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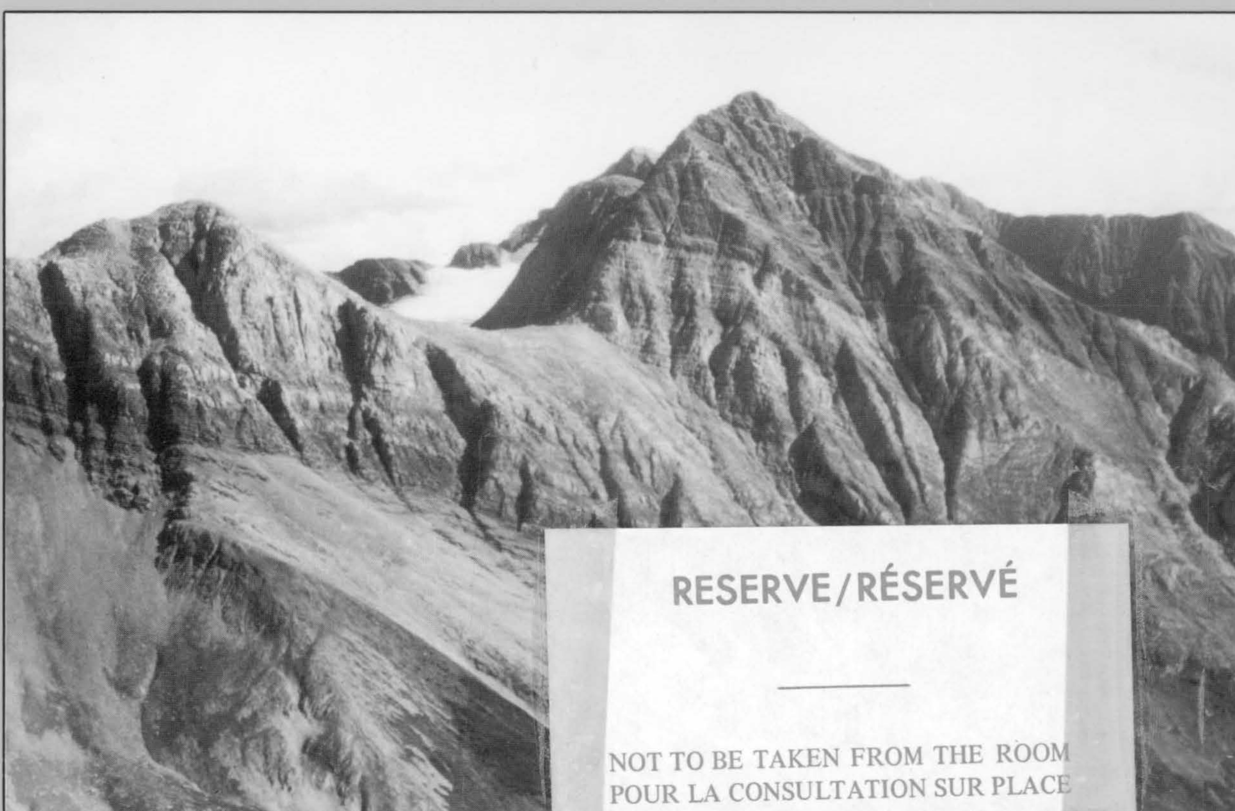
STRATIGRAPHY AND STRUCTURE OF THE MOUNT SELWYN AREA, ROCKY MOUNTAINS, NORTHEASTERN BRITISH COLUMBIA

M.E. McMECHAN



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STRATIGRAPHY AND STRUCTURE OF THE MOUNT SELWYN AREA, ROCKY MOUNTAINS, NORTHEASTERN BRITISH COLUMBIA

Abstract

Upper Proterozoic to Middle Jurassic, miogeoclinal, clastic and carbonate deposits, Upper Jurassic to Lower Cretaceous foredeep deposits, and Upper Cretaceous to Tertiary intermontane basin deposits outcrop in the Mount Selwyn area. Three structural levels, each characterized by distinctive structural styles, are recognized in the Rocky Mountains. Middle Devonian and older strata of the lower structural level form large thrust sheets and folds. Predominantly incompetent, disharmonically folded and faulted Upper Devonian to Middle Triassic strata of the middle structural level have been shortened approximately twice as much as the folded, more competent, Upper Triassic to Upper Cretaceous strata of the upper structural level, across the Foothills belt. Shortening across the Rocky Mountains is approximately 70 km. Pre-Late Cretaceous strata exposed adjacent to and within the Rocky Mountain Trench were regionally metamorphosed to greenschist facies and penetratively deformed prior to Late Cretaceous-Paleocene thrust faulting in the Rocky Mountains.

The disappearance of folded and faulted Upper Cambrian to Middle Devonian strata, and the folding of major thrust faults in the southern part of the Mount Selwyn area are probably a consequence of southeastward convergence in the position of ramps through Upper Proterozoic to Middle Devonian strata in the hanging walls of the Murray Range and Hidden faults, and the juxtaposition of the intervening deformed wedge of rock along a flat in the footwall of the Hidden Fault.

Prospective structures for petroleum accumulation may occur at the leading edges of the 'blind' (nonsurfacing) thrust sheets carrying Middle Devonian and older strata under the western part of the Foothills, and in faulted anticlines of Lower Carboniferous carbonate strata.

Résumé

Des dépôts clastiques et carbonatés de miogéosynclinal datant du Paléozoïque supérieur au Jurassique moyen, des dépôts d'avant-fosse datant du Jurassique supérieur au Crétacé inférieur, et des dépôts de bassin d'entremont datant du Crétacé supérieur au Tertiaire affleurent dans la région du mont Selwyn. Trois niveaux structuraux caractérisés par des géométries structurales distinctes ont été identifiées dans les Montagnes Rocheuses. Des strates datant du Dévonien moyen et avant et appartenant au niveau structural inférieur forment de vastes nappes de charriage et de grands plissements. Des strates datant du Dévonien supérieur au Trias moyen qui s'avèrent généralement incompétentes et caractérisées par des failles et des plis disharmoniques, et qui proviennent du niveau structural intermédiaire, ont été environ deux fois plus comprimées que les couches plus compétentes et plus pliées dans le niveau structural supérieur, se situant dans la zone des Foothills. La compression au travers des Montagnes Rocheuses s'étend sur quelques 70 km. Les strates qui ont été dénudées datant avant le Crétacé supérieur à côté et à l'intérieur du sillon des Rocheuses ont été métamorphisées régionalement en faciès de schistes verts et ont été déformées par pénétration avant le chevauchement des Montagnes Rocheuses qui avait lieu pendant le Crétacé supérieur jusqu'au Paléocène.

La disparition de couches faillées et pliées datant du Cambrien supérieur au Dévonien moyen et le plissement de failles de poussée importantes dans la partie sud de la région de mont Selwyn sont probablement dus à la convergence vers le sud-est sous la forme de plans inclinés traversant les couches du Protérozoïque supérieur au Dévonien moyen, dans les lèvres supérieures des failles de Murray Ridge et de Hidden, et à la juxtaposition du prisme de roche intermédiaire le long d'une surface plate, dans la lèvre inférieure de la faille de Hidden.

Les structures susceptibles de renfermer des hydrocarbures sont situées sur les bords des nappes de charriage aveugles (n'affleurant pas) englobant des couches du Dévonien moyen et des couches plus anciennes, sous la partie ouest de la zone des Foothills, et dans des anticlinaux faillés composés de couches carbonatées du Carbonifère inférieur.

INTRODUCTION

Location and access

The Mount Selwyn area, in the Pine Pass-Peace River region of northeastern British Columbia, lies between latitudes 55°30' and 54°N, and longitude 123°W and Williston Lake (Fig. 1). Logging roads provide access up the west side of Clearwater Creek and some of its tributaries, and along the lower part of Selwyn Creek. Helicopters may be chartered in Mackenzie, B.C. to provide access to most of the area.

Fieldwork and acknowledgments

Fieldwork was undertaken in July and August, 1980, and involved geological mapping of the area at a scale of 1:50 000. Joan Lund provided able assistance in the field. Thanks are extended to G.C. Taylor for introducing the writer to the geology of the area, D.F. Stott for providing unpublished 1:50 000 compilations of the geology east of the Mount Selwyn area, and B.S. Norford for providing unpublished sections through Middle Ordovician to Middle Devonian strata.

This manuscript benefitted from the constructive comments and suggestions of D.G. Cook, B.S. Norford and A.V. Okulitch.

Previous geological work

The major drainage systems of the Peace and Parsnip rivers provided access for early exploration in northern British Columbia. The first geological expedition through northern British Columbia followed these valleys as it traversed from Quesnel to Fort St. John (Selwyn, 1877). On July 11, 1875, A.R.C. Selwyn, accompanied by biologist J. Macoun, climbed the prominent mountain southeast of the confluence of the Peace and Parsnip rivers and named it Mount Selwyn. In 1879, G.M. Dawson (1881) examined the geology immediately south of the Mount Selwyn area, along Pine Pass, while en route from Port Simpson, near Prince Rupert, B.C., to Edmonton, Alberta. In 1893, R.G. McConnell (1896) briefly re-examined the geology along the uppermost Peace River Valley. In 1929 and 1930, M.Y. Williams and J.B. Bocock mapped the Peace River Valley for the Pacific Great Eastern Survey of Resources under the joint auspices of the Province of British Columbia, Canadian National Railways and Canadian Pacific Railways. Only the stratigraphic results were published (Williams and Bocock, 1932). In 1959 and 1960, the Mount Selwyn area was mapped by J.E. Muller (1961) as part of the systematic mapping of Pine Pass (NTS 93-O) map area. Subsequent fieldwork by Muller in 1966 led to significant reinterpretations of his original work (Muller, 1967). In 1969, Pine Pass map area was remapped during Operation Smoky (Stott, 1970a; Taylor, 1970). The geology of the Mount Selwyn area

