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THE ATLIN ULTRAMAFIC ALLOCHTHON: OPHIOLITIC BASEMENT WITHIN THE CACHE CREEK TERRANE; TECTONIC AND METALLOGENIC SIGNIFICANCE

(104N/12)

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INTRODUCTION

Quartz-carbonate lodes are the accepted source of the abundant placer gold deposits in the Atlin region of northwestern British Columbia. Gold recovered from these deposits between 1898 and 1982 totaled 19.1 million grams (Debicki, 1984) and remains the economic mainstay for the town of Atlin.

Lode gold showings in the region are all structurally controlled by fault zones and spatially (genetically ?) associated with carbonatized ultramafic rocks (listwanites). A number of variably sized ultramafic bodies are exposed throughout the Atlin area, and are in all cases associated with oceanic crustal and sedimentary rocks. These ultramafic bodies were interpreted as intrusive in origin and termed the "Atlin intrusions" by Aitken (1959) but have not been adequately studied since that time, despite their economic significance.

A major objective of the Listwanite Project (Ash and Arksey, 1990a, this volume) is to classify the geotectonic environment of formation of the listwanite–lode gold association in British Columbia. Ultramafic rocks in the Atlin area were selected for detailed geological investigation, due to the excellent road access and current exploration activity. An area of roughly 50 square kilometres located along the eastern shore of Atlin Lake, encompassing the town of Atlin and Monarch Mountain, was mapped at 1:20 000 scale (Figure 3-3-1). Following this detailed mapping a regional reconnaissance survey of the area was undertaken in order to fit the detailed results into a broader geotectonic framework.

This report provides an updated assessment of the ultramafic rocks in the Atlin area and a new structural interpretation for the region.

REGIONAL GEOTECTONIC SETTING

The map area is situated near the western margin of the Atlin Terrane in northwestern British Columbia (Figure 3-3-1). The Atlin Terrane is an allochthonous package of tectonically emplaced and internally disrupted remnants of the mainly Late Paleozoic to possibly Late Triassic Tethyan oceanic crust (Monger *et al.*, 1982). It represents the northern extension of the Cache Creek Terrane which is presently interpreted as a subduction complex related to Late Triassic arc activity on Quesnellia and Stikinia. Radiolarian cherts are present within the subduction complex, and range in age

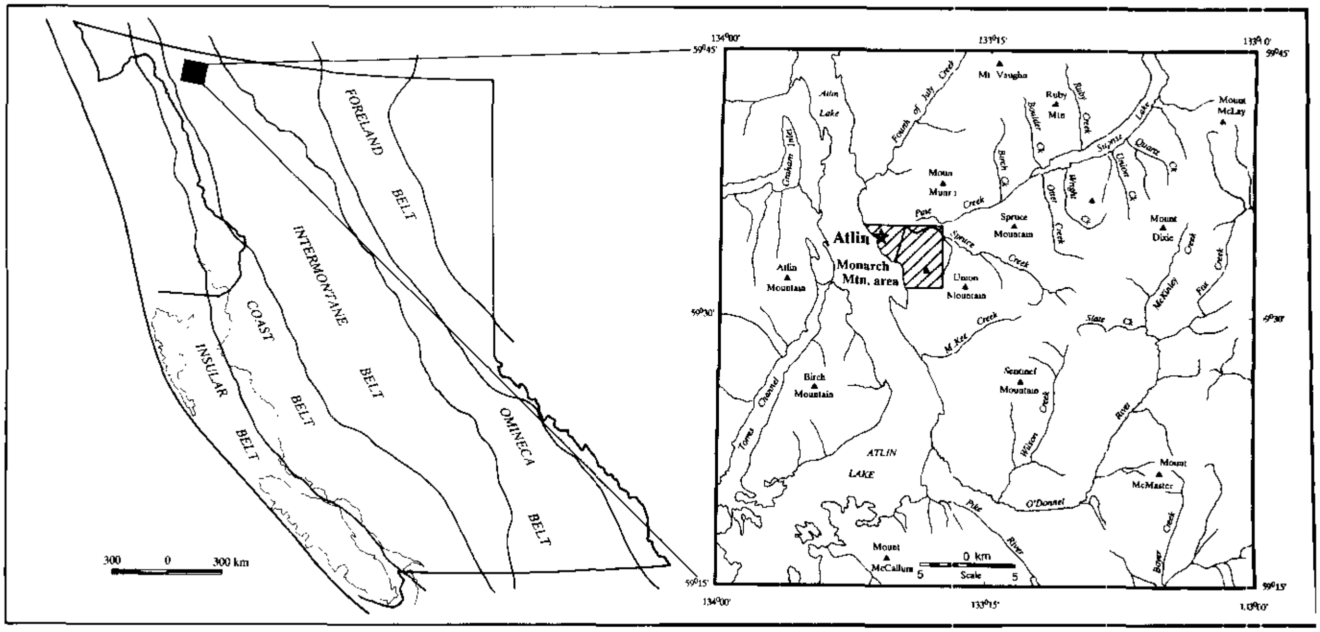

Figure 3-3-1. Location of the Atlin–Monarch Mountain map area within the tectonic framework of the northwestern Canadian Cordillera.

