GEOLOGY AND NOBLE METAL GEOCHEMISTRY OF THE WREDE CREEK ULTRAMAFIC COMPLEX, NORTH-CENTRAL BRITISH COLUMBIA*
(94D/9)

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INTRODUCTION

The Wrede Creek ultramafic complex is one of a series of northwesterly trending, Alaskan-type ultramafic bodies in north-central British Columbia, several of which have been described elsewhere (Nixon *et al.*, 1989a, b; 1990, this volume). The Wrede Creek ultramafite, however, is distinguished from those studied to date in the McConnell Creek and Aiken Lake map areas by anomalously high concentrations of platinum. In this respect, it is comparable to the Tulameen ultramafic complex in southern British Columbia where platinum group minerals are primarily associated with chromitites in the dunite-rich core of the complex (St. Louis *et al.*, 1986; Nixon *et al.*, 1989c).

In the past, the region surrounding the Wrede Creek complex has attracted considerable attention on account of its precious and base metal potential. The area experienced its first gold rush in 1899 with the discovery and subsequent exploitation of the McConnell Creek gold placers. Tiny platinum nuggets were reportedly found with the gold, but the placers never became as prominant a source of platinum as the rivers and creeks draining the Tulameen complex (O'Neill and Gunning, 1934; Rublee, 1986).

This report focuses on the results of geological mapping and geochemical sampling of the Wrede Creek complex completed during two weeks in July 1989. In addition, we have incorporated data, published in part by Wong *et al.* (1985), that was generated during an earlier investigation of the geology and economic potential of the ultramafic complex and its associated rocks. The reader is referred to this publication for further details concerning the geochronometry, microprobe phase chemistry and mineralization of the Wrede Creek complex.

LOCATION AND ACCESS

The Wrede Creek complex (56°40'N, 126°08'W) lies within the Ingenika Range of the Omineca Mountains, approximately 400 kilometres north-northwest of Fort St. James, and may be reached by well-travelled dirt road via Manson Creek and Germansen Landing (Figure 3-6-1). The complex is 8 kilometres north-northeast of Johanson Lake,

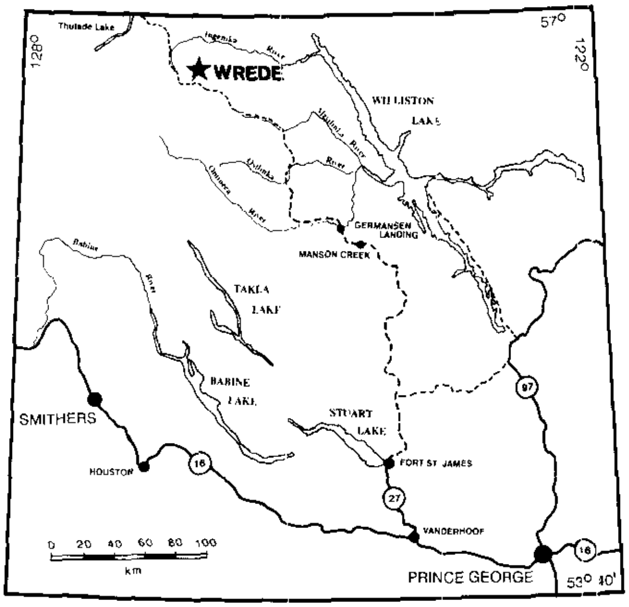

Figure 3-6-1. Location of the Wrede Creek ultramafic complex.

and is named for Wrede Creek which lies about 4 kilometres beyond its northern margin (Figure 3-6-2). The region is serviced via an airstrip at the northern end of the lake by chartered aircraft from Prince George or Smithers, or from the Sturdee airstrip some 100 kilometres to the northwest in the Toodogonne River area. Access from Johanson Lake is by helicopter, or a poorly maintained, four-wheel-drive road leading to the southernmost exposures of ultramafic rocks.

The map area is covered at a scale of 1:50 000 by NTS sheet 94D/9. Aeromagnetic survey maps are available at scales of 1:250 000 (Map 7778G-McConnell Creek) and 1:63 360 (Map 5272G-sheet 94D/9).

PREVIOUS WORK

Reconnaissance mapping (1:250 000) and geologic descriptions of the area were first completed by Lord (1948). More recently, remapping of various parts of the McConnell Creek map sheet was undertaken by Richards (1976a, b), Monger (1977) and Church (1974, 1975). These authors also describe the regional structure and stratigraphy of volcaniclastic and epiclastic rocks of the Upper Triassic Takla