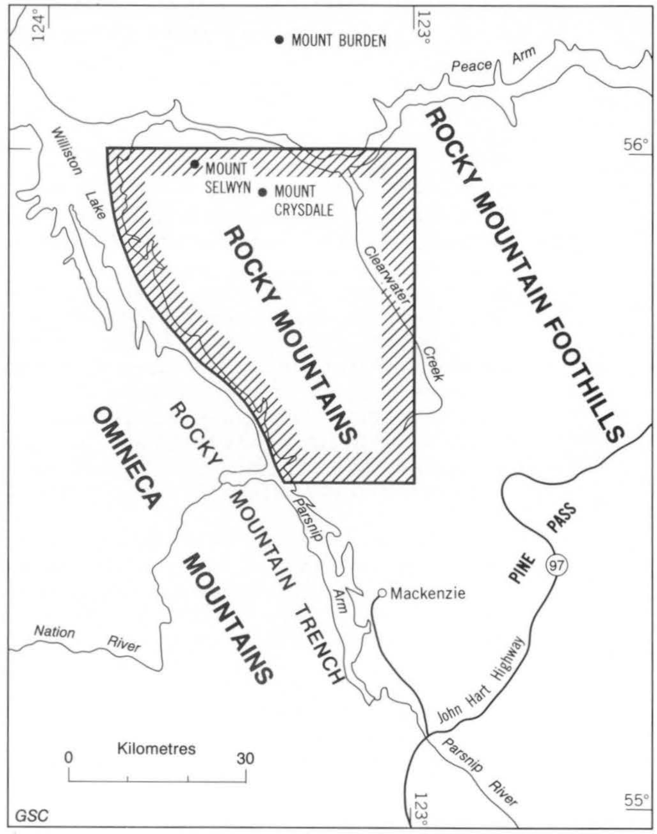

Figure 1. *Location map showing physiographic subdivisions (NTS 93-O/11, 12W, 13W, 14). The Mount Selwyn map area is outlined.*

was poorly understood, however, and the preliminary geological map of Pine Pass map area (Stott and Taylor, 1975) covered only the portion underlain by Jurassic and Cretaceous strata. G.D. Belik (1970) described Lower and Middle Cambrian strata, and B.S. Norford briefly examined Middle Ordovician through Middle Devonian strata in the Mount Selwyn area. Only the Silurian section was published (Norford, Gabrielse and Taylor, 1966). From 1966 to 1968, N.W. Rutter (1967, 1968, 1969, 1974) investigated the surficial geology of the Peace, Parsnip and Findlay river valleys prior to their flooding by Williston Lake.

Numerous resource evaluation and stratigraphic studies have been conducted in the Foothills east of the Mount Selwyn area. Stott (1973) and Gibson (1975) summarized most of these. The geology of Halfway River map area (NTS 94-B), to the north of the Mount Selwyn area, has been recently re-examined by Thompson (in press).

PHYSIOGRAPHY

Three major physiographic regions occur within the Mount Selwyn area: the Rocky Mountain Foothills, the Rocky Mountains, and the Rocky Mountain Trench (Fig. 1). The Foothills, predominantly underlain by Mesozoic strata, are characterized by northwest-trending ridges with up to 1000 m of relief. Two distinct topographic elements comprise the

Rocky Mountains of the Mount Selwyn area: rugged peaks and ridges with 1000 to 1500 m of relief underlain by resistant Paleozoic carbonate rocks and quartzite; and open, gentle ridges with 900 to 1200 m of relief, underlain by Proterozoic strata. In both elements, the northwest-trending ridges are cut by rugged northeast-trending valleys. The northwest-trending Rocky Mountain Trench forms the western boundary of the Rocky Mountains. At the latitude of the Mount Selwyn area, the Trench is 20 to 25 km wide. Its floor is generally between 600 and 750 m in elevation and is predominantly underlain by glaciofluvial and lacustrine deposits (Rutter, 1968, 1974). Locally, bedrock ridges covered with till rise up to 300 m above the general level of the Trench. In 1968, Williston Lake was formed by flooding those areas of the Rocky Mountain Trench and upper Peace River Valley below an elevation of 675 m (2205 ft).

Till covers low to moderately dipping slopes in the Rocky Mountains and Foothills of the Mount Selwyn area. Most valleys have U-shaped profiles, and cirques or tarns are common on the north side of ridges. Two small glaciers remain in the vicinity of Mount Crysdale.

STRATIGRAPHY

Introduction

Most of the Upper Proterozoic to Tertiary strata underlying the Mount Selwyn area are part of a northeast-tapering supracrustal wedge, within which structures of the Rocky Mountains and Foothills developed. Four distinct tectonostratigraphic assemblages are recognized within the supracrustal wedge of the Pine Pass-Peace River area. The three lower assemblages comprise a broad, continental, terrace wedge deposited along the western edge of the North American craton during the Late Proterozoic to Middle Jurassic. The clastic deposits of the youngest assemblage record the tectonic events that affected the Omineca Crystalline Belt and the Rocky Mountains from the Late Jurassic to early Tertiary.

Deeper water, marine, clastic rocks and subordinate shallow water carbonate rocks of the Upper Proterozoic Misinchinka Group make up the oldest assemblage. The overlying lower and middle Paleozoic assemblage consists of a basal shallow marine to fluvial(?) sandstone sequence (Gog Group) overlain by a series of shallow water carbonate shelves that pass westward into time-equivalent shale, limestone and siltstone of a deeper water facies (Thompson, 1976, 1979; Cecile and Norford, 1979). In the Mount Selwyn area, only Upper Cambrian to Lower Ordovician (Upper Lynx Formation and Kechika Group) and Upper Devonian to Tournaisian (Besa River Formation) strata are in the deeper water facies. An assemblage of upper Paleozoic and lower Mesozoic miogeoclinal shale, siltstone, carbonate rock and lesser quartz sandstone unconformably overlies the lower to middle Paleozoic assemblage. Upper Jurassic to Tertiary synorogenic deposits form the youngest tectonostratigraphic assemblage. Most of these clastic deposits accumulated in a foredeep that migrated northeastward between the Upper Jurassic and Paleocene (Bally et al., 1966; Thompson, 1979).

The Mount Selwyn area lies along the southern edge of an important lower Paleozoic embayment in the western margin of North America (Hay River Embayment of Pugh, 1975; Ospika Embayment of Thompson, in press). In the southern part of Halfway River map area, Lower and Middle Cambrian, Upper Ordovician, Lower Silurian, and Lower and Middle Devonian strata, similar to those in the Mount Selwyn area, change facies northward from shelf carbonate or sandstone to deeper water, shaly deposits in the embayment (Thompson, in press).

The northeast-trending Peace River arch is well defined in the subsurface of the Fort St. John-Grand Prairie area, 250 km east of the Mount Selwyn area (Pugh, 1975). Along the arch, Devonian strata unconformably overlie Precambrian basement. The thick sequence of lower Paleozoic strata preserved in the Mount Selwyn area shows that this area lay west and northwest of the Peace River arch during the lower Paleozoic. This is consistent with the reconstructions of Pugh (1975) and the Shell Oil Company (1975).

Precambrian

Late Proterozoic

Misinchinka Group

Lithology and thickness. In the western and southern part of the area, argillite, diamictite, carbonate, feldspathic quartzite and quartzite, comprising the Misinchinka Group (Dawson, 1881), are exposed above the Murray Range Fault. Three units – lower clastic (PM1), middle carbonate (PM2) and upper clastic (PM3) – are recognized.

The lower clastic unit (PM1) comprises a thick succession of phyllite, siltite, diamictite, feldspathic quartzite and minor carbonate, the base of which is not exposed. Major facies changes occur within the unit across the Weston Fault. To the east, the upper 1200 m of the unit consist of green, or less commonly, purple, sandy phyllite and schist, with 1 to 3 per cent (locally to 20%) granule to cobble sized chlorite-phyllite, quartzite, dolomite and greenstone clasts, forming diamictites; lesser laminated green argillite and siltite; and minor quartz sandstone and grey argillite. Limestone and dolomite interbeds up to tens of metres thick occur locally in the upper two hundred metres of the unit. Green, or less commonly, grey-purple, locally laminated, silty phyllite and argillaceous siltite underlie the diamictite. Two to ten metre thick packets of quartzite and pebble conglomerate occur as interbeds in the lower part. These coarse clastics are poorly sorted, graded and locally feldspathic. They appear to be the deposits of turbidity flows. Many of these 'quartzite' packets have abrupt, lateral terminations, and appear to be tabular channel deposits. West of the Weston Fault, grey-green, pyritic phyllite forms the upper 50 m of the lower clastic (PM1) unit. Packets of feldspathic, fine to coarse grained quartzite and pebble conglomerate interbedded with rusty weathering grey argillite characterize the remaining 450 m of the unit that is exposed. No diamictite beds were observed. The coarse clastics are poorly sorted and commonly graded. They are also probably the deposits of turbidity flows. In general, the 'quartzite' packets are thicker and comprise more of the section than similar packets found at lower stratigraphic levels east of the Weston Fault. Along the Trench, interbedded argillaceous sandstone and argillite have been metamorphosed and deformed into chlorite-muscovite-(garnet) schists. Even in eastern exposures, where

TABLE OF FORMATIONS

Era	Period or Epoch	Formation and maximum thickness (metres)	Lithology
Cenozoic	Quaternary	Glaciofluvial, lacustrine and glacial deposits; alluvium	Gravel, sand, silt, clay, till; unconsolidated
	Unconformity		
	Eocene or younger (?)	Unnamed clastic unit >150	Siltstone, mudstone, sandstone, granule conglomerate; minor coal; nonmarine
Relationships uncertain			
Mesozoic - Cenozoic	Upper Cretaceous and Paleogene	Sifton Formation >100	Conglomerate; minor sandstone; nonmarine
Unconformity			
Mesozoic	Lower Cretaceous	Beattie Peaks Formation >200	Silty mudstone, sandstone; marine
	Conformable contact		
	Upper Jurassic and Lower Cretaceous	Monteith Formation 700	Sandstone; minor shale; marine
	Conformable contact		
	Jurassic	Fernie Formation 350	Shale, siltstone; minor sandstone; marine
	Disconformity		
	Upper Triassic	Bocock Formation 70	Limestone; resistant; marine
		Disconformity	
		Pardonet Formation 150	Carbonaceous-argillaceous limestone, calcareous and dolomitic siltstone; minor shale; marine
		Conformable contact	
		Baldonnel Formation 155	Upper member: limestone and dolomite, siltstone, sandstone; resistant; marine Lower (Ducette) member: siltstone, sandstone,limestone; minor dolomite; marine
		Conformable contact	
		Charlie Lake Formation 290	Sandy to silty dolomite, dolomitic siltstone, sandstone; marine
	Conformable contact		
	Middle and Upper Triassic	Liard Formation 450 Ludington Formation (Facies equivalent to Baldonnel, Charlie Lake and, probably, Liard formations) 400	Dolomitic to calcareous sandstone and siltstone, dolomite, cherty limestone; marine Dolomitic to calcareous siltstone, sandstone, silty to sandy bioclastic limestone; marine
	Conformable contact		
	Lower and Middle Triassic	Toad Formation 295	Calcareous siltstone, silty limestone, silty shale; minor silty dolomite, calcareous sandstone; marine