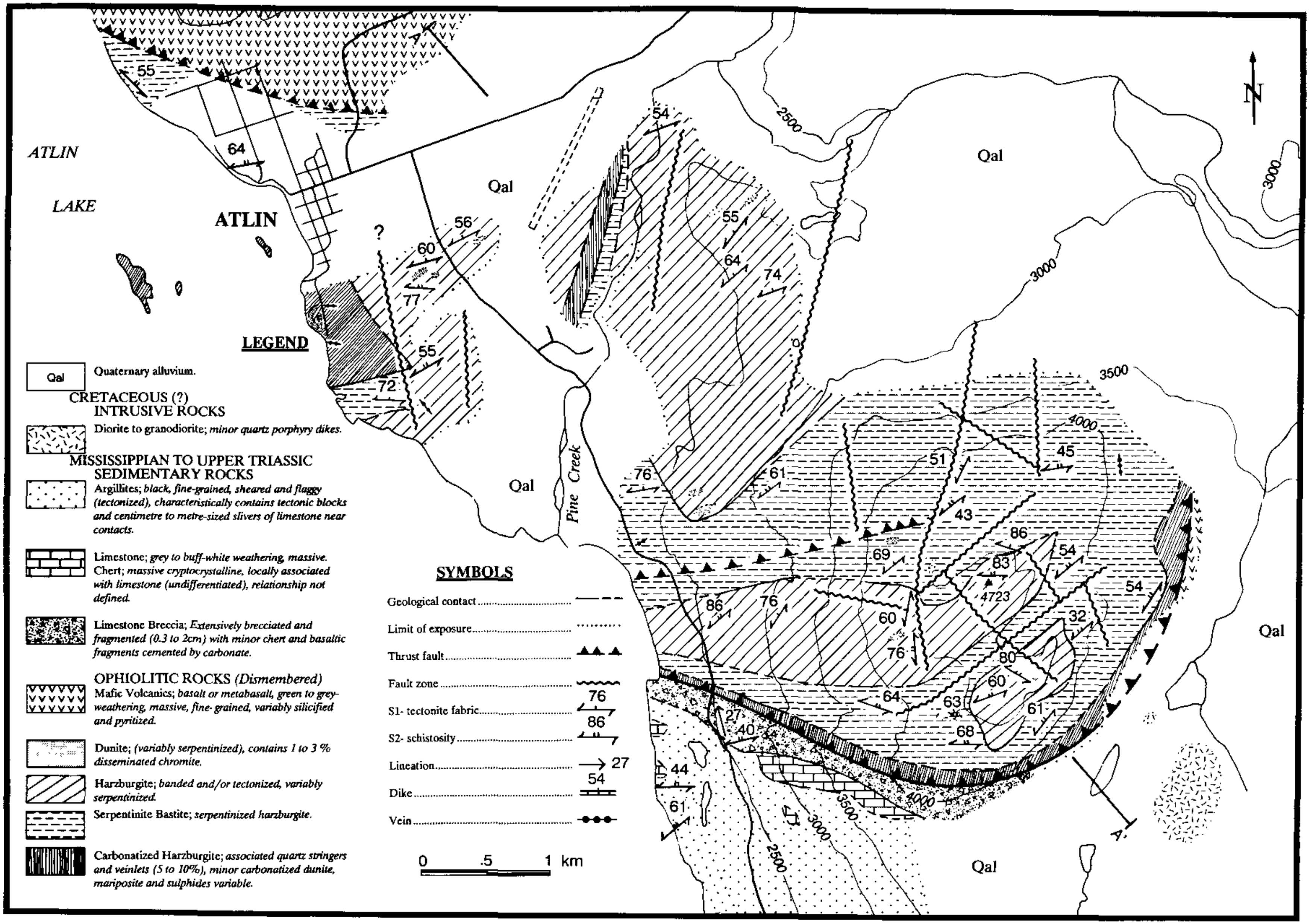

Figure 3-3-2. Simplified geology map of the Atlin–Monarch Mountain map area (*see* text for description of units).

from Permian to at least Late Triassic (Norian) (D.L. Jones *in* Monger *et al.*, 1982). This suggests that oceanic crust was forming for at least 100 million years and that the former ocean may have been quite large.

In the Late Triassic the Tethyan ocean basin was tectonically sandwiched between island arcs. This collage is Terrane I of Monger *et al.* (1982), or the Intermontane Superterrane of Gabrielse and Yorath (1989). The formation of the Omineca Belt to the east of Terrane I in the Middle Jurassic is thought to be the consequence of accretion of this composite superterrane to ancient North America (Monger *et al.*, 1982).

The combined effects of both closure of the Tethyan ocean in the Late Triassic and accretion of Terrane I in the Middle Jurassic resulted in the obduction of oceanic crust and upper mantle, represented by the Atlin "intrusions" in northern British Columbia. They are, therefore, typical Alpine ultramafic bodies.

