# THE GEOLOGY OF THE ATLIN AREA (DIXIE LAKE AND TERESA ISLAND) (104N/6 and parts of 104N/5 and 12)

## By Mary Anne Bloodgood and Kim A. Bellefontaine

*KEYWORDS:* Regional geology, Atlin Terrane, Stikine Terrane, Nahlin fault, Cache Creek Group, Laberge Group, structure, thrust faults, tear faults, McKee thrust, O'Donnel thrust, Silver Salmon thrust, mineralization.

## INTRODUCTION

The Dixie Lake (104N/6) and Teresa Island (104N/5) map areas are located approximately 20 kilometres south of Atlin in northwestern British Columbia (Figure 1-20-1). Geological mapping at 1:25 000 scale was conducted between mid-June and mid-September and compiled at a scale of 1:50 000. This work marks the second year of a regional mapping project begun during the summer of 1988. Work completed on Atlin Mountain (part of 104N/12) joins with 104M/9 mapped by Mihalynuk and Mountjoy (1990, this volume).

The main contributions of 1989 mapping have been to examine some of the complex structures that exist in Cache Creek rocks and to speculate on the possible boundary relationships between the Atlin and Stikine terranes. An understanding of the structural history is critical to the evaluation of mineral occurrences and economic potential of Atlin and surrounding areas. Lithologies mapped during the 1989 season closely resemble those previously described by Bloodgood *et al.* (1989) with the exception of strata belonging to the Stikine Terrane which outcrop west of the Nahlin fault.

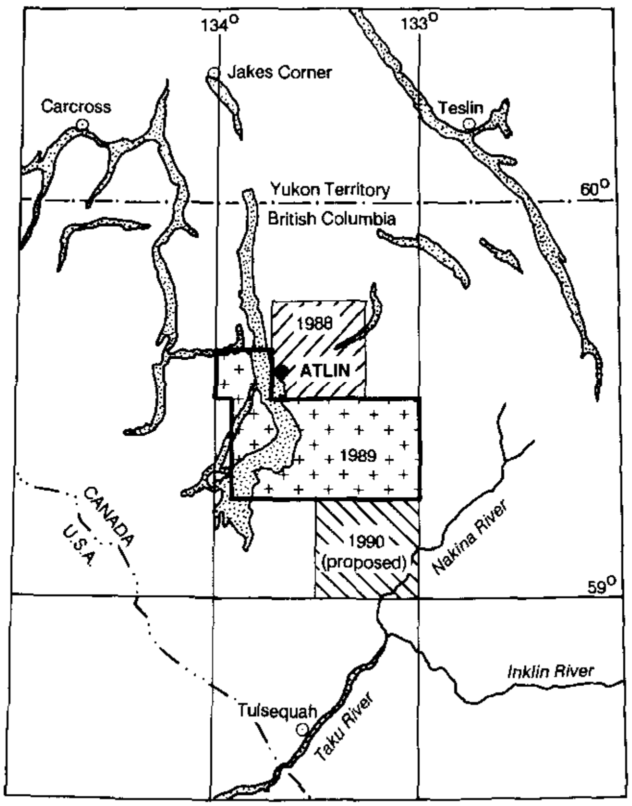



Figure 1-20-1. Location map showing 1988, 1989 and proposed 1990 field areas.

The region east of Atlin Lake is easily accessible by vehicle along a network of roads that follow most of the major creeks in the area. The western part of the map area is only accessible by boat or helicopter.

## REGIONAL SETTING

The study area lies entirely within the Intermontane Belt and straddles the tectonic boundary between the Atlin and Stikine terranes. The northwest-trending boundary is defined by the Nahlin fault (Figure 1-20-2). The area west of this structure is underlain by Mesozoic and Cenozoic clastic rocks of the Inklin overlap assemblage (Wheeler *et al.*, 1988) which covers Jurassic Stuhini island arc volcanic rocks. These strata have been examined by Bultman (1979), Mihalynuk and Rouse (1988), Mihalynuk *et al.* (1989) and Mihalynuk and Mountjoy (1990, this volume) near Tagish Lake. Equivalent strata in the Yukon Territory have been studied by Doherty and Hart (1988) and Hart and Pelletier (1989a, b).

East of the Nahlin fault the area is underlain by Paleozoic clastic and volcanic rocks of the Cache Creek Group (Aitken 1953, 1959; Monger, 1975). These rocks and associated Cretaceous plutons comprise the Atlin Terrane and are the focus of this study. The Cache Creek Group represents a major tectonostratigraphic unit within the Intermontane Belt. It extends almost continuously throughout the length of British Columbia (Figure 1-20-2) and is characterized by its structural and stratigraphic complexities (Monger, 1975, 1977a). The Atlin Terrane is the northernmost extension of the Cache Creek Group in the Canadian Cordillera. It is nearly everywhere fault bounded (Monger, 1975); the Thibert Creek fault marks the northeastern boundary of the terrane north of Dease Lake and extends to the northwest into the Teslin fault zone (Gabrielse, 1985). The extension of the Nahlin fault along the southern boundary of the terrane is characterized by a wide zone of thrust and reverse faults (Gabrielse and Wheeler, 1961; Gabrielse and Souther, 1962; Gabrielse *et al.* 1978, 1980). In the Dixie Lake map area, east of the Nahlin fault, structures characteristic of the southern terrane boundary are developed and occur as imbricate thrust sequences.

Relative timing of movement on the Nahlin fault is constrained by the Birch Mountain pluton which plugs the fault on Teresa Island. It is thought to be Tertiary in age based upon its similarity to dated Tertiary intrusions in northern British Columbia and southern Yukon (Aitken, 1959) and K-Ar ages of 56.6 ± 1.1 Ma and 46.3 ± 1.1 Ma based on biotite and hornblende, respectively (Bultman, 1979).

Monger (1975) established a broad stratigraphic succession based on his work throughout the Atlin Terrane. Mississippian to Pennsylvanian basalt of the Nakina Formation is the basal unit of the succession. It is overlain by and interfingers with chert, clastic sediments, minor carbonate and volcanic rocks of the Kedahda Formation. These are in turn gradationally overlain by a thick carbonate sequence of the upper Mississippian to upper Permian Horsefeed Formation. Locally, Mesozoic clastic rocks unconformably overlie the Cache Creek Group (Aitken, 1959; Monger, 1975, 1977b). Ultramafic rocks, including serpentinized harzburgite, dunite and gabbro, range in size from linear bodies many tens of kilometres in length to pods and slivers a few metres in extent (Figure 1-20-2). These rocks comprise some of the largest ultramafite bodies in British Columbia (Terry, 1977; Wheeler and McFeely, 1987) and were originally interpreted as ultramafic intrusions (Aitken, 1959). Later, Monger (1977) and Terry (1977) suggested that the large Nahlin ultramafite body may represent oceanic basement upon which the Nakina Formation was deposited. Recent work by Ash and Arksey (1990, this volume) supports this interpretation and indicates that thrust faulting has been the primary mechanism of emplacement for these slices of oceanic crust.

