# GEOLOGY BETWEEN NINA LAKE AND OSILINKA RIVER, NORTH-CENTRAL BRITISH COLUMBIA (93N/15, NORTH HALF AND 94C/2, SOUTH HALF)

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*KEYWORDS:* Regional mapping, Germansen Landing, Omineca Belt, Intermontane Superterrane, Slide Mountain Group, Paleozoic stratigraphy, Ingenika Group, metamorphism, lead-zinc-silver-barite mineralization

## INTRODUCTION

In 1989 the Manson Creek 1:50 000 mapping project encompassed the north half of the Germansen Landing map area (93N/15) and the south half of the End Lake map area (94C/2). As with previous years, the main aims of this project were: to provide a detailed geological base map of the area, to update the mineral inventory database, and to place known mineral occurrences within a geological framework.

The centre of the map area is located some 260 kilometres north-northwest of Prince George, immediately north of the settlement of Germansen Landing (Figure 1-11-1). Primary access is via all-season gravel roads from Fort St. James or Mackenzie which connect to secondary roads along Nina Creek, Nina Lake and the Osilinka drainage. A four-wheel-drive road along Nina Lake provides access to lead-zinc-silver showings northwest of Echo Lake. A major logging road along the Osilinka River services secondary logging roads providing access to the northern third of the map area. The remainder is reached on foot or by helicopter.

The northern and eastern sections of the map are bounded, respectively, by the Osilinka and Omineca rivers. At their confluence the terrain is a relatively subdued and tree covered area. This is in contrast to the Wolverine Range east of the Omineca River and a rugged, unnamed range of mountains to the southwest.

The southern part of the map area was first mapped at a 6-mile scale in the 1940s by Armstrong (1949). Gabrielse (1975) examined the northern half in the course of 1:250 000 mapping of the east half of the Fort Grahame map area. Monger (1973), and Monger and Paterson (1974) described rocks in the map area during a reconnaissance survey of Paleozoic stratigraphy. To the northwest, Roots (1954) published a 4-mile map of the Fort Graham west-half sheet. Many of the correlations made in this paper are with stratigraphy described by Gabrielse (1963, 1969), Nelson and Bradford (1987) and other workers in the Cassiar area where the miogeoclinal stratigraphy is quite similar and well known.

## REGIONAL GEOLOGY

The map area lies along the western edge of the Omineca Belt, one of the five morphogeological belts of the Canadian Cordillera (Wheeler and McFeely, 1987). This area contains rocks which are part of the Intermontane Superterrane (*i.e.* accreted) and displaced North American rocks (Wheeler and McFeely, *ibid*; Figure 1-11-1). Rocks of the Foreland Belt lie

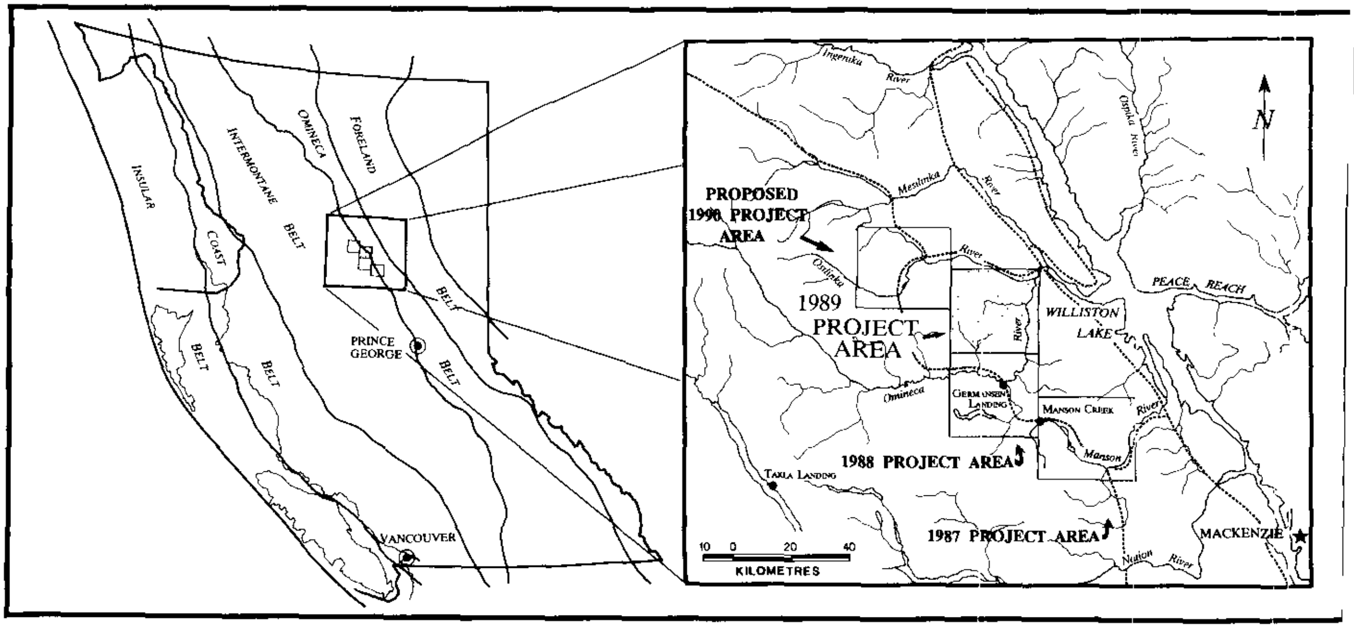



Figure 1-11-1. Location of the map area with respect to the five morphogeological provinces of the Canadian Cordillera with an expanded view in the right half of the diagram.

