CHAPTER 2
NORTHERN CACHE CREEK TERRANE
ATLIN CAMP

INTRODUCTION

The Atlin placer gold camp, located in northwestern British Columbia on the eastern shore of Atlin Lake (Figure 2.1, Photo 1) ranks as the second largest producer of placer gold in the province. Mining has been for most of its history the economic mainstay for the picturesque town of Atlin since the discovery of gold on Pine Creek in 1897 (Mandy, 1936), a discovery which interrupted the intended gold-rush journey for many fortune seekers to the Klondike. During its heyday near the turn of the last century, the former town of Discovery, 12 kilometres east of Atlin on Pine Creek, boasted a population in excess of 10 000.

Reported placer gold production between 1898 and 1946 from creeks in the Atlin area totaled 19 722 kg (634 147 ounces*, Holland, 1950). A number of the larger placers, including those on Otter, Spruce and Pine creeks, continued to produce significant quantities of gold into the late 1980s. During fieldwork in 1991, Otter Creek was the only active placer producer, aside from a number of small-scale operators. Although the total gold production from the area to date is not available, it probably exceeds 1 million ounces and could be significantly greater.

Numerous gold quartz veins occur in the immediate area of the gold placers and are considered to be the source (Aitken, 1959; Ballantyne and MacKinnon, 1986; Lefebure and Gunning, 1988; Rees, 1989; Ash and Arksey, 1990a,b). Many of these occurrences were identified at the turn of the twentieth century following the discovery of placer gold. The only recorded lode gold producer was from the Imperial mine (Figure 2.4) which during 1899 and 1900 produced 268 tonnes of ore with an average gold grade of 13.0 grams per tonne (Bloodgood et al., 1989a).

This chapter discusses the lithotectonic setting and timing of gold-quartz vein mineralization throughout the camp, in the context of the tectonic and plutonic history of the northern Cache Creek (Atlin) Terrane. Initial studies involved 1:25 000-scale mapping of the immediate Atlin area, in an attempt to establish the origin and tectonic setting of the ultramafic and related ophiolitic rocks (Ash, 1994; Ash and Arksey, 1990a, b, c).

PREVIOUS WORK

The first systematic geological mapping of the Atlin area was that of Aitken (1959). Monger (1975; 1977a) mapped ten specific areas of the northern Cache Creek (Atlin) Terrane and provided the first regional overview and tectonic synthesis. Bloodgood et al. (1989a, b) conducted 1:50 000-scale geological mapping of the Surprise Lake (104N/11W) and Atlin (104N/12E) map areas. Bloodgood and Bellefontaine (1990) mapped the Dixie Lake (104N/6) and Teresa Island (104N/5) sheets at a similar scale. Lefebure and Gunning (1989) compiled a 1:20 000 geological map of the Atlin mining camp using information obtained chiefly from exploration assessment reports.

Studies of lode-gold mineralization in the Atlin camp have been made by a number of researchers. Newton (1985) studied the mineralogical and geochemical character of listwanitic alteration assemblages from four lode gold properties in the area. Lueck (1985) completed a similar study focusing specifically on the Anna claims. Andrew (1985) describes the fluid inclusion and lead isotope characteristics of some of the mineralized quartz veins. A comparative study of the mineralogical and chemical characteristics of both placer and lode gold was conducted by MacKinnon (1986). Bozek (1989) investigated trace element signatures related to listwanitic alteration halos on the Yellowjacket and Pictou properties, and identified potential pathfinder elements indicative of gold mineralization. Lefebure and Gunning (1988) and Rees (1989), published property descriptions of the Yellowjacket and Pictou lode gold prospects, respectively. Studies of the surficial geology of the camp include those of Black (1953), Proudlock and Proudlock (1976), Levson (1992) and Levson and Kerr (1992).

In addition to these publications, results of a large volume of exploration work conducted in the immediate area are documented in assessment reports filed with the provincial government by mining and exploration companies. These reports include details of trenching, drilling and sampling programs as well as mapping and geophysical surveys.

REGIONAL GEOLOGICAL SETTING

The Atlin map area is located in the northwestern corner of the northern Cache Creek (Atlin) Terrane (Figure 2.2). It contains a fault-bounded package of late Paleozoic and early Mesozoic dismembered oceanic lithosphere (Monger, 1975, 1977a, b, 1984; Tempelman-Kluit 1979), intruded by post-collisional Middle Jurassic, Cretaceous and Tertiary felsic plutonic rocks (Wheeler and McFeely, 1991; Mihalynuk et al., 1992). The terrane is dominated by mixed graphitic argillite and pelagic sedimentary rocks that contain minor pods and slivers of metabasalt and limestone. Remnants of oceanic crust and upper mantle lithologies are concentrated along the western margin. Dismembered
Figure 2.1. Location of the Atlin map area.
Photo 2.1. View looking north over Atlin Lake with Monarch Mountain in the foreground and the town of Atlin at the centre of the photo.

Figure 2.2 Geological setting of the northern (Atlin) Cache Creek Terrane, modified from Monger, 1975.
ophiolitic assemblages have been described at three localities along this margin: from north to south they are the Atlin (Ash, 1994), Nahlin (Terry, 1977) and King Mountain (Leaming, 1980) assemblages. Each area contains imbricated mantle harzburgite, crustal plutonic ultramafic cumulates, gabbros and diorite, together with hypabyssal and extrusive basaltic volcanic rocks. Thick sections of late Paleozoic shallow-water limestone dominate the western margin of the terrane and are associated with alkali basalts. These are interpreted to be carbonate banks constructed on ancient ocean islands within the former Cache Creek ocean basin (Monger, 1977b).