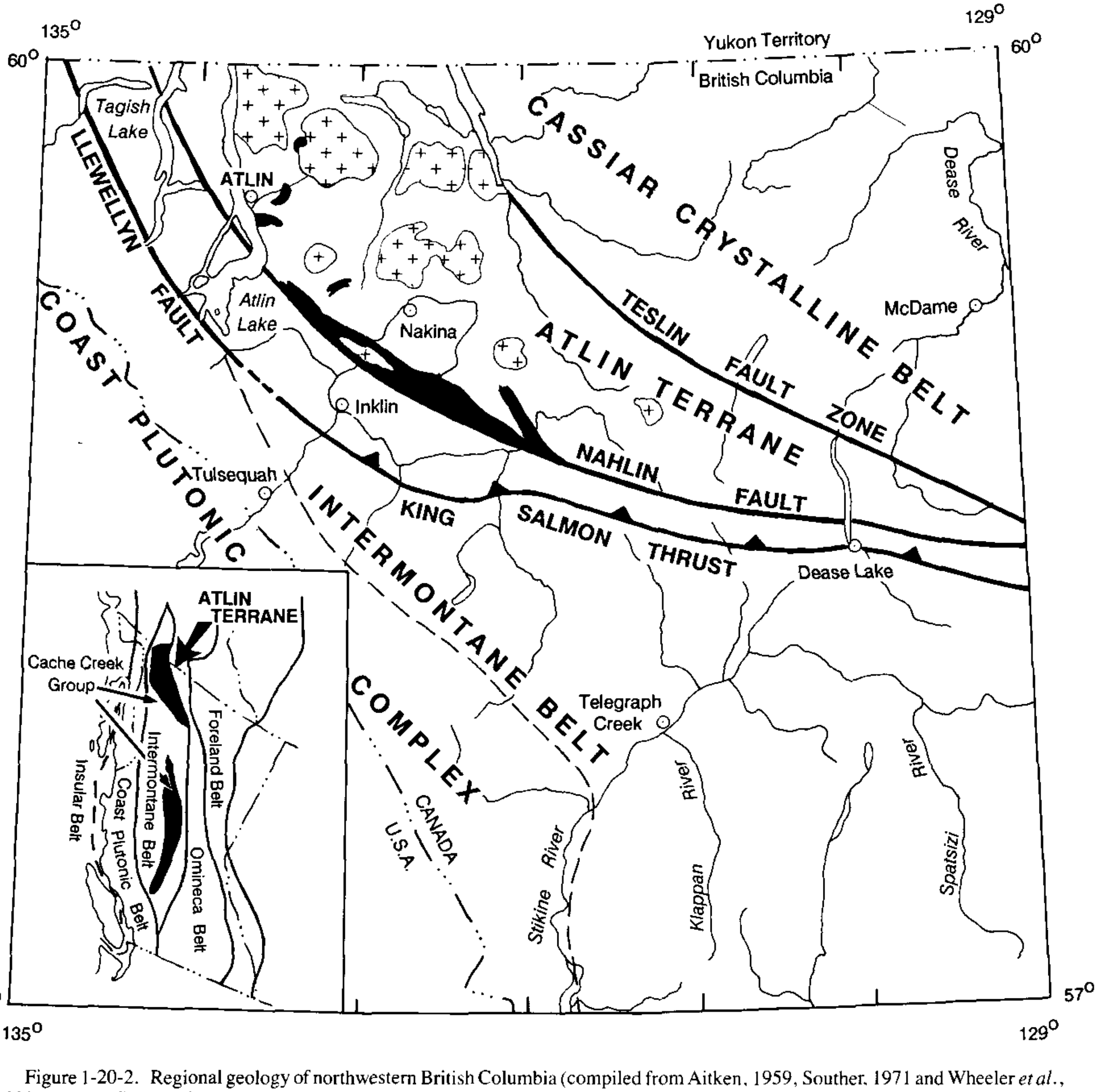



Figure 1-20-2. Regional geology of northwestern British Columbia (compiled from Aitken, 1959, Souther, 1971 and Wheeler *et al.*, 1989). Ultramafic rocks in the Atlin Terrane are shaded black and major plutons are represented by the crossed pattern. Inset map shows distribution of the Cache Creek Group in British Columbia.

## LITHOLOGY

### PALEOZOIC CACHE CREEK GROUP

#### CLASTIC SEDIMENTS

East of Wilson Creek (Figure 1-20-3), the map area is extensively underlain by a succession of clastic sediments consisting dominantly of fine-grained, locally siliceous mudstones, siltstones and sandstone/wackestones sometimes interbedded with minor impure chert. The sediments weather dark grey to rusty brown in colour and are typically dark grey to black on fresh surfaces. Bedding varies from fine internal laminations to distinctive centimetre-scale interbeds. Bedding-parallel cleavage varies in intensity from moderately to well developed slaty partings.

#### LIMESTONES

Massive limestone underlies an extensive area south of Sentinel Mountain where the exposures form large south-facing cliffs. Bedding is often difficult to discern in these large exposures but, from a more distant perspective, gross layering generally dips gently northward.

Grey, pale-weathering massive and featureless limestone characterizes much of the succession. The rocks are locally crinoidal and some corals, fusilinids, minor shell detritus and brachiopods have been recognized. Dark argillaceous limestone comprises one facies variation characterized by increasing silt and organic material accompanied by a distinctive fetid odour. Minor dolomitic limestones are also present.

Limestone within the volcanic and chert succession on Sentinel Mountain ranges from 1 to 10 metres in length and width. Some limestone bodies occur along contacts between other lithologies and are probably fault-bounded slices. Areas of extensive recrystallization and cleavage development along lithologic contacts suggest that these surfaces provided a locus for fault development. Zones of brecciation and recrystallization within the limestone bodies suggest that internal imbrication has also occurred. Limestone also occurs as blocks that are brecciated and completely enveloped by volcanics (Plate 1-20-1); these are interpreted as slumped masses incorporated during the deposition of the volcanic and chert succession.

#### CHERTS

Cherts underlie much of Sentinel Mountain where they are spatially associated with intermediate to mafic volcanics. They also outcrop north of Mount McMaster in the northeastern quadrant of the map area. The cherts are locally radiolarian-bearing and are characterized by a diverse range of colour; grey to black is the most common, but green, red, pink and cream varieties are also present. They show a wide variation from ribbon-bedded successions (Plate 1-20-2) to massive and unbedded chert.

North and west of the Sentinel Mountain summit repetitive interbeds of grey and red ribbon cherts vary from 1 to 10