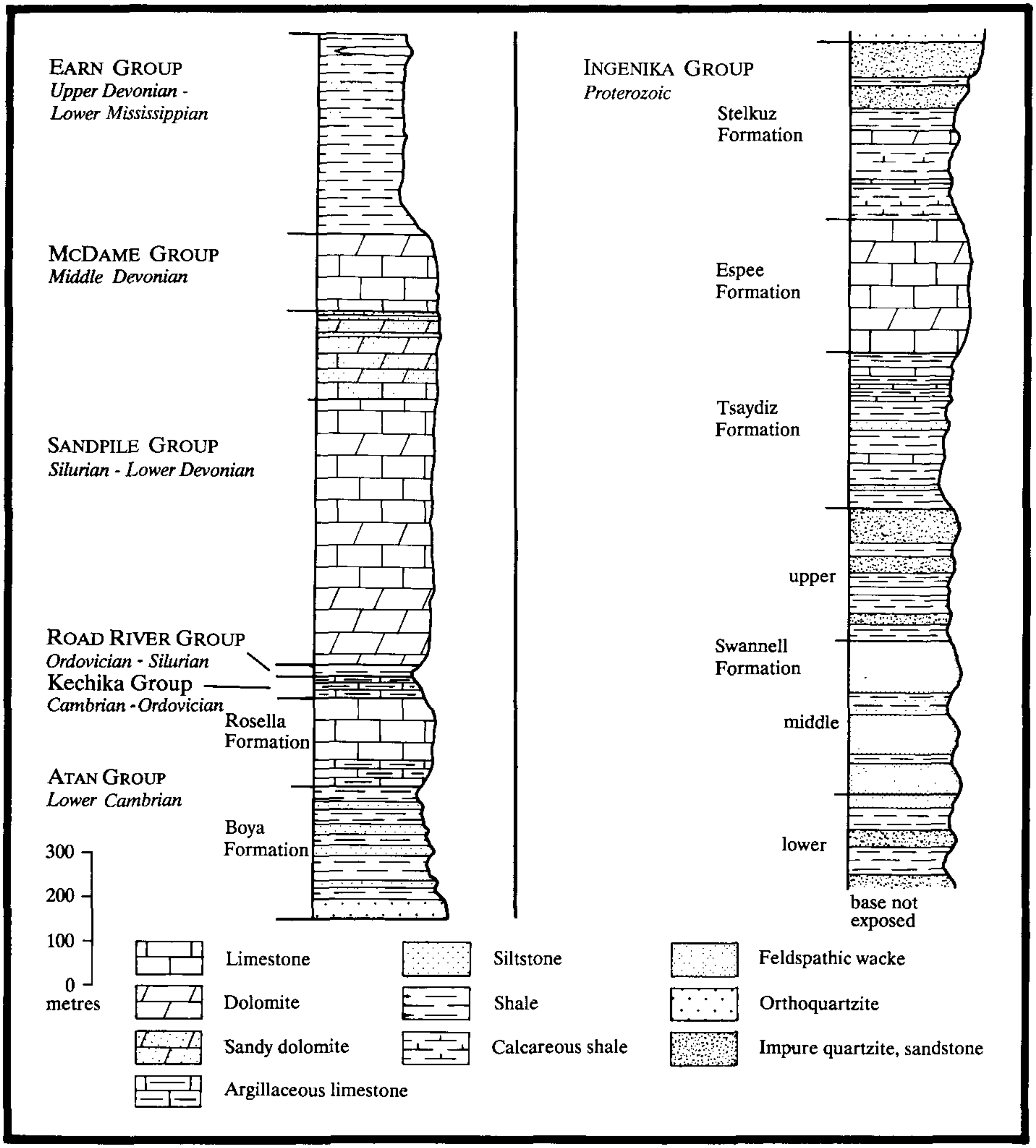
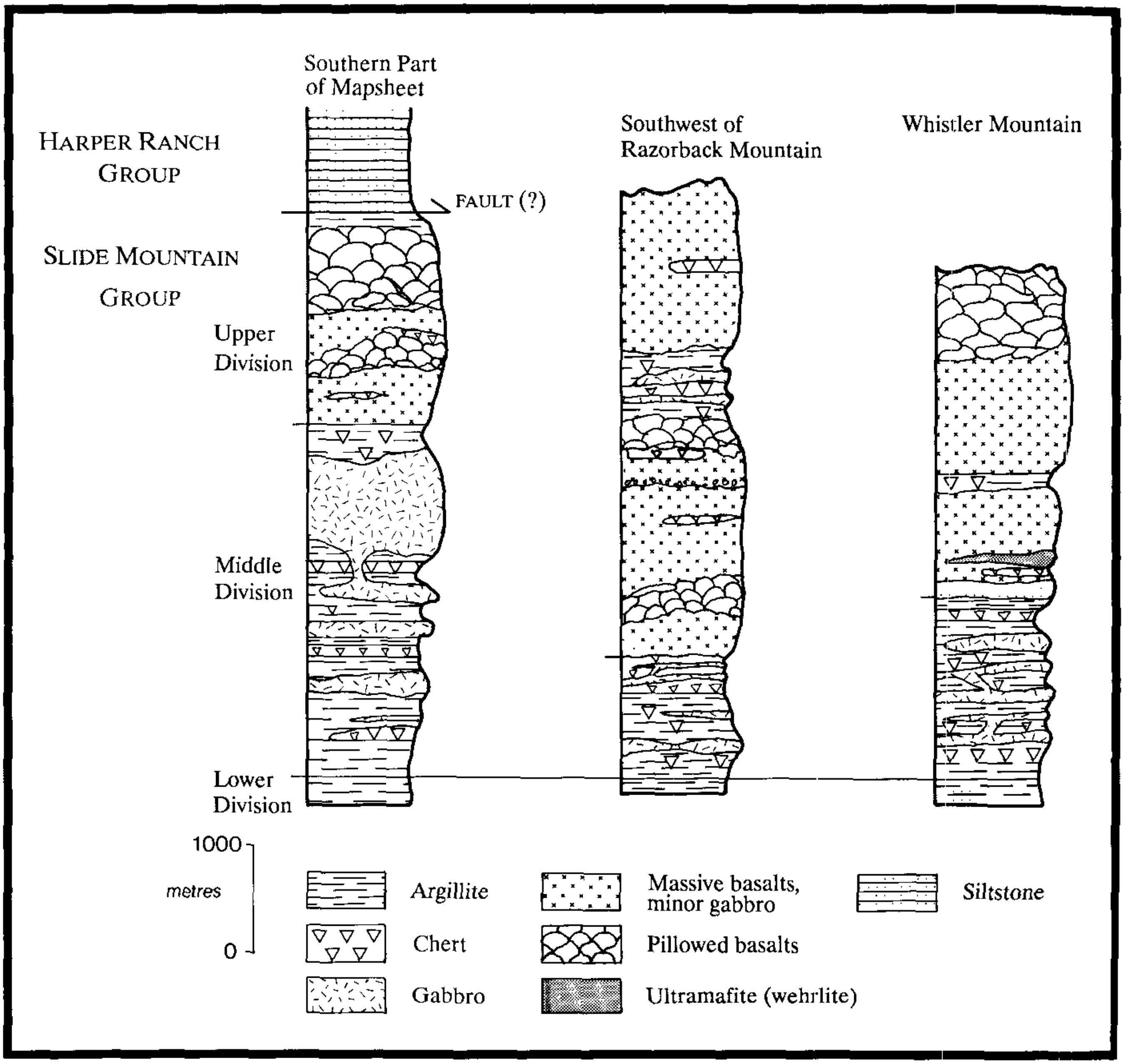



Figure 1-11-2. Generalized stratigraphic column of formations within the map area. (Includes material on facing page.)




to the east, across the Rocky Mountain Trench (now Williston Lake).

In the study area, the Intermontane Superterrane is represented by volcanic and sedimentary rocks of the Quesnel and Slide Mountain terranes. Quesnel rocks are composed of a volcanic and sedimentary assemblage of the Upper Triassic to Lower Jurassic Takla Group (Monger, 1977) and a poorly defined sedimentary and volcanic suite belonging to the Upper Paleozoic Harper Ranch Group which is basement to the Takla Group. The Slide Mountain Terrane is composed of oceanic rocks of the Upper Paleozoic Slide Mountain Group. The west side of the Quesnel Terrane is intruded by the multiphase, Triassic to Cretaceous Hogem batholith (Garnett, 1978) bounded to the west by the Pinchi fault which separates Quesnel rocks from middle Paleozoic to Triassic rocks of the Cache Creek Terrane.

Para-autochthonous rocks of North American affinity within the study area are part of a Proterozoic to Mississippian carbonate and siliciclastic miogeoclinal wedge which includes strata of the Proterozoic Ingenika Group to the Devono-Mississippian Earn Group (Figure 1-11-2). To the east, the lower parts of this sequence are highly metamorphosed (sillimanite grade) and deformed, and are incorporated within the Wolverine complex, one of several core complexes found along the length of the Omineca Belt.