The ages of rocks in the terrane are interpreted primarily from paleontological data. Isotopic age data for oceanic crustal plutonic rocks includes a single U-Pb zircon age of around 245 Ma for peridotite from Cache Creek rocks in Yukon (Gordy et al., 1998). Fusulinid-bearing limestones range in age from Carboniferous to Late Permian with Permian faunas dominating (Monger, 1975). Radiolarian assemblages range in age from Carboniferous to Late Permian with Kon (Gordy et al., 1998) giving the youngest fossil ages (Cordey et al., 1998). The oldest extrusive basaltic volcanic rocks. Thick sections of late Paleozoic shallow-water limestone dominate the western margin of the terrane and are associated with alkali basalts. These are interpreted to be carbonate banks constructed on ancient ocean islands within the former Cache Creek ocean basin (Monger, 1977b).

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The northern Cache Creek Terrane to the east is bordered mainly by the Thibert Fault which continues northeastward along the Teslin lineament. Discontinuous exposures of altered ultramafite along the fault suggest that it has previously undergone significant reverse motion and may be a reactivated thrust or transpressional fault zone. Latest movement on this fault is thought to be dextral strike-slip, of pre-Late Cretaceous age (Gabrielse, 1991).

The terrane is dominated by sub-greenschist, prehnite-pumpellyite facies rocks, however, local greenschist and blueschist metamorphism are recorded (Monger, 1975, 1977b). The terrane is characterized by a northwesterly-trending structural grain, however, in the Atlin - Sentinel Mountain area there is a marked deviation from this regional orientation with a dominant northeasterly trend. Reasons for this divergence in structural grain are poorly understood.

**LOCAL GEOLOGY**

The geology of the Atlin map area (Ash, 1994; Figures 2.4a and b) is divisible into two distinct lithotectonic elements. A structurally higher, imbricated sequence of oceanic crustal and upper mantle lithologies termed the “Atlin ophiolitic assemblage”, is tectonically superimposed over a lower and lithologically diverse sequence of steeply to moderately dipping, tectonically intercalated slices of pelagic metasedimentary rocks with tectonized pods and slivers of metabasalt, limestone and greywacke termed the “Atlin accretionary complex”. Locally these elements are intruded by the Middle Jurassic (Mihalynuk, et al., 1992) calcalkaline Fourth of July batholith and related quartz-feldspar porphyritic and melanocratic dike rocks.
Figure 2.4a. Geology and distribution of lode gold showings in the Atlin camp (simplified after Ash, 1994). Area of gold placers taken from Levson and Kerr (1992). For legend refer to Figure 2.4b.

Figure 2.4b. Schematic geological cross-section of the Atlin area. Lines of section illustrated on Figure 2.4a.
ATLIN OPHIOLITIC ASSEMBLAGE

The Atlin ophiolitic assemblage comprises an imbricated sequence of relatively flat-lying, coherent thrust slices of obducted oceanic crustal and upper mantle rocks. Mantle lithologies are dominated by harzburgite tectonite containing subordinate dunite and lesser pyroxenite dikes. The unit forms an isolated klippe that underlies Monarch Mountain and the town of Atlin (Figure 2.4), and is exposed on the northern and southern slopes of Union Mountain. Ductile deformational fabrics indicative of hypersolidus to subsolidus deformation, and the phase chemistry of primary silicates and chrome spinels in the harzburgite (Ash, 1994) indicate a uniform, highly refractory composition and support a depleted mantle metamorphic origin for the unit. The least serpentinized rocks with well preserved primary structures and textures crop out at the highest elevations on Monarch Mountain (Figure 2.4a and b, Photos 2.2 and 2.3). Primary features are less well preserved towards the base of the body and internally, where it is cut by high-angle fault zones, the unit becomes increasingly serpentinized. Serpentinite mylonite fabrics are locally preserved near the base of the body (Photo 2.4). Commonly the basal contact of the harzburgite unit is pervasively carbonatized and tectonized over distances of several tens of meters or more (Photo 2.5).

Oceanic crustal lithologies in the Atlin map area, in decreasing order of abundance, include metamorphosed basalt, ultramafic cumulates, diabase and gabbro with metabasalts dominating. They are generally massive, fine grained to aphanitic and weather a characteristic dull green-grey colour. Locally, the unit grades to medium-grained varieties or diabase. Primary textures locally identified in the metabasalt include flow banding, autobrecciation and rare pillow structures. Although rarely exposed, basalt contacts are commonly sheared or brecciated zones, sometimes intensely carbonatized. Petrochemical investigations of these basaltic rocks (Ash, 1994) indicate that they are similar in composition to basalts of normal mid ocean-ridge settings and the chemistry also suggest a genetic relationship to the associated depleted metamorphic mantle ultramafic rocks.

Serpentinized peridotite displaying ghost cumulate textures and sporadically preserved relict poikilitic texture is suspected to originally be wehrlite. The peridotite forms an isolated thrust sheet which outcrops discontinuously along an east-trending belt 1 to 3 kilometres wide on the south-facing slope of Mount Munro. Extensive exploration drilling along the base of Mount Munro at the Yellowjacket lode gold property indicates that the serpentinized body is in structural contact with metabasaltic rocks along a gently northwest-dipping thrust (Marud, 1988a,b). Along the contact zone hangingwall ultramafites and footwall metabasalts are tectonically intercalated and carbonatized. Projection of this fault across the Pine Creek valley suggests that carbonatized and serpentinized ultramafic rocks on the summit of Spruce Mountain represent a remnant above an extension of the same tectonized and altered basal contact.

Metagabbro is the least commonly seen ophiolitic component in the map area. It crops out on the northern slope of
Union Mountain and along the south-facing slope of Mount Munro. It is abundant in drill core from the Yellowjacket property along Pine Creek, where it occurs as isolated pods and lenses within the Pine Creek fault zone (Lefebure and Gunning, 1988; Marud, 1988 a, b). On Union Mountain, gabbro occurs along the Monarch Mountain thrust as isolated dismembered blocks with faulted contacts.