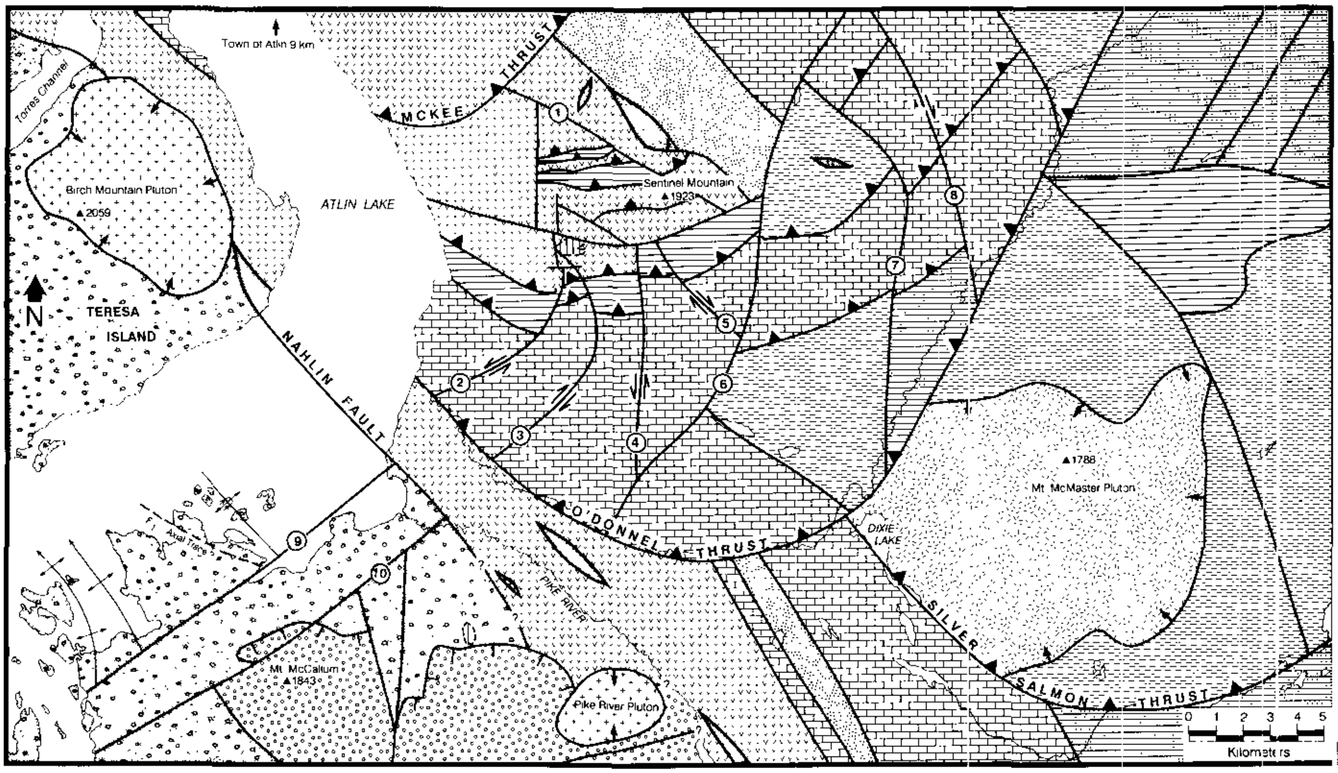
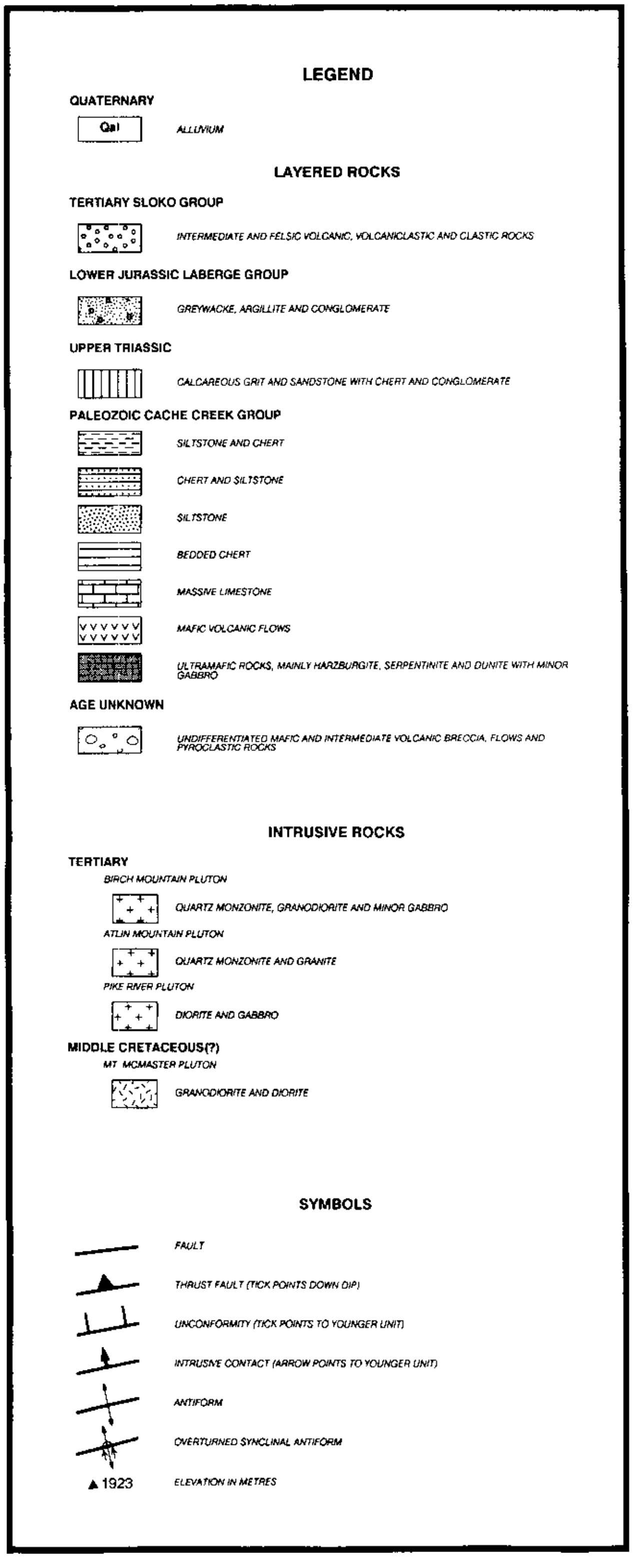



Figure 1-20-3. Simplified geology of Dixie Lake and Teresa Island map sheets (104N/5 and 6). Faults follow creeks and rivers and are numbered as follows: 1 – Eldorado Creek fault, 2 – Kennedy Creek fault, 3 – Jasper Creek fault, 4 – Burdette Creek fault, 5 – Little Creek fault, 6 – Wilson Creek fault, 7 – Canyon Creek fault, 8 – Baxter Creek fault, 9 – Anderson Bay fault, 10 – Mt. McCallum fault.




Legend to accompany Figure 1-20-3 and 1-20-4.

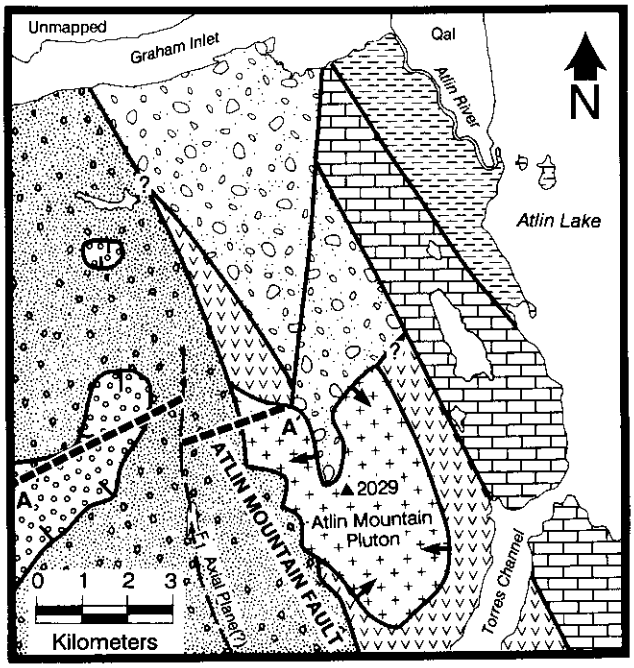



Figure 1-20-4. Simplified geology of Atlin Mountain (104N/12W).

centimetres in thickness. Fine colour variations between beds and colour laminations within individual beds are common. Both massive and laminated red-bedded cherts comprise a significant component of the succession immediately west of the summit. Along the western and southern flanks of the peak the cherts are poorly bedded or massive and are green, grey and black in colour. They are spatially associated with volcanic rocks.