The rocks above the garnet isograd roughly define a southwest-dipping package which is deformed by various generations of folds and faults. The most notable structure is

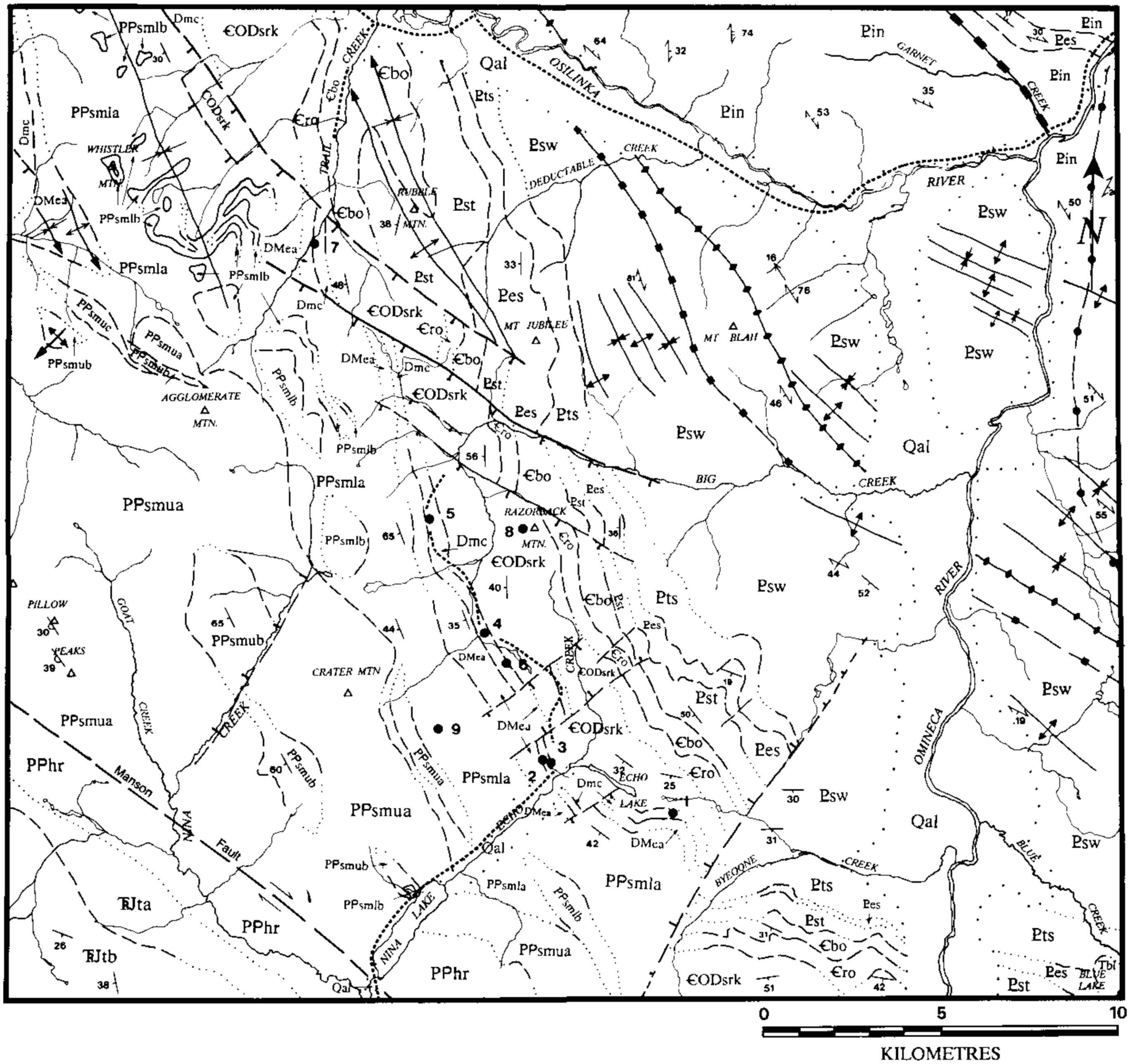



Figure 1-11-3a. Geology of the map area with location of known mineral occurrences described in Table 1-11-1.

the Manson fault zone, located along the Nina Creek valley (Figure 1-11-3a). The oldest rocks, the Proterozoic Ingenika Group, lie to the northeast. In this map area the contact between the Slide Mountain Group and North American rocks is not a west-side-down normal fault as shown by Ferri and Melville (1988) in the Manson Creek area. Its exact nature is indeterminate but, in accordance with observations made elsewhere along this contact, is assumed to be a layer-parallel thrust fault between lowermost Slide Mountain rocks and uppermost North American strata (Nelson and Bradford, 1987).

## STRATIGRAPHY: NORTH AMERICAN ROCKS

### INGENIKA GROUP (PROTEROZOIC)

The Ingenika Group is predominantly a clastic sequence with lesser amounts of carbonate. This package is in excess of 3.5 kilometres thick and composed of feldspathic and quartz wackes, siltstones, slates, sandstones, limestones and their higher grade metamorphic equivalents. Four subdivisions of the Ingenika Group (as defined by Mansy and Gabrielse, 1978) have been recognized in the area; these are, in ascending order, Swannell, Tsaydiz, Espee and Stelkuz formations.

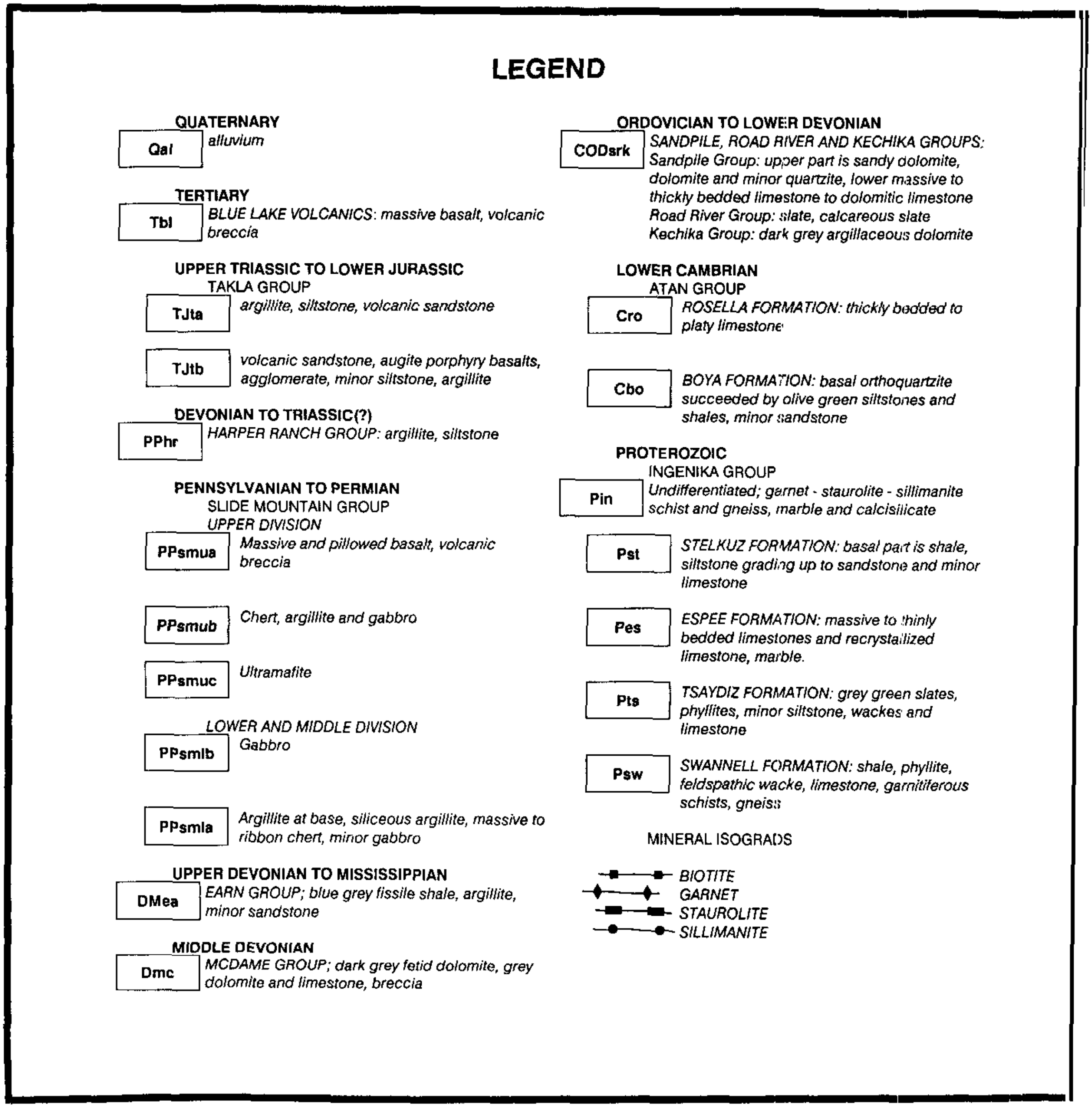



Figure 1-11-3b. Geological legend to accompany Figure 1-11-3a.

