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# GEOLOGY AND NOBLE METAL GEOCHEMISTRY OF THE JOHANSON LAKE MAFIC-ULTRAMAFIC COMPLEX, NORTH-CENTRAL BRITISH COLUMBIA*
## (94D/9)

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*KEYWORDS:* Economic geology, Alaskan-type intrusion, Johanson Lake, mafic-ultramafic complex, structure, geochemistry, platinum group elements.

## INTRODUCTION

The Johanson Lake mafic-ultramafic complex is the smallest of three Alaskan-type bodies in north-central British Columbia that were investigated during the 1989 field season. It is distinguished from the Wrede Creek and Polaris complexes (Hammack *et al.*, 1990; Nixon *et al.*, 1990) by a lack of olivine-rich ultramafic lithologies (dunite, wehrlite and olivine clinopyroxenite) and characterized by predominantly amphibole-bearing clinopyroxenites and gabbros. The gabbroic rocks appear to be volumetrically dominant and contain spectacular examples of comb layering as well as the more common centimetre-scale layering observed in the feldspathic phases of other complexes. The size and nature of the Johanson Lake body are traits shared by the Menard Creek complex situated 25 kilometres to the northwest. The Menard complex, however, is distinguished by clinopyroxene gabbros containing relatively high proportions of magnetite (Nixon *et al.*, 1989).

This report summarizes the results of fieldwork conducted during July, 1989, and presents geochemical analyses for platinum group elements and gold on representative lithological samples. The project area is covered at a scale of 1:250 000 by the McConnell Creek map sheet (94D) and 1:50 000 map sheet 94D/9. Aeromagnetic survey maps are available in the smaller scale (Map 7778G–McConnell Creek) and at a scale of 1:63 360 (Map 5272G–94D/9).

## LOCATION AND ACCESS

The Johanson Lake mafic-ultramafic complex (56° 34.5'N, 126°13'W) is situated in the Omineca Mountains approximately 2 kilometres southwest of Johanson Lake, for which the complex is named (Figures 3-7-1 and 3-7-2). Access to the area is by a well-travelled dirt road stretching some 400 kilometres north from Fort St. James via Manson Creek and Germansen Landing. An airstrip at the northern end of Johanson Lake is in good repair and suitable for light aircraft. The complex is situated entirely above treeline and excellent exposures are to be found in cirque headwalls and at the crests of ridges between altitudes of 1900 and 2300 metres. Talus aprons and glacial till blanket the lower slopes and valley floors.

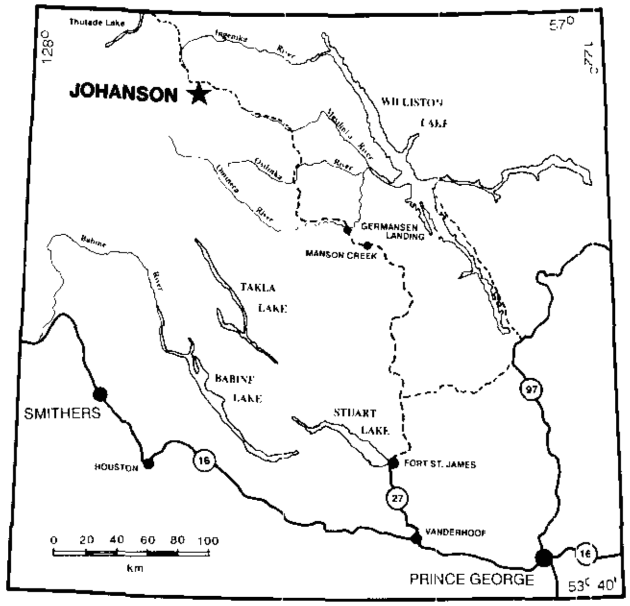


Figure 3-7-1. Location map of the Johanson Lake mafic-ultramafic complex.

## PREVIOUS WORK

Geologic reconnaissance of the McConnell Creek map area was first completed by Lord (1948) who also described many of the mineral prospects in the region. Much of the map sheet was later revised by Richards (1976a, b), Monger (1977) and Church (1974, 1975). The latter authors focused on the stratigraphy and structure of the Late Triassic Takla Group which hosts the majority of the Alaskan-type complexes in the region. More recently, Bellefontaine and Minehan (1988) and Minehan (1989) published the results of geologic studies of the Takla Group in the southwestern part of the Ingenika Range approximately 8 kilometres north of Johanson Lake.