### VOLCANIC ROCKS

Volcanic rocks are well exposed on Sentinel Mountain (Figure 1-20-3) and underlie much of Atlin Mountain (Figure 1-20-4); they also outcrop along the northeastern shore of Teresa Island and north of the Pike River. Intermediate to mafic flows, tuffs and diabase comprise the volcanic assemblage.

The volcanic flows are medium to pale green and pale green weathering. Minor colour laminations, interpreted as flow banding, are sometimes present in addition to tuffaceous horizons. The volcanics are generally non-amygdaloidal with an aphanitic groundmass; rarely they are pyroxene porphyritic. Associated tuffs are pale green, locally laminated and contain small angular pumice fragments in a fine-grained matrix.

Pillowed basalts have been recognized along a north-trending ridge west of the Sentinel Mountain summit. At the north end of this ridge, pillows have a maximum dimension of 1 to 1.5 metres; elsewhere pillows range from 10 to 50 centimetres in diameter and grade into pillow breccias. Flattened pillow margins indicate that the sequence is right way up. They are locally interlayered with bedded cherts and in one locality the pillows are silicified immediately adjacent to red cherts, indicating a primary stratigraphic relationship.

Plate 1-20-1. Limestone blocks enveloped by a submarine mafic volcanic flow. Well-preserved primary flow textures are deflected around the limestone clasts.

Plate 1-20-2. Outcrop photograph of ribbon-bedded cherts on Sentinel Mountain.

Massive diabase occurs locally on Sentinel Mountain, west and northwest of the summit. It is medium green on fresh surfaces but weathers a distinctive orange colour. Chilled margins along contacts with chert extend into the diabase for up to 10 centimetres; the adjacent chert is baked and recrystallized.

### ULTRAMAFIC ROCKS

Ultramafic rocks comprise only a small proportion of the Cache Creek Group in the map area. They occur as small, isolated fault-bounded exposures of serpentinite, harzburgite with lesser dunite, and gabbro. On Sentinel Mountain ultramafic rocks outcrop north of Eldorado Creek and several small bodies occur southwest of the summit; one isolated exposure was found east of Wilson Creek. Sporadic exposures have been mapped along the northwest trend of the Nahlin fault along the Pike River, and on Teresa Island and Atlin Mountain, however many of these bodies are too small to appear on Figures 1-20-3 and 1-20-4.

North of Eldorado Creek a relatively large, poorly exposed ultramafic body consists of recessive serpentinite. To the west of the main body, carbonatized harzburgite with minor dunite occurs in a series of north-trending outcrops locally cut by quartz-carbonate stockwork. Several small gabbro bodies are associated with the serpentinite and mylonitized gabbro occurs at the southern limit of exposure.

Southwest of Sentinel Mountain, several ultramafic bodies are present within a structurally complex area. They are localized along an east-trending thrust fault offset by two later, orthogonal tear faults. The ultramafites are strongly serpentinized and exhibit recessive weathering.

Along the eastern shore of Teresa Island ultramafic rocks appear to mark the base of the Atlin Terrane although the contact with the Jurassic Laberge Group is not exposed. At this locality the ultramafics are strongly altered to listwanite; mariposite and pyrite are pervasive.

East of the Pike River strongly carbonatized ultramafics occur along a northwest-trending linear belt parallel to the Nahlin fault. Exposures are sporadic but have been traced for approximately 5 kilometres. The primary lithology is harzburgite with lesser dunite occurring as small pods with finely disseminated chromite. Quartz-carbonate veins up to 0.5 metre wide are developed parallel to the regional trend.

## TRIASSIC CLASTIC SEDIMENTS

A distinctive suite of sedimentary rocks, recognized on Sentinel Mountain and in a small exposure southwest of the Pike River, are believed to be of Triassic age (Figure 1-20-3). They are lithologically similar to a succession exposed east of the confluence of the Nakina and Taku rivers (Figure 1-20-1) in the Hardluck Peaks area which has been assigned to the Triassic (Aitken, 1959). Well-laminated pale siltstones and sandstones characteristic of this unit are associated with gritty limestone, maroon chert and coarser clastic sediments, ranging from greywackes to conglomerates.

Southwest of the Pike River these sediments are unconformably overlain by the Laberge Group. Brown to tan-weathering, laminated gritty siltstones and fine sandstones are interbedded with grey and maroon chert and gritty dolomitic limestone. Millimetre-scale colour laminations define bedding within the siltstones and the cherts are thinly interbedded with tan-weathering mudstone containing minor carbonaceous debris. Silty to sandy laminated limestone and dolomitic limestone weather grey to tan. No fossils or shell debris have been recognized.

West of the main peak of Sentinel Mountain laminated siltstones are interbedded, on a metre-scale, with grey to tan-weathering sandy limestones that contain conodonts of Norian age (GSC Sample # 168203). Bedding in the limestone is defined by coarser grit beds, colour laminations and minor fragments of chert and mudstone.

To the north, a widely variable conglomerate is confined to a north-trending graben. The eastern boundary is a mélange zone containing pods and lenses of chert, volcanics and ultramafics; to the west, a sharp fault contact separates conglomerate from Cache Creek volcanic rocks. Facies variations within the unit are rapid and range from pebble to cobble conglomerate. Clasts are generally well-winnowed, and rounded to subrounded, however, some are angular;

including ripped-up blocks identical to the host conglomerate.

Clasts of all Cache Creek lithologies except the ultramafics have been recognized. Fragments derived from the Triassic sedimentary succession are well represented, occurring primarily as angular clasts varying from 5 centimetres to 2 metres in size. Two distinctive types of limestone clasts are observed: a crinoidal limestone thought to be part of the Cache Creek Group, and a gritty laminated limestone believed to be derived from the Triassic succession. Samples of each have been collected for microfossil identification. Numerous cobbles and boulders of a felsic plutonic rock are also present but do not appear to be locally derived. The clasts are leucocratic, contain abundant quartz eyes and bear no resemblance to any of the plutons in the area.

## JURASSIC LABERGE GROUP

Laberge Group rocks belonging to the Inklin overlap assemblage (Wheeler *et al.*, 1988) underlie much of the area along the southern and western shoreline of Atlin Lake, outcropping north of Mount McCallum, on Teresa Island (Figure 1-20-3) and Atlin Mountain (Figure 1-20-4). The contact of the Laberge Group with the Cache Creek Group is everywhere marked by a fault, either the Nahlin fault or the Atlin Mountain fault.

Massive grey to brown-weathering greywackes comprise a significant portion of the Laberge Group and are interbedded with grey to black siltstones, mudstones and shales; the shales rarely contain plant fossils. Individual beds vary in thickness from 0.5 to 3 metres and a bedding-parallel fissility is present in finer grained lithologies. Facing indicators include graded bedding, crossbedding and sole marks.