Era	Period or Epoch	Formation and maximum thickness (metres)	Lithology
	Conformable contact		
	Lower Triassic	Grayling Formation 75	Dolomitic siltstone, silty shale; minor calcareous siltstone, silty limestone, dolomite, sandstone; recessive; marine
Disconformity			
Paleozoic	Permian	Fantasque Formation 40	Bedded chert; minor lenses of cherty phosphatic dolomite; marine
		Disconformity	
		Kindle Formation 70	Argillaceous, silty limestone; calcareous siltstone and shale; marine
	Disconformity		
	Lower Carboniferous	Stoddart Group 100	Shale, sandstone, limestone, siltstone; marine
		Conformable contact	
		Prophet Formation 650	Limestone, calcareous mudstone, spiculite; chert nodules in upper part; marine
	Conformable contact		
	Upper Devonian and Lower Carboniferous	Besa River Formation 600 (?)	Dark grey argillite, calcareous shale; minor limestone, chert; marine
	Disconformity (?)		
	Middle Devonian	Dunedin Formation 600	Upper unit: limestone; argillaceous limestone; massive secondary dolomite; marine Lower unit: argillaceous limestone, calcareous shale; minor limestone, quartz sandstone; red shale, locally; predominantly marine
	Disconformity		
	Lower Devonian	Stone Formation 350	Upper unit: silty, light grey dolomite; marine Lower unit: tan weathering, silty dolomite, quartz sandstone, dolomitic sandstone; marine
	Disconformity		
	Upper Silurian and Lower Devonian	Muncho-McConnell Formation 280	Light grey dolomite, sandy dolomite; minor breccia
	Disconformity		
	Lower Silurian	Nonda Formation 300	Dark to light grey, silty and argillaceous dolomite; chert nodules; minor quartz sandstone; marine
	Disconformity		
	Upper Ordovician	Beaverfoot Formation 125	Dolomite, silty dolomite; minor quartz sandstone at base; marine
		Disconformity	
		Unnamed quartzite and dolomite unit 50	Quartzite, dolomitic quartzite, argillaceous dolomite; marine

Era	Period or Epoch	Formation and maximum thickness (metres)	Lithology
		Disconformity	
		Unnamed limestone, dolomite and shale unit 50	Argillaceous limestone; nodular, cherty dolomite; shale; marine
		Disconformity	
	Middle Ordovician	Skoki Formation 220	Grey dolomite, oncolitic dolomite; marine
		Conformable contact	
	Lower Ordovician	Kechika Group 1500	Upper unit: argillaceous, silty, nodular to wavy bedded limestone; minor calcareous argillite; marine Middle unit: wavy banded, silty limestone; minor quartz sandstone; marine Lower unit: cleaved, argillaceous, silty limestone; nodular, silty limestone; marine
		Conformable contact	
	Upper Cambrian	Lynx Formation 1200	Upper unit: calcareous argillite and argillite with limestone nodules; silty, argillaceous, nodular to wavy bedded limestone; minor resistant limestone; marine Lower unit: dolomite, sandy to silty dolomite; minor quartz sandstone at base; marine
		Conformable contact	
	Middle Cambrian	Arctomys Formation 45	Tan weathering, silty dolomite; black and red shale; argillaceous dolomite; marine
		Conformable	
		Titkana Formation 25	Dolomite, commonly laminated, resistant; marine
		Conformable contact	
		Snake Indian Formation 140	Red shale, tan weathering dolomite, sandy dolomite; dolomitic quartzite at base; marine
		Conformable contact	
	Lower Cambrian	Mahto Formation 90	White and maroon quartzite, red shale; marine
		Conformable contact	
		Mural Formation 35	Green and red dolomitic shale; argillaceous shale; tan weathering, dolomitic sandstone; dolomite; quartzite; marine
		Conformable contact	
		McNaughton Formation 230	Quartzite, dolomitic quartzite, argillaceous quartzite; minor shale; rare conglomerate; marine to nonmarine (?)
		Disconformity	
Precambrian	Upper Proterozoic	Misinchinka Group >3900 (base not exposed)	Upper unit: rusty weathering, silty argillite, quartzite, siltite; marine Middle unit: limestone, sandy limestone, quartzite; minor argillite; marine Lower unit: green, grey-purple or grey phyllite, siltite, diamictite, feldspathic quartzite; minor carbonate; marine

deformation has not destroyed the details of sedimentation, there is no evidence of shallow water deposition. The maximum exposed thickness of the lower clastic unit is estimated to be 2 km.

The middle carbonate unit (PM2) comprises blue-grey weathering, finely to medium crystalline, platy and sandy limestone, lesser quartzite, and minor argillite. The limestone has commonly been altered to tan weathering, light grey dolomite. Locally, east of the Weston Fault, a thick interbed of diamictite with a sandy limestone matrix and quartzite and dolomite clasts occurs near the base of the unit. Quartzites occur sporadically at all stratigraphic levels within the unit. Channelled bases are common and crossbeds occur. The abundance of quartz sand and the association with channelled quartzites suggest that most of the carbonate strata composing unit PM2 were deposited in a peritidal environment. The middle carbonate unit varies from approximately 600 to 900 m in thickness. This variation is apparently due to rapid lateral facies changes.

Argillite, quartzite and siltite constitute the upper clastic unit (PM3). The argillite is dominantly grey, silty and cleaved. Rusty weathering is common. Load casted to nodular laminae of argillaceous siltite or very fine grained quartzite are abundant. Syneresis cracks are rare. Quartzite occurs in very thin to thin bedded sheets that appear massive or graded. Most are probably the deposits of turbidity currents. These quartzite beds are distinct from typical "quartzites" of the lower clastic unit because of their fine grain size, better sorting and low feldspar content. The absence of mudcracks and ripple marks suggests that the upper clastic unit was deposited in a basinal environment. The thickness of the upper clastic unit cannot be determined in the Mount Selwyn area; however, it is at least 1100 m thick.

Correlation. Misinchinka strata are lithologically similar to and largely correlative with middle and upper Miette Group strata exposed in the McBride area, 300 km to the southeast. The lower clastic unit is approximately correlative with the middle Miette of Campbell et al. (1973) and the upper clastic unit with the upper Miette. The Byng Formation (Slind and Perkins, 1966), a prominent carbonate unit in the Miette Group of the Mount Robson area, is absent in the McBride area (Campbell et al., 1973) and, therefore, cannot be reliably correlated with the middle carbonate unit of the Mount Selwyn area. In the Mount Selwyn area, strata of the Misinchinka Group are abruptly overlain by feldspathic, shallow water sandstones of the Gog Group. This contact represents a marked change in sedimentary facies and suggests the presence of a disconformity. However, in the Fort Grahame east-half map area, 70 km to the northeast, Lower Cambrian sandstones pass into an argillaceous succession that appears to be gradational with the Upper Proterozoic strata. Because there is no easily mappable boundary, Gabrielse (1975) preferred to include the Lower Cambrian strata in the Misinchinka Group. Consequently, the Misinchinka of the Mount Selwyn area is correlative with only the lower main part of the Misinchinka Group as mapped farther north.

Paleozoic

Cambrian

Gog Group

The Gog Group (Deiss, 1940; Mountjoy, 1962), a sequence dominated by quartzite, is exposed in the footwalls of the Back Range and Murray Range faults. Three formations, (in ascending order, McNaughton, Mural and Mahto), are mappable on the high ridge south of Macoun Creek. Elsewhere, incomplete exposure and the thinness of the Mural Formation prevent easy differentiation of the formations, and the strata have been mapped as Gog Group. The Gog Group is 340 m thick on the high ridge south of Macoun Creek, and over 400 m thick east of Scott Creek (Belik, 1970).

McNaughton Formation. The McNaughton Formation (Walcott, 1913) consists of quartzite, dolomitic quartzite, argillaceous quartzite, minor shale and rare conglomerate. Quartzites are generally white, well cemented and fine to medium grained. Granule sized grains and feldspar are abundant near the base of the formation. Belik (1970, p. 39) observed trilobite fragments in the upper part of the formation. The abundance of crossbeds, bioturbation, channels, and rippled surfaces suggests deposition in very shallow, neritic to fluvial(?) environments. Strata of the McNaughton Formation are transitional into dolomitic strata of the overlying Mural Formation. On the high ridge south of Macoun Creek, the McNaughton Formation is 230 m thick (Belik, 1970).

Mural Formation. Dolomitic shale, arenaceous shale, dolomitic sandstone, quartzite and dolomite constitute the Mural Formation (Burling, 1923). Shales are green or red and poorly exposed. Dolomites are tan weathering and finely crystalline. No fossils were found in the Mount Selwyn area; however, Street (1966) found Lower Cambrian trilobites in the Mural Formation (Taylor and Bamber, 1970) 60 km to the south near Pine Pass (9 km west of Mount Hunter). Strata of the Mural Formation are transitional into quartzite of the overlying Mahto Formation. The contact was placed where quartzite becomes predominant. On the high ridge south of Macoun Creek, the Mural Formation is approximately 35 m thick.