ALPINE ULTRAMAFICS: TERMS AND CONCEPTS

Alpine ultramafic rocks are well exposed and documented in many mountain belts of the world and provide fundamental clues to their evolution. However, in the Canadian Cordillera these rocks have not received a great deal of attention and, as a result, many geologists in British Columbia still refer to them as "younger intrusions."

Originally, the term "alpine ultramafic" was used to describe the serpentinite-peridotite association occurring within orogenic belts, in contrast to the non-orogenic types or layered intrusions of stable cratons (Den Tex, 1969).

During the 1950s and 1960s, the accepted model for the origin of the alpine ultramafic rocks invoked incipient remelting of rocks from some kind of super-stratiform complex in the lower part of the crust or upper mantle during mountain building. The crystal mush produced was then injected into the upper crust under high tectonic pressure (Thayer, 1964, 1969). Aitken (1959) proposed a similar origin for the ultramafic rocks exposed throughout the Atlin region.

The geotectonic significance of the alpine ultramafic rocks was re-evaluated as a result of the evolution of plate tectonic theory. Most authors during the early 1970s came to support the hypothesis that ophiolites represent fragments of oceanic crust which were created at ocean ridges and subsequently transported to subduction zones at the convergent boundaries of lithospheric plates (Review in Coleman, 1977).

Moores (1973) redefined the term "alpine peridotite" to include ultramafic rocks occurring in linear Phanerozoic and late Precambrian deformed belts indicative of activity at accreting and consuming plate margins. Their formation involves diapiric rise at spreading centres, with subsequent emplacement and modification in subduction zones, and commonly results in mantle exposure.

Monger (1977a) used the term "ophiolitic terrane" for the Cache Creek Terrane in contrast to the non-ophiolitic, arc-related terranes of Quesnellia and Stikinia, to the east and west, respectively. The Nahlin ultramafic body in the Cache Creek Terrane of northwestern British Columbia consists predominantly of foliated peridotite (harzburgite tectonite) with minor mafic and ultramafic cumulates, trondhjemite and diabase dikes displaying chilled margins (Terry, 1977), and has been cited as a possible example of ophiolitic rocks in the Atlin Terrane (Monger, 1977a, b). Assessment of available data, combined with a limited reconnaissance survey of the body by the authors, indicates that it is indeed ophiolitic and may be more correctly referred to as the "dismembered Nahlin ophiolite".

The geotectonic significance of the ultramafic rocks representative of the type Atlin intrusions was not addressed by Monger (1977a), during his assessment of ophiolitic rocks in the Cache Creek Terrane. Subsequent workers in the Atlin region either maintained an intrusive origin for these ultramafic rocks (Christopher and Pinsent, 1979; Newton, 1985; Lefebure and Gunning, 1988, 1989) or suggested that they may represent oceanic crust but were inconclusive (Bloodgood *et al.*, 1989a).

There is clear evidence that the Atlin intrusions consist of parts of a typical ophiolite section (Coleman, 1977). They are comprised largely of mantle tectonite (described following); crustal plutonic rocks including both gabbro and diorite are also present, fitting Moores' (1973) definition of alpine ultramafics.

Mantle tectonite constitutes the basal section in most ophiolites (Nicolas *et al.*, 1980) and is now widely accepted as representing the oceanic uppermost mantle. These tectonites are comprised for the most part of foliated harzburgite (an ultramafic rock composed primarily of both olivine and orthopyroxene) with bodies of dunite, commonly in the shape of pods. Mantle tectonite represents the refractory residue from which a basaltic fraction has been extracted (depleted mantle) due to partial melting. Plutonic, hypabyssal and volcanic rocks characteristic of the typical ophiolite sequence crystallize from this basaltic melt (Coleman, 1977).

Mantle tectonites described from ophiolites throughout the world display geochemical signatures indicative of an origin by partial melting. When compared to the overlying cumulate rocks, the metamorphic harzburgites are depleted in the incompatible elements Ba, K, Rb, Sr, Zr, U, Th and rare-earth elements by one to two orders of magnitude and enriched in refractory elements Ni, Co and Cr to varying degrees (Coleman, 1977). Limited variations in both bulk rock and mineral phase chemistry throughout ophiolitic harzburgites also support a residual origin (Menzies and Allen, 1974; Malpas, 1978).

The metamorphic or tectonite fabric commonly exhibited by this rock type is developed by hypersolidus to subsolidus ductile deformation, attributed to asthenospheric flow in the mantle during and subsequent to partial melting (Nicolas *et al.*, 1980).

The term mantle tectonite is synonymous with metamorphic peridotite (Coleman, 1977), or harzburgite tectonite (Nicolas *et al.*, 1980) and may be more completely referred to as residual-mantle harzburgite tectonite. The term harzburgite tectonite will be used throughout the remainder of this report.

As is the case in the Atlin area, harzburgite tectonite exposed within Cache Creek Terrane near Fort St. James was interpreted to be intrusive in origin and was termed the "Trembleur intrusions" (Armstrong, 1949). Paterson (1973, 1977) identified the general association of ultramafics, gabbro, diabase and basalt in the area and suggested that the assemblage is most likely representative of oceanic crust and upper mantle. Ross (1977) conducted a detailed microstructural analysis of the Trembleur intrusion underlying Murray Ridge near Pinchi Lake. He concluded that penetrative F_1 and F_2 fabrics present are consistent with derivation from a mantle environment.