On Mount McCallum, brown to grey Laberge greywackes are massive, hard and weather orange to brown. They are bedded on a scale of 10 to 50 centimetres with abundant fine plagioclase laths within a sandy, poorly sorted matrix. Uncommon siltstone beds and lenses vary from 10 centimetres to 2 metres in thickness.

## TERTIARY SLOKO GROUP

Volcanics and associated volcaniclastic rocks of the Sloko Group, are well exposed on Mount McCallum and Atlin Mountain and unconformably overlie folded Laberge Group (Figures 1-20-3, 1-20-4 and 1-20-5). The sequence may range from Late Cretaceous to Eocene in age (Bultman, 1979). Porphyritic rhyolite, andesite and minor basalt dominate the Sloko Group, but volcaniclastic sediments including tuffs, greywackes and volcanic conglomerates also occur. Numerous pale coloured, buff to rusty weathering felsic dikes crosscut the Sloko Group on both Mount McCallum and Atlin Mountain.

On Mount McCallum the Sloko volcanics are characteristically brown, mauve or dark grey and weather brown. Intermediate volcanic flows underlie much of the area and spectacular columnar basalts cap several ridges west of the main peak. A broad range of facies are present and facies variations are rapid. Aphanitic to feldspar-porphyritic intermediate flows containing quartz eyes and minor acicular mafic phenocrysts are associated with ash tuffs and volcanic-

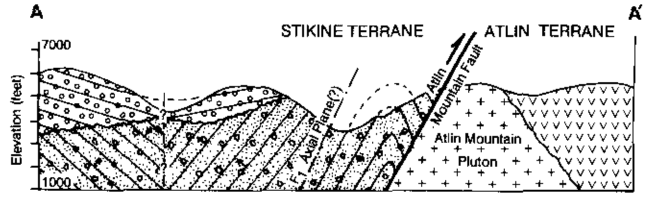



Figure 1-20-5. Cross-section of Atlin Mountain (*see* Figure 1-20-4 for location of cross-section; symbols as in legend). The Atlin Mountain fault places Laberge strata over Cache Creek volcanics and the Atlin Mountain pluton. A north-trending lineament west of the summit may correspond to an $F_1$ axial trace. Laberge strata west of this lineament are upward facing, whereas strata exposed east of it are overturned. A synclinal antiform occurs near the Atlin Mountain fault; it may be a drag fold associated with motion on the fault. To the west of the fault, the Laberge Group is unconformably overlain by Sloko volcanics and clastics. The occurrence of Sloko strata on mountain ridges and in valleys indicates the presence of significant topography in the Laberge rocks when the Sloko Group was deposited.

derived clastic sediments. The volcaniclastic sediments contain detrital quartz and feldspar and vary from brown, grey, and green to mauve in colour, and generally weather brown.

West of Atlin Mountain volcaniclastic conglomerates unconformably overlie Laberge sediments (Figure 1-20-4 and 1-20-5). Clasts vary from pebbles to boulders in a dominantly volcanic-derived matrix. Pebble conglomerate grades rapidly into cobble and boulder conglomerate. Abundant white quartz and dark grey chert pebbles varying from 1 to 20 millimetres in size are supported by a coarse wacke matrix with discontinuous silty horizons. Coarser conglomerates are locally clast supported and contain abundant well-rounded sandstone, greywacke and siliceous clasts up to 20 centimetres across.

Common crosscutting felsic dikes trend north and northeast. They are generally pale in colour, weather pale to rusty, and are locally completely bleached. Small white plagioclase laths are abundant and associated with small vitreous quartz eyes and minor mafic phenocrysts. The thickness of the dikes varies from 1 to 3 metres, with a maximum observed thickness of 5 metres.

## TERTIARY OLIVINE BASALT

Olivine basalt outcrops on the lakeshore, north of Mount McCallum. It is fine grained, green to brown in colour and weathers dark grey or brown. Vertical columnar joints, up to 20 metres in height, are well developed and indicate the basalts are upright, flat lying and probably unconformaby overlie Jurassic Laberge strata. A K-Ar whole-rock age of $27 \pm 4$ Ma was obtained by Bultman and he cites another age of $16.2 \pm 2$ Ma on a whole-rock fraction of the same sample (Armstrong and Harakal, unpublished data).

## UNDIFFERENTIATED VOLCANIC ROCKS/AGE UNKNOWN

A heterolithic succession of volcanic rocks of possible Mesozoic age (Aitken, 1959) underlies the area north of the

Atlin Mountain summit (Figure 1-20-4). These rocks are thought to be correlative with a similar succession exposed to the north of Graham Inlet on Table Mountain and Mount Minto. In part they comprise a roof pendant in the Atlin Mountain pluton and consist of fragmental rocks of intermediate composition. Grey-weathering, locally amygdaloidal breccias and tuffs grade into purple and grey trachytes.

## INTRUSIVE ROCKS

### MOUNT MCMASTER STOCK

The Mount McMaster stock underlies an extensive area east of the O'Donnel River and north of the Silver Salmon River (Figure 1-20-3). It consists of quartz diorite and granodiorite and intrudes sediments of the Cache Creek Group. Adjacent to the contact the sediments are metamorphosed to quartz muscovite schists and phyllites. Based upon lithologic similarities, the stock is correlated with the Fourth of July batholith north of Atlin from which Christopher and Pinsent (1979) obtained K-Ar ages of $73.3 \pm 2.6$ Ma and $110 \pm 4$ Ma, from biotite and hornblende respectively. The Mount McMaster stock weathers white to pale orange and is characterized by a medium to coarse-grained texture with local variations in the relative abundance of felsic and mafic minerals represented by quartz, plagioclase, biotite and hornblende. Potassium feldspar is a lesser constituent and several quartz potassium feldspar pegmatites were mapped east of the peak. Diorite xenoliths occur locally and are more abundant in the granodioritic phase of the stock.

### ATLIN MOUNTAIN PLUTON

The Atlin Mountain pluton consists of fine-grained, white-weathering quartz monzonite. Plagioclase and potassium feldspar comprise the phenocryst assemblage, occurring as small chalky to orange-weathering laths supported by an aphanitic groundmass. The pluton intrudes Cache Creek volcanic rocks and is truncated along its western margin by the Atlin Mountain fault (Figure 1-20-4). Small apophyses of the intrusion extend into the fault zone and the Laberge strata, indicating that the pluton may be synkinematic. The pluton is believed to be Tertiary in age (Aitken, 1959) and related to the Birch Mountain and Pike River plutons. Samples collected for U-Pb isotopic dating may provide more specific constraints on the timing of the emplacement of these bodies.

### BIRCH MOUNTAIN PLUTON

Underlying the northern part of Teresa Island, the Birch Mountain pluton is dominated by leucocratic quartz monzonite with lesser diorite and gabbro. The main phase is porphyritic, locally varying to phaneritic or aphanitic, and contains fine-grained granodiorite to diorite xenoliths. Diorite and gabbro constitute a minor phase near the southern margin of the stock, and appear to be similar to gabbro and diorite in the Pike River pluton.