The most detailed investigations of Alaskan-type complexes in the region, including Johanson Lake, have been made by Irvine (1974, 1976). Granitoid intrusions of predominantly Jurassic age in the area have been documented by Woodsworth (1976) and Woodsworth *et al.* (in press).

## GEOLOGIC SETTING

The Johanson Lake mafic-ultramafic complex lies within the Quesnel tectonostratigraphic terrane, a volcanic arc

* This project is a contribution to the Canada/British Columbia Mineral Development Agreement.

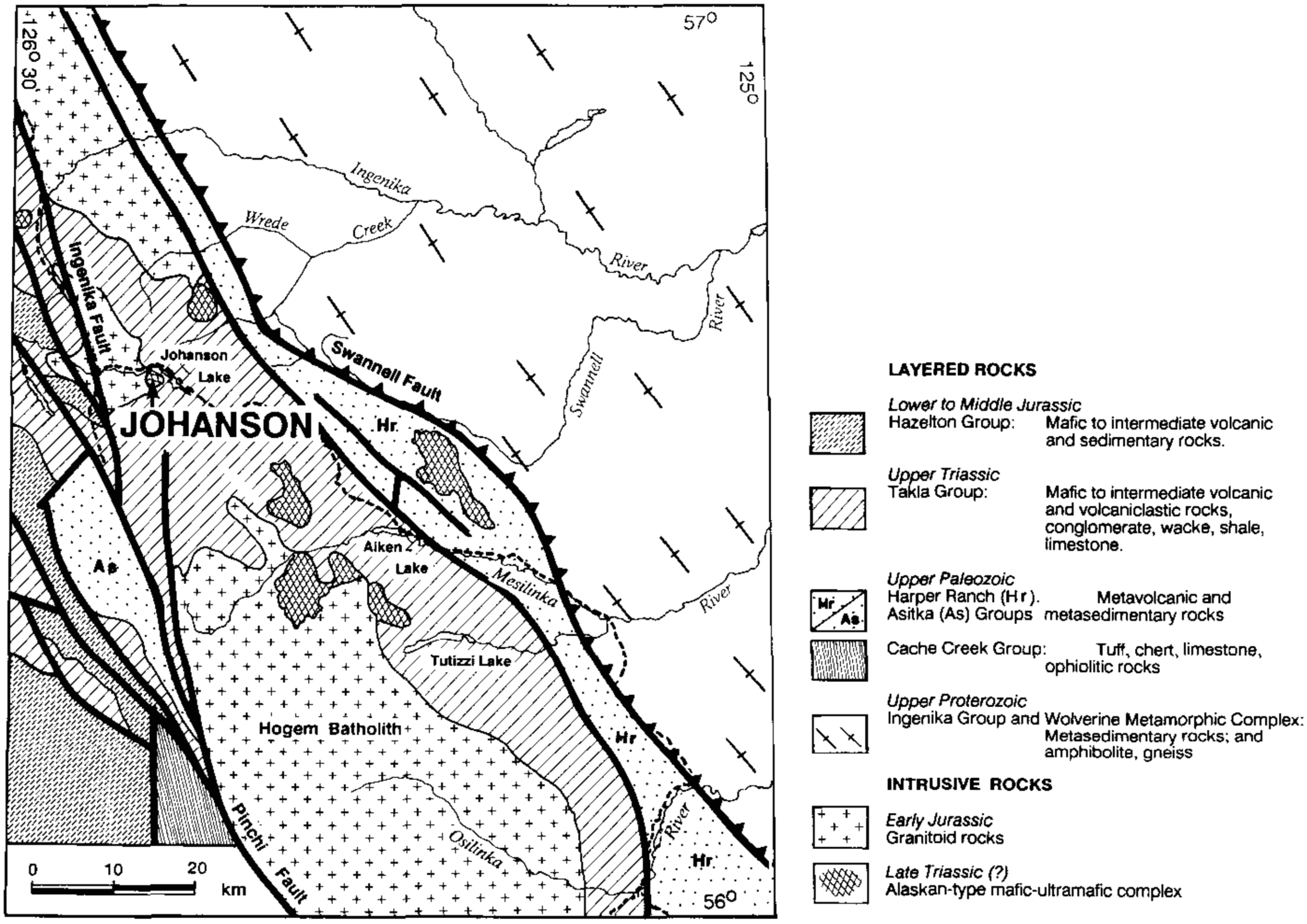


Figure 3-7-2. Geologic setting of the Johanson Lake mafic-ultramafic complex (modified after Irvine, 1974; Monger, 1977; and Richards, 1976b).