**ATLIN ACCRETIONARY COMPLEX**

The Atlin accretionary complex comprises a series of steeply to moderately-dipping lenses and slices of structurally intercalated metasedimentary and metavolcanic rocks that underlie the southern half and northwest corner of the map area. Pelagic metasedimentary rocks dominate the unit and consist of argillites, cherty argillites, argillaceous cherts and cherts with lesser limestones and greywackes. They range from highly mixed zones with well-developed flattening fabric indicative of tectonic melange to relatively coherent tectonic slices. Individual slices range from metres to several hundreds of metres in width. Indications of internal deformation are moderate or lacking; in a few slices original stratigraphy is well preserved. Contact relationships between many of the individual units of the complex have not been established due a lack of exposure, however, most are inferred to be tectonic. Internal bedding within the individual lenses in some places is parallel to the external contacts, but is more commonly strongly discordant. This argues against simple interfingering of different facies.

A common feature throughout the accretionary complex, particularly in areas of moderate overburden, is closely spaced outcroppings of different lithologies with no clearly defined contacts. Such relationships are interpreted to represent areas of mélange in which the exposed lithologies that commonly include chert, limestone and basalt are more competent than the intervening, recessive fis-

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Photo 2.3 Folded pyroclnite dike in harzburgite tectonite near the summit of Monarch Mountain.

Photo 2.4 Serpentinite-bastite mylonite developed in harzburgite near the base of the Monarch Mountain Allochthon.

Photo 2.5 Shoreline outcrop of brecciated and pervasively carbonatized harzburgite, shore of Atlin Lake south of Atlin.
sile and argillaceous matrix. Such relationships are confirmed where sections are exposed along road cuts and in areas of trenching.

**INTRUSIVE ROCKS**

**Fourth of July Batholith**

The southern extension of the Middle Jurassic Fourth of July batholith (Aitken, 1959; Mihalynuk et al., 1992) into the northeastern corner of the map area is the only major intrusive unit exposed in the region. The potassium feldspar megacrystic granite to granodiorite phase of this composite pluton predominates. Pink potash feldspar megacrysts set in a coarse-grained equigranular groundmass of mottled pale green to buff-white plagioclase and grey quartz typifies the unit in this area. Prismatic megacrysts range from 1 to 4 centimetres in length and comprise from 15 to 30% of the unit. Mafic minerals are restricted to the groundmass and consist of both amphibole and biotite, with combined modal abundances of 5 to 20%. Primary clinopyroxene typically mantled by amphibole is a common but minor mafic phase. Accessory magnetite comprises 1 to 2% of the groundmass.

Uranium-lead analysis on zircon from two samples representing distinct phases of this multiphase pluton indicate a range in the age of crystallization from 166.5 to 174 Ma that gives a combined best estimate of 171.7±3 Ma (Mihalynuk et al., 1992). A lack of evidence for inheritance in these zircons, combined with low ⁸⁷Sr/⁸⁶Sr initial ratios, suggest derivation of the magma from a primitive, unevolved source, consistent with thickened oceanic lithosphere and derivation of the magma from a primitive, unevolved source, consistent with thickened oceanic lithosphere and arc rocks.

Biotite from a small stock of orthoclase feldspar megacrystic granodiorite that crops out in the valley midway between Monarch and Union mountains yielded a K-Ar age of 173±4 Ma (Dawson, 1988). This is within error of the Middle Jurassic U-Pb crystallization age reported for the main body of the Fourth of July batholith. The pluton cuts fabrics as well as faulted contacts within the oceanic Cache Creek rocks but itself lacks penetrative fabrics and therefore postdates accretion of the ophiolitic assemblage. The timing of the cross-cutting plutonism gives a minimum age of accretion and imbrication of the oceanic Cache Creek Complex. A similar age and inferred tectonic relationship are reported for a granodiorite stock (K-Ar, biotite of 173±4 Ma) which intrudes sedimentary and ultramafic rocks in the southern part of the northern Cache Creek Terrane near Tachilta Lakes, 60 kilometres northwest of Dease Lake (Stevens et al., 1982).

**Feldspar ± Quartz Porphyritic Dike Suite**

A suite of felsic, two feldspar quartz-porphyritic dikes that are considered to be related to the Fourth of July batholith are sporadically exposed in the map area. They consistently occur near gold bearing quartz veins. Dikes are usually from 0.5 to 2 metres wide, have variable orientations and dip steeply. They lack penetrative deformation and crosscut fabrics and deformed tectonic contacts between all oceanic rocks. Typical dikes consist of randomly oriented, dull white, prismatic plagioclase phenocrysts 1 to 4 millimetres long, set in a grey anhedral groundmass and comprising from 20 to 50% of the rock. Variable amounts of amphibole and quartz (0 to 20%) also occur as phenocrysts of comparable size. Many of the dikes contain secondary carbonate and sericite from trace to several percent in modal abundance. Feldspar phenocrysts weather a distinctive orange-brown colour due to the effects of carbonate alteration. The groundmass is variably silicified and carbonatized and contains from 3 to 15% fine-grained disseminated pyrite. Altered dikes are commonly anomalous in gold. Lefebure and Gunning (1989) report the occurrence of altered porphyritic dikes in association with gold mineralization at the Beavis, Imperial, Yellowjacket and Anna properties. Rich (1985) reports a similar relationship on the Golden View property. Dikes also occur at the Anaconda showing and have been reported in drill core from the Heart of Gold property (McIvor, 1988a).

**GOLD MINERALIZATION IN THE ATLIN CAMP**

**TECTONIC SETTING**

Gold-quartz vein mineralization in the Atlin camp appears to be confined to carbonatized fissure zones within and in close proximity to ultramafic rocks of both the mantle harzburgite and the plutonic oceanic crustal units of the Atlin ophiolitic assemblage. Many of the known gold quartz vein mineralization occurrences are localized along the tectonized basal thrust fault of the harzburgite unit, the Monarch Mountain thrust (Ash, 1994; Figure 2.4a and b). These include the Beavis, Pictou, Heart of Gold, Aitken Gold, Anaconda and Goldenview prospects, which are all located along the annular surface trace of the basal fault contact. Others, including the Goldstar and Anna showings, are hosted by carbonatized fault zones within the harzburgite. These faults are interpreted as second order splays of the Monarch Mountain thrust.