### PIKE RIVER PLUTON

A small dioritic to gabbroic stock outcrops south of the Pike River, near the southern margin of the map area and is thought to be correlative with the Atlin Mountain and Birch Mountain intrusions. The rocks are medium to coarse grained, with abundant dark plagioclase laths and a weakly developed foliation. This and several other small stocks of similar composition mapped south of the study area are thought to be related to the mafic volcanic members of the Sloko Group (Aitken, 1959).

# STRUCTURE

Structures in the map area can be divided into three distinct groups; those east of the Nahlin fault in the Atlin Terrane, those west of the fault in the Stikine Terrane, and structures along the Nahlin fault itself.

## ATLIN TERRANE

Faulting, rather than folding, is the dominant form of deformation in Cache Creek rocks of the Atlin Terrane. The most prominent structural features of the map area are numerous low-angle thrust faults and associated tear faults. The presence of thrusts in the Atlin area is expected as ocean-floor ultramafic rocks (ophiolites) outcrop throughout the region (Ash and Arksey, 1990, this volume; Monger, 1975; Terry, 1977). The presence of thrusts is also supported by previous work; Monger (1975) suggested that most, if not all of the lithological contacts on Sentinel Mountain show some degree of bedding-parallel shear, and Cole (1989) described the occurrence of horizontal faults near the summit of Sentinel Mountain. Homestake Mineral Development Company interpreted shallow northwest-dipping faults near Atlin in drill core at the Pictou showing (MINFILE 104N 044), the Yellowjacket property (MINFILE 104N 014) and the Heart of Gold property (MINFILE 104N 101) (personal communication, D. Marud, 1989). In addition, Ash and Arksey (1990, this volume) have mapped several thrust faults on Monarch Mountain.

Thrusts of all scales occur in the Dixie Lake map area. The three largest are the McKee, O'Donnel and Silver Salmon thrusts, which are named after the major drainages they follow (Figure 1-20-3). The curvature of their traces, structural measurements and strong air photo linears suggest that these large thrust faults dip gently northwest. The surface expression of each is a major mélange zone consisting of slivers of all Cache Creek lithologies. The O'Donnel thrust is exposed on the O'Donnel River, 3 kilometres west of Dixie Lake. It outcrops as a spectacular northwest-dipping fault zone 20 metres wide and cored by 1.5 metres of fault gouge (Plate 1-20-3). The Silver Salmon thrust was not seen in outcrop in the map area but is inferred from structural data and well-defined air photo linears. A series of northeast-trending slivers of intercalated ultramafic, sedimentary and volcanic rocks occurs at Chikoida Mountain (Aitken, 1959; 104N/3 – southeast of the map area). This map pattern suggests these strata lie in the footwall of the Silver Salmon fault and may be part of a complex imbricate thrust system.

Internally each thrust sheet consists of numerous imbricate slices. Several are exposed throughout the map area (Plate 1-20-4) but most are indicated by outcrops of small lenticular pods of sheared ultramafite and other Cache Creek lithologies, mylonitic fabrics, subhorizontal fractures, minor folds and slickenside lineations on bedding and fracture surfaces. Although contacts between cherts and volcanics on

Sentinel Mountain are primary, most lithological contacts show evidence of some degree of bedding-parallel slip. The traces of thrust faults are often marked by topographic depressions along mountain ridges; south of Sentinel Mountain several north-facing dip slopes are underlain by footwall strata of thrusts exposed in cols.

Cache Creek lithologies are also cut by northwest to northeast-trending, high-angle tear faults, which are an inherent part of the thrust deformation. These faults include the Kennedy Creek, Jasper Creek, Burdette Creek, Little Creek, Wilson Creek, Canyon Creek, Baxter Creek and several other unnamed faults. Marker units allow determination of relative motion on several of them, and displacement on most does not appear to be in excess of 1 or 2 kilometres. In addition to thrusts and tear faults, several high-angle east-trending faults are mapped. These structures truncate both thrusts and tear faults and are therefore later, however, their exact age and significance are not known.

Overall, Cache Creek rocks in the Dixie Lake map area display only one major phase of deformation. Deformation was previously thought to be Triassic to Late Jurassic in age (Monger, 1975), however mapping in the southeast part of the area has shown that the mid-Cretaceous(?) Mount McMaster stock is internally deformed and is confined to the Silver Salmon thrust sheet. This suggests that the intrusion may be riding on the fault and that thrusting may be as late as post mid-Cretaceous in this part of the Atlin Terrane. Structural data indicate that the McKee Creek, O'Donnel and Silver Salmon thrust sheets were once rooted somewhere to the northwest and have moved toward the southeast, placing older rocks on top of younger strata. This interpretation is supported by fossil ages obtained by Monger, 1975, 1977b and preliminary ages from 1989 mapping. The amount of movement on these major structures is not known with certainty, but displacement is thought to be large. Data are too limited to allow a predeformational reconstruction of Cache Creek rocks at this time, however, limestone and chert samples collected for conodont and radiolarian microfossils may provide sufficient age constraints to permit restoration of the collage of thrust sheets and fault blocks that are characteristic of the Dixie Lake area.

## STIKINE TERRANE

Jurassic Laberge Group strata are folded into a series of upright anticlines west of the Nahlin fault. These folds plunge moderately to the northwest and have wavelengths of approximately 2 kilometres. Folds are mapped on the basis of regional limb orientations; one minor fold was observed in the field. This deformation is thought to be Late Jurassic in age and related to the collision of Superterrane I with cratonic North America (Tempelman-Kluit, 1979). Eocene deformation is indicated by northeast-trending faults such as the Anderson Bay and the Mount McCallum faults which crosscut the Tertiary Sloko stratigraphy and Laberge strata in the Teresa Island map area.

## NAHLIN FAULT

Structural trends of both the Atlin and Stikine terranes are more complicated near the Nahlin fault. According to Souther (1971) the Nahlin fault is a high-angle, northwest-trending, east-dipping structure that places Cache Creek rocks over strata belonging to the Stikine Terrane. However, observations made in the Dixie Lake and Teresa Island map areas indicate that it is a wide, complex zone with both a history and a geometry that are still unclear. The trace of the Nahlin fault is probably more complex than Aitken (1959) identified and it may be offset on northeast-striking Eocene faults. In addition, exposure is very poor along the fault; any inferences of the attitude of this structure based on its apparent surface trace are tenuous.

Cache Creek rocks near the Nahlin fault strike northwest and dip steeply. This trend is consistent with the structural grain of the Cordilleran orogen but diverges significantly from the southeast-directed thrust sheets common in the eastern part of the map area. This raises the problem of how Cache Creek rocks can be transported for long distances to the southeast and be emplaced over Laberge strata to the southwest, without having major transcurrent motion on the fault between them, yet only one dextral transcurrent kinematic indicator was found in the area (Plate 1-20-5).