assemblage that amalgamated with other allochthonous terranes of the Intermontane Belt before being accreted to the North American craton in the Mesozoic (Wheeler and McFeely, 1987). Quesnellia is bounded on the west by Stikinia along the line of the Pinchi-Ingenika dextral fault system (Figure 3-7-2; Gabrielse, 1985; Wheeler *et al.*, 1988). Its eastern boundary is marked by the Swannell fault, a southwesterly directed thrust zone which superimposes Upper Proterozoic pericratonic rocks of the Ingenika Group on Quesnellia (Bellefontaine, 1989). Thrusting occurred in the Mesozoic during collision of the Intermontane Superterrane with the North American miogeocline (Gabrielse and Yorath, in press).

The Alaskan-type complexes are considered to be comagmatic and coeval with arc-related augite-phyric lavas, pyroclastic and epiclastic rocks of the Upper Triassic Takla Group (Irvine, 1976). West of the Ingenika-Pinchi fault system, Takla Group lithologies reach prehnite-pumpellyite grade whereas to the east these rocks have been metamorphosed to the greenschist facies (Richards, 1976b; Monger, 1977).

The Johanson Lake complex is hosted by the eastern facies of the Takla Group, an undifferentiated package of predominantly greenschist-grade, subaqueous mafic to intermediate volcaniclastic rocks interbedded with minor sedimentary material (Richards, 1976b; Monger, 1977; Bellefontaine and Minehan, 1988). These rocks are intruded by granitoid plutons of predominantly Jurassic age, the largest and possibly longest-lived of which is the composite Hogem batholith (Figure 3-7-2; Woodsworth *et al.*, in press). The prevalent regional structures are represented by northwesterly trending, high-angle brittle faults and shear zones.

## COUNTRY ROCKS: TAKLA GROUP

Upper Triassic hostrocks of the Takla Group are well exposed in northeasterly trending ridges at the northern and southeastern margins of the complex, and farther south where they form a northwesterly trending ridge (Figure 3-7-3). At the faulted northern margin of the complex, the Takla Group is composed of metavolcanic and minor metasedimentary (epiclastic?) strata that dip to the north. The predominant lithologies comprise grey-green, well-cleaved, plagioclase-actinolite schists and massive, mafic to intermediate flows that vary from aphanitic to plagioclase-augite porphyries. In thin section, the latter rocks are seen to contain euhedral to subhedral phenocrysts or glomerocrysts (less

