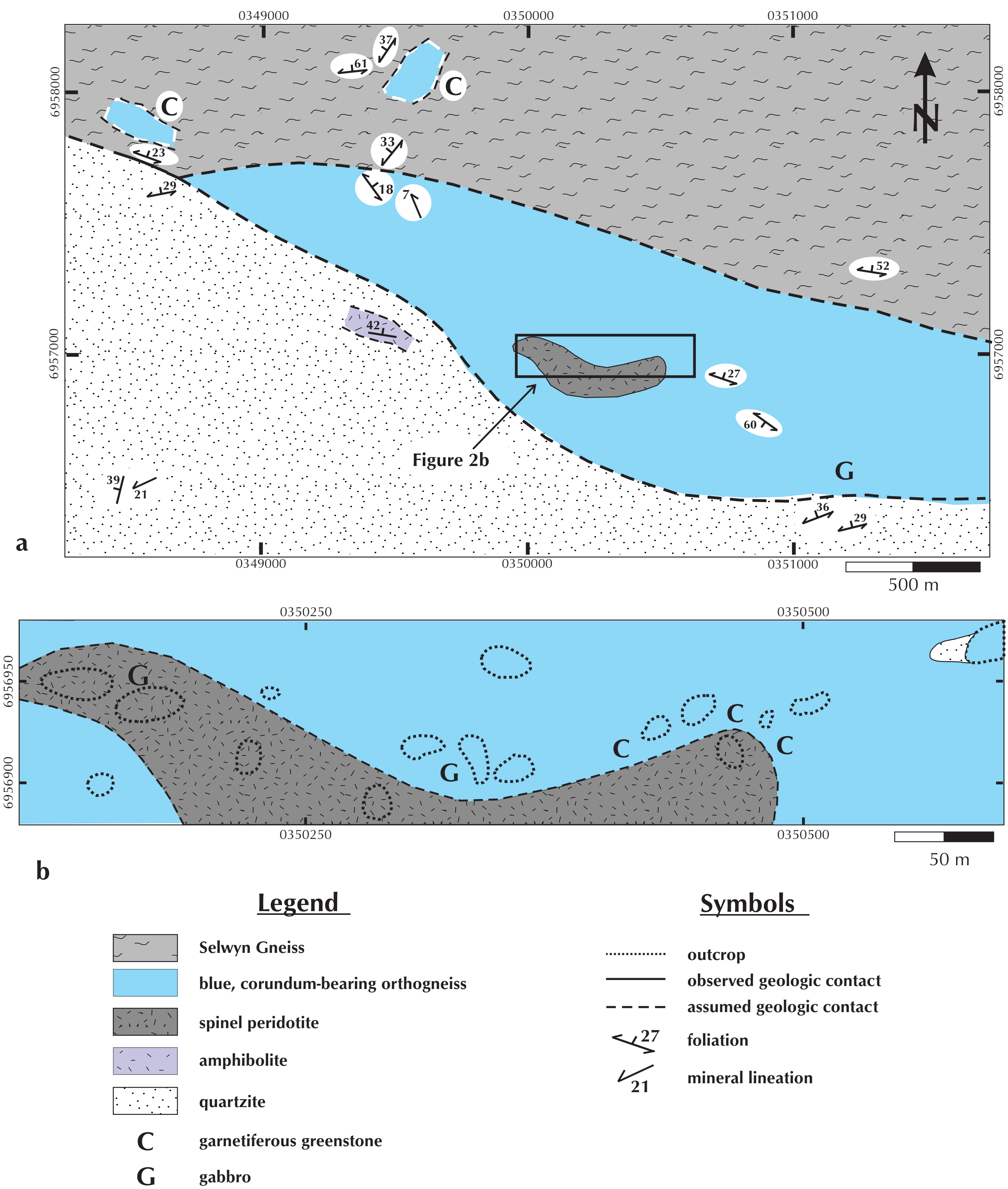

Figure 2. *Geology of the study area, the location of which is indicated in Figure 1. The Minto-Battle fault lies 1.5 km south of the study area; (a) shows the relation of the BPP to its wall rocks; (b) detailed geology of the BPP.*