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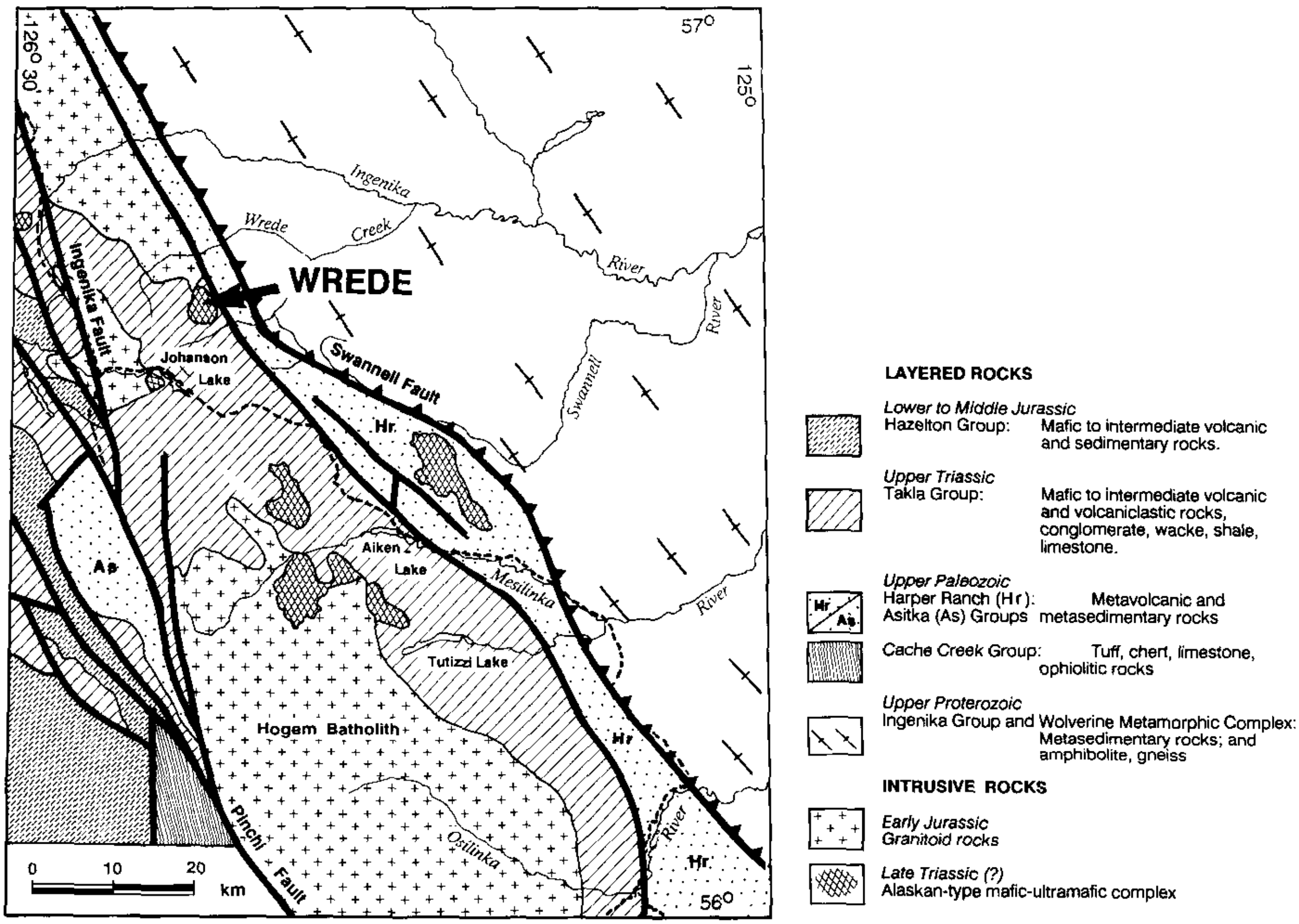

Figure 3-6-2. Regional geologic setting of the Wrede Creek ultramafic complex (modified after Irvine, 1974a; Richards, 1976b; and Monger, 1977).

Group, which hosts many of the Alaskan-type ultramafic complexes in the area (*see* also Bellefontaine and Minehan, 1988). Jurassic granitic plutonism in the region has been summarized by Woodsworth (1976) and Woodsworth *et al.* (in press). Modern studies of the Alaskan-type ultramafic complexes that occur within both the McConnell Creek and Aiken Lake map areas to the east, including the Wrede Creek complex, were made by Irvine (1974a; 1976). Wong *et al.* (1985) and Irvine (1976) presented the most detailed descriptions of the ultramafic complex.

REGIONAL GEOLOGY AND GEOCHRONOMETRY

The Wrede Creek ultramafic complex intrudes volcanic and volcaniclastic rocks of the Upper Triassic Takla Group that forms part of Quesnellia (Figure 3-6-2), one of several tectonostratigraphic terranes that make up the Intermontane Superterrane. To the west, the boundary between Quesnellia and the Stikine Terrane of the Intermontane Belt is tentatively delineated by the Pinchi-Ingenika dextral fault system (Wheeler *et al.*, 1988). Type sections for the Takla Group, as presented by Monger (1977) and Monger and Church (1977), are exposed west of the Ingenika fault in Stikinia, as is one of the Alaskan-type intrusions in this region, the Menard Creek complex (Nixon *et al.*, 1989b). East of the Wrede complex, a high-angle fault separates these supracrustal volcanosedimentary sequences from a tectonic sliver of rocks assigned to the Upper Paleozoic Lay Range assemblage (Richards, 1976a, b; Monger, 1977). This assemblage has recently been correlated with the Harper Ranch Group which forms the basement of Quesnellia in southern British Columbia (Wheeler and McFeely, 1987; Monger *et al.*, in press). Quesnellia is separated from pericratonic rocks of the Ingenika Group by the Swannell fault, an imbricated thrust zone with evidence of southwesterly tectonic transport (Bellefontaine, 1989). Deformation likely occurred in the Mesozoic, during collision of the Intermontane Superterrane with the North American miogeocline (Gabrielse and Yorath, in press).

The Takla Group west of the Ingenika-Pinchi fault boundary is little metamorphosed whereas correlative rocks to the east are characterized by greenschist-grade assemblages (Richards, 1976a, b; Monger, 1977). The predominant structural grain in the region is northwesterly. The main lithologies in the Ingenika Range west of the Wrede Creek complex include mafic to intermediate, plagioclase and augite-phyric volcaniclastic and epiclastic rocks, subaqueous and minor subaerial lava flows, and interbedded black argillites, siltstones, sandstones and minor limestones (Bellefontaine and Minehan, 1988).