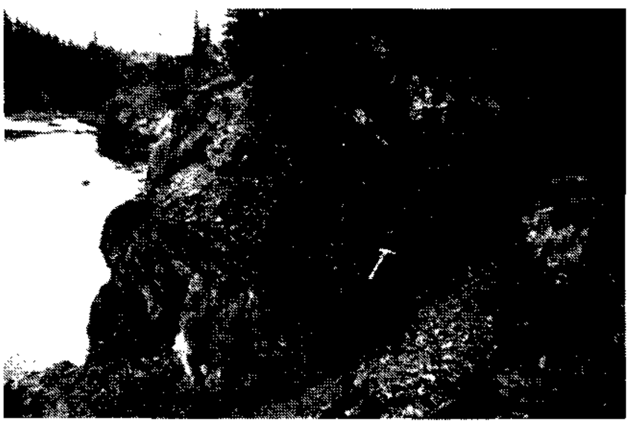


Plate 1-20-3. The O'Donnel thrust outcrops as a spectacular 20-metre fault zone that dips 25° northwest and contains 1.5 metres of fault gouge. View to the southwest.

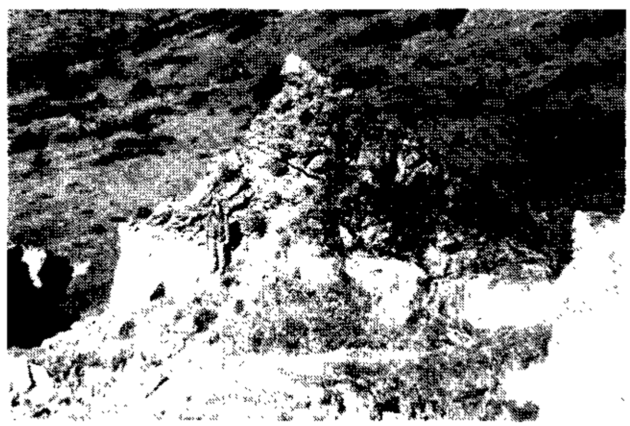


Plate 1-20-4. Horizontal thrust contact between sheared mafic volcanics (hangingwall) and massive limestone (footwall) on Sentinel Mountain. View to the west.

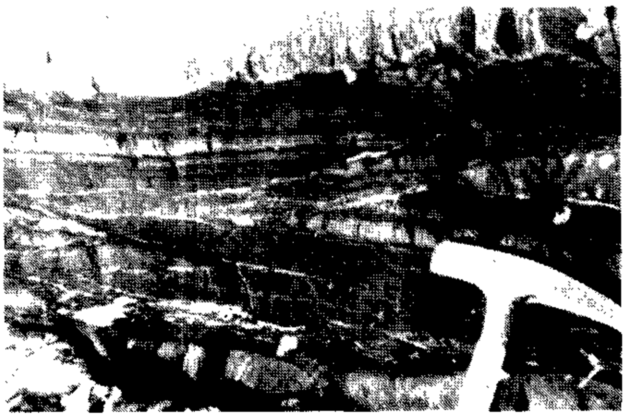


Plate 1-20-5. Kinematic indicator in steeply dipping Laberge wackes showing a minor component of dextral motion on the Nahlin fault. Outcrop is on the southern shore of Teresa Island.

Plate 1-20-6. The Atlin Mountain fault outcrops on several ridges west of the summit of Atlin Mountain (arrows point to fault; view to the southeast). It is a southwest-dipping thrust that places Laberge Group strata against Cache Creek volcanic rocks and the Atlin Mountain pluton.

Laberge rocks within 1 to 7 kilometres of the Nahlin fault display two phases of coaxial folding. Synclinal antiforms and overturned strata occur on Atlin Mountain (Figure 1-20-4), Teresa Island and on the lakeshore north of Mount McCallum (Figure 1-20-3). This structural orientation has not been previously described in the Laberge Group; it may be related to compression during or after convergence of the terranes. Because the geometry of the Nahlin fault is so poorly constrained in this area, it is difficult to assess whether these structures indicate that the Stikine Terrane has locally overridden the Atlin Terrane.

The Nahlin fault zone is crosscut by several intrusions including the Birch Mountain, Atlin Mountain and Pike River plutons. The Birch Mountain pluton plugs and distorts the trace of the Nahlin fault on Teresa Island. On Atlin Mountain, the pluton and the Nahlin fault are cut by the Atlin Mountain fault which outcrops on several ridges west of the summit (Plate 1-20-6). It is a northeast-directed reverse fault that dips approximately 50° southwest and places Laberge Group strata over Cache Creek volcanic rocks and the Atlin Mountain pluton (Figure 1-20-5). A synclinal antiform in the Laberge Group next to the fault may be a drag fold associated with motion on it.

The relationship between the Atlin Mountain fault and the Nahlin fault is not certain although they appear to be separate and distinct structures based on the width of the zone of deformation associated with each. The Nahlin fault is represented by a complex zone of imbrication approximately 5 kilometres wide in the Pike River, whereas the Atlin Mountain fault is confined to a zone only a few metres in width. The Atlin Mountain fault is interpreted as a later structure, possibly representing a back thrust that truncates the Nahlin fault zone. Samples collected from the plutons for U-Pb isotopic dating may help constrain the age of these structures.

## MINERALIZATION

Known mineral occurrences in the Dixie Lake area are limited to placer gold deposits. Small placer operations are active on McKee Creek, Wilson Creek and the O'Donnel River. All of these deposits occur along major fault zones. Bloodgood *et al.* (1989) and Ash and Arksey (1990, this volume) have demonstrated that many lode deposits are associated with the occurrence of ultramafic rocks along major faults in the Atlin area and have suggested that these structures are the pathways for mineralizing fluids. This is supported in the Dixie Lake area by the development of pervasive pyrite mineralization and minor carbonatization within the O'Donnel thrust. However, the lack of known lode occurrences in the Dixie Lake area may reflect the relative absence of ultramafic rocks. The Atlin Provincial Park occupies a large segment of the Teresa Island map sheet and is closed to mineral exploration.

Altered ultramafic rocks, including listwanite and carbonatized harzburgite and dunite, occur intermittently along the entire trace of the Nahlin fault in the Dixie Lake, Teresa Island and Atlin Mountain areas. The Nahlin fault zone is thought to be a deep penetrating structure, and like the Llewellyn fault (Mihalynuk, *et al.* 1989) may serve as a conduit for extensive fluid flow. Thus the Nahlin fault zone may have significant economic potential especially where sizeable ultramafic bodies occur.

Potential for epithermal mineralization exists along east-northeast trending Eocene faults which crosscut the Sloko Group and the Nahlin fault. North of the Pike River, sporadic exposures of ultramafic rocks occur within a linear belt at least 11 kilometres in length. Extensive quartz-carbonate stockworks are developed parallel to the regional trend and are crosscut by chalcedonic veins trending consistently east-northeast. Similar relationships have been observed farther south along the Nahlin fault, and in the Atlin area an epithermal overprint has been observed at the Pictou showing. Mineralization on the Atlin Ruffner property is confined to a series of structures with a similar northeast trend. Areas of alteration and mineralization associated with the Nahlin fault zone which are crosscut and overprinted by these later northeast-trending epithermal features may provide specific targets for mineral exploration.