**SWANNELL FORMATION**

The Swannell Formation is the most areally extensive formation of the Ingenika Group, occupying roughly the northeastern third of the map area. The exact thickness is difficult to deduce due to polyphase deformation and lack of continuous outcrop. It is upwards of 2 kilometres thick and is tectonically thickened to the northeast. The basal part of the formation is polydeformed, metamorphosed to sillimanite grade and intruded by pegmatite and related granodiorite.

Three general subdivisions of the Swannell Formation have been recognized locally but could not be mapped out along strike. The lowest member, at least 1 kilometre thick, is composed primarily of thin to thickly bedded, very fine to medium-grained quartz and feldspathic wackes (feldspar content is typically less than 15 per cent). Subordinate to these lithologies are very fine grained impure sandstones, siltstones, grey to white marble, greenish slates and green to grey phyllite and schist. These rocks are metamorphosed to garnet, staurolite and sillimanite grade, with the metamorphic grade increasing to the northeast. Schists in the vicinity of Garnet Creek commonly contain distinct needles of metamorphic tourmaline in association with large porphyroblasts of staurolite (up to 2 centimetres long) and garnet.

Along the Wolverine Range, basal rocks of the Swannell Formation are metamorphosed to sillimanite grade (Figure 1-11-3a). They are coarsely crystalline schists, micaceous quartzites, calcsilicate, and quartz and feldspar-rich gneisses. They are injected by several generations of pegmatitic sills, dikes and related granodioritic and granitic bodies comprising over 50 per cent of the outcrop. Many of the pegmatitic sills, primarily the thinner ones, are folded or boudinaged (Plate 1-11-1), but the larger pegmatite bodies are foliated only on their margins. Later pegmatites crosscut the foliation and are undeformed.

The middle member of the Swannell Formation, some 300 to 400 metres thick, is characterized by massive beds of feldspathic wacke. These wackes are very coarse grained and approach granule conglomerates in some areas. They contain up to 30 per cent feldspar clasts and the quartz has a characteristic blue to purplish opalescence which disappears as the garnet isograd is approached. Greenish grey to silvery slate and phyllite, fine to coarse-grained quartz wackes and sandstones make up the remaining lithologies of this unit.

The upper member is approximately 300 metres thick and is characterized by massively bedded, brown-weathering, coarse-grained, impure quartzite and sandstone. These rocks may grade into or be interbedded with siltstones. Dark grey to greenish grey slates, phyllites and feldspathic wackes are also abundant.

### TSAYDIZ FORMATION

The Tsaydiz Formation is typified by light greenish grey to grey crenulated slates and phyllites that are commonly interlayered with thinly bedded, buff-weathering limestone to argillaceous limestone. Lesser siltstones, quartz and feldspathic wackes and recrystallized brown-weathering, grey limestone layers 1 to 5 metres thick are also present. Limestones are more prevalent toward the base of the formation.

The formation is poorly exposed and has been inferred throughout most of the map area. The lower contact is placed at a recessive point which generally corresponds to the top of the highest resistant layer in the Swannell Formation. The thickness of the Tsaydiz Formation varies from 300 metres in the south to approximately 750 metres in the north where it may be exaggerated by tectonism.

Plate 1-11-1. Boudinaged pegmatite within lower Swannell Formation near Granite Creek. This pegmatite was intruded during either $F_1$ or $F_2$ deformation whereas other (later) pegmatites crosscut the foliation and are undeformed.

### ESPEE FORMATION

The Espee Formation is a prominent cliff-forming carbonate unit which ranges from 200 to over 400 metres in thickness. It is easily traced through the entire length of the map area and is one of several marker horizons in the stratigraphic package. It is a buff, tan or grey-weathering limestone to dolomitic limestone which is moderately to thinly bedded and typically recrystallized to a coarse marble. It rarely fractures along bedding, but joints or spaced cleavage planes are common.

Its lower contact is generally not exposed but where it is seen, there is a transitional zone as interlayered slates and limestones of the Tsaydiz Formation give way to the more massive limestone of the Espee Formation. Similarly, at the upper contact with the Stelkuz Formation, buff-weathering, thickly layered Espee limestones are interlayered with green slates of the Stelkuz Formation across a zone some 50 metres thick.

### STELKUZ FORMATION

Approximately 400 to 500 metres of green to grey slate and siltstone, brown to grey impure quartzite and sandstone, together with minor dolomitic limestone, make up the Stelkuz Formation. Slate and siltstone predominate in the lower part of the formation whereas sandstone, which is characteristically fine grained and planar bedded, becomes predominant toward the top. The upper part of the Stelkuz Formation contains a 100-metre-thick coarsening-upward sequence in which the amount of sandstone increases toward the top of the formation where thickly bedded, coarse-grained, impure quartzites, light grey to grey in colour, are very similar to basal Atan Group quartzites. Typically though, Stelkuz quartzites are impure and lack the glassy appearance of Atan orthoquartzites. The top of the Stelkuz Formation (and of the Ingenika Group) is placed at the base of the first thick (greater than 2 metres) sequence of white to light grey orthoquartzites. Thin layers (0.5 metre or less) of light-coloured orthoquartzites can be found below this contact, within the impure quartzites.

## LOWER PALEOZOIC

Clastic and carbonate rocks exposed in the study area appear to be very similar to sedimentary rocks described in the Cassiar area by Gabrielse (1963), Fritz (1978, 1980) and Nelson and Bradford (1987). In the Cassiar area, the lower Paleozoic is represented by the Lower Cambrian Atan Group, the Cambrian to Ordovician Kechika Group, the Ordovician to Silurian Road River Group, the Silurian to Lower Devonian Sandpile Group (containing the Tapioca sandstone unit), the Middle Devonian McDame Group and the Upper Devonian to Mississippian Earn Group. We believe that a similar stratigraphy is present in the study area (as suggested by Gabrielse, 1975), but with some differences, such as the thinner nature of the Kechika and Road River groups. Where possible the formational names used in the Cassiar area are applied to units in the present map area.

Struik (1989a, b) describes a sequence of Lower to Middle Paleozoic rocks in the McLeod Lake area (east of the McLeod Lake fault) with characteristics similar to those of the study area, but containing volcanics and interlayered clastics and carbonates not encountered in our mapping.

## ATAN GROUP (LOWER CAMBRIAN)

Orthoquartzites, siltstones, shales, sandstones and a thick carbonate unit above the Stelkuz Formation are assigned to the Atan Group as designated in the Cassiar area (Fritz; 1978, 1980); both the Boya and Rosella formations have been recognized.

### BOYA FORMATION

The Boya Formation varies in thickness from 200 metres northeast of Echo Lake to upwards of 375 metres in the southeast. It is characterized by a white, grey, beige or maroon, massive to thickly bedded orthoquartzite, 10 to 30 metres thick, at the base of the section. It is typically fine to medium grained, but thin beds of quartz-granule conglomerate are also present. This basal unit is very distinct and therefore very useful in outlining the megascopic structures.