Alaskan-type ultramafic complexes in the McConnell Creek and Aiken Lake areas have been considered to be coeval and comagmatic with Late Triassic volcanic rocks of the Takla Group (Irvine, 1974a, 1976). Potassium-argon dating of two hornblende mineral separates from feldspathic pegmatites in the Wrede Creek complex appear to confirm this supposition, yielding Late Triassic isotopic ages of 219 ± 10 ($1\ \sigma$) and 225 ± 8 Ma (Wong *et al.*, 1985).

Granitoid rocks intrude both the Takla Group and Wrede Creek ultramafic rocks. Potassium-argon dating of hornblende has established a Middle Jurassic age of 172 ± 6 ($1\ \sigma$) Ma for these intrusions in the Wrede Creek complex (Wong *et al.*,1985). This is compatible with K-Ar dates on hornblende from plutons comprising part of the Hogem batholith to the south (*e.g.* the Duckling Creek syenite dated at 171 ± 6 ($1\ \sigma$) Ma; Eadie, 1976). The Fleet Peak pluton, a diorite to monzodiorite body northwest of the Wrede Creek complex (Woodsworth, 1976), has yielded K-Ar dates on hornblende and biotite of 144 ± 8 ($2\ \sigma$) Ma and 156 ± 5 Ma respectively (Wanless *et al.*, 1979). This pluton apparently belongs to the Three Sisters suite of predominantly calcalkaline intrusions that are well represented in the Stikine arch to the northwest of the project area (Woodsworth *et al.*, in press).

COUNTRY ROCKS: TAKLA GROUP

The Wrede Creek ultramafic complex lies within the predominantly subaqueous eastern facies of the Takla Group (Richards, 1976a, b). Adjacent to the complex, rocks of the Takla Group are predominantly brown to grey weathering, medium grey-green and dark grey augite and augite-plagioclase crystal tuffs, flows and volcanic breccias. These rocks are characterized by euhedral to subhedral black augite crystals up to 1 centimetre in diameter, and white to pale green, variably saussuritized plagioclase laths up to 5 millimetres in length. In thin section, clinopyroxene is observed to be completely pseudomorphed by actinolite, or at least partially altered to this mineral at crystal margins and along cleavages. Plagioclase is partially to completely altered to sericite, epidote and carbonate. Actinolite is also abundant within the fine-grained groundmass and locally takes on a weak preferred orientation. These mineral assemblages indicate a regional metamorphism of upper greenschist grade.

WREDE CREEK ULTRAMAFIC COMPLEX

In common with certain other Alaskan-type intrusions (*e.g.* Duke Island; Irvine, 1974b), the Wrede Creek ultramafic complex exhibits a rude concentric zonation of rock types that is marked by a complete gradation from ultramafic lithologies in the core to mafic phases at the margins (Figure 3-6-3). Dunite in the central part of the body grades outwards through a narrow wehrlitic transition zone into olivine clinopyroxenite and clinopyroxenite, and these units ultimately pass into hornblende-rich gabbroic rocks at the periphery of the complex. Olivine-hornblende and hornblende clinopyroxenites are present, at least locally, between clinopyroxenitic rocks and gabbroic rocks with minor hornblendite.

The complex underlies an area of approximately 10 square kilometres. The dunite core is well exposed along the crest of a northwesterly trending ridge, whereas outcrops of other map units lower down on the flanks of the ridge are much more limited and exposure in valleys is poor. In a region of little outcrop at the eastern margin of the body, the position of the contact between the ultramafite and country rocks has been estimated from the aeromagnetic map. The geometry of the intrusion is poorly constrained, but based on a limited number of short diamond-drill holes at the southern margin of the complex (Wong *et al.*, 1985), the body may represent a high-level intrusive stock.

DUNITE

Dunite (5 square kilometres) forms the dominant lithology of the Wrede Creek complex and is well exposed along a major northwesterly trending ridge at the centre of the map area. On weathered surfaces, dunite is characteristically orange-brown, yellow-orange or buff, and contains disseminated, variably magnetic, euhedral to subhedral chromite crystals (up to 1 millimetre in diameter) that weather with positive relief. The rock is generally medium grained and consists of black, glassy olivine crystals with minor chromite (1 to 5 per cent); fine-grained varieties are dark-grey.

Thin section analysis of dunite reveals an equigranular texture, or rare inequigranular fabric in which small olivine crystals (0.5 to 1 millimetre) comprising up to 80 per cent of the rock are interstitial to, and poikilitically enclosed within, coarse olivine crystals (up to 5 millimetres across). Clinopyroxene was not observed within the dunite except at the gradational contact between dunite and clinopyroxenite (well exposed at Locality 5, Figure 3-6-3). The black colour of the olivine crystals is attributed to an abundance of tiny, opaque, rod-like inclusions which range from 2 to 5 microns in length, which are evenly distributed throughout the crystal and have a preferred orientation which is crystallographically controlled. Attempts to establish the composition of these inclusions by microprobe analysis have been unsuccessful but we believe that they are an exsolution phenomenon related to oxidation during slow cooling of the dunite. The lack of these inclusions within dunite dikes which cut the dunite body suggests the diking postdates this oxidation stage.

Microfractures are prominent along crystal boundaries and within crystals, and have acted as loci for serpentinization. On average, olivine is approximately 5 per cent serpentinized, but the degree of alteration varies widely, ranging from thin envelopes surrounding microfractures, to complete serpentinization, particularly in samples collected near brittle shear zones. Altered areas are composed of antigorite, secondary magnetite, and minor brucite, talc and carbonate.