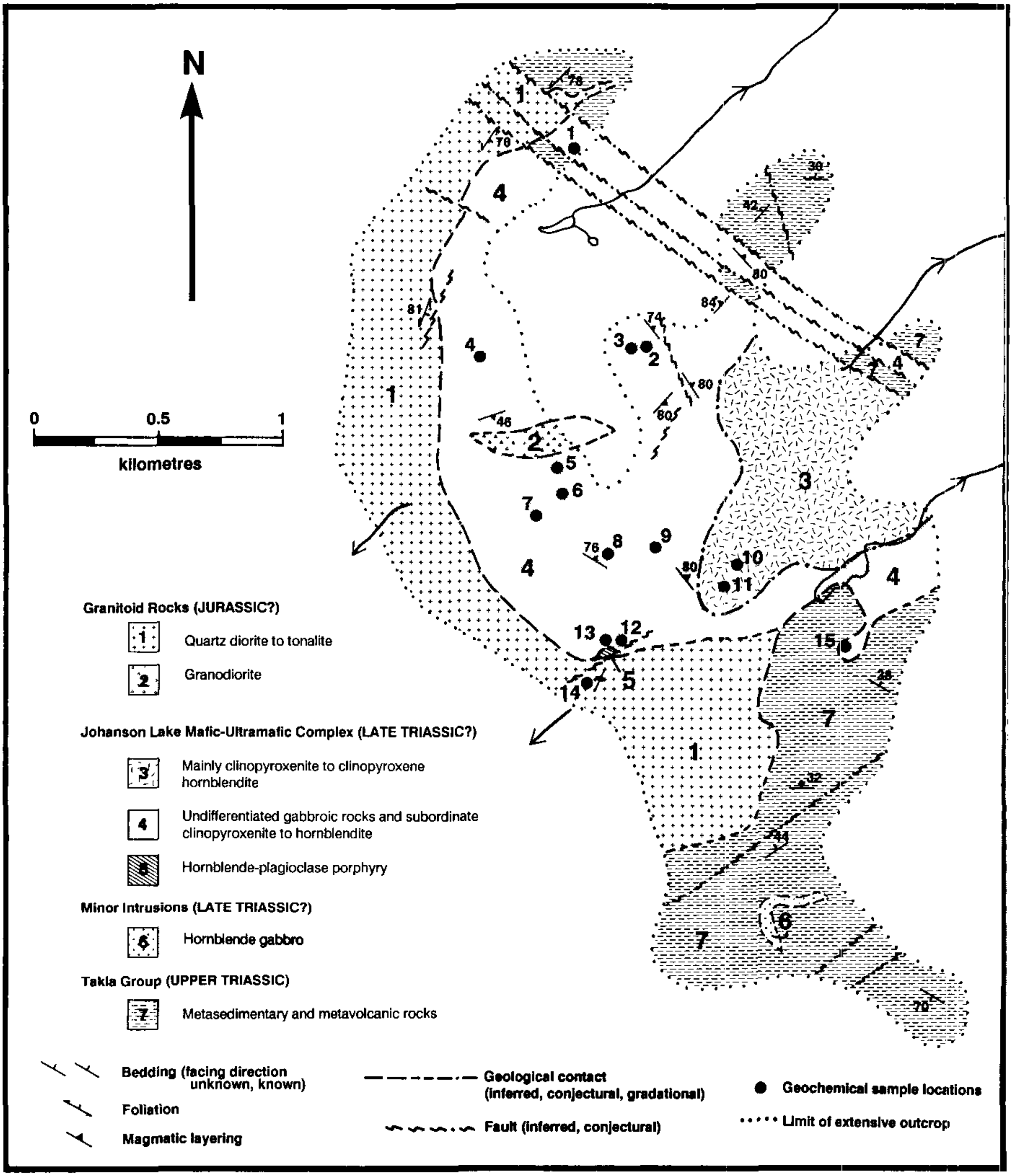


Figure 3-7-3. Generalized geology of the Johanson Lake mafic-ultramafic complex.

than 4 millimetres across) of lamellar-twinned plagioclase and actinolite pseudomorphs after augite set in a granoblastic matrix of plagioclase and actinolite (up to 50 per cent of the matrix). Textures in aphanitic flows are also granoblastic and, locally, actinolite is pseudomorphous after rare mafic phenocrysts (up to 2 millimetres in length). Relict igneous plagioclase in these rocks commonly exhibits subgrain boundaries and shows only incipient alteration to clay minerals.

In the southern part of the map area, the Takla Group contains dark grey to rusty weathering, hornblende-augite-plagioclase-phyric lavas, massive crystal and crystal-lithic tuffs, volcanic breccias, altered amygdaloidal mafic flows, and thickly bedded, greenish grey silicified siltstones and mudstones. These rocks have similar textures and metamorphic mineral assemblages to lithologies to the north. Graded bedding has been observed locally and suggests that the rocks are the right way up. The proportion of rusty weathering outcrop varies according to the abundance of pyrite, which locally reaches 10 per cent of the rock, and occurs as disseminations and in quartz veins. On the whole, the hostrocks of the Johanson Lake complex resemble Takla Group volcanic and volcaniclastic sequences north of Johanson Lake described by Bellefontaine and Minehan (1988) and Minehan (1989).

## JOHANSON LAKE MAFIC-ULTRAMAFIC COMPLEX

The Johanson Lake mafic-ultramafic complex underlies an area of approximately 4 square kilometres (Figure 3-7-3). The major areas of outcrop comprise a prominent unnamed peak (2327 metres) in the southern part of the complex and several northeasterly to northerly trending ridges of rugged to gentle relief.

Previous work by Irvine (1976) established the predominantly gabbroic nature of the complex but showed a large unit of olivine clinopyroxenite occupying the southeastern portion of the body (Irvine, ibid., Figure 15.3J). This is an error since the area in question is underlain mostly by hornblende clinopyroxenite and clinopyroxene hornblendite with minor clinopyroxenite and melanocratic gabbro.