Mahto Formation. The Mahto Formation (Walcott, 1913) consists of quartzite and lesser shale. The quartzite is generally fine grained, silica cemented, and white or maroon coloured. The shale is predominantly red, and occurs as thin partings between quartzite beds, except in the basal 20 m, where it forms recessive intervals up to 2 m thick. Common

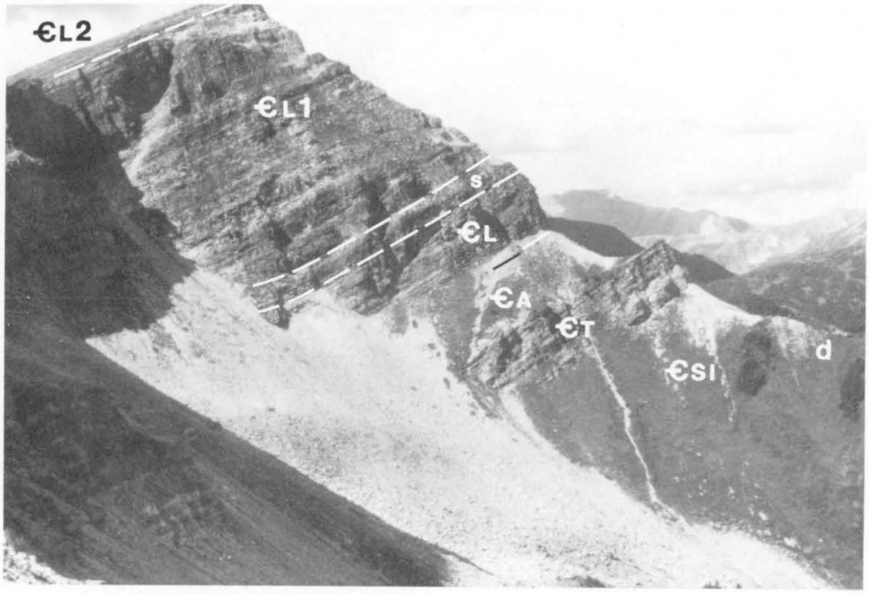

Plate 1. *Middle and Upper Cambrian strata exposed on the high ridge south of Macoun Creek.* €SI *- Snake Indian Formation, d - dolomite unit within Snake Indian Formation;* €T *- Titkana Formation;* €A *- Arctomys Formation;* €L1 *- Lynx Formation (lower unit), s - dolomite and shale unit,* €L2 *- upper unit of Lynx Formation. ISPG photo 1820-3.*

crossbeds (locally with a herringbone aspect), wave formed ripples, and *Skolithos* tubes suggest that the Mahto Formation was deposited in a shallow neritic to intertidal environment. Strata of the Mahto Formation grade over about 5 m of section into the dolomite and sandy dolomite of the overlying Snake Indian Formation. The Mahto Formation is approximately 90 m thick on the high ridge south of Macoun Creek.

Middle Cambrian

On the basis of stratigraphic position and regional correlation, a succession of varicoloured shale and dolomite exposed along the footwalls of the Murray Range and Back Range faults has been assigned to the Middle Cambrian. No fossils have been collected from these rocks in the Mount Selwyn area. Slind and Perkins (1966) examined the Middle Cambrian from the well studied sections in the Mount Robson area northward to Pine Pass. In the northern part of this region, Slind and Perkins (1966), could not recognize all the formations present in the Mount Robson area, and they used a threefold breakdown: the Tatei-Chetang, Titkana and Arctomys formations. Mountjoy and Aitken (1978) established the Snake Indian Formation for the inner detrital facies (Robison, 1960; Palmer, 1960; Aitken, 1966) equivalents of the carbonate rocks comprising the type Tatei and Chetang formations. Because strata underlying the Titkana Formation and overlying the Gog Group in the Mount Selwyn area belong to the inner, detrital facies, they are included in the Snake Indian Formation.

Immediately north of the Mount Selwyn area, major facies changes occur within the Middle Cambrian succession. The varicoloured shales and dolomites constituting the Snake Indian, Titkana and Arctomys formations are replaced by a dolomitic sandstone unit overlain by a tan weathering dolomite unit in the Halfway and Fort Grahame (east-half) map areas (Irish, 1970; Gabrielse, 1975). These unnamed units contain Middle Cambrian trilobites (W.H. Fritz in Irish, 1970 and in Gabrielse, 1975).

Snake Indian Formation. Shale, dolomite, and sandy dolomite make up the Snake Indian Formation (Mountjoy and Aitken, 1978). The shale is predominantly red, commonly has silty laminae and is recessive weathering. The dolomite is tan weathering and finely crystalline. Fine algal laminae and argillaceous partings are locally abundant. Dolomite forms a relatively resistant unit, approximately 25 m thick, near the middle of the formation (Pl. 1). Sandy dolomite and dolomitic quartzite predominate in the basal 10 m of the formation. The abundance of mudcracks, flat-pebble conglomerates, collapse breccias and algal laminites suggests deposition in intertidal to supratidal environments. The contact with the overlying, resistant dolomite of the Titkana Formation is not exposed. In the type area, this contact is gradational over a 3 to 9 m interval (Mountjoy and Aitken, 1978). The Snake Indian Formation is 140 m thick on the high ridge south of Macoun Creek, and approximately 80 m thick west of Macoun Fault.

Titkana Formation. The cliff-forming Titkana Formation (Pl. 1; Walcott, 1913), consists of medium-light grey, very light grey weathering, finely (algal) laminated, finely crystalline dolomite, and lesser, medium grey, light grey weathering, finely to medium crystalline dolomite. Small, irregular, chert "nodules" and calcite veining are locally abundant. Algal laminites, rare intraclasts, and the general absence of mudcracks suggest deposition in a shallow neritic environment. Strata of the Titkana Formation grade into silty dolomite and minor shale of the overlying Arctomys Formation over approximately 1 m of section. The Titkana Formation is 25 m thick on the high ridge south of Macoun Creek, and approximately 15 m thick west of Macoun Fault.

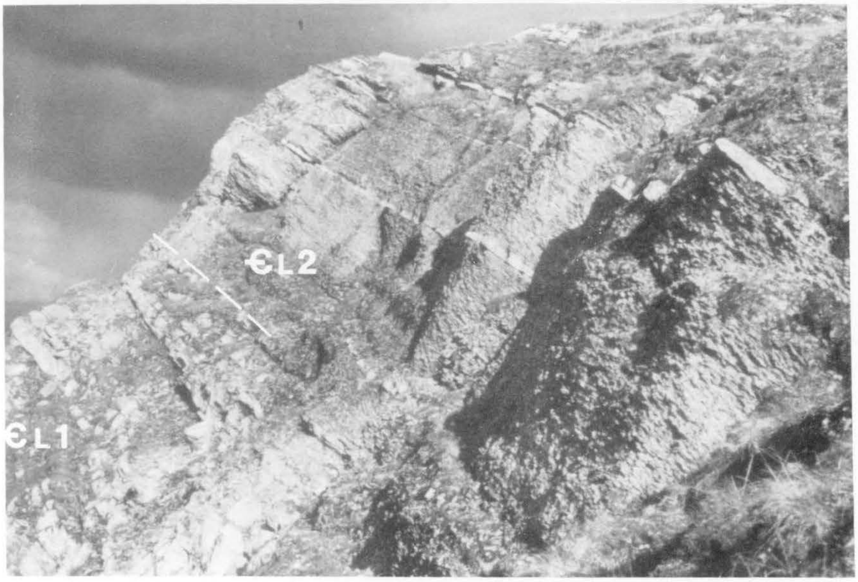

Plate 2. *Silty, argillaceous, wavy banded, and nodular limestone with resistant, light grey weathering limestone interbeds at base of the upper unit €L2 of the Lynx Formation. €L1 - Lynx Formation (lower unit). High ridge south of Macoun Creek. ISPG photo 1820-5.*

Arctomys Formation. The Arctomys Formation (Walcott, 1923) consists predominantly of tan weathering, silty, finely crystalline dolomite with thin partings, and beds of black or red shale and argillaceous dolomite. Fine laminae, apparently of algal origin, are common. On the high ridge south of Macoun Creek, light grey weathering, very finely crystalline, locally stromatolitic, cherty dolomite forms a relatively resistant band up to 10 m thick within the generally recessive weathering Arctomys. The abundance of algal laminites, mudcracks and intraclasts suggests deposition in a shallow neritic to intertidal environment. The change into the grey dolomite of the overlying Lynx Formation occurs over approximately 1 m of section. The Arctomys Formation is 45 m thick on the high ridge south of Macoun Creek (Belik, 1970) and approximately 40 m thick west of Macoun Fault.

Lynx Formation. Dolomite, argillite and limestone constitute the Lynx Formation (Walcott, 1913; Mountjoy, 1962). Two mappable units were recognized by the author. The lower unit (€L1), consists of cliff-forming, light and medium grey weathering dolomite, and sandy to silty dolomite that is exposed in the footwalls of the Back Range and Murray Range faults. Lenses of crosslaminated quartz sandstone occur locally near the base. Dolomites are very coarsely to finely crystalline and commonly bioturbated. Beds of oncolites and fossil debris or intraclasts occur locally. Approximately 35 m above the base of the formation, tan weathering, finely crystalline dolomite with black shale partings forms a unit approximately 10 m thick (Pl. 1). West of Macoun Fault, strata underlying this unit are predominantly finely crystalline and locally algal laminated. The abundance of subhorizontal burrows and the occurrence of oncolites, intraclasts and algal laminae suggest deposition in a (shallow) neritic environment. The lower unit of the Lynx Formation is approximately 200 m thick on the high ridge south of Macoun Creek and greater than 230 m thick west of Macoun Fault.

The upper unit (€L2) is exposed on the high ridge south of Macoun Creek and in the area between Macoun Fault and Clearwater Creek. It consists of calcareous and non-calcareous cleaved argillite with silty limestone, calcareous siltite laminae, or limestone nodules; silty, argillaceous, wavy banded, nodular or laminated limestone; and minor, very light grey, resistant weathering, thin bedded limestone (Pl. 2) that commonly contains trilobite debris. Spicules are common in at least some of the nodular limestones, and the unit most probably was deposited in an outer neritic to slope environment. Two conodont identifications indicate a Late Cambrian age for this unit (see Appendix). Strata of the upper unit of the Lynx Formation are conformably overlain by strata of the Kechika Group. The upper unit of the Lynx Formation is estimated to be at least 1000 m thick in exposures along the footwall of Macoun Fault.

The distinction between Upper Cambrian (upper Lynx Formation) and Lower Ordovician (Kechika Group) strata made in the Mount Selwyn area cannot be readily extended into the Halfway River map area to the north, and in that area, Thompson (1978; in press) included the Upper Cambrian strata in the Kechika Group.

Ordovician

Kechika Group

Cleaved argillaceous silty limestone, argillite, and calcareous argillite of the Kechika Group (Gabrielse, 1963) are exposed over much of the Mount Selwyn area between Macoun Fault and Clearwater Creek. Three mappable units were recognized by the author.