GEOLOGY OF THE STUDY AREA

The geology of the Atlin–Monarch Mountain area is illustrated in Figures 3-3-2 and 3-3-3. The area is underlain predominantly by variably serpentinized harzburgite tectonite which is continuous throughout, except for sporadic and volumetrically minor (2 to 3 per cent), lenticular masses of dunite enveloped by the host harzburgite. Minor pyroxenite dikes, 1 to 5 centimetres wide, occur throughout the harzburgite unit.

The division between harzburgite tectonite and serpentinite-bastite (alteration products after olivine and orthopyroxene respectively) in Figures 3-3-2 and 3-3-3 simply reflects differences in the degree of alteration of the harzburgite. Harzburgite tectonite preserves a clearly identifiable mantle tectonite mesoscopic texture. Contacts between partially altered harzburgite tectonite and the more intensely altered serpentinite-bastite are gradational.

The ultramafic rocks structurally overlie, along a northwesterly dipping thrust fault (Monarch Mountain thrust), a mélange assemblage of deep-water clastic to shallow-water carbonate sedimentary rocks to the south and massive metabasalts to the north. The sedimentary clastic and carbonate rocks are assigned to the Kedahda and Horsefeed formations, respectively (Monger, 1975). The age of the sedimentary rocks is poorly constrained but may range from upper Paleozoic to lower Mesozoic.

Metabasalts of the Nakina Formation (Monger, 1975) are interpreted to structurally overly the harzburgite tectonite unit along the Beavis fault zone near the northern margin of the map area.

The ultramafic rocks are cut by two distinct intrusions. The oldest intrusive phase is represented by granodiorite which forms a small, medium-grained, equigranular plug outcropping near the summit of Monarch Mountain. Porphyritic dike-equivalents of the granodiorite, 0.5 to 1.5 metres wide, intrude at several isolated locations. Potassium-argon isotopic ages from a small granodiorite body outcropping in the valley south of Monarch Mountain indicate a Middle to Late Jurassic age for the intrusions. Biotite obtained from the granodiorite and muscovite from a mineralized quartz vein cutting the granodiorite yield radiometric ages of 167.2±4.7 Ma and 160.6±7 Ma, respectively (K. Dawson, personal communication, 1989). These ages are consistent with the timing of granitic plutonism related to the collision of Terrane I with the North American craton.

Younger, fine-grained, occasionally plagioclase-porphyritic mafic dikes, 0.5 to 1.0 metre wide, were mapped at several locations. A mafic dike exposed in a trench on the Anna claims, near the summit of Monarch Mountain, crosscuts the carbonatized ultramafic rock and appears to postdate the listwanitic alteration. A tentative correlation with Recent olivine-phyric vesicular basalts which outcrop as small cinder cones (?) near Ruby Mountain is suggested. The basalts display spectacular columnar jointing where the unit overlies Tertiary to Quaternary pay-zone placer gravels along the banks of Ruby Creek.

ULTRAMAFIC ROCKS

HARZBURGITE

Harzburgite displays a relatively homogeneous modal distribution of both olivine and orthopyroxene (olivine: orthopyroxene ratio averages 7:3) or their altered equivalents, serpentine and bastite. Preferential orientation of the orthopyroxene imparts a weak to moderate foliation fabric upon most of the harzburgite. The rock is medium to coarse grained with a xenomorphic granular fabric.

Weathering gives rise to uneven, mottled surfaces on which lustrous brown to bottle-green pyroxenes and black chromite crystals are visible within a matrix of rusty brown olivine (Plate 3-3-1). Fresh surfaces are dark green and massive with the orthopyroxene grains readily distinguishable due to their lustre.

Three types of harzburgite have been recognized on the basis of structural style. In decreasing order of abundance these are: (1) foliated with no compositional banding, (2) massive, and (3) foliated with parallel compositional banding. Both the foliated and massive harzburgite are relatively

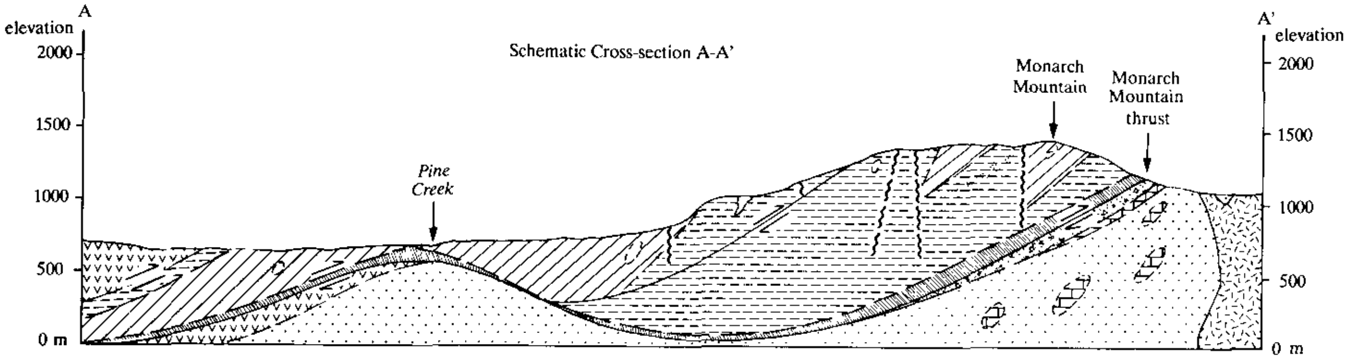

Figure 3-3-3. Schematic cross-section of the Atlin–Monarch Mountain area. See Figure 3-3-2 for line of section. Legend as in Figure 3-3-2.