At the chosen scale of mapping, we have been able to subdivide the complex into two main lithologic units: clinopyroxene and hornblende-rich ultramafic rocks with minor melanocratic gabbros; and hornblende ± clinopyroxene gabbroic rocks with minor interlayered ultramafic lithologies. The latter map unit appears to be the most voluminous.

Intrusive contacts with the Takla Group are exposed at the southeastern margin of the complex. Internally, contacts between the major map units are usually sharply gradational, as are the contacts of interlayered minor rock types within each of the major units.

### CLINOPYROXENITE

Small outcrops of medium grey-green, medium to coarse-grained clinopyroxenite occur at the northwestern extremity of the region underlain by mainly ultramafic lithologies and in gabbroic rocks at Locality 3 in Figure 3-7-3. The clinopyroxenites contain pale brown weathering, serpentinized olivine grains (2 to 5 per cent) distributed evenly throughout the rock and rare pods of olivine wehrlite to dunite up to 1 metre in length. These olivine-rich pods are elongate and irregular, and commonly exhibit a pronounced internal foliation in contrast to their massive pyroxenitic hostrocks. In thin section, subhedral to anhedral clinopyroxenes (up to 1 centimetre across) form an interlocking mosaic containing subhedral cumulus olivine crystals (5 to 10 per cent) up to 8 millimetres in diameter, and pale green, pleochroic, intercumulus hornblende (5 to 10 per cent). Olivines have been almost completely replaced by serpentine, magnetite and secondary amphibole (tremolite-actinolite). These olivine and hornblende-bearing clinopyroxenites represent the most primitive lithologies in the complex.

### HORNBLENDE CLINOPYROXENITE AND CLINOPYROXENE HORNBLENDITE

A complete gradation exists among clinopyroxenite, hornblende clinopyroxenite (less than 50 per cent hornblende) and clinopyroxene hornblendite (less than 50 per cent clinopyroxene) in the ultramafic lithologies in the southeastern part of the complex. These rocks are medium to coarse grained and weather medium grey-green to dark greenish grey depending on the clinopyroxene:amphibole ratio. In thin section, hornblende crystals (up to 3.5 centimetres) poikilitically enclose clinopyroxene and appear to be replacing corroded pyroxene relicts. Iron-titanium oxides, largely magnetite, occur in small amounts (less than 5 per cent). Clinopyroxenes have been partly replaced by actinolite-tremolite, and other secondary minerals include minor calcite and epidote. These ultramafic lithologies grade through melanocratic gabbros into surrounding gabbroic rocks.

### GABBROIC ROCKS

The gabbroic map unit in Figure 3-7-3 contains significant proportions of interlayered hornblende clinopyroxenites, clinopyroxene hornblendites, hornblendites and their feldspathic equivalents. Gabbroic pods are quite common within these ultramafic lithologies. The dominant rock type is medium-grained to pegmatitic hornblende gabbro or diorite that weathers pale to dark grey or grey-green, and locally contains rusty zones rich in pyrite (2 to 3 per cent). Hornblende-clinopyroxene gabbros occur locally and contain as little as 20 per cent amphibole and up to 40 per cent clinopyroxene. A complete gradation exists among these rock types.

The gabbroic unit is characterized by two types of layering. Medium-grained equigranular gabbroic rocks may exhibit centimetre-scale modal layering comprising alternating hornblende ± clinopyroxene and plagioclase-rich horizons (Plate 3-7-1). In many places, pegmatitic zones have developed spectacular comb layering defined by acicular hornblende crystals up to 20 centimetres in length (Plates 3-7-2 and 3-7-3). Almost invariably, amphibole crystals are preferentially oriented at high angles (70°–80°) to the trend of the layering. These comb-textured layers generally alternate with more equigranular, feldspathic layers (Plate 3-7-2). The boundaries between layers are curvilinear and sharply transitional, and the terminations of large prismatic hornblendes locally penetrate the adjacent layer (Plate 3-7-3). These features suggest that comb layering developed by *in situ* crystal growth under conditions where silicate melts became periodically supersaturated in amphibole.