Tabular zones of bright orange weathering, medium green-grey, carbonate-quartz alteration are common throughout the dunite. Such zones are composed mainly of ankerite and minor magnesite, and have abundant closely spaced, white

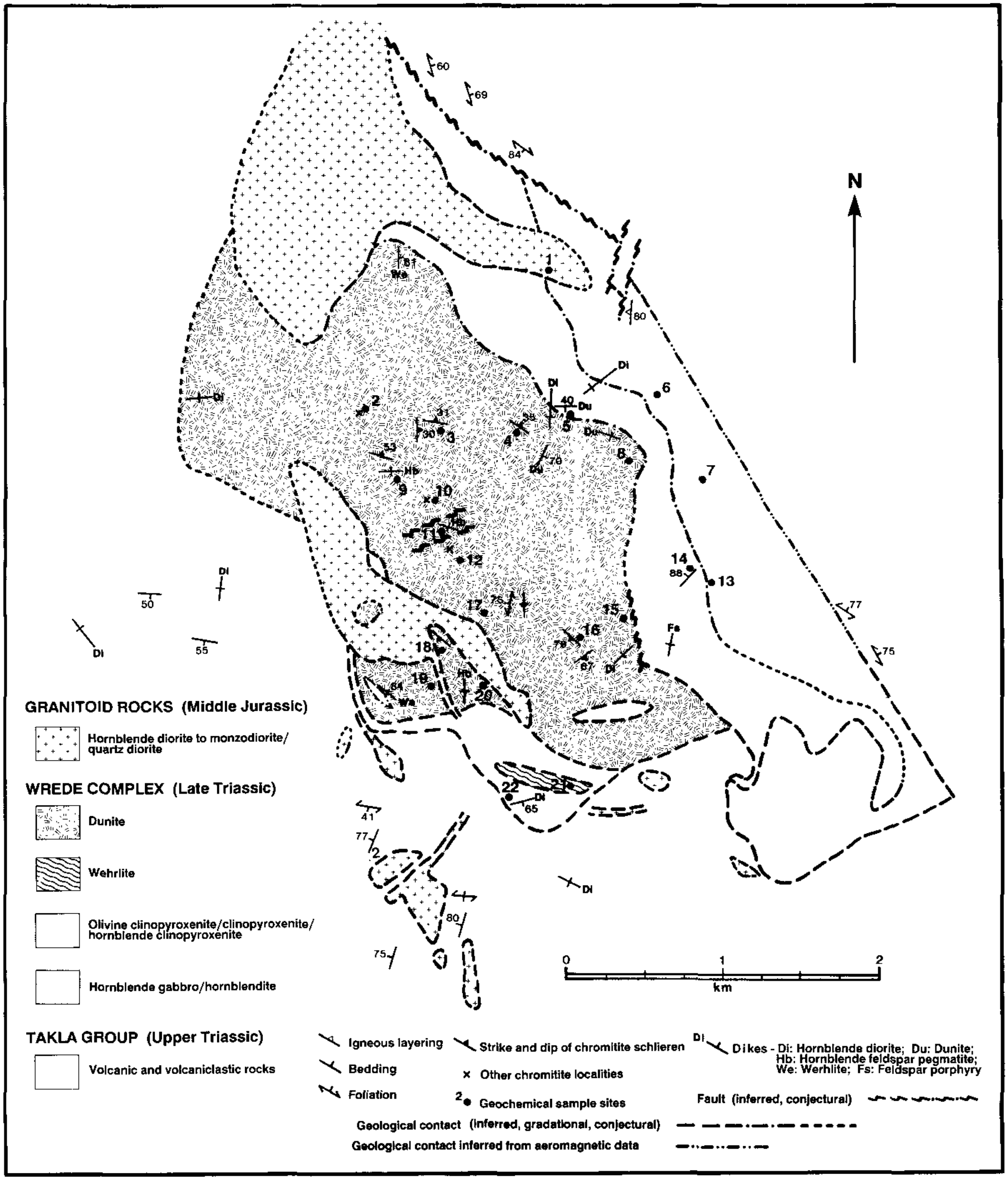

Figure 3-6-3. Generalized geology of the Wrede Creek ultramafic complex. Numbered locations represent geochemical sample sites listed in Table 3-6-1.

chalcedony veins which are commonly folded (Plate 3-6-1). Minor disseminated bornite and pyrite were observed in one of these zones at the southwestern end of the dunite outcrop (Locality 19, Figure 3-6-3). The alteration most likely occurs along faults, which possibly serve as channelways for the same fluids which introduced the sulphides so prevalent at the southern end of the complex (discussed below).

Microprobe analyses of olivines in the dunite indicate forsteritic compositions in the range of Fo_{88} to Fo_{92}. These analyses represent samples collected along an east-west traverse across the dunite core and provide little evidence of compositional zoning with respect to distance from the clinopyroxenitic rocks nearer the margin of the intrusion.

Plate 3-6-1. Quartz-carbonate alteration in dunite showing folded chalcedony veins in outcrops approximately 300 metres south of Locality 5 in Figure 3-6-3.

CHROMITITE

Although chromite is ubiquitous as tiny euhedral crystals in dunite, it is concentrated locally into irregular pods and schlieren. Chromitite schlieren range from 0.1 to 5 centimetres in width and between 5 and 40 centimetres in length; most are less than 1centimetre wide and 15 centimetres long. The schlieren are found as isolated occurrences within the dunite, or more commonly in clusters forming chromitite-rich zones several metres in width (Plate 3-6-2, Locality 2 in Figure 3-6-3). It is common to find schlieren in various orientations within a single outcrop, indicating some degree of remobilization of previously consolidated chromite cumulates. However, in rocks that exhibit a penetrative foliation (*e.g.* Localities 16 and 18) schlieren are usually oriented in the plane of the fabric.