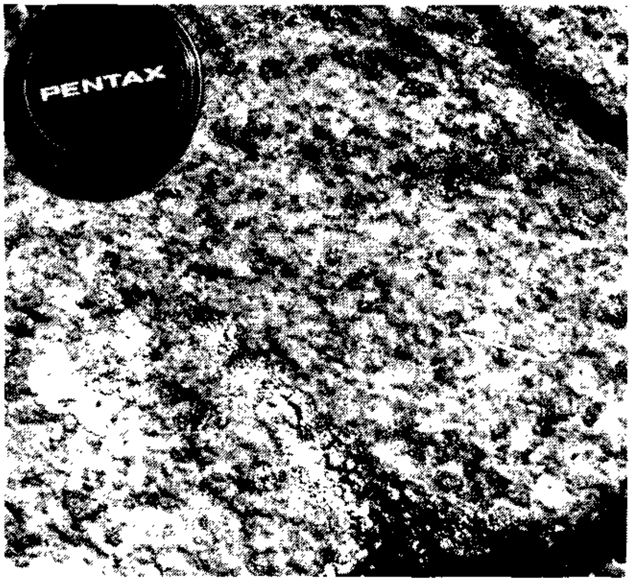

Plate 3-3-1. Weathering appearance of harzburgite with studded orthopyroxene in recessive dunite.

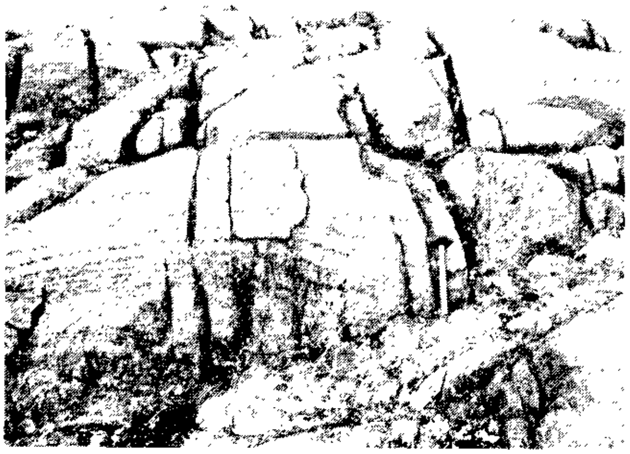

Plate 3-3-2. Tectonite banding (S_1) defined by alternating orthopyroxene-rich and poor layers. Hammer is 35 centimetres long.

homogeneous in modal composition, containing 65 to 85 per cent olivine and 15 to 35 per cent orthopyroxene uniformly dispersed with trace to accessory amounts of chrome spinel. Clinopyroxene may also be present as an accessory phase.

Areas of compositional banding generally consist of alternating pyroxene-poor and pyroxene-rich zones, on a 1 to 2-centimetre scale. Banding is commonly laterally discontinuous and disrupted. Well-developed banding is best exposed on a north-trending knoll 500 metres southwest of the summit of Monarch Mountain (Plate 3-3-2).

Texturally the harzburgite is medium to coarse grained porphyroclastic (as defined by Nicolas *et al.*, 1980). In thin section, chrome-spinel is typically dark red-brown and has an irregular habit. Larger orthopyroxene grains commonly have clinopyroxene exsolved along cleavage and kink planes.

DUNITE

Dunite bodies, hosted by harzburgite, are generally elongate and podiform with long axes concordant with the harzburgite foliation. These bodies vary from a few metres to several hundred metres in length. Weathering of dunite produces smooth tan-brown surfaces which are easily distinguishable from the rough-textured and slightly darker weathering harzburgite (Plate 3-3-3). The rocks generally display 1 to 4 per cent (0.2 to 0.4 mm) disseminated subhedral to euhedral black chrome-spinel grains. Contacts with the enveloping harzburgite are sharply defined by dramatic changes in orthopyroxene content over distances of less than a centimetre. Smaller, 0.5 to 1-metre, dunite pods occur for several metres into the harzburgite marginal to the larger dunite bodies.

These dunite bodies are interpreted to represent open-system magma chambers in the mantle, from which olivine and chromite have accumulated during fractional crystallization of ascending basaltic melts. This interpretion is consistent with the accepted origin of such bodies in other mantle sequences (Malpas, 1978; Duke, 1983; Gregory 1984).