The homogeneity and lithology of the gneiss is consistent with interpretation as an orthogneiss derived from an intrusion. Dykes intrude and post-date the corundum-bearing orthogneiss. A U-Pb zircon age determination of 355.4 +13.7 / -6.1 Ma for a sample of the Selwyn Gneiss collected northwest of the study area has been interpreted as the age of crystallization of the igneous protolith of the orthogneiss (Mortensen, 1986, 1992). A sample of orthogneiss thought to be correlative with the Selwyn orthogneiss from south of the study area (Johnston and Hachey, 1993b) yielded a similar U-Pb zircon age of 357.9 ± 3.5 Ma (S. Johnston and J. Mortensen, pers. comm., 1994; Johnston and Shives, 1995).

CORUNDUM-BEARING ORTHOGNEISS

A blue- to orange- to brown-weathering, blue-grey, fine- to medium-grained, leucocratic, granitic orthogneiss occurs between the Selwyn Gneiss to the north and the quartzite to the south. Isolated outcrops occur over an area 3.5 km long by 1.1 km wide, mostly in the immediate vicinity of the BPP (Fig. 2). The rock consists largely of potassium feldspar (45%), quartz (25%) and plagioclase feldspar (20%), with lesser amounts of biotite and muscovite (>2%). The presence of minor amounts of corundum (≤ 1%) imparts a remarkable blue colour to this rock. Anhedral to subhedral microcline is the dominant potash feldspar and ranges from 0.5 to 2.5 mm long, and is characterized by tartan twinning, microperthitic texture and quartz inclusions. Less abundant, 0.5- to 2.0-mm-long, anhedral to subhedral orthoclase grains with common quartz inclusions are locally present. Anhedral to subhedral plagioclase grains, 0.2 to 3 mm long, exhibit albite and Carlsbad twinning. Myrmekitic texture is common along grain boundaries with microcline and quartz. Quartz, and to a lesser extent plagioclase, exhibit a bimodal grain-size distribution, with fine-grained mosaic quartz and plagioclase forming an equigranular groundmass that forms 25% of the rock, and larger grains forming continuous bands that define a foliation (Fig. 3). Quartz grains in the groundmass consist of 5- and 6-sided grains that commonly intersect at 120° and define a polygonal, granoblastic texture (Fig. 3). Foliaform anhedral to subhedral quartz porphyroblasts range from 0.5 to 2 mm in length, and exhibit undulose extinction and sutured grain boundaries.

The groundmass includes minor amounts of muscovite, biotite, garnet, and corundum. Brown to red-brown, subhedral to euhedral biotite grains range in length from 0.3 to 1.5 mm. Colourless, subhedral to euhedral muscovite grains range from 0.1 to 0.5 mm in length and commonly grow across and at the expense of biotite. Large mica grains are commonly kinked and deformed. Irregular relic garnet grains occur within micaceous clots. Garnet is overgrown and is interpreted as being replaced by biotite grains.

Corundum occurs as blue, subhedral to euhedral blebs 0.05 to 0.3 mm long and up to 1 mm in diameter. The blue colour of some corundum is commonly attributable to trace amounts of Fe^{2+} and Ti^{4+} (Nesse, 1991; Klein and