In thin section, the gabbroic rocks contain subhedral, brown to deep green pleochroic hornblende (20 to 50 per cent), subhedral to anhedral plagioclase (30 to 60 per cent), euhedral to subhedral clinopyroxene (0 to 40 per cent), and accessory iron-titanium oxides (less than 5 per cent), apatite and minor sphene. Plagioclase is extensively saussuritized and generally occurs as intercumulus and cumulus material. Clinopyroxene invariably forms cumulus grains which are commonly partially altered to actinolite. Hornblende is generally a cumulus mineral but forms large (up to 2 centimetres)

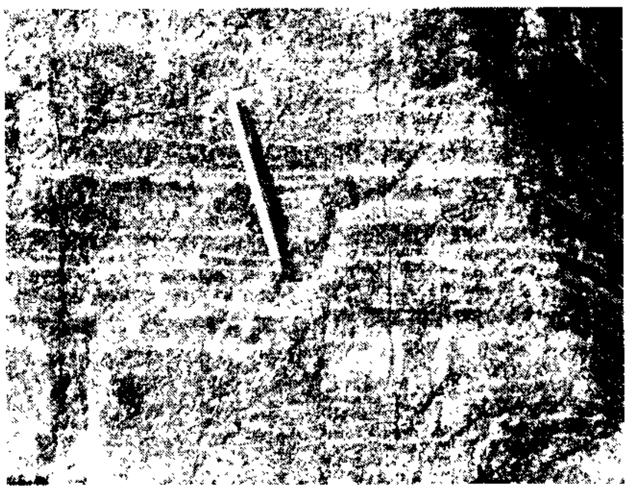

Plate 3-7-1. Centimetre-scale layering formed by modal variations in plagioclase and amphibole in hornblende gabbro. Magnet is 11 centimetres long.

Plate 3-7-2. Comb layering in hornblende gabbro formed by acicular amphibole crystals oriented nearly perpendicular to more equigranular, centimetre-scale layers.

Plate 3-7-3. Well-developed comb layering in coarse-grained to pegmatitic hornblende gabbro. Note penetration of adjacent feldspathic layer by large amphibole crystal to right of magnet.

poikilitic intercumulus crystals in a rare variety of hornblende-megacrystic gabbro. Magnetite, apatite and sphene form euhedral cumulus crystals up to 1 millimetre in length. Quartz may occur in minor amounts (less than 5 per cent) in the groundmass of hornblende gabbros and appears to be largely primary.

## Hornblende-Plagioclase Porphyry

A medium grey, fine to medium-grained, porphyritic dioritic rock is exposed at the southern margin of the complex (Figure 3-7-3). The rock contains subequant saussuritized plagioclase (40 per cent), acicular hornblende crystals partly altered to biotite and actinolite, and minor quartz (5 per cent). Locally the rock is sheared and enriched in chlorite and epidote, and cut by quartz veins. Intrusive contacts with coarse-grained gabbroic rocks are sharp and the porphyry contains irregular gabbro xenoliths (cognate?). Thin (1 to 2 centimetres) feldspathic veinlets cut the porphyry and adjacent gabbroic rocks and may represent more differentiated residual liquids derived from within the complex. The porphyry is distinguished from the adjacent quartz diorite/tonalite pluton by its more melanocratic character, and appears to represent a late marginal phase of the Johanson Lake complex.

## Minor Intrusives

Narrow dikes of hornblende-rich gabbro or diorite, hornblende pegmatite, and fine-grained felsite cut mafic and ultramafic lithologies of the Johanson Lake complex. Hornblende-plagioclase pegmatite dikes up to 3 metres wide cut clinopyroxene hornblendites interlayered with gabbroic rocks. Prismatic hornblende crystals (up to 15 centimetres long) are commonly arranged haphazardly in the centre of the intrusion but may lie parallel to wallrock contacts near the margins of the dike. These rocks are compositionally identical to the comb-layered pegmatite zones of the gabbroic unit.

Dark grey-green melanocratic microgabbro or microdiorite dikes less than 1 metre wide are observed locally. They consist almost entirely of saussuritized plagioclase and hornblende variably altered to actinolite. Most textures are equigranular although a few dikes contain larger crystals of hornblende (up to 2 millimetres). These dikes are characterized by a conspicuous alignment of hornblende prisms parallel to their margins.