Thin to moderately bedded olive-green to grey siltstone, shale and beige to tan, very fine to fine-grained sandstone comprise the remainder of the formation. Typically the sandstone makes up less than 30 per cent of the sequence, although sections of sandstone and quartzite up to 10 metres thick occur in the upper part of the Boya Formation. These massive sandstones contain rare vertical *Skolithus*(?) and bedding-parallel burrows.

### ROSELLA FORMATION

Uppermost Boya Formation shales are succeeded by brown-weathering nodular limestone and basal Rosella Formation limestones over a distance of approximately 5 metres. The basal part of the Rosella Formation comprises 20 to 50 metres of dark grey to grey, thin-bedded and platy, finely crystalline limestone and argillaceous limestone. This platy limestone gives way upwards to approximately 150 to 180 metres of massive, thick bedded, fine to coarsely crystalline limestone and rare dolomite. Bedding is typically outlined by thin, discontinuous to wispy argillaceous layers less than 1 metre long. Horizons of oolites, which may be silicified in the lower part of the section, are very rare.

## KECHIKA GROUP (CAMBRIAN TO ORDOVICIAN)

Approximately 50 metres of argillaceous limestone is assigned to the Kechika Group. Where not exposed, this unit and the succeeding Road River Group can usually be inferred by the recessive slope between the Rosella Formation and the Sandpile Group. Correlative units thicken to the north (Nelson and Bradford, 1987).

This unit is characterized by thin-bedded, grey to black argillaceous limestone separated by thinner, tan to brown-weathering argillaceous dolomite layers.

## ROAD RIVER GROUP (ORDOVICIAN TO SILURIAN)

Above the Rosella Formation is approximately 25 metres of thinly bedded grey and dark grey shale and slate together with thin-bedded, dark grey to black argillaceous limestone assigned to the Road River Group. This argillaceous limestone can be up to 10 metres thick and is found toward the top of the formation. This unit is poorly exposed in the area and is inferred over most of the map sheet. Graptolites recovered from the shales indicate a Silurian age, perhaps Llandoverian (B. Norford, personal communication, 1989).

## SANDPILE GROUP (SILURIAN TO LOWER DEVONIAN)

This package of limestone, dolomite, sandy dolomite and minor quartzite has similarities to the Sandpile Group described by Gabrielse (1963) east of the Kechika fault. It is the thickest Paleozoic unit of continental affinities in the area (750 to 1000 metres) and forms prominent cliffs around Echo Lake. It is made up of two units; a lower limestone and dolomite sequence ("Echo Lake limestone", approximately 600 metres thick), and an upper sandy dolomite and quartzite sequence (100 to 200 metres thick). The upper part of this sequence resembles the Tapioca sandstone of the Cassiar area (Gabrielse, 1963; Nelson and Bradford, 1987).

The lower carbonate is characterized by sequences of light to medium grey, massively bedded limestone up to 2 metres thick. Semicontinuous quartz "vugs" and lenses (replaced algal structures), 1 to 2 centimetres thick, are found within these horizons and sometimes form an interwoven network comprising up to 20 per cent of the rock (Plate 1-11-2); rare, thin beds or lenses of grey chert or isolated bodies of polymict carbonate breccia up to 5 metres thick are also associated with these horizons. Thickly bedded limestone is interlayered with thinly bedded limestone and dolomite which commonly exhibit algal laminae and layers of silicified oolites and pisolites up to 2 centimetres in diameter.

The upper 100 to 200 metres of the Sandpile Group contains beds of sandy dolomite comprised of up to 30 per cent well-rounded, medium-grained quartz grains. Grey quartzite layers, 1 to 2 metres thick, and rare argillite or siltstone beds, together comprise about 5 per cent of the upper unit of the Sandpile Group.

Plate 1-11-2. Quartz "vugs" and lenses within the Sandpile Group. These vugs are typically infilled with calcite and may be replaced algal features.

### McDAME GROUP (MIDDLE DEVONIAN)

Some 150 to 200 metres of grey to black fetid limestone and dolomite make up the McDame Group. Exposures are poor and, away from known mineral occurrences, the map trace is tentative. The lower part of the McDame Group is characterized by thin to thick-bedded, dark grey to black fetid limestone. The limestone, though not abundantly fossiliferous, contains rugosan corals, brachiopods, gastropods, bryozoa(?), amphipora and beds of crinoid osicles, some of which exhibit twin-holed columnals. Parts of this unit are coarsely recrystallized and contain calcite and pyrobitumen-filled vugs.

The upper part of the McDame Group is slightly fetid grey to tan, finely crystalline dolomite and minor limestone which may exhibit faint bedding.

The presence of twin axial canal columnals within this formation makes it no younger than early Middle Devonian (early Eifelian; B. Norford, personal communication, 1989). Conodonts recovered from the upper part of the unit also indicate the Middle Devonian as the upper age limit on this formation (M.J. Orchard, personal communication, 1989).

### EARN GROUP (UPPER DEVONIAN TO MISSISSIPPIAN)

Approximately 400 to 500 metres of blue-grey, grey or dark grey shales, argillites and minor sandstones comprise the Earn Group. The lower shales are extremely fissile, forming large, thin sheets several millimetres thick. They have a characteristic blue-grey colour typical of the Earn Group in the Cassiar area. Up-section these shales become interlayered with thicker bedded argillites and silty argillites. Uppermost Earn shales and argillites are distinguished from lowermost Slide Mountain rocks by their lack of wavy bedding.

In the area immediately south of Big Creek, thickly bedded quartz sandstones, forming a sequence up to 30 metres thick, have been assigned to the uppermost Earn Group. This lithology is not typical of the Slide Mountain Group but has been reported from the Earn Group in the Cassiar area (Nelson and Bradford, 1987).

# STRATIGRAPHY: ALLOCHTHONOUS ROCKS

## SLIDE MOUNTAIN GROUP (PENNSYLVANIAN TO PERMIAN)

Upwards of 7 kilometres of basalt, argillite, chert and gabbro make up the Slide Mountain Group. These rocks were first mapped by Armstrong (1949) and Roots (1954) who grouped them with the Cache Creek Group due to their very similar lithologies. Monger (1973) first recognized that these rocks belong to the Slide Mountain Group and its equivalents.

Three subdivisions are recognized in the map area and are similar to those described by Ferri and Melville (1989) to the south. The lower division is composed primarily of argillite with minor amounts of clastics and limestone. The middle division is made up of siliceous argillites, cherts and gabbro. Pillowed and massive basalt, gabbro, argillite, chert and ultramafite comprise the upper division.

In the study area, the three subdivisions of the Slide Mountain Group appear to form a continuous stratigraphic package; there is no evidence for major tectonic breaks. Elsewhere along the Cordillera, rocks equivalent to the Slide Mountain Group have been shown to be made up of repeated thrust slices, even though the package appears to be in stratigraphic continuity (Struik and Orchard, 1985; Schiarizza and Preto, 1987; Nelson and Bradford, 1987).

### LOWER DIVISION

This unit is composed of 200 to 300 metres of grey to dark grey or black, rusty weathering, thin-bedded, wavy to platy argillites. The lighter coloured varieties tend to be slightly siliceous. At one locality, light coloured felsic tuff is present within this unit and appears very similar to felsic tuff seen within the Slide Mountain Group farther south (Ferri and Melville, 1989). The upper part of the unit may contain a 5 to 10-metre section of thickly bedded, interlayered buff-weathering and siliceous limestone that has yielded Lower Permian conodonts (M.J. Orchard, personal communication, 1989). Below this carbonate, and immediately above the sandstone in the uppermost Earn Group, is a 10 to 20-metre section of dark grey to black, massive to poorly bedded, chert-quartz wacke. The clasts are fine to coarse grained, predominantly chert, and make up less than 50 per cent of the rock.