PYROXENITE DIKES

Pyroxenite dikes are medium to coarse grained and display sharp contacts with harzburgitic hosts. Dikes are interpreted to be intruded as liquidus melts during the deformation of the host ultramafics. Orientations of the dikes are predominantly concordant but may also be oblique to highly discordant with the tectonite fabric, indicating synkinematic to postkinematic intrusion (Plate 3-3-4).

ALTERATION

Serpentinization has produced rocks partially or wholly altered to serpentine (predominantly antigorite) and minor magnetite. The degree of serpentinization varies from 20 per cent (rare) to totally altered varieties which characteristically develop close to fault zones. Most rocks are 40 to 70 per cent altered but the relict primary mineralogy is readily discernible. Bastitized orthopyroxene forms diffuse black spots in a dull grey background of serpentinized olivine. The least-

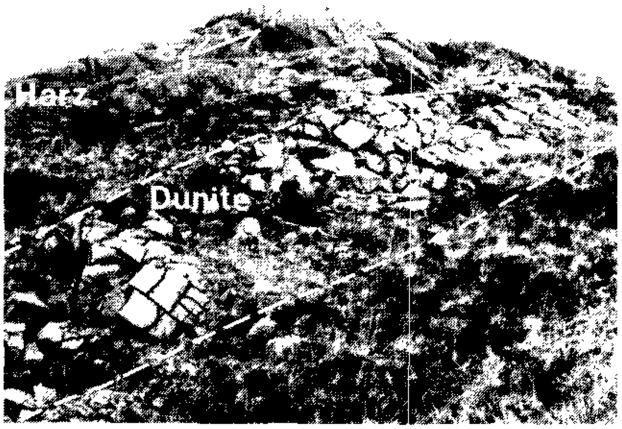

Plate 3-3-3. Typical lenticular (podiform) dunite body, with the long axis concordant with the tectonite fabric.

Plate 3-3-4. Concordant and discordant pyroxenite dikes in harzburgite suggest synkinematic to postkinematic emplacement under mantle conditions.

altered harzburgite exposures outcrop along a north-trending ridge approximately 60 metres southwest of the summit of Monarch Mountain.

Carbonatization (CO_2 metasomatism) of the ultramafic rocks is everywhere localized along fault zones. Alteration commonly envelopes or mantles the faults and produces a characteristic listwanitic alteration assemblage. Generally, this alteration decreases in intensity away from the fault as indicated by the inwardly zoned mineralogical variation: talc, talc + carbonate, carbonate + quartz + talc, carbonate + mariposite + quartz ± sulphides ± gold.

The onset of carbonatization of the ultramafic rocks is indicated by the appearance of talc in the serpentinized harzburgites seen in thin section. Initial replacement of bastite by talc and possibly mariposite was noted. Talc alteration of the ultramafic rocks extends from one to tens of metres away from the fault and is apparently a direct function of the scale of the structure. Intense alteration, most important economically because it hosts quartz veins that may be auriferous, is commonly concentrated in the fault zone itself.

Pervasive alteration of the ultramafics produces carbonate rocks consisting predominantly of iron-rich magnesite (Newton, 1985) and ankerite. Dolomite is common in microveinlets to veins up to 10 to 15 centimetres wide. These veins consist of white dolomite with millimetre to centimetre-scale inclusions of iron-magnesite, which may represent xenoliths of the host carbonatized ultramafite.

Quartz veining appears to be episodic and occurs on a variety of scales. Millimetre-scale quartz veinlets are common and may be preferentially oriented, however, vein networks are also present. These quartz veins may be related to desilicification of the ultramafic rocks during carbonatization. Generally later quartz veins are several centimetres to tens of centimetres wide.

Weathering of the pervasively altered ultramafics produces easily identified potentially gold-bearing targets. Outcrops are orange-brown in colour with conspicuous white dolomite and quartz veins which stand out due to differential erosion.

Chemical variations related to the alteration and mineralization of these carbonatized fault zones are currently under investigation.

TECTONIC MÉLANGE ASSEMBLAGE

Massive fine-grained grey-weathering limestone characteristically forms tectonic blocks from centimetres to hundreds of metres in size. These carbonate (±chert) knockers are hosted in a fine-grained, extremely fissile and flaggy argillite unit (Kedahda Formation, Monger, 1975). The mélange is extensive throughout the southern part of the map area. The larger scale tectonic features are well exposed along the shore of Atlin Lake.

STRUCTURE

The harzburgite tectonite unit displays both an early (S_1) mantle fabric that is overprinted by a later (S_2) fabric related to thrusting which is also well developed within the argillites.

Field measurements obtained from the harzburgite unit include:

S_1: A twofold division defined by a foliation (solid state dislocation) fabric outlined by elongate grains or crystal aggregates of orthopyroxene, and compositional banding (metamorphic differentiation). Both these features are typically formed by mantle processes (Plate 3-3-2).

S_2: A serpentinite-bastite fabric, defined by black-weathered bastite (after orthopyroxene) within the lighter grey weathered serpentine (after olivine). Structures may range from partially serpentinized harzburgites which display trails of bastite around orthopyroxene cores, to highly strained and commonly more altered varieties in which a mylonitic texture is developed as thinly banded (1 to 3 mm) bastite-serpentinite with bastite porphyroclasts after orthopyroxene (Plate 3-3-5). These structures are consistent with the thrusting direction and are interpreted to be related to emplacement.