White to pink-weathering, aphanitic felsite dikes up to 0.5 metre wide cut gabbroic and ultramafic rocks alike. Mafic minerals form less than 5 per cent of the rock and have been replaced by epidote, chlorite and carbonate. The origin of these rocks is uncertain but they bear a strong resemblance to rather widespread feldspathic veinlets that represent leucocratic differentiates of the gabbroic rocks.

A dike-like body of grey-green, medium-grained hornblende gabbro or diorite intrudes volcanic rocks of the Takla Group south of the Johanson Lake complex (Figure 3-7-3). The rock contains euhedral prismatic hornblende (50 per cent) and subequant plagioclase laths up to 2 millimetres long set in a fine-grained recrystallized feldspathic groundmass. Amphibole crystals define a pronounced flow fabric subparallel to the contacts of the intrusion. Plagioclase is saussuritized and hornblende partly replaced by actinolite. Euhedral to subhedral magnetite and apatite occur as accessory minerals, and secondary pyrite (1 to 2 per cent) is disseminated throughout the rock. This intrusion is probably coeval, and may be cogenetic, with hornblende-rich gabbroic rocks of the Johanson Lake complex.

## GRANITOID ROCKS

A large body of quartz diorite to tonalite delineates much of the western and southern margins of the Johanson Lake complex. Intrusive contacts with the Takla Group are well exposed in the northern and southern parts of the map area, but contact relationships with gabbroic rocks are not clear. We suspect that the Johanson Lake complex is older and tentatively consider the quartz diorite/tonalite to be post-Late Triassic and pre-Late Jurassic in age.

The quartz diorite/tonalite unit is a pale grey weathering, massive, medium-grained subequigranular rock containing variable proportions of anhedral quartz (10 to 30 per cent) with subgrain mosaics, euhedral to subhedral plagioclase (45 to 55 per cent), dark green pleochroic hornblende (10 to 20 per cent), minor biotite and iron-titanium oxides (less than 5 per cent). Hornblende crystals are largely replaced by actinolite at their rims and some biotite appears to be secondary. Plagioclase is partly saussuritized and disseminated pyrite is common near fault zones.

A small body of pale pinkish grey weathering, medium-grained granodiorite intrudes the western part of the complex. It contains euhedral to subhedral, partly saussuritized plagioclase (50 per cent) up to 5 millimetres in length; anhedral quartz crystals (30 per cent) up to 2 millimetres across; subhedral to anhedral potassium feldspar (20 per cent) up to 2 millimetres in length; and minor biotite and trace amounts of hornblende. The age of the granodiorite is uncertain and it has been tentatively assigned to the Jurassic.

## STRUCTURE AND METAMORPHISM

The lack of distinctive marker horizons in the eastern facies of the Takla Group hampers interpretations concerning the mechanism of deformation in the area. The attitude of bedding could have resulted from folding or rotation by faulting. Northwesterly trending, high-angle fault zones bounding the northern margin of the mafic-ultramafic complex have incorporated metavolcanic hostrocks as a thin fault slice within the complex.

The grade of metamorphism throughout the map area appears to have reached middle to upper greenschist facies. A sample of crystal tuff in the Takla Group near the fault contact with clinopyroxene hornblendite at the northeastern margin of the complex has granoblastic texture and a lower amphibolite (hornblende + plagioclase ± quartz) grade mineral assemblage. Other volcanic rocks farther northwest along the same contact exhibit uppermost greenschist grade assemblages. Faulting and retrograde regional metamorphism may, therefore, have obscured a weak, and as yet poorly defined, metamorphic aureole of lowermost amphibolite grade at the margins of the complex.

## GEOCHEMISTRY AND MINERAL POTENTIAL

Analytical results for platinum, palladium, rhodium and gold in 15 lithogeochemical samples of the Johanson Lake mafic-ultramafic complex are presented in Table 3-7-1. Sample localities are shown in Figure 3-7-3. All analyses were conducted 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) was monitored by hidden duplicates and internal standards. The noble metals were preconcentrated by fire assay from 30-gram splits of 200 grams of rock powder (–200 mesh).

The highest abundances of platinum and palladium, 41 and 88 ppb respectively, are found in hornblende-plagioclase pegmatites within the gabbroic sequence. The tenor of gold peaks at 41 ppb in the gabbros and rhodium is below the detection limit in all samples. In general, palladium abundances are higher in gabbroic than pyroxenitic lithologies and the noble metals are uniformly low in quartz diorites. Unlike other Alaskan-type complexes studied to date, platinum shows no systematic depletion from ultramafic to gabbroic rock types. This may be due to the relatively small number of samples analyzed or the limited range of ultramafic lithologies represented. Another notable feature is the relatively high average abundance of gold in the Johanson Lake mafic-ultramafic complex as a whole.