Combined outcrop and drill-hole information indicates that the Monarch Mountain thrust is a relatively flat-lying, gently undulating structure, characterized by a zone of tectonic brecciation and carbonatization several metres to tens of metres wide that affects hangingwall and footwall lithologies. Hangingwall peridotites are the most intensely and pervasively altered due to their reactivity with fluids rich in carbon dioxide. The intensity of alteration in footwall lithologies is highly variable, due to the heterolithic nature of the underlying accretionary complex. Basalts within and adjacent to the basal fault zone are typically carbonatized and, like the ultramafic rocks, are cut by discontinuous silicified shear zones which may be anomalous in gold content. Footwall cherts are subject to brittle fracture and form tectonic breccias commonly cemented by hydrothermal carbonate with lesser silica. Argillaceous rocks within the thrust are intensely sheared and commonly form gouge zones.

The arcuate surface trace of the Monarch Mountain thrust is not exposed on the lower southern and eastern slopes of Monarch Mountain. However, its approximate location is well constrained by outcropping with contrasting lithologies, styles of deformation and carbonate alteration.
Along the northeastern side of the allochthon the thrust trace is completely covered by overburden. Its location is constrained by drill-hole data and ground magnetometer surveys conducted on the Heart of Gold property which covers the contact in this area (McIvor, 1988a). Drill holes straddle and also penetrate the thrust contact. Three holes parallel to the contact spaced 100 metres apart are collared in variably serpentinized harzburgites. The succession of rock types intersected in each hole is generally similar: first serpentinized ultramafics, followed by an interval of carbonatized ultramafic rocks with intermittent carbonatized shear zones. Below this is a tectonically mixed zone of basalt, diabase and sediments, locally cut by felsic dikes, and ending in brecciated cherts or strongly sheared mixed chert and argillaceous footwall lithologies. No anomalous metal concentrations were reported along this contact.

Tectonized and carbonatized ultramafic rocks exposed at the Pictou prospect (Rees, 1989; Bozek, 1989; Minfile 104N 044), 2.5 kilometres east-southeast of Atlin, are interpreted to be the hangingwall of the Monarch Mountain thrust. Rusty-brown weathering, pervasively carbonatized ultramafic rocks are exposed in an elongate outcrop area measuring roughly 12 by 150 metres at the main Pictou showing (Photo 2.6). The altered rocks are intensely fractured and cut by several generations of quartz veining. Veinlets are restricted to the margins of these dikes, either from this exposure and the intervening area consists entirely of pervasively carbonatized harzburgite. The showing comprises a sparsely mineralized massive white quartz vein that is partially exposed in a caved trench within an area of thick overburden. Several tens of metres west of the vein a pervasively sericitized feldspar-phyric felsic dike with several percent disseminated pyrite is exposed in a roadside outcrop.

The Beavis property (MINFILE 104N 007) is located on the northern edge of the Atlin townsite and covers the northern contact of the Monarch Mountain thrust. This is the only identified mineralization in which gold bearing quartz veins are hosted by accretionary complex sedimentary rocks. Pelagic sedimentary rocks form a strongly tectonized northwest-trending zone several hundred metres wide that separates hangingwall ultramafic rocks from footwall basalts. In this poorly exposed area a series of 15 exploration trenches spaced at 30 to 50 metre intervals exposes the footwall contact and permitted it to be mapped in detail (Figure 2.6) (Photo 2.7). Sheared argillite forms the matrix of the fault zone which also contains lensoid, centimetre-scale chert fragments (Photo 2.8) as well as localized metre-scale blocks of limestone breccia. The unit is highly incoherent and varies from a broken formation to mélange as defined by Raymond (1984). The prominent shear fabric within the argillite trends northwesterly with moderate to gentle dips consistently toward the southwest. Carbonatization of footwall basalts takes place along the contact with the sediments and marginal to undeformed melanocratic and feldspar-phyric dikes related to the Fourth of July Batholith. These dikes are generally steeply-dipping and oriented more or less parallel to the contact and the shear fabric in the sediments. Gold-bearing quartz veins and veinlets are restricted to the margins of these dikes, either within sediments (Photo 2.9) or carbonatized basalts. Ultramafic rocks consisting of serpentinized harzburgite are not exposed in the trenches but crop out several hundred metres to the southwest and along the shore of Atlin Lake (Figure 2.6). The intervening contact zone between the trenches and outcrops of ultramafic rocks forms a broad linear depression.
Figure 2.5. Cross-section illustrating the flat-lying character of the Monarch Mountain thrust at the Pictou property.

Figure 2.6. Geology of the Beavis prospect. Map location shown on Figure 2.4a.
devoid of outcrop. The proximity of auriferous quartz veins to the ultramafic rocks suggests that the contact area adjacent to the ultramafic rocks has potential for the development of high-grade ore shoots. An explanation of this relationship is presented in Appendix III, Deposit Characteristics.

The Golden View showing (MINFILE 104N 042) is located on the western flank of Union Mountain, approximately 6 kilometres southeast of Atlin. It is associated with carbonatized harzburgite along the southern edge of the Monarch Mountain thrust. The showing comprises several quartz veins, 10 to 20 centimetres wide, hosted by carbonatized ultramafic and metabasaltic rocks within the fault zone.