The lower contact of this division, with the Earn Group, is not seen, however, Slide Mountain shales and argillites are typically more siliceous, and lack the fissility of the Earn Group rocks.

### MIDDLE DIVISION

Dark argillites of the lower division become less prominent up-section and are succeeded by thin to moderately bedded grey argillites, light grey to greenish siliceous argillites, light grey, green and maroon cherts and ribbon cherts of the middle division. These rocks are intruded by gabbroic sills and dikes in the upper parts of the division. The maroon and salmon-coloured cherts are only found in the uppermost part of the middle division, either in association with the gabbro or immediately below the basalts of the upper division. Minor constituents are buff-weathering micritic limestone layers less than 0.5 metre thick and a quartz-bearing tuff, 10 to 20 metres thick, present toward the base of the unit. The latter is exposed near Whistler Mountain and is similar to quartz-bearing tuffs described within the Slide Mountain Group to the south (Ferri and Melville, 1989). Rare constituents within the lower part of the division are thin beds (less than 1 metre) of chert wackes within the argillites. The thickness of the middle division varies from approximately 2500 metres in the south to 700 metres on the western margin of the map area.

Gabbroic sills up to 1000 metres thick intrude the upper parts of the middle division and, in places, are traceable for several kilometres. These gabbros are found at various stratigraphic levels and are beautifully exposed around Whistler Mountain (Plate 1-11-3). They are fine to coarsely crystalline, with subequal pyroxene and highly altered plagioclase.

Plate 1-11-3. Gabbro sills intruding upper middle division sediments of the Slide Mountain Group near Whistler Mountain. In this photograph the sediments form the recessive sequence in the middle of the slope with gabbro sills above and below. These gabbro bodies are several hundred metres thick.

### UPPER DIVISION

A thickness of at least 5 kilometres of massive and pillowed basalts, minor sediments, gabbroic and ultramafic sills are assigned to the upper division. Whether this is a true stratigraphic thickness or the result of tectonic thickening is not known. In the southern part of the map area only 2000 metres of basalt are found, overlain by siltstones of the Harper Ranch Group (*see* section on Harper Ranch). In the map area to the southwest (*see* Figure 1-11-1), these sediments were assigned to the middle division of the Slide Mountain Group by Ferri *et al.* (1989).

More than 80 per cent of the division is composed of dark green to greyish green, variolitic, pillowed to massive basalt which may contain irregular bodies of fine-grained gabbro (Plate 1-11-4). Massive and interpillow basaltic breccia is also common.

In the northwest, the basal part of the upper division contains lenticular bodies of wehrlite up to 200 metres thick, composed of undeformed clinopyroxene, olivine, serpentine (after olivine) and magnetite. They are associated with mafic gabbros and are believed to be sills.

Light to dark grey siliceous argillite, varicoloured cherts (cream, grey, green, salmon, maroon) and gabbro sills are found in sequences upward of 1 kilometre. The similarity of these sedimentary packages to middle division lithologies may indicate that they are fault slices of the upper part of the middle division. A fault contact was observed at the base of a sedimentary lens northwest of Nina Lake, but the present evidence does not allow these packages to be confidently interpreted as fault repetitions. More accurate fossil ages are required to fully resolve this problem.

Plate 1-11-4. Large pillows within basalts of the upper division of the Slide Mountain Group on the ridge containing Pillow Peaks.

## HARPER RANCH GROUP(?) (MIDDLE TO UPPER PALEOZOIC)

Light brown to greenish weathering siltstones and minor dark grey phyllites and argillites along the Nina Creek valley are assigned to the Harper Ranch Group. Similar sediments overlie basalts of the upper division on the slope southeast of Nina Lake valley and were originally mapped as middle division sediments of the Slide Mountain Group. As described above, these rocks have been reinterpreted as Harper Ranch as similar lithologies are not present in the middle division of the Slide Mountain to the north; they may, however, be a western facies of the middle division of the Slide Mountain Group.

Sediments equivalent to the Harper Ranch were designated Slide Mountain Group by the authors in map areas to the south (Ferri and Melville, 1988, 1989) where these siltstones and argillites are found within lithologies similar to middle division sediments of the Slide Mountain as described above. This season's mapping has restricted these rocks to an area south of the Manson fault, indicating that they may be separate from the Slide Mountain Group.

## TAKLA GROUP (UPPER TRIASSIC TO LOWER JURASSIC)

Argillites, siltstones, lapillistone(?), volcanic sandstones and massive augite and feldspar porphyry flows assigned to the Takla Group outcrop in the southwest corner of the map area (south of Nina Creek). Two units are recognized: a lower, predominantly argillaceous unit and an upper unit composed primarily of volcanic sediments and minor flows. These are very similar to the lower two units of the Takla Group as described by Ferri and Melville (1989b) to the south.

The lower Takla Group (approximately 500 metres thick) is made up of thickly bedded green to light green siliceous argillites, grey-green to brown siltstones and fine-grained sandstones which contain volcanic and chert clasts.

The upper unit is composed predominantly of thin-bedded grey-green to brown volcanic siltstone or tuffs, thick to massively bedded volcanic sandstone with lesser dark green to green augite or feldspar porphyry flows. The volcanic sandstones are polymictic, containing volcanic clasts from several sources.

### BLUE LAKE VOLCANICS (TERTIARY (?)

Immediately northwest of Blue Lake, in the southeastern corner of the map area, are massive, dark grey, augite-bearing basalts and volcanic breccia (A. Halleran, personal communication, 1989). Only a few scattered outcrops of basalt were observed and based on aeromagnetic data, it is believed that these basalts are restricted to this area.

## STRUCTURE

Major tectonic elements in the study area are the left-lateral Manson fault zone and the boundary between the Slide Mountain Group and the para-autochthonous North American miogeoclinal strata. The Slide Mountain–North American contact relationship is inferred from other areas in the Canadian Cordillera (Nelson and Bradford, 1987) and is assumed to be a layer-parallel thrust fault along the contact between the two suites. Because of this, rocks on both sides of the contact appear to be in stratigraphic continuity. It should be noted that evidence for this thrust fault is not apparent in the study area; slates and argillites of the lowermost Slide Mountain Group *appear* to grade into those of the Earn Group.

The Manson fault has been placed separating Harper Ranch from Slide Mountain strata. Direct evidence for the fault (*i.e.* tectonized strata) is not present in the area due to poor exposure, but the fault trace is marked by a well-developed topographic lineament.

South of the map area the Manson fault was placed along Nina Creek due to the presence of highly deformed rocks (Ferri and Melville, 1989; Ferri *et al.*, 1989). The Manson fault is interpreted as a broad zone and clearly contains anastamosing to en echelon faults in the region between the Takla and Slide Mountain groups. It is believed the same relationship is present in the current map area.

The area can be broadly divided into two structural regions; the northeastern sector where polyphase deformation and metamorphism dominate, and the southwestern half which is typified by a west-dipping sequence where brittle deformation is more prevalent. The dividing line, or zone, between these two domains lies within the upper part of the Swannell Formation and roughly corresponds to the garnet-biotite boundary.

To the north the west-dipping package is modified by folding. In the Whistler Mountain area broad folds can be traced out within the Slide Mountain Group. Earn shales and MacDame carbonates reappear on the west side of the large syncline in this area. Across Trail Creek the Atan Group and Espee Formation delineate an upright to northeast-verging fold pair. Minor folds are rare in this area.