There appears to be no structural control reflected in the spatial distribution of chromitite-rich zones, most of which are separated by broad expanses of chromitite-free dunite. Chromitite schlieren appear to be absent within 200 metres of the dunite/clinopyroxenite contact, but this may be due to more limited outcrop in this part of the complex.

CLINOPYROXENITES

The clinopyroxenite unit includes olivine clinopyroxenite, clinopyroxenite, olivine-hornblende clinopyroxenite, and

Plate 3-6-2. Zone of chromitite pods and schlieren at Locality 2 in Figure 3-6-3.

hornblende clinopyroxenite. These lithologies typically form a complete gradation from olivine-rich phases adjacent to the dunite contact to hornblende-rich phases adjacent to the gabbro-hornblendite contact.

Clinopyroxenites form a semicontinuous rim around the dunite core of the complex (Figure 3-6-3). The width of the clinopyroxenite unit varies from 50 metres at the southwestern end, to 900 metres at the northern end of the complex. Along the eastern margin, clinopyroxenites are in gradational contact with clinopyroxene hornblendite and hornblende ± clinopyroxene gabbro. To the south, clinopyroxenites intrude hornfelsed volcanic rocks of the Takla Group.

OLIVINE CLINOPYROXENITE AND CLINOPYROXENITE

Olivine clinopyroxenite and clinopyroxenite are usually coarse grained, and composed of medium brown-green weathering, pale green, cumulus clinopyroxene and brown-weathering, black cumulus to intercumulus olivine. Olivine clinopyroxenite contains an average of approximately 30 per cent olivine, but modal variations range from 10 to 40 per cent. The modal abundance of olivine in clinopyroxenite averages about 5 per cent, but may vary between 0 and 10 per cent.

Olivine clinopyroxenite is most common near the dunite contact where it forms part of the gradation from dunite to clinopyroxenite. Locally, olivine forms up to 50 per cent of the rock, which is more appropriately termed wehrlite. The olivine clinopyroxenite unit varies in width from approximately 2 metres at the eastern margin of the dunite body (approximately 200 metres south of Locality 8 in Figure 3-6-3), to 250 metres at the southwestern edge of the dunite (100 metres south of Locality 20) where it is in intrusive contact with hornfelsed hostrock.

Clinopyroxenite is well exposed in the eastern part of the complex, where it is sandwiched between olivine clinopyroxenite to the west, and hornblende-bearing clinopyroxenite to the east. The clinopyroxenite zone varies in thickness from approximately 100 to 200 metres.

In thin section, equigranular clinopyroxene (0.5 to 6 millimetres in diameter) exhibits cumulus textures, and olivine occurs as cumulus and intercumulus crystals and equigranular crystal clots which range from 0.5 to 1 millimetre across. Olivine is partially to completely serpentinized. Euhedral to subhedral chromite (0.5 to 1 millimetre) makes up less than 1 per cent of the rock.

Microprobe analyses of clinopyroxene from olivine clinopyroxenite yield diopsidic compositions with relatively low alumina (1.5 to 2.6 weight per cent); olivine compositions range from Fo_{83} to Fo_{86}. Clinopyroxenes in clinopyroxenite are also diopsidic with 1 to 3 weight per cent alumina. These mineral compositions fall within the general range of silicate compositions in equivalent rock types in the Tulameen complex (Findlay, 1969; Nixon *et al.*, 1989c).

HORNBLENDE CLINOPYROXENITE AND OLIVINE-HORNBLENDE CLINOPYROXENITE

Hornblende clinopyroxenite is most extensive at the northern end of the complex where it reaches an apparent thickness of approximately 500 metres. In some exposures in the eastern part of the complex (100 metres west of Locality 6, Figure 3-6-3), a complete gradation between clinopyroxenite and hornblende-bearing clinopyroxenite is observed. In this area hornblende-bearing clinopyroxenite averages between 50 and 150 metres in width and grades into gabbro and hornblendite to the east.

Hornblende clinopyroxenite is medium brown weathering, and comprises about 20 to 50 per cent black hornblende and 50 to 80 per cent dark green clinopyroxene. Three main types are observed: a variety containing euhedral, cumulate hornblende crystals (up to 2 centimetres in length) surrounded by smaller grains (2 millimetres) of cumulus to intercumulus clinopyroxene; a coarse-grained variety comprising large crystals (1.5 centimetres) of cumulus clinopyroxene partially enclosed by intercumulus hornblende (1.5 centimetres); an equigranular coarse-grained variant of the second type with large (2 centimetres) interlocking crystals of subhedral cumulus hornblende and clinopyroxene. Locally, plagioclase appears as an intercumulus phase forming up to 5 per cent of the rock. A significant amount of both primary and secondary magnetite has made these hornblende-bearing lithologies very strongly magnetic.

Thin section analysis of hornblende clinopyroxenite reveals fresh, pale brown pleochroic hornblende and unaltered clinopyroxene. Magnetite forms up to 2 per cent of the mode and occurs as small euhedra (0.1 to 1 millimetre) disseminated throughout the rock. Apatite (less than 1 per cent) occurs as an accessory phase.

Olivine within olivine-bearing hornblende clinopyroxenite was recognized only in thin section. Where present [*e.g.* near Locality 13, and in a drillhole at the southern end of the complex (Wong *et al.*, 1985)] it may form up to 10 or 15 per cent of the rock. Typically it occurs as small (0.5 to 1 millimetre) subhedral crystals completely pseudomorphed by amphibole (cummingtonite) and magnetite and poikolitically enclosed by clinopyroxene and hornblende.