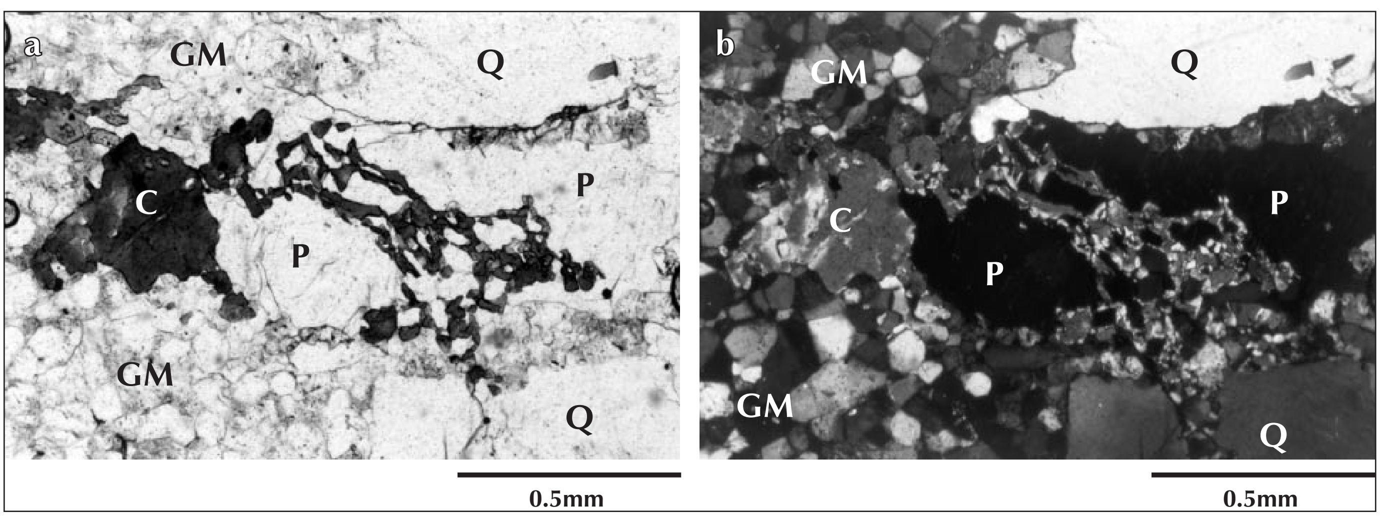

Figure 3. *Photomicrographs of blue corundum-bearing orthogneiss, (a) in plane-polarized light and (b) with crossed nicols. Quartz (Q) and plagioclase (P) megacrysts are surrounded in a predominantly quartz groundmass (GM) in which grains of corundum (C) are apparent.*

Hurlbut, 1993). The corundum appears to be developed, at least in part, at the expense of plagioclase. Rare optically continuous, relic megacrysts of plagioclase are divisible into domains separated by finely crystalline, corundum-bearing groundmass (Fig. 3). Minor retrogressive alteration of the blue orthogneiss is common. Sericite after feldspar and biotite is common, while chlorite after biotite is less common.

Garnetiferous greenstone weathers green to dun-brown, is grey-black to black, has grain sizes ranging from 0.2 to 1.5 mm in diameter, and locally consists of 50% disseminated garnet grains. Massive garnet is locally developed. Garnetiferous greenstone is intimately associated with blue corundum orthogneiss and is ubiquitous near the eastern end of the peridotite body.

Blue corundum orthogneiss intrudes quartzite, amphibolite and peridotite. Garnetiferous greenstone, thought to be the product of metasomatism and contact metamorphism of the peridotite body, is commonly developed along the margins of the blue corundum orthogneiss, and also occurs as 10- to 100-cm-long boudins and inclusions within a mortar of blue corundum orthogneiss (Fig. 4).

The blue corundum orthogneiss, together with the garnetiferous greenstone, is folded, and is locally strongly foliated to gneissic. The gneissosity consists of alternating colour intensity between normal pale grey blue, and bright blue. Dykes of leucocratic orthogneiss intrude the folded and foliated blue corundum orthogneiss. Dykes consist of 5- to 10-cm-wide grey-weathering, grey, medium- to coarse-grained, leucocratic tonalitic veins and are lithologically similar to the leucocratic tonalite gneiss that forms the bulk of the Selwyn Gneiss. These rocks contain quartz and plagioclase, with minor to trace amounts of hornblende and mica. The dykes increase in size and volume northward toward the main body of the Selwyn Gneiss. Based on their lithology and spatial association with the Selwyn Gneiss, they are interpreted as marginal intrusions of the Selwyn Gneiss.