Plate 3. *Kechika Group strata exposed on the northwest side of the unnamed 7605 foot high ridge east of Scott Creek. Wavy banded, silty limestone of middle unit* OK2 *forms prominent light grey weathering band. ISPG photo 1820-11.*

Plate 4. *Nodular, dark grey dolomite with chert nodules and shale partings. Unnamed Ordovician limestone, dolomite and shale unit, 6.3 km northeast of Mount Crysdale. ISPG photo 1820-14.*

The basal unit (OK1) consists predominantly of light brownish grey weathering, cleaved, variably argillaceous, silty, finely crystalline limestone with nodular interbeds of silty limestone. In the upper 40 m, the unit is grey-brown weathering and consists of calcareous argillite, nodular silty limestone and wavy bedded, argillaceous limestone similar to that comprising the upper unit. A conodont sample is indicative of an Early Ordovician [early to mid-Canadian (Tremadoc)] age for the middle portion of the unit (see Appendix). Unit OK1 is estimated to be approximately 500 m thick in the region south of the headwaters of Point Creek.

The middle unit (OK2) consists of light grey weathering, thin to thick bedded, wavy banded, silty limestone. Oolite beds, low-angle crossbeds, crossbedded quartz sandstone and chert nodules occur locally. This relatively resistant unit is easily distinguished from the overlying and underlying units (Pl. 3) and forms an important marker for mapping the Kechika Group. Unfortunately, the unit thins rapidly to the north and could not be recognized in the good exposures northeast of Mount Crysdale. Unit OK2 is estimated to be approximately 200 m thick in the southern part of the map area.

The upper unit (OK3) consists of brown weathering, argillaceous, silty, nodular- to wavy-bedded limestone and minor calcareous argillite. Very fine grained quartz sandstones occur locally in southeastern exposures. Burrows, spicules and pelmatozoan fragments are locally abundant. A conodont sample is indicative of an Early Ordovician [late Canadian (early to mid-Arenig)] age for this unit (see Appendix), with the fauna probably representing an outer shelf or basin environment (G.S. Nowlan, pers. comm., 1981). At the top of the unit are found argillaceous limestones with numerous gastropods and trilobite fragments. The local abundance of mud-chip conglomerates, burrows, oncolites and oolites suggests that these uppermost Kechika Group sediments were deposited in a peritidal environment. These limestones are abruptly but apparently conformably overlain by dolomite of the Skoki Formation. Unit OK3 is estimated to be approximately 800 m thick in the southern part of the area.

In the Halfway and Fort Grahame map areas, Upper Cambrian argillaceous limestone and calcareous shale, similar to Lower Ordovician argillaceous limestone and shale, are included in the Kechika Group (Thompson, 1978, in press; Gabrielse, 1975). North of this area, in the Trutch and Ware map areas, Cecile and Norford (1979) were able to separate Cambrian strata from the Kechika Group with ease where there was an unconformity, and with difficulty where lithologically similar Upper Cambrian argillaceous limestone and calcareous shale occurred. Five subtle units were recognized by Cecile and Norford (1979) within the Kechika Group. The lower unit of the Kechika Group in the Mount Selwyn area is probably equivalent to the cleaved, putty-grey weathering, nodular, argillaceous limestone that forms the second unit of Cecile and Norford. No equivalent to their basal, thin bedded, platy limestone unit was recognized. The wavy banded limestones of the middle unit in the Mount Selwyn area may be correlative with the middle, banded limestone unit of Cecile and Norford. This correlation suggests that the upper unit of the Kechika Group in the Mount Selwyn area is equivalent to the fourth and fifth units (upper recessive and yellow weathering) of Cecile and Norford, even though it is somewhat different in lithology.

Skoki Formation

Light and medium grey weathering, finely crystalline dolomite of the Skoki Formation (Walcott, 1928), is exposed in several narrow bands between Macoun Fault and Clearwater Creek. Oncolitic beds and zones of bioturbation characterize the formation. Minor, crosslaminated, sandy, and argillaceous dolomite to dolomitic sandstone occur in the lower part. Gastropods, brachiopods and echinoderm plates occur locally. The abundance of oncolites suggests deposition in shallow water. Brachiopods collected by B.S. Norford of the Geological Survey of Canada are suggestive of an early Middle Ordovician (Whiterock) age (see Appendix). In the Mount Selwyn area, the Skoki is disconformably overlain by Upper Ordovician strata. The thickness of the Skoki varies from approximately 100 m southeast of the headwaters of Point Creek to 220 m near Peace Arm. Northward thickening continues in the Halfway River map area, as a result of preservation of younger strata (lower Caradoc) beneath the sub-Upper Ordovician disconformity (Thompson, in press).

The first exposures of Ordovician strata south of the Mount Selwyn area occur at Pine Pass, where a 450 m thick quartz sandstone unit (Monkman Quartzite) underlies dolomites of the Skoki Formation. In contrast to its relatively abrupt northern termination, the Monkman Quartzite thins gradually to the southeast and extends over a distance of 220 km (Slind and Perkins, 1966). The Monkman Quartzite is the same age as strata included in the upper part of the Kechika Group and the lower part of the Skoki Formation in the Mount Selwyn area (Barnes et al., 1981, columns 7 and 8) and it is, therefore, probable that the quartz sand found in the upper part of the Kechika Group and the Skoki Formation in the Mount Selwyn area came from the same source as the sand that formed the Monkman Quartzite.

Unnamed limestone, dolomite and shale unit

An unnamed unit of limestone, dolomite and shale occurs in the vicinity of Mount Crysdale and on the unnamed ridge south of Point Creek. In the Mount Selwyn area, the unit comprises a thin (0.5 m) basal sandstone overlain by dark, fossiliferous, argillaceous limestone with minor shale, that is in turn overlain by a very distinctive, light yellowish grey weathering, undulatory bedded to almost nodular, dark grey dolomite, with chert nodules and shale partings (Pl. 4). Norford (pers. comm., 1982) recognized this unit on Advance Mountain, 11 km north of Mount Crysdale, in the Halfway River area, and assigned it a Late Ordovician age (see Barnes et al., 1981, column 9). The unit is disconformably overlain by an unnamed Upper Ordovician quartzite and dolomite unit. Maximum thickness of the limestone, dolomite and shale unit in the Mount Selwyn area is approximately 50 m. Norford measured 72 m of the unit on Advance Mountain (Norford, pers. comm., 1982).

Unnamed quartzite and dolomite unit

An unnamed unit of quartzite and dolomite is exposed between the Macoun Fault and Clearwater Creek. The quartzite is fine to coarse grained and forms several resistant bands. Dolomite cement, burrows and crossbeds are locally abundant. The dolomite is argillaceous, dark grey and commonly fossiliferous. Solitary corals, collected by B.S. Norford (see Appendix), are indicative of a Late Ordovician (Barneveld to Richmond) age for the unit. The unit is disconformably overlain by strata of the Beaverfoot or Nonda formations. The quartzite and dolomite unit varies from approximately 20 to 50 m in thickness. On the ridge north of Macoun Creek, Norford (pers. comm., 1982) measured 51.5 m of the unit.

Equivalent strata occur in the Murray Range at Pine Pass (Taylor and Bamber, 1970) and near Advance Mountain in the southernmost part of the Halfway River map area (Thompson, in press; Barnes et al., 1981). At Pine Pass, the strata lie between the Skoki and Beaverfoot formations. Near Advance Mountain, Irish (1970) collected material that correlated with the lower part of the Beaverfoot Formation of the southern Rockies (Ashgill), and Barnes et al. (1981; columns 7, 8 and 9) correlated this unnamed unit with the Beaverfoot Formation. More recent fossil collections by B.S. Norford from the Advance Mountain area, reported in a paper by Thompson (in press), are suggestive of a late Caradoc age, which is consistent with the pre-Beaverfoot relationships seen in the Mount Selwyn area and at Pine Pass.

Beaverfoot Formation

Resistant, brownish grey weathering dolomite of the Beaverfoot Formation (Burling, 1922) is exposed on the ridge north of Macoun Creek. The formation was not recognized elsewhere in the Mount Selwyn area. The dolomite is finely to very finely crystalline and commonly silty and fossiliferous. Sandy beds with abundant echinoderm debris occur locally at the base (Norford, pers. comm., 1982). The Beaverfoot is of relatively open marine origin and contains colonial and solitary corals, nautiloids, stromatoporoids, echinoderm fragments, and brachiopods indicative of a Late Ordovician age (see Appendix). The unit is disconformably overlain by dolomite of the Nonda Formation. Norford (pers. comm., 1982) measured 125 m of the unit on the northeastern arm of the ridge north of Macoun Creek.

Silurian

Nonda Formation

Dark and light grey weathering dolomites of the Nonda Formation (Pl. 5; Norford et al., 1966) are exposed in several narrow bands between Macoun Fault and Clearwater Creek. The dolomites are generally silty and argillaceous, finely crystalline and thinly bedded to massive. Minor, fine grained quartz sandstone and sandy dolomite occur near the middle and, locally, near the top of the formation. At some places along the base, an erosion surface, with 30 cm of relief and rare quartz sandstone lenses, is developed (Norford, pers. comm., 1982). Chert nodules, stromatoporoids, corals, echinoderm fragments and brachiopods are locally abundant. Fossils are indicative of an Early Silurian (late Llandoverian) age (Norford et al., 1966). Strata of the Nonda Formation are disconformably overlain by dolomite of the Muncho-McConnell Formation. The formation thickens from 148 m on the ridge north of Macoun Creek (Norford et al., 1966) to approximately 300 m near Peace Arm.

Silurian and Devonian

Muncho-McConnell Formation

Resistant, light grey weathering dolomite of the Muncho-McConnell Formation (Pls. 5, 6; Taylor and MacKenzie, 1970) is exposed in several narrow bands between Macoun Fault and Clearwater Creek. The dolomite is light grey, very finely to finely crystalline and locally calcareous or sandy. Minor quartz sandstone occurs locally at the base of the formation. Bedding is moderately developed, and the dolomite is slabby to massive. Breccias that appear to be of solution collapse origin, irregular dolomite or silica veins and silica blebs occur in places. Fossils are rare in the Muncho-McConnell and most of those collected are not diagnostic (Taylor and MacKenzie, 1970). The age of the formation is based on the identification of fish fragments from the lower part of the formation, that are now considered by R. Thorsteinsson (pers. comm., 1982) to be of latest Silurian (Pridolian) age, and on stratigraphic position. The character of the dolomite, presence of solution collapse breccias, and rarity of fossils suggest deposition in a restricted shelf to supratidal environment. Strata of the Muncho-McConnell Formation are disconformably overlain by dolomite and quartz sandstones of the Stone Formation. Thickness of the Muncho-McConnell Formation varies from approximately 280 m in the northeastern part of the Mount Selwyn area to 143 m on the ridge north of Macoun Creek (Norford, pers. comm., 1982). South of Pine Pass, the formation has been completely removed by pre-Stone Formation erosion (Taylor and Bamber, 1970).