HORNBLENDE GABBRO AND HORNBLENDITE

The hornblende gabbro/hornblendite map unit includes rocks that contain variable proportions of hornblende, plagioclase and clinopyroxene, and that locally weather white to black depending on the modal abundance of feldspar. This unit occupies some 3.5 square kilometres at the eastern and southeastern periphery of the complex. Outcrop is sparse, particularly along the eastern margin of the body, and thus contact relationships are rarely seen. It appears, however, that gabbroic rocks are invariably in contact with pyroxenitic rocks toward the core of the complex, and in contact with country rocks externally. Where the contact between gabbroic and pyroxenite rocks is observed (near Localities 6 and 7), it is gradational over a few metres. This contact is typified by a decrease in clinopyroxene and an increase in plagioclase as the gabbroic unit is approached. An intrusive contact between gabbroic rocks and country rocks is observed in a stream-cut approximately 500 metres east of Locality 1. Here, both the main gabbro body and numerous gabbroic dikes intrude country rocks that have been metamorphosed to lower amphibolite grade by contact metamorphism (discussed below). Also at this locality, excellent examples of primary, centimetre-scale, rythmic layering are found within the hornblende gabbro. This texture is formed by modal variations in plagioclase and hornblende which form practically monomineralic layers from 2 millimetres to 2 centimetres thick (Plate 3-6-3).

Gabbroic rocks generally contain 10 to 40 per cent white to pale green, variably saussuritized plagioclase and euhedral to subhedral hornblende with cumulus to intercumulus textures. Locally, dark green cumulate clinopyroxene forms up to 30 per cent of the rock. Hornblendites typically have less than 5 per cent white to pale green feldspar interstitial to large (up to 2 centimetres) cumulus hornblende. In places, these rocks enclose pods of feldspathic clinopyroxene hornblendite with up to 50 per cent dark green clinopyroxene.

In thin section, the gabbroic rocks are seen to be intensely altered. Pale green, pleochroic hornblende is locally altered

Plate 3-6-3. Magmatic, centimetre-scale layering in hornblende gabbro in a stream cut approximately 500 metres east of Locality 1 in Figure 3-6-3.

to chlorite, clinopyroxenes are partially to completely transformed to uralite, and plagioclase is almost completely saussuritized. Plagioclase relicts with albite twinning are observed rarely. Minor phases include euhedral magnetite (up to 3 per cent) and apatite (1 per cent) with cumulate textures. Epidote is found as euhedral crystals in open-space fillings as well as in granular aggregates forming part of the plagioclase alteration.

MINOR INTRUSIONS

Minor intrusions within the complex include dikes of dunite, wehrlite, olivine clinopyroxenite and hornblende-plagioclase pegmatite. These dikes are mineralogically identical to the main lithologic units of the Wrede Creek complex, which they intrude, and appear to be rooted entirely within the complex.

Ultramafic dikes composed of dunite, wehrlite and olivine clinopyroxenite, averaging approximately 10 centimetres in width, are found throughout the dunite body, but appear to be most common near the dunite-clinopyroxenite contact. Dunite and olivine wehrlite dikes that intrude olivine clinopyroxenite near the dunite-clinopyroxenite contact are particularly well exposed at Locality 5, and locally incorporate xenoliths of clinopyroxenite wallrocks. Also at this locality, olivine clinopyroxenite dikes cut earlier dikes of olivine wehrlite, attesting to a rather complex crystallization history. In areas where these dikes occur in a high concentration (*e.g.* Locality 5), there is a resemblance to the wehrlitic/clinopyroxenitic mixed units described from the Polaris ultramafic complex (Nixon *et al.*, 1990).

In thin section, dunite dikes are seen to be composed of equigranular olivine crystals (0.5 millimetre) which poikilitically enclose smaller grains (less than 0.1 millimetre) of subhedral chromite that locally form up to 5 per cent of the rock. Olivine is variably serpentinized along closely spaced microfractures.

In olivine clinopyroxenite dikes, olivine occurs as glomerocrystic aggregates (0.5 millimetre) and as single crystals poikolitically enclosed by large clinopyroxenes (up to 2 centimetres in diameter). Olivine is typically completely serpentinized. In olivine clinopyroxenite dikes near the dunite-clinopyroxenite contact at Locality 5, olivine crystals appear to be entirely cumulate in origin, whereas olivine crystals in the host clinopyroxenite have both cumulate and intercumulate textures.

Buff-white weathering, hornblende plagioclase dikes with pegmatitic textures range from 1 to 5 metres wide and appear restricted to the dunite. They are characterized by fresh, euhedral, black hornblende crystals that measure up to 20 centimetres long and form 5 to 80 per cent of the rock. Pale greenish white, variably saussuritized plagioclase forms the remainder of the rock, together with accessory opaque oxides, apatite and sphene. Contacts between the pegmatite dikes and the dunite are everywhere sharp. As noted earlier, hornblende separates from two of these dikes gave Middle Jurassic K-Ar isotopic dates.

CONTACT AUREOLE

Metamorphism associated with intrusion of the Wrede Creek ultramafic complex is reflected in an amphibolitic contact aureole developed in volcanic rocks of the Takla Group. The aureole is variable in width but is most extensive at the southern end of the complex where it is up to 400 metres wide. Sparse outcrop along the eastern margin of the complex shows some evidence of contact metamorphism, although the aureole does not appear to be as extensive as that to the south. Drillhole data from the southern end of the complex suggest that the contact between country rock and ultramafite dips gently to the south (Wong *et al.*, 1985). The relatively wide metamorphic aureole in this area may therefore be the surface expression of a contact at shallow depth.