These contact relations suggest that the blue corundum-bearing orthogneiss post-dates rocks of the Wolverine Creek metamorphic suite. If the tonalitic dykes that intrude the blue corundum orthogneiss are marginal intrusions of the Selwyn Gneiss, then the corundum-bearing orthogneiss is older than about 357 Ma, the age of the Selwyn Gneiss and correlative orthogneiss mapped to the south (Mortensen, 1986; Johnston and Shives, 1995). However, the fact that the region includes Devonian, Mississippian, Permian, Jurassic and Cretaceous granitoids requires that further work be done to verify the source of these dykes.

SPINEL PERIDOTITE

The Buffalo Pitts Peridotite outcrops near the centre of the study area forming an east-trending exposure that is 580 m long and 100 m wide. It is surrounded on all sides by blue, corundum-bearing orthogneiss (Fig. 2). Peridotite is a dun-brown-weathering, dark green to black spinel lherzolite composed of olivine (50%), orthopyroxene (25%) and clinopyroxene (< 20%). The rock is commonly fresh (Figs. 5, 6).

Rust-brown-weathering, deep green to black, anhedral to euhedral olivine range from 0.4 to 2.5 mm in diameter. Partially serpentinized grains are blue-black on a fresh

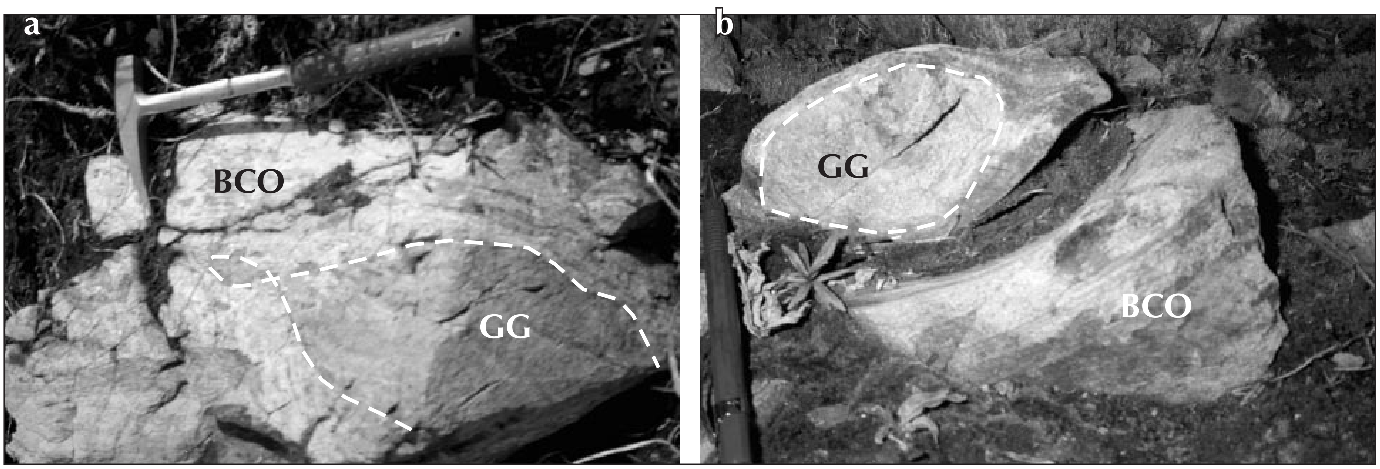

Figure 4. *(a) Garnetiferous greenstone (GG) boudin within blue corundum orthogneiss (BCO). Rock hammer is 40 cm long. (b) 12-cm-long ovoid garnetiferous greenstone (outlined by dashed line) within blue corundum orthogneiss.*

surface. Iddingsite alteration along irregular fractures is locally developed. Beige-weathering, deep green, anhedral to subhedral orthopyroxene range from 0.3 to 2.5 mm. Rare unidentified inclusions are locally present along cleavage planes. Grey-black weathering, ruby red spinel is commonly mantled by thin (< 0.5 mm), white rims thought to consist largely of plagioclase (P. Erdmer, written communication, 1993; Fig. 5). Spinel grains are typically 2 to 5 mm in diameter, being larger and more abundant in the more easterly outcrops. Rare, emerald green, fresh, anhedral to euhedral chromium diopside grains are 0.25 to 2.5 mm in diameter.