Devonian

Stone Formation

Resistant dolomite and quartz sandstone of the Stone Formation (Taylor and MacKenzie, 1970), are exposed in several narrow bands between Macoun Fault and Clearwater Creek. Two mappable units are recognized (Pls. 5, 6). The lower consists of thinly interbedded quartz sandstone, dolomitic sandstone and tan weathering, light grey, sandy or silty, finely crystalline dolomite. Sand grains are subrounded to rounded and predominantly very fine to medium grained. Crossbeds and burrows are locally abundant in the sandstones, and, with the dolomite, are suggestive of deposition in a shallow marine environment. The upper unit comprises light grey weathering, silty, very finely to finely crystalline dolomite. Fine laminae of probable algal origin are common. Breccias, suggestive of the original presence of evaporites, and oncolites, occur locally. The unit is probably a very shallow marine to supratidal deposit. Fossils are rare in the Stone Formation and none were found in the Mount Selwyn area. Corals from the upper part of the Stone Formation in the Monkman Pass area to the south were assigned a latest Early Devonian (Zlichovian or Dalejan) age by A.E.H. Pedder of the Geological Survey of Canada (in Geldsetzer, 1982). T. Uyeno (unpublished GSC Paleontology report) assigned a late Early Devonian (Emsian) age to conodonts from the Stone Formation of northernmost British Columbia (59°42'N, 125°33'W). The Stone Formation is disconformably overlain by the Dunedin Formation. The lower unit of the Stone Formation varies in thickness from approximately 70 m in the south, to 120 m in the northwest part of the Mount Selwyn area. The upper unit varies in thickness from approximately 280 m in the south, to 120 m in the northwestern part of the area.

Dunedin Formation

Middle Devonian limestones outcrop on the flanks and in the cores of folds between the Macoun Fault and Ducette Creek. Two mappable units (Pl. 6) are recognized. The lower, recessive unit consists of dark grey, argillaceous limestone and calcareous shale; minor, silty, resistant limestone; and, near the base, quartz sandstone that is locally crossbedded. Brachiopods, echinoderm debris, corals, bryozoans, ostracodes and fish fragments are locally abundant. On the ridge north of Macoun Creek, red shales occur sporadically at the base of the unit. Fossils collected by B.S. Norford are indicative of a Middle Devonian (early Givetian) age (see Appendix). The upper unit is more resistant and well bedded. It consists of medium grey weathering lime mudstone, lesser wackestone, and, especially near the base and top, argillaceous limestone. Much of the upper unit is dolomitized on the north-trending ridge 4 km east of Mount Selwyn. Brachiopods, corals, echinoderm debris, *Amphipora* and stromatoporids are locally abundant. The presence of *Stringocephalus* indicates a late Middle Devonian (Givetian) age (see Appendix).

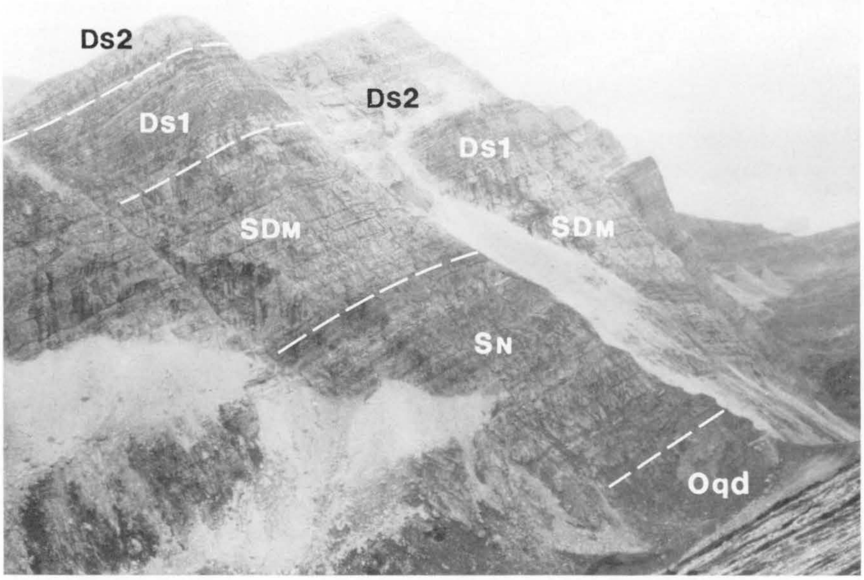

***Plate* 5.** *Middle Ordovician to Middle Devonian strata exposed on the 6700 foot high ridge 14.5 km southeast of Mount Crysdale. Oqd - unnamed Ordovician quartzite and dolomite unit;* SN - *Nonda Formation;* SDM - *Muncho-McConnell Formation;* DS1 - *Stone Formation (lower unit);* DS2 - *Stone Formation (upper unit). ISPG photo 1820-6.*

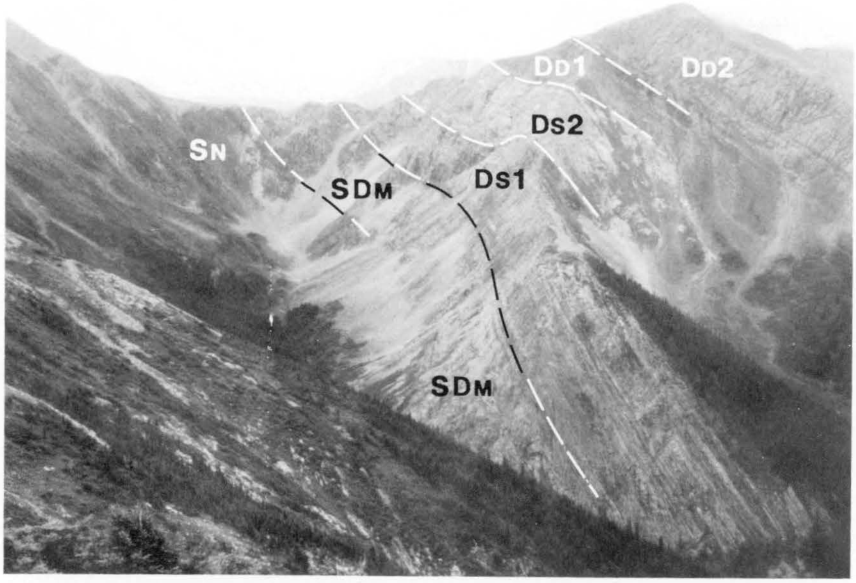

***Plate* 6.** *Devonian strata exposed on the 6400 foot high ridge 4.5 km west-northwest of Mount Crysdale.* SN - *Nonda Formation;* SDM - *Muncho-McConnell Formation;* DS1 - *Stone Formation (lower unit);* DS2 - *Stone Formation (upper unit);* DD1 - *Dunedin Formation (lower unit);* DD2 - *Dunedin Formation (upper unit). ISPG photo 1820-8.*

Taylor and Bamber (1970) named these strata Pine Point Formation. However, both Thompson (in press) and Geldsetzer (1982), who recently studied equivalent strata exposed north and south of the Mount Selwyn area, concluded that it was more appropriate to include these Middle Devonian limestones in the Dunedin Formation of Taylor and MacKenzie (1970). The terminology of Thompson (in press) and Geldsetzer (1982) is used in this report.

The limestone of the Dunedin Formation is abruptly and, probably, disconformably overlain by shale of the Besa River Formation. Total thickness of the Dunedin cannot be directly determined. It is estimated to be approximately 600 m thick in the southern part of the area. The lower recessive unit varies in thickness from approximately 100 m in the south to 70 m in the northeastern part of the area.

Devonian and Carboniferous

Besa River Formation

Dark grey or, near the top of the formation, brown weathering argillite and calcareous shale, and minor limestone and chert of the Besa River Formation (Kidd, 1963) underlie most of Clearwater Creek Valley. The strata are recessive and poorly exposed. In the few exposures examined, the argillites are silty, commonly finely laminated, and possess a cleavage developed at a moderate angle to bedding. Taylor and Bamber (1970) suggested that strata of the formation were deposited in a basinal, open marine environment.

In some places, approximately 75 m above the base, a relatively resistant unit of brown weathering, nodular, argillaceous limestone and calcareous shale occurs. An early Late Devonian (early Frasnian) age was given for this calcareous unit based on a brachiopod identification (see Appendix). An upper age limit of Tournaisian is suggested for the Besa River Formation by the presence of late Tournaisian to early Viséan corals in the lower part of the overlying Prophet Formation east of the Mount Selwyn area (Taylor and Bamber, 1970). The contact with the overlying Prophet Formation is gradational (E.W. Bamber, pers. comm., 1982). The thickness of the Besa River Formation cannot be determined in the Mount Selwyn area; however, it is probably in the order of 600 m thick (E.W. Bamber, pers. comm., 1982).

Carboniferous

Prophet Formation

Limestone, calcareous mudstone, and spiculite of the Prophet Formation (Sutherland, 1958), occur in a series of folds along Clearwater Creek Valley. The lower part of the formation consists of relatively recessive, very thin bedded spiculite, lime mudstone and calcareous mudstone. The upper part of the formation consists of lime mudstone to wackestone, and relatively resistant, skeletal packstone and grainstone. Chert nodules grading into chert layers are common throughout the upper unit and locally constitute up to 50 per cent of the section. Coral faunas, collected and identified by Bamber from sections east of the Mount Selwyn area, are indicative of a late Tournaisian or early Viséan to early late Viséan age (Taylor and Bamber, 1970). The Prophet Formation is abruptly but conformably overlain by strata of the Stoddart Group. The Prophet Formation is over 550 m thick and is probably as much as 650 m thick (Bamber, pers. comm., 1982) in the Mount Selwyn area.

Stoddart Group

In the Mount Selwyn area, shale, sandstone, limestone and siltstone of the Stoddart Group (Rutgers, 1958; Halbertsma, 1959), are poorly exposed on the ridge extending southeast from Ducette Peak. Equivalent strata have been studied in adjacent areas by Irish (1963, 1970), McGugan (1967) and Bamber (in press). East of the Mount Selwyn area, coral identifications indicate an Early Carboniferous (late Viséan) age for these shallow marine deposits (Bamber, pers. comm., 1982). The Stoddart Group is disconformably overlain by strata of the Kindle Formation. Bamber (pers. comm., 1982) measured 97.5 m of the Stoddart Group at Peck Creek (55°44.5'N, 122°56'W), immediately east of the Mount Selwyn area. Because of poor exposure, the Stoddart Group and the Kindle Formation could not be differentiated and are mapped as one unit in the Mount Selwyn area.