In hand sample, hornblende hornfels is dark grey to black and fine grained. White-weathering subhedral feldspar and rare euhedral augite pseudomorphs help to distinguish this rock as a part of the hostrock suite. In thin section, pleochroic green to blue-green hornblende or actinolitic hornblende crystals reach 1 millimetre in length and comprises 50 to 75 per cent of the rock. The matrix comprises fine-grained granoblastic feldspar, acicular actinolite and opaque oxides. Actinolitic amphibole probably formed, in part, at the expense of hornblende as a retrograde assemblage during regional greenschist facies metamorphism.

GRANITOID INTRUSIONS

Quartz monzonite, monzonite, quartz diorite and diorite dikes of Middle to possibly Late Jurassic age intrude both the Wrede Creek complex and its hostrocks. These dikes vary from 2 to 250 metres wide and do not appear to have a preferred orientation.

Granitoid rocks in the area weather a distinctive buff-white and are white on a fresh surfaces. Typically they are medium grained and equigranular, however, a porphyritic texture is developed locally. In hand sample, black hornblende (0 to 35 per cent) occurs as euhedral to subhedral laths up to 5 millimetres long. Plagioclase forms euhedral to subhedral white to pale green crystals. Potassium feldspar and quartz form very fine grained (less than 1 millimetre), white anhedral crystals which are easily overlooked in hand sample.

Thin sections of the granitoid intrusions reveal zoning of plagioclase in some samples, particularly in plagioclase-porphyritic varieties. Plagioclase is moderately to highly sausseritized and hornblende is commonly completely pseudomorphed by chlorite, epidote and calcite, although some relatively fresh varieties were found which have a pale green pleochroism. Where quartz and potassium feldspar are observed, they are unaltered and are interstitial to hornblende and plagioclase. All minerals are overprinted with very fine acicular actinolite which probably formed during upper greenshist grade regional metamorphism.

The southern terminus of the Fleet Peak pluton, which, based on K-Ar dates detailed earlier, is latest Jurassic in age (Wanless *et al.*, 1979), lies approximately 3 kilometres to the north of the Wrede complex. This pluton is the southernmost extension of the predominantly Middle Jurassic Three Sisters plutonic suite (Woodsworth *et al.*, in press). Accordingly, the granitoid intrusions in the vicinity of the Wrede Creek complex are provisionally assigned to the calcalkaline Three Sisters suite.

STRUCTURE AND METAMORPHISM

Regionally, faulting is the dominant deformation mechanism within rocks of the Takla Group (Richards, 1976b; Monger, 1977). Folds have been observed only in the less competent lithologies, so that the attitude of primary layering within the Takla Group is presumably caused by rotation on block faults. Our limited structural observations in the vicinity of the Wrede complex shed no light on this supposition.

Faulting is common within the Wrede Creek complex, its country rocks and at the contact between them. Typically faults are manifest as zones of foliated rock from 1 to 20 metres wide. A well-developed shear foliation parallels the northern margin of the complex and appears offset by crossfaults in the south. The linear eastern boundary of the complex, inferred from aeromagnetic data, may represent a fault boundary. Northwesterly trending faults occur just beyond the western and eastern margins of the complex (Wong *et al.*, 1985). As discussed above, a well-developed contact aureole in hostrocks at the southern perimeter of the complex provides strong evidence for an intrusive contact. The grade of regional metamorphism outside this aureole attained upper greenschist facies, and promoted the formation of a relatively inconspicuous retrograde assemblage within the contact aureole.

ECONOMIC GEOLOGY

The Wrede ultramafic complex is associated with two unrelated types of mineralization. Most extensively explored is a porphyry-style sulphide mineralization at the southern end of the complex which contains anomalous copper and molybdenum. The second type of mineralization, realized in this study, is platinum enrichment within chromitite layers in the ultramafic rocks.

SULPHIDES

Wong *et al.* (1985) have described sulphide mineralization at the southern end of the complex. The sulphides are hosted by dioritic to granitic dikes which cut the complex, and also occur in the Takla Group and some pyroxenitic rocks adjacent to the contact. Mineralization is expressed as disseminations and fracture fillings of pyrite, chalcopyrite, molybdenite and bornite. The mineralized areas are covered by the NIK 1 to 9 claims which were staked in 1976 and explored by BP Minerals Limited. Exploration of the area included 1:5000-scale geologic mapping, geochemical sampling of soils, stream sediments and rock chips, magnetometer and induced polarization surveys, 2550 metres of trenching, 3050 metres of percussion drilling and 3100 metres of diamond drilling. Multi-element analysis of soils (Hoffman and Wong, 1986) delineated zones with anomalous copper and molybdenum. The most extensive sulphide mineralization was found within clinopyroxenite and hornfelsed country rocks at the southern contact of the intrusion. The sulphide mineralization appears to be structurally controlled and is most likely related to Jurassic granitoid plutonism.

Locally, disseminated bornite and pyrite are found in quartz-carbonate alteration zones within the dunite. The planar nature of these zones suggest that they are alteration envelopes surrounding faults. Here again, these zones may be formed by hydrothermal fluids with metal concentrations bearing the signature of nearby granitoid plutonism.

CHROMITE AND PLATINUM

Chromite is restricted to, and locally abundant in, the dunite core of the intrusion where it forms disseminations, pods and schlieren. The main chromitite outcrops, however, lack surface continuity but have not been tested at depth. Geochemical analyses (discussed below) indicate that these chromitites are significantly enriched in platinum. Platiniferous chromitites are now well known in other Alaskan-type bodies in British Columbia, notably the Tulameen complex (*e.g.* Nixon *et al.*, 1989c).