A weak, planar fabric is present and is defined by 3- to 40-mm mafic bands and <3-mm layers of spinel, plagioclase, opaques and groundmass (Fig. 6). Serpentinization is minor (< 5%). Serpentine and talc occur as thin veinlets and as rare, blue and white, veins that commonly crosscut layering at high angles. Accessory minerals include magnetite (along the margins of serpentinized olivine grains), chlorite, plagioclase and ilmenite. Alteration products include talc, serpentine and magnetite after olivine and pyroxenes, iddingsite after olivine, and uralite after pyroxenes.

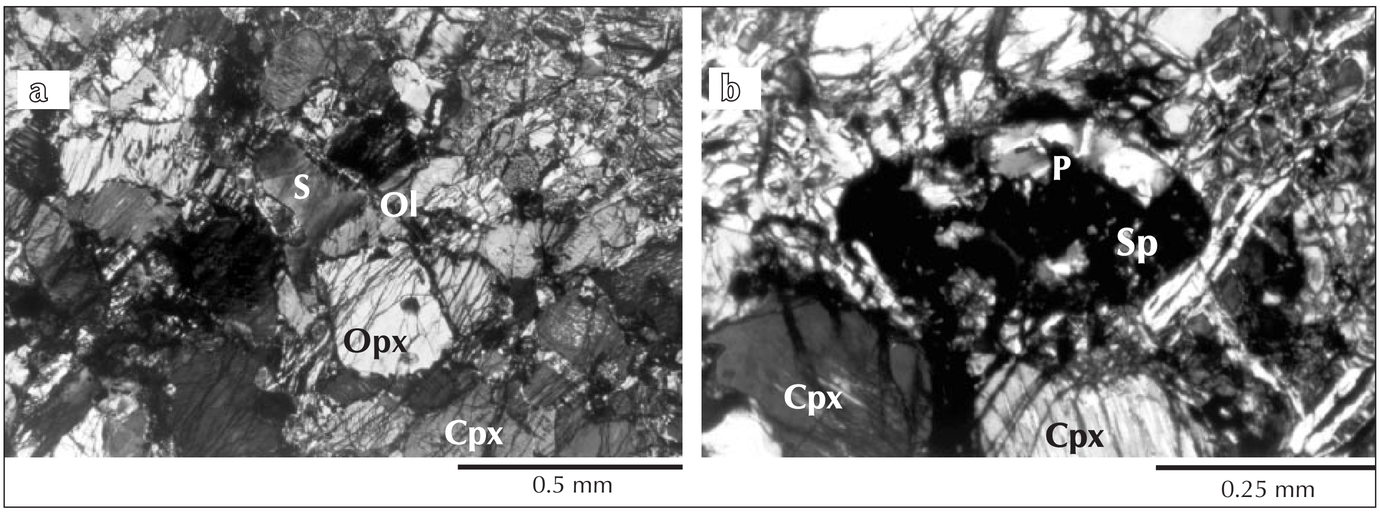

Figure 5. *Photomicrographs with crossed nicols of spinel lherzolite. (a) Orthopyroxene (Opx), olivine (Ol) and clinopyroxene (Cpx). Olivine grain at centre is partially altered to serpentine (S). (b) Spinel (Sp) grain with partial plagioclase (P) halo.*

Figure 6. *Weak planar-fabric development in peridotite (P). (a) Rare white to blue-white, 1- to 2-cm-thick serpentine (S) veins parallel fabric. (b) Subtle planar fabric within peridotite. One band is highlighted by dashed line. Rock hammer for scale.*

A 1-m-wide lens of coarse crystalline, strongly sheared to locally gneissic, gabbro was found near the western extent of the BPP. The rock contains chalky white plagioclase and grey to green pyroxenes, 3 to 5 mm long. To the southeast of the BPP, a second occurrence of gabbro exists as an isolated lens.

Corundum-bearing orthogneiss locally intrudes peridotite, suggesting that the BPP pre-dates the intrusion of the corundum-bearing orthogneiss.