Strongly sheared and schistose grey-green serpentinite containing dark brown harzburgite knockers, 2 to 15 centimetres across, exposed along the shore near the town of Atlin, represents a typical serpentinite mélange assemblage (Plate 3-3-6). The mélange and related schistosity are S_2 deformation features.

Pronounced schistosities developed within the argillite unit are consistent with the S_2 fabric in the ultramafic rocks.

THRUST FAULTING

The arcuate surface trace of the Monarch Mountain thrust fault follows the lower southern and eastern slopes of Monarch Mountain. The fault contact does not outcrop, however, its approximate location is well constrained by the contrasting lithologies and styles of deformation across it. Lithologies on both sides of the fault display evidence of intense deformation with associated hydrothermal carbonate alteration. Mantle harzburgite exposed near the basal surface of the Monarch Mountain thrust is ductilely deformed and intensely carbonatized (listwanitic) with quartz stingers oriented parallel to the thrust surface (Plate 3-3-7).

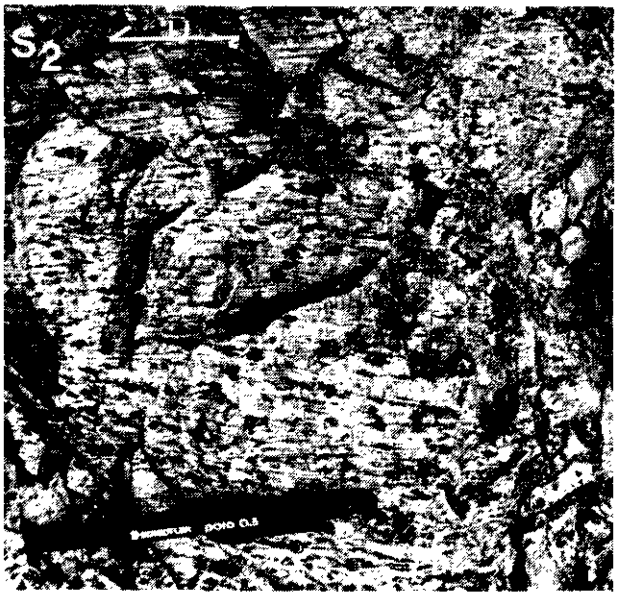

Plate 3-3-5. Well-banded mylonitic serpentinite bastite fabric (S_2) with relict orthopyroxene porphyroclasts.

Massive limestones and basalt in the footwall of the thrust yield to brittle fracture and brecciation as evidenced by the cataclastic features produced. Massive limestone exposed directly below the thrust, in a road cut along Warm Bay road, is intensely brecciated into 1 to 3-centimetre angular fragments which are cemented (flooded) by hydrothermal carbonate. Within this outcrop well-developed mullions plunge at roughly 30° to the northwest, providing further support for the concept of southeasterly directed emplacement (Plate 3-3-8).

Drill-core information from the Pictou property (MINFILE 104N 044; Homestake Mineral Development Company) defines a similar fault contact dipping at approximately 30° to the northwest. Core logs indicate that intensely carbonatized (listwanitic) harzburgite at this location sits structurally above intensely brecciated basalt cemented by carbonate.

Numerous, later high-angle faults are evident throughout the Monarch Mountain plateau. They are clearly evidenced in the field by linear topographic depressions tens of metres deep. Exposures on both sides of the depressions are increasingly altered toward the centre of the fault zone.

STRUCTURAL INTERPRETION

A dominantly northeast structural grain characterizes the map area. S_2 fabric elements and thrust plane geometry are essentially parallel and reflect the southeasterly directed emplacement within the map area. S_1 fabric elements are more or less consistent with the northwest structural grain but also show the most deviation from it. The variation in S_1 may not reflect primary mantle geometry since the ultramafic nappe has been affected by later high-angle normal faulting. This may, in part, reflect crushing of the body during emplacement at higher structural levels. It may also be due, in part, to high-angle regional-scale transcurrent faulting which has affected the region (Monger, 1984).

Plate 3-3-6. Serpentinite mélange with harzburgite knockers in a matrix of highly sheared serpentinite, exposed along the shore of Atlin Lake near the town of Atlin.

Plate 3-3-7. Quartz stringers within intensively carbonatized harzburgite near the base of the Monarch Mountain thrust. Note the dilational zones at moderate to high angles from S_2.

Plate 3-3-8. Northwesterly plunging mullions in brecciated limestone cemented by carbonate, exposed in road cut along Warm Bay road below the Monarch Mountain thrust.

REGIONAL GEOTECTONIC IMPLICATIONS

Analysis of the available regional geological data supplemented by new observations from aerial photography and the authors' reconnaissance suggests that the locally defined thrusting is consistent with the regional structural pattern. The 1:70 000 aerial photographs of the area display curvilinear features, on a scale of tens of kilometres, which verge toward the southeast.