Permian

Kindle Formation

In the Mount Selwyn area, siltstone and shale of the Kindle Formation (Laudon and Chronic, 1949) are very poorly exposed on the ridge extending southeastward from Ducette Peak. Near Pine Pass, the formation consists of greyish brown weathering, grey, very finely crystalline, argillaceous, silty limestone, calcareous siltstone and minor calcareous shale (Taylor and Bamber, 1970) deposited in a marine environment (Bamber, pers. comm., 1982). At Pine Pass, a sparse, poorly preserved brachiopod fauna of Early Permian (Wolfcampian to Leonardian) age occurs in the Kindle (Taylor and Bamber, 1970). Strata of the Kindle Formation are abruptly overlain by chert of the Fantasque Formation. A widespread disconformity is documented between the Kindle and Fantasque formations north of the Peace River (Bamber et al., 1968). Bamber (pers. comm., 1982) measured 70.5 m of the Kindle Formation at Peck Creek (55°44.5'N, 122°56'W), immediately east of the Mount Selwyn area. Because of poor exposure, the Stoddart Group and Kindle Formation could not be differentiated, and are mapped as one unit in the Mount Selwyn area.

Fantasque Formation

In the Mount Selwyn area, the Fantasque Formation (Harker, 1961), comprises resistant, dark grey, bedded chert with minor lenses of cherty phosphatic dolomite, and is exposed on the ridge extending southeast from Ducette Peak. Dateable fossils are rare in the Fantasque and the formation is assigned a late Early Permian (Artinskian) age on the basis of *Helicoprion* found on the Dunedin River approximately

300 km north of the Mount Selwyn area (Bamber and Macqueen, 1979; Bamber, pers. comm., 1982). The Fantasque was deposited in a marine shelf slope to basinal environment (Bamber et al., in press). It is disconformably overlain by Lower Triassic strata (Gibson, 1975). Bamber (pers. comm., 1982) measured 41.3 m of Fantasque Formation at Peck Creek (55°44.5'N, 122°56'W), immediately east of the Mount Selwyn area.

Mesozoic

Triassic

Triassic strata underlie the relatively low-lying (1200-1600 m) tree covered hills in the northeastern corner of the Mount Selwyn area. Gibson (1971, 1972, 1975) investigated stratigraphic relationships within the Triassic of the Rocky Mountain Foothills between 54° and 57°N. Although he did not examine the poorly exposed Triassic of the Mount Selwyn area, he examined several well exposed sections to the east and southeast, and recognized the Grayling, Toad, Liard, Charlie Lake, Baldonnel, Pardonet and Bocock formations. North of Peace River, the Ludington Formation replaces the Liard, Charlie Lake and Baldonnel formations (Gibson, 1975; Thompson, 1978). South of Peace River, poor exposure in the map area prevents distinction of the Grayling, Toad, Liard, Charlie Lake, Baldonnel and Pardonet formations, and the succession is subdivided into two map units. The dark weathering, calcareous, clastic strata of the Grayling, Toad and Liard formations form a lower map unit (T1), and the carbonate strata of the Charlie Lake, Baldonnel and Pardonet formations constitute an upper map unit (T2). Locally, resistant limestone of the Bocock Formation is developed at the top of the Triassic, and forms a distinctive map unit. The following descriptions are based mainly on the work of Gibson (1971, 1975), and the reader is referred to Gibson's publications for greater detail.

Grayling Formation

Dark grey, recessive, platy weathering, dolomitic siltstone, silty shale and minor calcareous siltstone, silty limestone, dolomite and sandstone make up the Grayling Formation (Kindle, 1944). These strata are rarely exposed, and have been mapped with the overlying formation(s). The Grayling Formation contains an Early Triassic (Dienerian to Smithian) fauna. Strata of the Grayling are gradational into those of the Toad Formation (Gibson, 1971, 1975). Gibson (1971) measured 74 m of Grayling Formation near Clearwater Lake (55°40'N, 122°55'W), east of the Mount Selwyn area.

Toad Formation

The Toad Formation (Kindle, 1944; McLearn, 1946) consists of dark grey, very calcareous siltstone, silty limestone, silty shale and minor, silty dolomite and calcareous sandstone. The alternation of thin, relatively resistant and relatively recessive weathering units is characteristic of the formation. Strata of the Toad Formation are gradational into those of the overlying Liard Formation. The Toad Formation contains an Early Triassic (Smithian) to Middle Triassic (Ladinian) fauna (Gibson, 1971, 1975). Gibson (1971) measured 295 m of Toad Formation near Clearwater Lake (55°40'N, 122°55'W), east of the Mount Selwyn area.

Liard Formation

Dark, dolomitic to calcareous sandstone and siltstone, lesser dolomite, and cherty limestone compose the Liard Formation (McLearn, 1946). In the Pine Pass-Peace River area, good index fossils are indicative of a late Middle Triassic (late Ladinian) to early Late Triassic (early Karnian) age (Gibson, 1971). Strata of the Liard Formation are gradational into those of the overlying Charlie Lake Formation. East of the Mount Selwyn area, the thickness of the Liard varies from approximately 380 to 450 m (Gibson, 1975).

Charlie Lake Formation

The Charlie Lake Formation (Hunt and Ratcliffe, 1959), in the Mount Selwyn area, is a surface or western facies (Gibson, 1971). It consists of buff to light grey weathering, sandy to silty dolomite and dolomitic siltstone, and sandstone. Few fossils occur within the Charlie Lake Formation, probably because the strata were deposited in shallow water, evaporitic conditions (Gibson, 1971, 1975). South of Peace River, the contact with the overlying Baldonnel Formation is abrupt and distinct. East of the Mount Selwyn area, the thickness of the Charlie Lake Formation varies from approximately 160 to 290 m (Gibson, 1975).

Ludington Formation

Grey weathering, dolomitic to calcareous siltstone, sandstone, and silty to sandy bioclastic limestone comprise the Ludington Formation (Gibson, 1971). The formation ranges in age from probable Middle Triassic (Ladinian) to Late Triassic (late Karnian). It is the western facies equivalent of the Charlie Lake and Baldonnel formations, and probably the Liard Formation (Gibson, 1975; Thompson, 1978). Contact relations with the overlying Pardonet Formation are not exposed. The Ludington is approximately 400 m thick immediately north of Peace River. An arbitrary cutoff at the Peace River, suggested by Gibson (1971), limits its distribution to the south.

Baldonnel Formation

The Baldonnel Formation (Hunt and Ratcliffe, 1959) consists of a lower (Ducette) member of dark grey weathering siltstone, sandstone, limestone and minor dolomite, and an upper (unnamed) member of pale- to brownish-grey weathering, resistant limestone and dolomite with lesser siltstone and sandstone. A few pelecypod and brachiopod identifications suggest a Late Triassic (Karnian) age (Gibson, 1971). Contact with the overlying Pardonet Formation is generally sharp and distinct. The Baldonnel Formation is about 155 m thick east of the Mount Selwyn area (Gibson, 1975).

Pardonet Formation

Dark weathering, carbonaceous-argillaceous limestone, calcareous and dolomitic siltstone, and minor shale compose the Pardonet Formation (McLearn, 1960). Whole and fragmented pelecypod shells commonly forming dense coquinas characterize the formation. Abundant ammonites and pelecypods are indicative of a Late Triassic (early to late Norian) age (Gibson, 1971). Strata of the Pardonet Formation are disconformably overlain by Triassic strata of the Bocock Formation or Jurassic strata of the Fernie Formation (Gibson, 1971; Tozer, 1982). The Pardonet Formation is approximately 150 m thick east of the Mount Selwyn area (Gibson, 1975).

Bocock Formation

The Bocock Formation, comprising resistant, light grey weathering limestone (Gibson, 1971) occurs along the eastern edge of the Mount Selwyn area east of Ducette Peak. The limestone occurs in very thick to massive beds and varies from aphanitic to coarsely crystalline to bioclastic (Gibson, 1971). Small sinkholes are locally developed. Conodonts, collected and identified by M.P. Orchard (in Tozer, 1982) from the Bocock Formation at Pine Pass, are indicative of a Late Triassic age. Strata of the Bocock Formation are disconformably overlain by Jurassic strata of the Fernie Formation. East of Ducette Peak, the Bocock Formation is approximately 70 m thick.

Jurassic

Fernie Formation

Shale, siltstone and sandstone of the Fernie Formation (McEvoy and Leach, 1902; Leach, 1903) underlie two prominent synclines northeast of the ridge extending from Ducette Peak. Recessive and poorly exposed black shale, siltstone and a basal cherty limestone unit constitute the thin, lower part (Stott, 1967, 1970b), and siltstone, silty sandstone and shale form the thick, upper part of the formation. In the Pine Pass-Peace River area, the Fernie Formation ranges in age from Early to Late Jurassic (lower Hettangian to Portlandian) (Stott, 1970b; Tozer, 1982). The sandstone, siltstone and shale of the upper Fernie Formation grade upward into sandstone of the Monteith Formation over several tens of metres of section. The contact was placed where sandstone becomes predominant and the unit cliff-forming. Approximately 350 m of strata were included in the Fernie Formation.

Jurassic and Lower Cretaceous

Minnes Group

The thick sequence of sandstone, siltstone, and shale that gradationally overlies the Jurassic Fernie Formation, and is unconformably overlain by the Lower Cretaceous Cadomin Formation, makes up the Minnes Group (Ziegler and Pocock, 1960; Stott, 1967) in northeastern British Columbia. Four formations are recognized east of the Mount Selwyn area, where these strata have been studied by Mathews (1947) and Stott (1962, 1970b, 1975, 1981). Only the two lower formations are preserved in the Mount Selwyn area.

Monteith Formation. Sandstone and minor shale of the Monteith Formation (Mathews, 1947), are exposed in the two prominent synclines northeast of the ridge extending from Ducette Peak. The sandstone is predominantly fine grained and argillaceous, and Stott (1970b) interpreted it as a shallow marine deposit. The Monteith Formation ranges in age from Latest Jurassic (Tithonian) to Early Cretaceous (earliest Valanginian) (Stott, 1970b). Strata of the Monteith are gradationally overlain by shaly strata of the Beattie Peaks Formation. The Monteith Formation is estimated to be approximately 700 m thick in the northeastern syncline.