STRUCTURE AND METAMORPHISM

All the units described here share the regionally developed, northwest-trending, northeast-dipping fabric (Fig.2; schistosity and compositional layering in the quartzite and quartz-mica schist; layering and mineral alignment in the amphibolite; gneissosity and foliation in the Selwyn Gneiss and the blue corundum gneiss). Weak fabric development in the peridotite is interpreted to have developed at this time, and is thought to be poorly developed due to the rheological contrast between the peridotite and its wall rocks. Rare intrafolial folds, and folds of an older foliation with axial planes parallel to the regional foliation (observed in quartzite, amphibolite and blue corundum orthogneiss), indicate that the regional fabric (S_2) developed in response to folding and transposition of an older foliation (S_1). Regional fabric development was synchronous with metamorphism, indicated by the development of foliation-parallel muscovite and biotite in the quartz-mica schist, and hornblende in the amphibolite, consistent with syn-kinematic amphibolite facies metamorphism.

Plagioclase halos developed on spinel grains in the peridotite are consistent with syn-kinematic decompressive metamorphism, with spinel breaking down to plagioclase during exhumation from sub-crustal depths, to mid- to upper-crustal levels.

Skeletal corundum ± garnet ± biotite in the corundum orthogneiss is thought to predate regional metamorphism, as these grains are overgrown by muscovite. Therefore, high-temperature metamorphism recorded in the blue corundum orthogneiss is thought to predate the regional S_2 fabric.

CONCLUSIONS

Our data are consistent with interpretation of the Buffalo Pitts Peridotite (BPP) as an alpine peridotite emplaced during the latest Devonian. The important observations are as follows:

1. The lack of zoning within the peridotite body, its mineralogy, and the evidence for decompressive metamorphism during exhumation from mantle depths indicate that the BPP is tectonically emplaced and constitutes an Alpine-type peridotite (cf. Hall, 1996; Mezger, 2000).
2. The peridotite is spatially associated with, and appears to be largely hosted within, an intrusive body. High-temperature metamorphism of this intrusive body resulted in the recrystallization of igneous minerals and the development of corundum ± garnet ± biotite.
3. The peridotite body and the blue corundum orthogneiss predate, and are intruded by, tonalitic dykes, which may be marginal intrusions of the Selwyn Gneiss. If so, this would restrict the age of emplacement of the peridotite to pre-357 Ma, which is the age of the Selwyn orthogneiss.
4. Subsequent regional deformation and syn-kinematic, amphibolite-facies metamorphism post-dated emplacement of the peridotite and intrusion by the Selwyn Gneiss.

A number of questions remain to be answered. For instance:

1. What is the nature of the relation between the blue corundum orthogneiss and the peridotite? The peridotite body appears to be entirely housed within the intrusive blue corundum orthogneiss, a rock which has not been previously documented anywhere in the Yukon-Tanana Terrane. It seems likely that emplacement and preservation of the BPP is related to this intrusive body, however, the nature of that relation remains a matter of conjecture.
2. What is the relation between regional syn-kinematic amphibolite facies metamorphism and the presence of metamorphic corundum in the blue orthogneiss? High temperatures, significantly in excess of those required to produce the regional metamorphic mineral paragenesis, are required to produce the metamorphic corundum. How this high temperature event relates to emplacement of the BPP, and to the regional metamorphism and deformation, remains to be resolved.

3. Are the tonalite dykes that intrude the blue corundum orthogneiss related to the Selwyn Gneiss? This important relation needs to be confirmed, as interpretation of the peridotite being emplaced prior to about 357 Ma is based entirely on this correlation.
4. What is the tectonic significance of the BPP? Recent studies (see results of ongoing Ancient Pacific Margin NATMAP project, Colpron and Yukon-Tanana Terrane Working Group, this volume) have demonstrated that Yukon-Tanana Terrane is characterized by a significant regional Early Mississippian tectono-magmatic event. Is emplacement of the BPP somehow related to the Early Mississippian orogenesis?

Toward addressing these questions, comprehensive petrological, geochronological and geochemical studies of the BPP and its wall rocks are being pursued. In addition to addressing these questions, these studies will provide an improved understanding of the processes responsible for the emplacement and preservation of mantle rocks within the upper crust.

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