Anna and Aitken Gold are characteristic of lode gold showings hosted by high angle fracture zones within the ultramafic body. The Aitken Gold showing (MINFILE No. 104N019) is a relatively well exposed vein system on the lower western slopes of Monarch Mountain, 3.8 kilometres south of Atlin roughly 50 metres east of the Warm Bay road. Bull quartz veinlets with several percent mariposite form weakly developed stockworks along an east-trending, high angle, variably carbonatized fault zone that cuts variably serpentinized harzburgite. A shallow pit blasted into the hillside exposes several steeply-dipping, anastomosing, quartz-mariposite±carbonate veins 1 to 5 centimetres wide that pinch and swell laterally and vertically (Photo 2.10). Veining is restricted to the core of the fault zone. A characteristic listwanitic alteration halo is developed for several tens of metres on either side of the fault. Alteration passes laterally outward from carbonatized to pervasively serpentinized harzburgite into partially serpentinized harzburgite.

The Anna showing (MINFILE 104N 101; Photo 2.11) is located near the plateau of Monarch Mountain, roughly a kilometre west of its summit. The showing occurs along the same northeast-trending, steeply-dipping fault zone that hosts the Goldstar showing. Similar to the Goldstar showing, a listwanitic alteration halo envelopes the fault (Lueck, 1985). Quartz fills erratically developed fractures within the pervasively carbonatized fault which grades outward through a variably developed talc-carbonate altered zone into serpentine. Mariposite is abundant in the strongly altered core; locally it comprises up to 40% of the rock. Abundant, angular, mariposite-rich fragments, from several
centimetres to several tens of centimetres in size, are dispersed about a pit blasted 1.5 metres into the fractured and veined core zone. A porphyritic felsic dike, 10 metres in width, that appears to parallel the fault and vein system, has been exposed by trenching near the showing. The ultramafic rocks along the dike contact are talc-carbonate altered and cut by gold-bearing quartz veins.

Lode gold mineralization is also associated with the thrust sheet of ultramafic cumulate rocks along the lower southern slopes of Mount Munro and capping Spruce Mountain. Showings hosted by faults bounding this thrust sheet include the Imperial, Yellowjacket, Surprise and Lakeview. The Yellowjacket showing (MINFILE 043; Lefebure and Gunning, 1988; Bozek, 1989) is associated with the basal faulted contact of this ultramafic body along the Pine Creek valley. The contact between the hangingwall ultramafites and footwall metabasalts is not exposed, but is well defined by 86 exploration drill holes (Marud, 1988 a, b; Marud and Southam, 1988). The zone of thrusting is characterized by up to 15 metres of carbonate alteration that contains intermittent zones of quartz-carbonate veining in both hangingwall and footwall rocks. On the Yellowjacket property the thrust fault is disrupted by a later, east-trending, steeply dipping structure referred to as the Pine Creek Fault. This high-angle fault zone averages approximately 70 metres in width and is described by Marud (1988b) as a fault breccia. It is characterized by strongly broken and fractured rocks, with gouge and rubble zones ranging from centimetres to more than 10 metres wide. The zone contains irregular blocks and lenses of all the lithologies that are typical of the Atlin ophiolitic assemblage, metamorphosed basalt, diabase, gabbro and ultramafics as well as younger felsic rocks. Ultramafic rocks vary from completely serpentinized to completely carbonized, with or without quartz veining. Along the fault trend on the shore of Atlin Lake a well washed exposure of monolithic tectonic breccia typifies the character of the fault zone within harzburgite tectonite unit (Photo 2.12). Subangular to subrounded blocks of dark brown harzburgite are enveloped by schistose serpentine.

Marud (1988b) suggested that the later high-angle faulting might be contemporaneous with mineralization along the structure, however, it is more likely that the Pine Creek fault post-dates mineralization. In addition to carbonatized and silicified ultramafic rocks, the fault breccia is dominated by strongly sheared incoherent serpentine that forms the matrix to the carbonate-altered lithologies. If the serpentine had been present during the introduction of the CO2-rich mineralizing hydrothermal fluids one would expect that it too would be altered, or at least show...
some degree of carbonate veining. A preferred interpretation is that movement on the Pine Creek Fault resulted in both the development of the serpentinite and the tectonic entrapment of blocks and lenses of carbonatized and mineralized ultramafic rocks that had formed earlier along the basal fault of the ultramafic thrust sheet. Dikes of the Fourth of July batholith affinity that are considered to be coeval with carbonate alteration and associated mineralization. They occur as pods and slivers within the fault zone. This relationship provides evidence that the fault is later than the mineralizing event. Age data presented elsewhere in this chapter provide additional evidence in support of this interpretation.

The Surprise showing (MINFILE 104N 076) is located on the northeastern flank of Spruce Mountain approximately 1 kilometre northeast of the summit. The occurrence is a steeply dipping north-trending quartz vein approximately 3.5 metres wide, hosted by carbonatized metabasaltic rocks near a faulted contact with intensely carbonatized ultramafic rocks. Ultramafic rocks form a north-northeast trending lens with a width of roughly 150 metres at the showing and appears to thin significantly to the north-northeast. The exposed vein consists of fractured white carbonate alteration and associated mineralization. They occur as pods and slivers within the fault zone. This relationship provides evidence that the fault is later than the mineralizing event. Age data presented elsewhere in this chapter provide additional evidence in support of this interpretation.

The Imperial deposit (MINFILE 104N 008) and Lake View showing (MINFILE 104N 009) are hosted by mafic volcanic and plutonic crustal rocks near the carbonatized, faulted borders of the western and eastern ends of the wehrlitic ultramafic body respectively (Figure 2.4a).

The abandoned Imperial mine is located on the southwestern flank of Mount Munro, 8 kilometres northeast of Atlin. Two northwest-trending auriferous quartz veins dip moderately toward the southwest and are hosted by fissures in carbonatized basalt/diabase and gabbro close to their faulted contact with the ultramafic cumulates. The gold quartz veins are associated with pyrite-sericite-carbonate altered feldspar-phyric dikes that are also anomalous in gold. The Lakeview showing is located between Birch and Boulder creeks north of the east end of Surprise Lake, at the eastern end of the ultramafic thrust sheet. A mineralized northwest-trending quartz vein, 2 centimetres to 1 metre wide, dips steeply to the northeast. The vein is hosted by carbonatized metabasalt adjacent to a faulted contact with serpentined and carbonatized ultramafic rocks.