The distribution of noble metals bears no apparent relationship to the presence of sulphides (disseminated pyrite) or proximity to fault zones. The potential for economic concentrations of precious metals appears to be low.

## SUMMARY AND CONCLUSIONS

The Johanson Lake mafic-ultramafic complex is a relatively small (4 square kilometres) Alaskan-type intrusion hosted by augite-plagioclase-phyric mafic to intermediate

TABLE 3-7-1
NOBLE METAL GEOCHEMISTRY OF THE JOHANSON LAKE MAFIC-ULTRAMAFIC COMPLEX

| Locality | Sample | Rock Type | Pt (ppb) | Pd (ppb) | Rh (ppb) | Au |
|---|---|---|---|---|---|---|
| 3 | GN-89-9031 | Ol-Hb-bearing clinopyroxenite | 9 | 5 | <2 | 4 |
| 9 | GN-89-6034 | Hb clinopyroxenite | 6 | 5 | <2 | 4 |
| 11 | GN-89-9011 | Hb clinopyroxenite | 17 | 15 | <2 | 15 |
| 4 | GN-89-8032 | Feldspathic Hb clinopyroxenite | 5 | 4 | <2 | 7 |
| 12 | GN-89-9009 | Feldspathic Hb clinopyroxenite | <1 | <2 | <2 | 26 |
| 1 | GN-89-9048 | Feldspathic Cpx hornblendite | 5 | 5 | <2 | 10 |
| 5 | GN-89-8027A | Hb-Cpx gabbro | 19 | 22 | <2 | 41 |
| 8 | GN-89-6031 | Hb-Cpx gabbro | 5 | 13 | <2 | 14 |
| 7 | GN-89-8023 | Cpx-Hb gabbro | 20 | 7 | <2 | 41 |
| 10 | GN-89-8007 | Cpx-Hb gabbro | 15 | 33 | <2 | 22 |
| 6 | GN-89-8022 | Hb gabbro | 7 | 11 | <2 | 13 |
| 2 | GN-89-9034 | Hb-Plag pegmatite | 8 | 42 | <2 | 21 |
| 13 | GN-89-9001C | Hb-Plag pegmatite | 41 | 88 | <2 | 28 |
| 15 | GN-89-9004 | Melanocratic Qz diorite | 5 | 8 | <2 | <1 |
| 14 | GN-89-9006Z | Qz diorite/tonalite | <1 | <2 | <2 | <1 |

Abbreviations: Ol, olivine; Cpx, clinopyroxene; Hb, hornblende; Plag, plagioclase; Qz, quartz. Detection limits: 1 ppb for Pt and Au; 2 ppb for Pd and Rh. Sample localities are given in Figure 3-7-3.

volcanic and volcaniclastic rocks of the Late Triassic Takla Group that forms part of Quesnellia. The complex is dominated by hornblende-bearing gabbroic rocks with lesser proportions of clinopyroxene hornblendite, hornblende clinopyroxenite, hornblendite and clinopyroxenite. The pegmatitic gabbros exhibit spectacular comb layering that records *in situ* crystal growth from supersaturated liquids that crystallized within the central part of the intrusion.

The northeastern margin of the complex is fault-bounded and the western and southern margins are bordered by a quartz diorite to tonalite pluton of probable Jurassic age. A small body of granodiorite intrudes the western part of the complex, and other minor intrusive rocks include dikes of microdiorite to microgabbro, felsite, and hornblende-plagioclase pegmatite.

The regional metamorphic mineral assemblages within the project area, which is situated within the eastern facies of the Takla Group west of the Pinchi-Ingenika fault system, indicate middle to upper greenschist facies conditions. However, vestiges of a metamorphic aureole of lower amphibolite grade at the northeastern margin of the Johanson Lake complex may have been largely obscured by faulting and retrograde metamorphism.

The abundance of noble metals in representative samples of the mafic and ultramafic lithologies of the complex is relatively low and there appears to be little evidence for economic mineralization.

## ACKNOWLEDGMENTS

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