This west-dipping sequence is cut by two sets of normal faults; northwest and northeast trending. The northeast-trending set is found to the south; the most notable structure is the Bygone fault with a vertical displacement on the Espee Formation of approximately 2.5 kilometres (northwest side down). To the north, the northwest-trending, west-side-down normal faults form an en echelon array cutting both the North American Paleozoic sequence and the Slide Mountain Group, with the Trail Creek fault forming part of the boundary between the two stratigraphic packages.

Megascopic, upright to slightly east-verging folds in the west give way to shallower dipping east-verging folds north-eastward into the Swannell Formation. Above the garnet isograd (*i.e.* to the northeast) schistosity or foliation becomes layer parallel as folds become tight to isoclinal. This same relationship was described by Mansy and Dodds (1976) within the Ingenika Group of the Swannell Ranges north of the map area.

At least three phases of deformation and folding ($F_1$ to $F_3$) are recognized in the map area. $F_1$ is characterized by tight to isoclinal folds which are synmetamorphic (*i.e.*, micas and other metamorphic minerals are axial planar to $F_1$ hinges). $F_2$ folds are axial planar with $F_1$ folds but are generally more open and also postmetamorphic, with micas folded and crenulated around their hinges. Along $F_2$ limbs, $S_1$ foliation has been transposed parallel to $F_2$ axial planes. $F_2$ folds are rare and only seen in the higher grade regions. In the metamorphic rocks to the northeast, compositional layering, together with the above foliations, is folded into megascopic upright to southwest-verging $F_3$ folds which may be associated with similarly oriented and commonly observed fold crenulations. Southwest-verging structures were observed within the high-grade metamorphic rocks of the Wolverine Range.

Parrish (1976), describes very similar fold hierarchies in the Aiken Lake area where $F_2$ folds appear to be more prevalent and may reflect the higher metamorphic grade (sillimanite).

In the Ingenika Range, Bellefontaine (personal communication, 1989), describes early, east-verging $F_1$ folds which predate main-stage metamorphism and are the same as $F_1$ folds in this study. Bellefontaine (1989) also describes megascopic $F_2$ folding that is west verging and may be related to $F_3$ folding in the present study area. In the Ingenika Range tight to isoclinal folds in the schistosity are rarely present and only seen in the higher grade metamorphic areas (K.A. Bellefontaine, personal communication, 1989) and are attributed to late $F_1$ folding.

Evenchick (1988) sees the same progression of metamorphism and deformation farther north in the Sifton Ranges.

## METAMORPHISM

The southwestern two-thirds of the map area is greenschist grade or lower. Chlorite, muscovite, actinolite, clinozoisite and chloritoid are the main metamorphic minerals. To the northwest, metamorphic grade steadily increases until sillimanite is present in the Wolverine Range.

The first appearances of index metamorphic minerals (biotite, garnet, staurolite and sillimanite) is shown on Figure 1-11-3. Mineral isograds outline part of several large metamorphic highs or domes which, for the most part, follow the structural trend in the area (Gabrielse, 1975). The exception to this is the sillimanite isograd which follows the trend of the Wolverine Range (thermal event ?).

A retrograde metamorphic event has affected these higher grade metamorphic rocks and is manifested by the partial or complete pseudomorphing of garnet and biotite by chlorite. This retrogression is developed locally and is evident primarily in the lower amphibolite grade rocks.

Pegmatites and related granodiorite bodies intrude schists and gneisses of the Swannell Formation in the higher grade metamorphic areas (staurolite and above). Many of these are boudinaged or exhibit deformed margins (*see* Plate 1-11-1 and section on Swannell Formation) indicating that they were intruded during $F_1$ or $F_2$ deformation. Some pegmatites crosscut the structural fabric and are undeformed, indicating they were intruded after deformation ceased. These later pegmatites are rare.

Textural relationships between prograde metamorphic minerals and deformational fabrics (*i.e.*, $S_1$, $S_2$) are illustrated in Plate 1-11-5. In these photomicrographs an example of moderately deformed, upper greenschist grade rocks from higher in the stratigraphic package (uppermost Stelkuz Formation) is compared to isoclinally folded, amphibolite grade material from the lower Swannell Formation. In Plate 1-11-5(a) chloritoid porphyroblasts, which for the most part grew parallel or subparallel to $S_1$, are overgrowing the $S_1$ foliation outlined by layer-parallel muscovite crystals. The $S_1$ foliation is slightly "bowed" or flattened around porphyroblasts oriented perpendicular to foliation. A later crenulation cleavage ($S_2$) is superimposed on this foliation. Chloritoid porphyroblasts do not overgrow crenulation hinges or the associated cleavage, in fact this solution cleavage wraps around the chloritoid porphyroblast and is roughly parallel to the hinge planes of megascopic folds outlined by markers at this level.

Plate 1-11-5(b), from the higher grade rocks, shows porphyroblasts which can contain inclusion trails typically parallel to $S_1$ foliation or, less commonly, with helicitic patterns. $S_1$ foliation is wrapped around the porphyroblasts and is almost always parallel to $S_2$ foliation. Crenulations that overprint these foliations are believed to be related to a later deformation $D_3$, as they are upright.

From the forgoing one can confidently assume that metamorphic minerals from the different stratigraphic and deformational levels formed at the same time. Similarly $S_1$ foliations seen in both examples in Plate 1-11-5 are genetically equivalent. Relationships in the high-grade areas indicate that the main metamorphic event was syn-$F_1$. In the lower grade regions the peak of metamorphism seems to be (for the most part) late to post-$F_1$, unless one assumes that the layer-parallel micas were formed during an earlier metamorphic event. In higher grade rocks, later $F_2$ folding may have obliterated the exact timing relationships between $F_1$ formation and porphyroblast growth. Therefore, whether the $S_2$ crenulation cleavage seen in Plate 1-11-5(a) is the same as $S_2$ in Plate 1-11-5(b) or the later $D_3$ crenulation is uncertain.