## CONCLUSIONS

- Lithologies similar to those described by Monger (1975) outcrop in the Dixie Lake map area and primary lithologic contacts have been recognized within Cache Creek rocks.
- Southeast-directed thrust faults are important structural features east of the Nahlin fault. Faults correspond to major drainages, and movement is frequently accommodated along lithologic contacts, placing older over younger strata within imbricate sequences.
- Tear faults are an integral part of thrust deformation and have significantly influenced the map pattern within the Cache Creek rocks.
- The Nahlin fault is thought to extend to deep structural levels. Its surface expression is characterized by a wide zone of deformation and imbrication.
- A minimum age of movement on the Nahlin fault is constrained by the Birch Mountain pluton which plugs the fault on Teresa Island. The precise age of this intrusion has yet to be determined.
- Areas of highest mineral potential are structurally complex zones in which ultramafic rocks occur. The southern extension of the Nahlin fault and the Nahlin ultramafic body are good targets for gold exploration. In addition, the potential for epithermal gold mineralization has been recognized along late east-northeast-trending structures.

## ACKNOWLEDGMENTS

The authors would like to express their thanks to Ingrid Gertz and Louise Maddison for their excellent assistance which contributed greatly to the success of the field season. Jay Jackson of the University of Arizona, Chris Ash, Ron Arksey of the Geological Survey Branch, and the staff of Homestake Mineral Development Company, especially Darcy Marud and Joanne Bozek, are gratefully acknowledged for their willingness to share information and discuss the geology of the Atlin area. Special thanks are due to Fabrice Cordey of the Laboratoire de Stratigraphie, Paris for an educational and enjoyable field visit. Enlightening discussions with Bill McMillan, Don MacIntyre, Dave Lefebure and Tom Schroeter are greatly appreciated, and sincere thanks are extended to Gordon Heynen for safe and reliable helicopter service.

## REFERENCES

Aitken, J.D. (1953): Greenstones and Associated Ultramafic Rocks in the Atlin Map-area, British Columbia; unpublished Ph.D. thesis, *University of California*, Los Angeles, 147 pages.

——— (1959): Atlin Map-area, British Columbia; *Geological Survey of Canada*, Memoir 307, 89 pages.

Ash, C.H. and Arksey, R.L. (1990): The Atlin Ultramafic Allochthon: Ophiolitic Basement within the Cache Creek Terrane; *B.C. Ministry of Energy, Mines and Petroleum Resources*, Geological Fieldwork 1989, Paper 1990-1, this volume.

Bloodgood, M.A., Rees, C.J. and Lefebure, D.V. (1989): Geology and Mineralization of the Atlin Area, Northwestern British Columbia (104N/11W and 12E); *B.C. Ministry of Energy, Mines and Petroleum Resources*, Geological Fieldwork 1988, Paper 1989-1, pages 311-321.

Bultman, T.R. (1979): Geology and Tectonic History of the Whitehorse Trough West of Atlin, British Columbia; unpublished Ph.D. thesis, *Yale University*, 284 pages.

Christopher, P.C. and Pinsent, R.H. (1979): Geology of the Ruby Creek and Boulder Creek Area near Atlin (104N/11W) (Adanac Molybdenum Deposit); *B.C. Ministry of Energy, Mines and Petroleum Resources*, Preliminary Map No. 52.

Cole, F. (1989): Paleomagnetic and Structural Analyses of the Northern Cache Creek Terrane Near Atlin, British Columbia; Abstract from Cordilleran Tectonics Workshop, 1989, *The University of British Columbia*.

Doherty, R.A. and Hart, C.J.R. (1988): Preliminary Geology of the Fenwick Creek (105D/3) and Alligator Lake (105D/6) Map Areas; *Indian and Northern Affairs Canada*, Open File 1988-2, 65 pages.

Gabrielse, H. (1985): Major Dextral Transcurrent Displacements Along the Northern Rocky Mountain Trench and Related Lineaments in North-central British Columbia; *Geological Society of America Bulletin*, Volume 96, pages 1-14.

Gabrielse, H., Anderson, R.G., Learning, S.F., Mansy, J.L., Monger, J.W.H., Thorstad, L. and Tipper, H.W. (1978): Geology of the Cry Lake Map-area; *Geological Survey of Canada*, Open File 610.

Gabrielse, H., Anderson, R.G., Learning, S.F., Monger, J.W.H. and Tipper, H.W. (1980): Dease Lake Map-area; *Geological Survey of Canada*, Open File 707.

Gabrielse, H. and Souther, J.G. (1962): Dease Lake, British Columbia; *Geological Survey of Canada*, Map 32-1962.

Gabrielse, H. and Wheeler, J.O. (1961): Tectonic Framework of Southern Yukon and Northwestern British Columbia; *Geological Survey of Canada*, Paper 60-24, 37 pages.

Hart, C.J.R. and Pelletier, K.S. (1989a): Geology of Carcross (105D/2) and part of Robinson (105D/7) Map Areas; *Indian and Northern Affairs Canada*, Open File 1989-1, 84 pages.

——— (1989b): Geology of Whitehorse (105D/11) Map Area; *Indian and Northern Affairs Canada*, Open File 1989-2, 51 pages.

Mihalynuk, M.G., Currie, L.D. and Arksey, R.L. (1989): The Geology of the Tagish Lake Area (104M/9W and 10E); *B.C. Ministry of Energy, Mines and Petroleum Resources*, Geological Fieldwork 1988, Paper 1989-1, pages 293-310.

Mihalynuk, M.G. and Mountjoy, K.J. (1990): Geology of the Tagish Lake Area (Edgar Lake 104M/8 and Fantail Lake 104M/9E); *B.C. Ministry of Energy, Mines and Petroleum Resources*, Geological Fieldwork 1989, Paper 1990-1, this volume.

Mihalynuk, M.G. and Rouse, J.N. (1988): Preliminary Geology of the Tutshi Lake Area, Northwestern British Columbia (104M/15); *B.C. Ministry of Energy, Mines and Petroleum Resources*, Geological Fieldwork 1987, Paper 1988-1, pages 217-231.

Monger, J.W.H. (1975): Upper Paleozoic Rocks of the Atlin Terrane; *Geological Survey of Canada*, Paper 74-47, 63 pages.

——— (1977a): Upper Paleozoic Rocks of the Western Canadian Cordillera and their Bearing on Cordilleran Evolution; *Canadian Journal of Earth Sciences*, Volume 14, pages 1832-1859.

——— (1977b): Upper Paleozoic Rocks of Northwestern British Columbia; *Geological Survey of Canada*, Report of Activities, Paper 77-1A, pages 255-262.

Souther, J.G., (1971): Geology and Mineral Deposits of Tulsequah Map-area, British Columbia (104K); *Geological Survey of Canada*, Memoir 362, 84 pages.

Tempelman-Kluit, D.J. (1979): Transported Cataclasite, Ophiolite and Granodiorite in Yukon: Evidence of Arc-Continent Collision: *Geological Survey of Canada*, Paper 79-14, 27 pages.

Terry, J. (1977): Geology of the Nahlin Ultramafic Body, Atlin and Tulsequah Map-areas, Northwestern British Columbia; *in* Report of Activities, Part A, *Geological Survey of Canada*, Paper 77-1A, pages 263-266.

Wheeler, J.O., Brookfield, A.J., Gabrielse, H., Monger, J.W.H., Tipper, H.W. and Woodsworth, G.J. (1988): Terrane Map of the Canadian Cordillera; *Geological Survey of Canada*, Open File Map 1894, 9 pages and 1:2 000 000 map.

Wheeler, J.O. and McFeely, P. (1987): Tectonic Assemblage Map of the Canadian Cordillera; *Geological Survey of Canada*, Open File 1565.

# NOTES