NOBLE METAL GEOCHEMISTRY

Analytical results for gold, platinum, palladium and rhodium in 29 lithogeochemical samples of the Wrede Creek ultramafic complex are presented in Table 3-6-1. Sample localities are shown in Figure 3-6-3. All analyses were done by inductively coupled plasma emission spectrometry at Acme Analytical Laboratories, Vancouver. Accuracy was checked by in-house standards, and analytical precision (and any nugget effect) monitored by hidden duplicates and internal standards. The noble metals were preconcentrated by fire assay from 30 gram aliquots of 200 grams of rock powder (-200 mesh).

Chromitite horizons in the core of the Wrede Creek complex are markedly enriched in platinum. Five samples of relatively high-grade chromitite ran between 120 and 2400 ppb platinum. Some of these samples also have significant abundances of rhodium; all are characterized by high platinum:palladium ratios, and one (Locality 10, Figure 3-6-3) contains some gold. Interestingly, the dunite samples, even where collected adjacent to chromitite layers, are low in platinum group elements, although two specimens of dunite (Localities 3 and 12) have anomalous gold (60 to 80 ppb). In general, pyroxenitic rocks contain low abundances of platinum group elements, hornblende-bearing varieties exhibit the lowest platinum:palladium ratios, and hornblende-plagioclase pegmatites are low in the noble metals. The highest gold abundance occurs in a gabbro near the northeastern margin of the complex (Locality 6) but another sample from the same locality is markedly less enriched (Table 3-6-1).

Apart from the fact that the platiniferous chromitites are confined to the dunite core of the intrusion, they appear to have no systematic spatial distribution within the complex. Their economic significance is obviously highly dependent upon the concentration of chromitite schlieren which, to date, remains to be more thoroughly tested.

SUMMARY AND CONCLUSIONS

The Late Triassic Wrede Creek ultramafic complex fits well into the Alaskan-type classification. Cumulate textures, igneous layering, rude concentric zonation, and gradational contacts between ultramafic and mafic lithologies are consistent with the pattern of crystallization of a differentiating primitive magma. This complex is one of only two Alaskan-

TABLE 3-6-1
NOBLE METAL GEOCHEMISTRY OF THE WREDE CREEK ULTRAMAFIC COMPLEX

Locality	Sample	Rock type	Pt	Pd	Rh	Au
2	GN-89-6006-1	Chromitite	248	<2	28	3
17	GN-89-6026	Chromitite	125	<2	6	2
16	GN-89-7027A	Chromitite	2002	5	17	4
10	GN-89-8000A	Chromitite	2388	12	72	29
3	GN-89-8002B	Chromitite	123	<2	5	<1
2	GN-89-6006-2	Dunite within chromite-rich zone	<1	<2	<2	<1
4	GN-89-6017A	Dunite within chromite-rich zone	<1	<2	<2	3
16	GN-89-7027B	Dunite within chromite-rich zone	19	<2	6	<1
10	GN-89-8000B	Dunite within chromite-rich zone	11	<2	<2	3
3	GN-89-8002A	Dunite within chromite-rich zone	14	<2	<2	63
12	GN-89-7005	Dunite	2	<2	<2	80
5	GN-89-6008-1	Dunite dike	6	<2	<2	4
19	GN-89-6024	Carbonatized dunite	5	<2	<2	8
21	G-89-8020	Wehrlite	31	<2	<2	<1
5	GN-89-6008-2	Olivine clinopyroxenite	3	<2	<2	7
8	GN-89-8011	Olivine clinopyroxenite	26	<2	<2	2
15	GN-89-9030	Olivine clinopyroxenite	30	<2	<2	5
5	GN-89-6008-3	Olivine clinopyroxenite dike	9	<2	<2	<1
22	GN-89-8018B	Clinopyroxenite	15	44	<2	2
14	GN-89-9026	Hornblende clinopyroxenite	9	<2	<2	23
6	GN-89-7007A	Clinopyroxene-hornblende gabbro	4	3	<2	9
6	GN-89-7007B	Clinopyroxene-hornblende gabbro	15	12	<2	195
13	GN-89-7032	Clinopyroxene-hornblende gabbro	8	10	<2	5
7	GN-89-7011	Hornblende gabbro	5	5	<2	10
1	GN-89-6023	Hornblendite	8	11	<2	7
9	GN-89-6004	Hornblende pegmatite dike	<1	<2	<2	7
11	GN-89-7001	Hornblende pegmatite dike	<1	<2	<2	26
18	GN-89-7041Z	Hornblende pegmatite dike	<1	<2	<2	23
20	GN-89-7043Z	Hornblende pegmatite dike	<1	<2	<2	4

Detection limits are 1 ppb for Pt and Au; 2 ppb for Pd and Rh. Sample localities are shown on Figure 3-6-3.

type bodies in the region, the other being the Polaris complex (Nixon *et al.*, 1990), that have a well-documented intrusive relationship with their hostrocks. The external geometry of the Wrede Creek complex is poorly constrained, but it may represent a stock-like intrusion. At the contact, Takla Group volcanic and volcaniclastic rocks have been hornfelsed to lower amphibolite grade, however, the contact effects have been largely overprinted by upper greenschist facies regional metamorphism.

Economic potential of the Wrede Creek complex is under explored. Enrichment of platinum group elements in chromitite pods and schlieren is encouraging and should warrant further investigation in order to determine the extent of these chromitite-rich zones. Of potentially added interest is the porphyry-style copper-molybdenum mineralization in the southern part of the complex. Renewed interest in base metal exploration may spur further exploration here.

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