**ALTERATION AND MINERALIZATION**

Gold-bearing quartz veins in the Atlin camp are typically associated with carbonatized ultramafic or mafic lithologies. Studies of the alteration mineralogy show that the Fe-Mg carbonate, breunnerite (a type of magnesite with 40-80 weight % Mg) is the dominant carbonate replacing the serpentined ultramafic hostrocks. Iron-dolomite is the principal vein carbonate and also occurs in the altered host rocks (Newton, 1985; MacKinnon, 1986; Bozek, 1989). The Fe-Mg content of the magnesite shows considerable variability which is considered to result from differences in the primary composition of the host rocks, whereas Fe-dolomite showed much less variation. A marked increase in potassium content adjacent to the gold-bearing veins is a consistent feature. Unlike the broad halo of secondary carbonate, zones of silicification and quartz veins associated with mariposite are restricted or adjacent to the controlling fracture.

Mariposite (Cr-muscovite) is associated with many of the quartz veins, occurring either within the veins or in the pervasively carbonate-altered wall-rocks. Newton (1985) studied samples of mariposite from four different showings throughout the camp and identified a relatively uniform compositional range in the major elements Si, Al, K as well as in Cr. In contrast, measured concentrations of trace elements including Fe, Mg, Ni, Ba and V showed some marked variation between individual groups of samples. All samples contained trace amounts of iron but mariposite from two of the gold vein occurrences contained only Mg, Ba and V with no Ni. Where Ni is present in the other two occurrences it is the only trace element present. These differences can be attributed to differences in the character of the ultramafic rock types that are hosts for the mariposite. Samples characterized by selective trace element enrichment only in Ni from the Discovery and Goldenview occurrences are hosted by harzburgite tectonite. Those enriched in Mg, Ba, and V with no Ni from the Lakeview and Surprise showings are hosted by ultramafic cumulate rocks.

It is well established that Ni, which is refractory during processes of mantle partial melting, is selectively enriched in residual metamorphic harzburgite tectonites relative to genetically associated ultramafic cumulate rocks. Ba and V, in contrast are mobile and would be selectively enriched in the melt fraction produced during partial melting in the derived ultramafic cumulate rocks. The provenance of Mg enriched mariposite in the ultramafic cumulates is less clear cut.

These data, although limited, suggest that trace element compositions of mariposite may be used to determine the original composition of the altered ultramafic rocks in which they are hosted. This relationship deserves to be tested further for consistency, but is one that could be used to potentially characterize small zones of ultramafic rocks lacking recognizable primary textures or mineralogy due to intense and pervasive alteration.

Gold occurs either within quartz veins or in zones of carbonatized, potassium metasomatized and pyritized ultramafic and mafic hostrocks immediately adjacent to the veins. It occurs as free gold and as inclusions in sulphide minerals. Gold-bearing hydrothermal systems are generally low in overall sulphide content, ranging from 2 to 5% where they occur as 1 to 3 millimetre, disseminated grains. At both the Pictou and Surprise showings intensely carbonatized ultramafic rocks form zones containing from 10 to 15% finely disseminated sulphides. At these showings gold is anomalous only in the sulphidized zones; white bull quartz veins are barren. At the Pictou showing Bozek (1989) found that there is a positive correlation between elevated gold and higher concentrations of other metals (Cu, Pb, Zn, Sb, As, Ag). Ballantyne and Mackinnon (1986) examined a number

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of gold occurrences and reported that associated elements; Ag, As, Ni, Co, Bi, Sb, Te and Pb are consistently present in the gold-bearing quartz veins.

A range of ore mineralogies and gold compositions have been determined by microprobe and scanning electron microprobe (SEM) examination of quartz vein samples from a number of the occurrences (Table 2.1; S.B Ballantyne and D.C. Harris, personal communication, 1992). Sample analyses were conducted at the Geological Survey of Canada, Ottawa on samples collected by S.B Ballantyne. All samples are from quartz veins in outcrop or dump material except for the Yellowjacket, which is from drill core. The most notable relationship is the wide variation of sulphide minerals between prospect. An increased number of sulphides present in vein systems hosted in ultramafic rocks (Anna and Pictou) suggest inheritance of metallic elements that are primary to the host ultramafic, e.g. Ni, and account for some of the additional sulphide minerals. In contrast, samples from veins hosted by mafic hypabyssal-volcanic rocks such as those at Discovery, Goldenview, Surprise display limited variation in sulphide mineralogy.

The composition of individual gold grains is relatively uniform, but wide variations are possible, even within the same vein sample (see Lakeview and Anna). Neither copper nor mercury was detected in the gold grains analyzed.

AGE OF MINERALIZATION

A number of researchers in the Atlin area have attempted to establish the age of the gold mineralization. Based on lead isotope data for galena from quartz veins, An-