A 1:20 000 geological compilation map of the Atlin area by Lefebure and Gunning (1989) depicts elongate bodies of ultramafic rocks which also define a lobate distribution pattern consistent with the structural grain seen on the aerial photographs. This map pattern is similar to that described by Monger (1975) for the Nakina Lake area, in which fault planes are marked by serpentinite slices. These strongly altered and deformed ultramafic slivers are generally contained in fault or mélange zones that may attain hundreds of metres in width. An example is the Beavis fault, described by Bloodgood *et al.* (1989a) as "characterized by brecciation and intercalation of diverse Cache Creek lithologies." Lithological diversity is clearly evident in exposures along McKee Creek, which include ultramafic, volcanic and sedimentary rocks chaotically distributed on a scale of tens of metres. Varying degrees of alteration and deformation of all lithologies by both shearing and brecciation are evident. Observation of limited outcrop exposed by placer operations on Pine Creek and Spruce Creek also suggests the presence of fault or mélange zones.

Detailed drilling by Homestake on the Yellowjacket property (MINFILE 104N 014) has demonstrated that the Pine Creek fault is a low-angle reverse fault dipping approximately 25° northwest (D. Marud, personal communication, 1989)

Recent 1:50 000 geological mapping by Bloodgood and Bellefontaine (1990, this volume) has demonstrated that southeasterly directed thrusting is a significant structural feature of the Atlin Terrane to the south of the study area.

No coherent ophiolite stratigraphy is evident in the Atlin area, however all the lithological components are represented and have been juxtaposed by tectonic imbrication.

The amount of oceanic crust emplaced or preserved in a classical ophiolite sequence is clearly a function of both the dynamics of oceanic plate consumption (obduction) and the degree of deformation that has affected that obducted crust. In the Atlin map area syn-emplacement deformation is related to the compressional tectonics during thrusting which dismembered the oceanic suite. This dismemberment is further complicated by later transcurrent faulting (post-emplacement deformation).

ECONOMIC GEOLOGY

LODE GOLD

Gold-bearing quartz-carbonate veins have been unanimously proposed by workers in the Atlin area as the source for placer deposits (Aitken, 1959; Monger, 1975; Ballantyne and MacKinnon, 1986; Lefebure and Gunning, 1988; Rees, 1989). Although placer mining has won significant quantities of gold in the Atlin region (Debicki, 1984), only minor amounts of lode gold have been recovered (Lefebure and Gunning, 1988).

Lode gold showings in the Atlin area are characteristically located within faults or fault zones and are spatially associated with carbonatized ultramafic rocks (Bloodgood 1989b; Rees, 1989), as is common with this type of deposit (*see* discussion by Ash and Arksey, 1990, this volume). As these deposits are structurally controlled, an adequate understanding of the structural environment of the area is critical to their exploration. The new structural interpretation outlined above will hopefully facilitate that process.

Interestingly, most of the current and past placer operations in the area occur along streams which follow the linear depressions that define the inferred thrust contacts. Locally the surface trace of the Monarch Mountain thrust along the southeastern flank of Monarch Mountain (Figure 3-3-2) is covered by overburden and may represent a potential zone of gold mineralization.

Aspects of the timing of carbonatization of the ultramafic rocks and related quartz veining and possible relationships between intrusive granitoids and quartz lodes are currently under investigation.

CHROMITE

Dunite bodies within the harzburgite unit represent potential hosts for podiform chromite deposits (Duke, 1983) but only minor amounts (1 to 4 per cent) of disseminated chromite were noted during our field studies.

CONCLUSIONS

Ultramafic rocks in the Atlin area represent an allochthonous unit of predominantly residual mantle harzburgite tectonite. Structural data indicate that thrust emplacement was southeasterly directed.

The "Atlin intrusions" are clearly not intrusive but rather are of ophiolitic origin for the following reasons:

- The lithological association of foliated harzburgite with pockets of dunite and pyroxenite dikes is consistent with that identified in residual mantle sequences from ophiolites throughout the world.
- The identification of synkinematic high-temperature ductile subsolidus to hypersolidus deformation features (S_1), combined with mineralogical homogeneity of the harzburgite, supports a residual mantle origin for the ultramafic rocks. Malpas (1978) demonstrated that simultaneous crystallization of both olivine and orthopyroxene from a basaltic melt is not possible by cumulate processes, due to the reaction relationship between olivine and orthopyroxene at pressures compatible with the environment of oceanic crustal formation.
- Oceanic upper mantle material is presently resting on deep to shallow-water sediments and basalts and, therefore, invokes a structural unconformity.

Mapping by Bloodgood *et al.* (1989b), indicates that tectonic imbrication has created slivers of ultramafite associated with other oceanic lithologies, displaying consistent structural relationships. Tectonic slices are separated in places by tectonic mélange that displays a range of brittle to ductile deformational features reflecting the contrasting lithological elements present and differing levels of associated deformation.

Later crustal-scale transcurrent faulting may have obscured the paleo-emplacement direction and could account for the local diversity of the structural fabrics relative to the general northwest structural grain characteristic of the Atlin Terrane (Monger, 1975, 1977b).

An understanding of the geotectonic framework is critical to the successful exploration for lode gold deposits in the Atlin area.

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