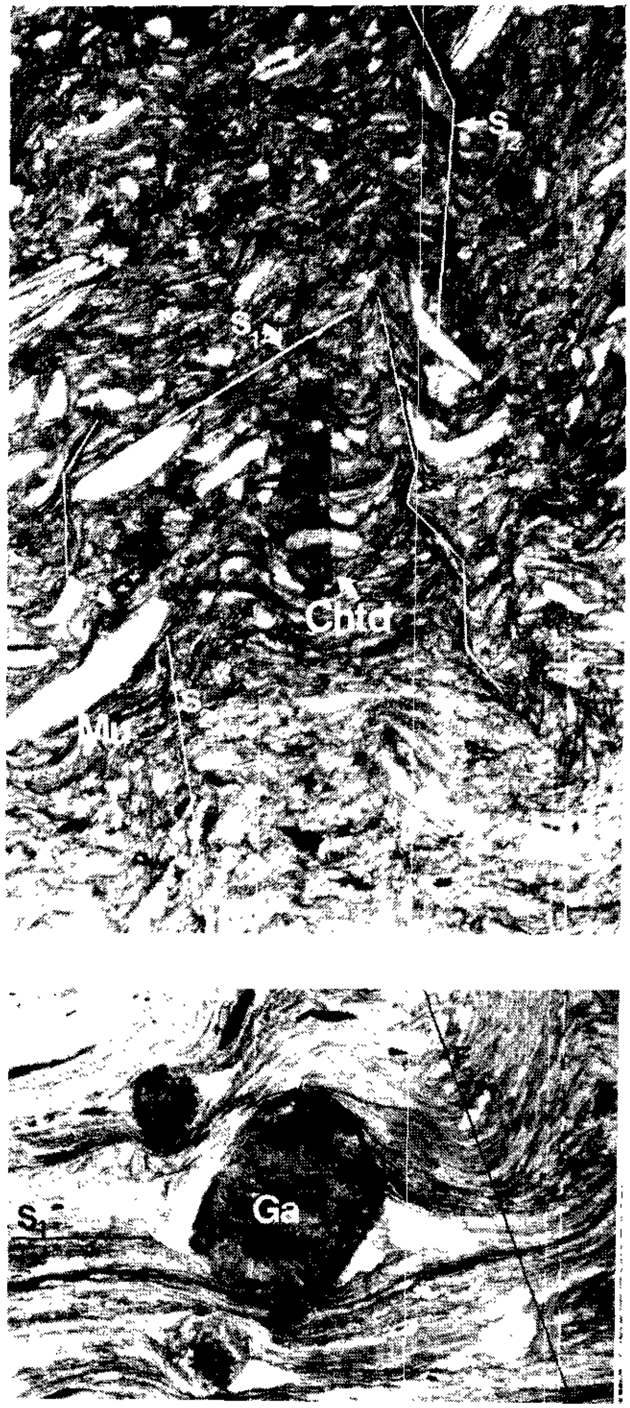



Plate 1-11-5. (a) Photomicrograph of chloritoid phyllite to schist from the upper part of the Stelkuz Formation. The large muscovite grains (Mu) form a layer-parallel fabric ($S_1$) which is later crenulated with an associated pressure solution cleavage ($S_2$). The chloritoid porphyroblasts (Chtd) overgrow $S_1$ but are pre-$S_2$. See text for details. (b) Photomicrograph of garnet-biotite schist from the Swannell Formation. In this plate the garnet (Ga) has been totally chloritized. $S_1$ (here parallel to $S_2$) is delineated by the phyllosilicate minerals which are flattened around the porphyroblasts. These are later crenulated forming the $F_3$ crenulations seen in the photomicrograph. See text for details. Length of each photomicrograph is 3.3 millimetres.

TABLE 1-11-1
KNOWN MINERAL OCCURRENCES
(93N/15-NORTH HALF and 94C/02-SOUTH HALF)

| Map No. | Type | MINFILE Number | Name | Commodities | Geological Description |
|---|---|---|---|---|---|
| 1 | Statabound carbonate-hosted base metals | 093N 172 | Sheila | Zn, Ba, Pb, Ag | Sphalerite occurs disseminated within a fine-grained dolomite and massively with coarse galena in a barite-cemented dolomitic breccia of the McDame Group. |
| 2 | " | 093N 075 | W. Vernon | Zn, Pb, Ba, Ag | Sphalerite occurs as disseminated grains in fine-grained dolomite and as brecciated pods in arenaceous dolomite. Galena primarily occurs massively with barite in small localized shear zones with varying amounts of sphalerite. The hostrocks are primarily dolomites and dolomitic breccias of the McDame Group. |
| 3 | " | 093N 076 | Vernon | Zn, Pb, Ba, Ag | " |
| 4 | " | 093N 114 | Biddy | Zn, Pb, Ge, Ag | " |
| 5 | " | 093N 158 | Crin | Pb, Zn | " |
| 6 | " | 093N 010 | Jemima | Zn, Pb | Sulphide mineralization occurs in discontinuous and irregular shaped pods within arenaceous dolomites of the McDame Group. |
| 7 | " | new | new | Zn, Pb, Ba | Sphalerite, galena, barite and pyrite occur within a coarsely crystalline dolomite of the McDame Group. |
| 8 | Stockwork-hosted base metals | 093N 170 | Osi | Pb, Zn, Ag | A stockwork of siderite and hematite veinlets within massive limestone and dolomitic limestone in the upper unit of the Sandpile Group contains disseminated galena and sphalerite. |
| 9 | Shear-zone-hosted base and precious metals | 093N 011 | Nina | Au, Ag, Cu | Sulphide mineralization with varying gold, silver and base metal concentrations occurs as podiform lenses within a shear zone. The hostrocks are predominantly fine-grained gabbros or basalts(?) with lesser argillaceous cherts within the middle unit of the Slide Mountain Group. |

Potassium-argon ages of metamorphism in the area consistently return dates in the 40 to 65 Ma range (unpublished analysis of metamorphic rocks by the authors from the Manson Lakes map sheet, as well as Gabrielse, 1975; Parrish, 1979) and are most likely related to the low-grade retrogression seen in the map area. Parrish (1979) presents Rb-Sr data which indicate a Middle to Late Jurassic (or earlier) age for the prograde metamorphism in the Aiken Lake area.

## MINERALIZATION

Known mineral occurrences within the map area are predominantly associated with the McDame dolomitic units, except for a lead-zinc-silver showing within the Sandpile Group and a gold-silver-copper prospect in Slide Mountain rocks.

Stratabound sulphide mineralization occurs throughout an interval which extends from the Earn–McDame contact down to the uppermost Tapioca sandstone unit of the Sandpile Group. Mineralization consists primarily of argentiferous galena, brown to red sphalerite, barite and minor amounts of pyrite. In the Biddy area, germanium-bearing sphalerite is reported with the average tenor being 0.05 per cent of the sphalerite which averages about 3 to 4 per cent in mineralized areas (Leighton, 1988). Sulphide mineralization, predominantly sphalerite, is typically disseminated in arenaceous dolomites, fine-grained dolomites and sandstones. Semimassive sphalerite and galena typically favour dolomitic breccias as hostrocks and occur as matrix or carbonate-clast replacements, or a combination of both. In the McDame Group, mineralization exhibits a strong affinity with the dolomitic successions (Sonnendrucker, 1975). Remobilization has further concentrated the sulphide mineralization along shear zones where galena, sphalerite and megacrystic barite occur as irregular pods (Leighton, 1988) or as the matrix of fault breccia (Sonnendrucker, 1975).

The map area has potential for stratabound carbonate-hosted base metal deposits throughout the McDame Group. This is exemplified by the 1989 discovery of a new mineral occurrence in the northern trace of this sequence (*see* Table 1-11-1 and Figure 1-11-3a).

Fracture-hosted mineralization occurring lower in the stratigraphy is exemplified by the Osi showing where two types of occurrences have been identified. Both occur within the massive limestones and dolomitic limestones of the upper Sandpile Group. They are either a stockwork of siderite and hematite veinlets containing disseminated galena and sphalerite or larger, siliceous veins containing massive galena (Sonnendrucker, 1975).

Shear zones cutting fine-grained gabbros and argillaceous cherts in the middle unit of the Slide Mountain Group may host podiform lenses of sulphide mineralization as at the Nina prospect. Mineralization is primarily pyrite and minor chalcopyrite with varying amounts of gold and silver (Cope, 1988).

## CONCLUSIONS

- Rocks of North American affinity within the study area form a continuous sequence from the Proterozoic Ingenika Group to the Devono-Mississippian Earn Group. The Paleozoic and Proterozoic stratigraphy appears very similar to that described in the Cassiar and northern Omineca Mountains. Stratigraphic nomenclature from the Cassiar area has been suggested for these rocks.
- A three-fold subdivision has been recognized within the allochthonous Slide Mountain Group; an upper basaltic sequence, a middle siliceous sediment/gabbro sequence and a lower argillite sequence. These correspond to subdivisions recognized to the south by Ferri and Melville (1988, 1989).
- The western part of the map area forms a west-dipping homoclinal succession. To the east, the lower parts of the Ingenika Group record at least three phases of deformation together with syn-$F_1$ prograde metamorphism (to sillimanite) and a later chlorite-grade retrograde event.
- Stratabound lead-zinc-barite-silver mineralization is found disseminated or in breccia zones within McDame Group and Tapioca sandstone equivalents. Copper-gold-silver mineralization is associated with siliceous sediments and gabbro of the middle division of the Slide Mountain Group.

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