### TABLE 2.1
GOLD COMPILATION AND SULPHIDE MINERALOGY OF SELECTED QUARTZ VEINS IN THE ATLIN CAMP

<table>
<thead>
<tr>
<th>Mineral Occurrence</th>
<th>Mineralogy (generally in decreasing order of abundance)</th>
<th>Average Gold Composition Fineness Range</th>
</tr>
</thead>
<tbody>
<tr>
<td>Anna</td>
<td>pyrite, galena, gersdorffite (NiAsS), bismuthinite (Bi₂S₃), tetradymite (Bi₂Te₂S), sphalerite, chalcopyrite, pyrhotite, millerite</td>
<td>native gold 844 (835-855)</td>
</tr>
<tr>
<td>Discovery</td>
<td>pyrite, galena, pyrhotite</td>
<td>native gold 885</td>
</tr>
<tr>
<td>Shuksan</td>
<td>pyrite, galena, pyrhotite</td>
<td>native gold 885</td>
</tr>
<tr>
<td>Goldenview</td>
<td>pyrite, chalcopyrite, galena</td>
<td>N/A</td>
</tr>
<tr>
<td>Goldenview</td>
<td>galena, pyrite</td>
<td>N/A</td>
</tr>
<tr>
<td>Little Spruce Creek</td>
<td>galena, pyrite</td>
<td>N/A</td>
</tr>
<tr>
<td>Surprise</td>
<td>galena, pyrite</td>
<td>N/A</td>
</tr>
<tr>
<td>Spruce Mtn.</td>
<td>galena, pyrite</td>
<td>N/A</td>
</tr>
<tr>
<td>Lakeview</td>
<td>galena, pyrite, sphalerite, hessite (Ag₂Te), tetradymite (Be₂Te₂S)</td>
<td>native gold with hessite 809 (769-792)</td>
</tr>
<tr>
<td>Shoran</td>
<td>galena, pyrite</td>
<td>N/A</td>
</tr>
<tr>
<td>Birch Creek</td>
<td>galena, pyrite</td>
<td>N/A</td>
</tr>
<tr>
<td>Yellowjacket</td>
<td>galena, pyrite, gersdorffite (NiAsS), rammelsbergite (NiAs₉), millerite</td>
<td>electrum 766</td>
</tr>
<tr>
<td>Pine Creek</td>
<td>galena, pyrite, gersdorffite (NiAsS), rammelsbergite (NiAs₉), millerite</td>
<td>electrum 766</td>
</tr>
<tr>
<td>Pictou</td>
<td>pyrite, freibergite [(Ag,Cu)₁₂(Sb,As)₄S₁₃], chalcopyrite, gersdorffite (NiAsS), rammelsbergite (NiAs₉), sphalerite, acanthite (Ag₂S), millerite</td>
<td>N/A</td>
</tr>
<tr>
<td>Atlin airport</td>
<td>pyrite, chalcopyrite, sphalerite, rutile</td>
<td>N/A</td>
</tr>
<tr>
<td>Beavis</td>
<td>pyrite, chalcopyrite, sphalerite, rutile</td>
<td>N/A</td>
</tr>
<tr>
<td>Atlin Lake</td>
<td>pyrite, chalcopyrite, sphalerite, rutile</td>
<td>N/A</td>
</tr>
</tbody>
</table>

Gold Fineness: approximately \([\text{Au}/(\text{Au}+\text{Ag})] \times 1000\)
drew (1985) proposed a Triassic age. Rees (1989) concluded that mineralization occurred during the period of post-magmatic high-angle faulting associated with the Pine Creek Fault.

In an attempt to establish the timing of listwanite alteration considered to be attendant with gold mineralization, samples of Cr-muscovite were collected from five gold showings in the camp. Three of the samples were taken from listwanite alteration zones within or marginal to the harzburgite body at the Anna, Aitken Gold and Pictou showings. The other two were collected from the basal fault zone of the other ultramafic thrust sheet, at the Yellowjacket and Surprise prospects. Mariposite from the Anna and Goldstar showings occurs in quartz veins and was sampled from blasted pits, to avoid the effects of weathering. The sample from the Yellowjacket was obtained from quartz in drill core supplied by Darcy Marud, formerly of Homestake Mining Company. Mariposite from both the Surprise and Pictou showings was taken from pervasively carbonatized altered ultramafic rocks adjacent to the quartz veins in which there is no visible mariposite.

Results of Ar-Ar Dating

Mariposites from the Surprise, Aitken Gold, Yellowjacket and Pictou lode gold showings (Figure 2.1) were analyzed at Dalhousie University by the conventional $^{40}$Ar/$^{39}$Ar step-heating method described in Appendix II. Age spectrum plots are shown in Figure 2.7.

Samples for the Surprise, Yellowjacket and Aitken Gold showing yielded fairly consistent ages over the major portions of the gas released. There is a tendency for apparent ages to decrease at the highest extraction temperatures. Because these concentrates are fine-grained and relatively impure, irregular spectral features may be produced by irradiation-induced recoil of $^{39}$Ar out of micas and into other, perhaps more argon retentive phases. To compensate for this effect, total gas ages (employing all but the low-age first steps) have been calculated to give the preferred ages indicated in Figure 2.7. These are respectively 168±3, 171±3 and 167±3 Ma. The spectrum obtained for the sample from the Pictou showing is more variable and yields a preferred age of 165±4 Ma. This spectral variation and overall lower apparent ages may both be a consequence of the relatively finer-grained nature of this sample.

Results of K-Ar Dating

Initially K-Ar dating was conducted at The University of British Columbia on mariposite from the Surprise, Pictou, Warm Bay and Anna showings. The analytical data and calculated ages for these hydrothermal micas are given in Table 2.2. The ability to obtain a sufficient amount of mariposite separate needed for K-Ar dating (1 g) proved to be a problem for the majority of the samples. The fine-grained nature of the mineral and a specific gravity similar to that of hydrothermal carbonate, made mineral separation by heavy liquids difficult. Sufficient mariposite to provide a homogeneous clean mineral separate was obtained only from the Surprise showing. It gave an apparent age of 171±6 Ma; an age which is in excellent agreement with the calculated $^{40}$Ar/$^{39}$Ar plateau ages. The other three
samples taken for K-Ar dating failed to provide sufficient mariposite separate and were treated as "whole rocks". This approach had limited success and gave a range of apparent mineralization ages with questionable reliability. The Anna showing was dated at 169±6 Ma which is in agreement with the 40Ar/39Ar data presented above. The Aitken Gold sample gave an apparent K-Ar age of 156±5 Ma years. This is inconsistent with the apparent 40Ar/39Ar date for the same sample, which shows a remarkably uniform plateau, consistent with the other dates, with no indication of a thermal event at 156 Ma. The K-Ar date is therefore considered suspect due to these conflicting data combined with the nature of the sample used. A 121±4 Ma K-Ar cooling age obtained from the Pictou sample (Table 2.3) is markedly discordant with the other mariposite ages. The low potassium content of the analyzed sample suggests that it was relatively deficient in mariposite. This sample provides the most discordant of all the Atlin Ar-Ar plateau ages which may be due to the very fine-grained nature of the hydrothermal mica.

The isotopic data indicate that the formation of mariposite and attendant gold mineralization throughout the Atlin camp is Middle Jurassic in age. The consistency of uniform plateau ages, without indications of significant resetting suggests that the mineralizing episode was a single, relatively short-lived event.

The age data establish a synchronous relationship between gold mineralization (167 to 171 Ma) and intrusion of the late syn-orogenic Fourth of July batholith (166-172 Ma). A direct genetic relationship between gold mineralization and the spatially and temporally associated felsic magmatism appears likely, but remains equivocal.

**SOURCE OF PLACER GOLD**

The gold veins described above have been widely accepted as the source of the abundant gold won from Tertiary and Quaternary placer gravels (Aitken, 1959; Monger, 1975; Ballantyne and MacKinnon, 1986; Lefebvre and Gunning, 1988; Rees, 1989; Ash and Arksey, 1990a). Two convincing lines of evidence support this relationship:

- The coarse, free gold in the veins is similar physically and chemically to the gold recovered from the placer gravels (MacKinnon, 1986; Ballantyne and MacKinnon, 1986).
- The two most productive placer gold streams, Spruce Creek and Pine Creek, drain erosional windows through the basal fault zones of the ultramafic thrust sheets that are hosts for most of the gold mineralization throughout the camp.

Historically, significant economic concentrations of placer gold are restricted to streams in the Pine Creek and McKe Creek watersheds (Figure 2.1). It appears that preferential erosion through flat-lying mineralized thrust contacts in both these areas was accelerated along high-angle, post-accretionary fault zones. This interpretation is supported by the presence of fault breccia zones within both these valleys. The fault breccia along the Pine Creek Fault on the Yellowjacket property has been described previously. A similar tectonic breccia, with lenticular inclusions of various competent lithologies in a sheared and flaggy argillaceous matrix has been recognized at the headwaters of McKe Creek (Photo 2.13a, b). As at the Yellowjacket, the breccia contains isolated tectonic inclusions of altered feldspar-phyric dike rock. Because intrusion of these dikes is interpreted to be coeval with vein mineralization, it can be concluded that movement on the fault postdates the gold mineralization.

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**TABLE 2.2**

**K-Ar MINERALIZATION AGES FOR SELECTED GOLD SHOWINGS IN THE ATLIN CAMP**

<table>
<thead>
<tr>
<th>Showing</th>
<th>K (%)</th>
<th>Rad. Ar40 (%)</th>
<th>Sample Type</th>
<th>Age (Ma)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Anna</td>
<td>0.41</td>
<td>70.4</td>
<td>WR (Marip)</td>
<td>169 ± 6</td>
</tr>
<tr>
<td>Aitken Gold</td>
<td>3.32</td>
<td>91.7</td>
<td>WR (Marip)</td>
<td>156 ± 5</td>
</tr>
<tr>
<td>Pictou</td>
<td>0.18</td>
<td>53.8</td>
<td>WR (Marip)</td>
<td>121 ± 4</td>
</tr>
<tr>
<td>Surprise</td>
<td>7.09</td>
<td>95.7</td>
<td>MS (Marip)</td>
<td>171 ± 6</td>
</tr>
<tr>
<td>FJB Stock1</td>
<td></td>
<td></td>
<td>MS (Sericite)</td>
<td>160 ± 2</td>
</tr>
</tbody>
</table>

1Age reported by Dawson (1988)
MS - Mineral Separate, WR - Whole Rock
All age dates reported where obtained by Joe Harakal and D. Runkel, The University of British Columbia.

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Photo 2.13.a, b. Tectonic melange within the McKe Creek fault zone, headwaters McKe Creek (Photo courtesy of Mitch Mihalynuk).
**SUMMARY**

The northern Cache Creek terrane in the area of the Atlin placer gold camp is lithotectonically divisible into both ophiolitic assemblages and accretionary complexes. Gold veins are only found within or immediately adjacent to the ophiolitic assemblage rocks.

Occurrences of gold quartz vein mineralization throughout the camp are localized along pervasively carbonatized fissure and fracture zones within and marginal to serpentinized mantle tectonite and ultramafic cumulate rocks of the Atlin ophiolitic assemblage.

Gold quartz veins are poorly and erratically developed within the ultramafic rocks and more commonly occur as random fracture fillings. Wider, more continuous tabular fissure veins have been identified only in the mafic igneous crustal components (gabbro, diabase) of the Atlin ophiolitic assemblage where immediately adjacent to carbonatized ultramafic rocks.

Ages of hydrothermal Cr-muscovite (mariposite) associated with the gold mineralization suggest a limited interval of vein formation between 171 and 167 Ma. This age of mineralization is consistent with the timing of Middle Jurassic magmatism at around 171 Ma. There is also a consistent spatial association between known gold vein occurrences and high level dikes and stocks. Both mineralization and magmatism appear to closely follow Middle Jurassic orogenic activity.

Placer deposits within the camp are situated in stream valleys cutting erosional windows through the carbonatized relatively flat lying thrust faults within the Atlin ophiolitic assemblage. The placers are considered to be derived from quartz lodes previously contained within the ophiolitic crustal rocks.

Variations in the trace element composition of Cr-muscovite as defined by Newton (1985) appear to be related to differences in the primary composition of the altered ultramafic host. These data, although limited, suggest that the trace element compositions of mariposite may be used to determine the original composition of the altered ultramafic rocks in which they are contained. This relationship deserves to be tested further to determine if it can be used to characterize small zones of ultramafic rocks that lack recognizable primary textures or mineralogy due to intense and pervasive alteration.