Beattie Peaks Formation. Silty mudstone and sandstone of the Beattie Peaks Formation (Mathews, 1947) are exposed in the large syncline northeast of Ducette Creek. They are interpreted by Stott (1970b) as delta front deposits. The formation is recessive weathering relative to the underlying Monteith Formation, and contains a fauna dated by Jeletzky as Early Cretaceous (middle to late Valanginian) (Stott, 1970b). Only the basal 200 m of the formation are exposed in the Mount Selwyn area.

Mesozoic and Cenozoic

Late Cretaceous and Tertiary

Sifton Formation

Nonmarine conglomerate and minor sandstone of the Sifton Formation (Hedley and Holland, 1941) underlie the small hill immediately east of Williston Lake and north of Weston Creek in the Rocky Mountain Trench. Good outcrops are exposed along the shore of Williston Lake, particularly when the water level is low. The conglomerate is polymictic, poorly sorted, generally massive and rarely imbricated. Where examined, platy, blue-grey weathering limestone, green (chloritic), argillaceous siltite, and vein quartz were the dominant clast types. The limestone and green siltite clast lithologies are unique to the Misinchinka Group. Provenance and outcrop location along the northwestward continuation of a ridge formed by limestone of the Misinchinka Group (see Figure 3) suggest that the Sifton Formation unconformably overlies previously faulted Misinchinka Group strata. The flora collected from the Sifton Formation exposed in the Rocky Mountain Trench north of Williston Lake, is suggestive of a Late Cretaceous to Paleocene, or possibly Eocene age (summarized in Eisbacher, 1974). The Sifton Formation is at least 100 m thick in the Mount Selwyn area.

Cenozoic

Tertiary

Unnamed clastic unit

Carbonaceous siltstone, mudstone, sandstone, granule conglomerate and minor coal outcrop along the shore of Williston Lake at the entrance to Scott Creek (Pl. 7). Erosional bases to coarser beds, local crossbeds, ripples, and the occurrence of coal and mudstone suggest deposition in a fluvial-lacustrine environment. The base of the unit is not exposed, and it is not known whether the unit overlies the Sifton Formation or the Misinchinka Group. Palynomorphs are indicative of an Eocene or younger age (see Appendix). Similar sediments, exposed in the Rocky Mountain Trench, approximately 70 km south of this locality, were assigned an Early Oligocene age by Hopkins et al. (1972). Approximately 150 m of section with no top or base is exposed at the Scott Creek locality.

REGIONAL METAMORPHISM

Proterozoic strata adjacent to and within the Rocky Mountain Trench have been regionally metamorphosed to the greenschist facies, whereas Late Cretaceous and Tertiary strata exposed within the Trench are unmetamorphosed. Muscovite, biotite, and chlorite are the dominant metamorphic minerals. Garnet and chloritoid occur locally. The grade of metamorphism decreases rapidly to the northeast, and five kilometres from the Trench, fine grained sericite is the only metamorphic mineral.

Latest Jurassic to Early Cretaceous K-Ar dates (Leech et al., 1963; Wanless et al., 1979) from metamorphosed (greenschist facies) Misinchinka strata, exposed near the Rocky Mountain Trench along the highway through Pine Pass, imply that this regional metamorphism is at least as old as Late Jurassic. From regional considerations, Gabrielse (1975) thought that metamorphism in the Omineca Mountains of the Fort Grahame map area, northwest of the Mount Selwyn area, probably occurred during the Middle Jurassic. Metamorphic minerals reveal penetrative cleavage or schistosity in Misinchinka Group strata exposed near the Rocky Mountain Trench. Folding of this cleavage about the south-plunging Cut Thumb Anticline (see section on cleavage) suggests that the metamorphism predates the formation of most of the major faults and related folds in the Mount Selwyn area.

STRUCTURE

The Rocky Mountain thrust and fold belt in the Pine Pass-Peace River area comprises two structural subprovinces: the Rocky Mountain Foothills, and the Rocky Mountains. Folded, upper Paleozoic through Cretaceous strata (Fig. 4) are exposed in the Foothills subprovince. The folds merge eastward with the undeformed strata of the Plains. A fold-thrust terrane of Upper Proterozoic and lower and middle Paleozoic strata (Fig. 5) makes up the Rocky Mountains subprovince. A major strike-slip fault system within the physiographic Rocky Mountain Trench forms the western boundary of the Rocky Mountains structural subprovince. The Mount Selwyn area borders the Rocky Mountain Trench, and straddles the Foothills and Mountains structural subprovinces (Fig. 2).

The regional trend of structures in both the Rocky Mountains and Foothills subprovinces swings from south-

Plate 7. *Steeply dipping carbonaceous siltstone, mudstone, sandstone, granule conglomerate and minor coal of the unnamed Tertiary clastic unit exposed along Williston Lake at the entrance to Scott Creek. ISPG photo 1820-2.*

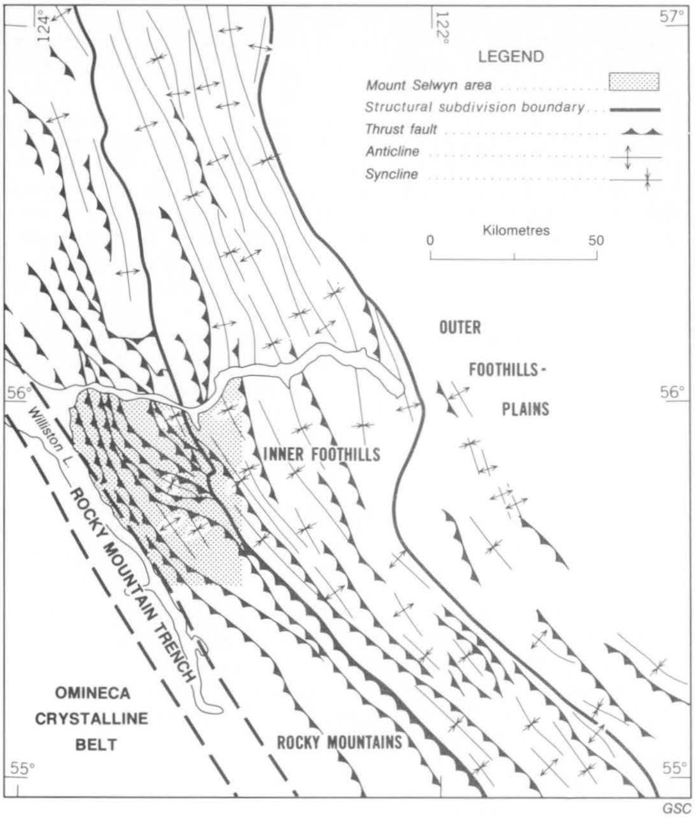

Figure 2. Major geological subdivisions, axial traces of prominent folds, and traces of thrust faults in the Pine Pass-Peace River area. The Mount Selwyn area is stippled. Geology after Thompson (1978), and Stott et al. (1983).

southeast in the north, to southeast in the south across the Pine Pass-Peace River area (Fig. 2). Anomalous east and east-northeast trending structures occur locally in the Rocky Mountain subprovince of the Mount Selwyn area. In order to understand the structural constraints on the origin of these anomalous trends, two regional structure sections were drawn across the Foothills and Rocky Mountains belts (Fig. 3, in pocket). In addition, a transverse section was drawn across the Mount Selwyn area. The regional sections also illustrate important changes observed in structural geometry within stratigraphic levels in the Foothills belt, and form the basis for estimating shortening across the foothills and mountains of the Pine Pass-Peace River area.

Regional structure sections

Two regional structure sections were drawn using surface and well data, and the principles of balanced structure sections (Dahlstrom, 1969a) which require geometric compatibility in a section. Each section was oriented perpendicular to the local structural grain in order to facilitate the projection of data along the plunge of structures into the plane of the section. The error introduced in the estimation of tectonic displacement by the 15° difference in orientation of the two regional sections is not significant (<4%) because it varies with the cosine of the angle between the section and the direction of tectonic transport.

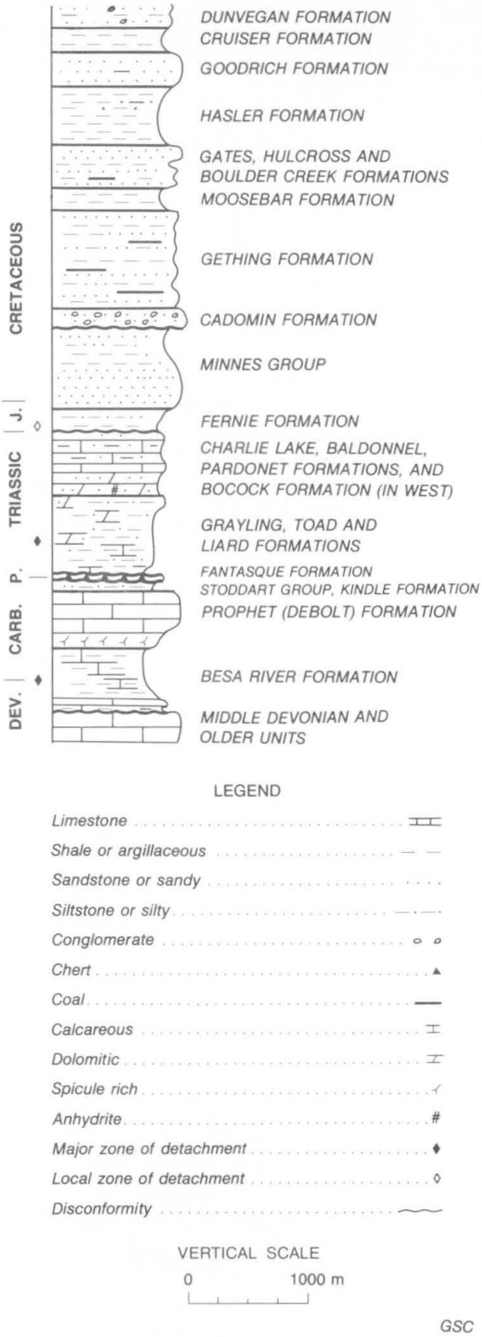

Figure 4. Generalized stratigraphic column for the Foothills subprovince, Pine Pass-Peace River area.

Foothills segment

Structural geometry

Upper Triassic through Upper Cretaceous strata exposed in the Foothills of the Pine Pass-Peace River area are generally folded into broad synclines separated by

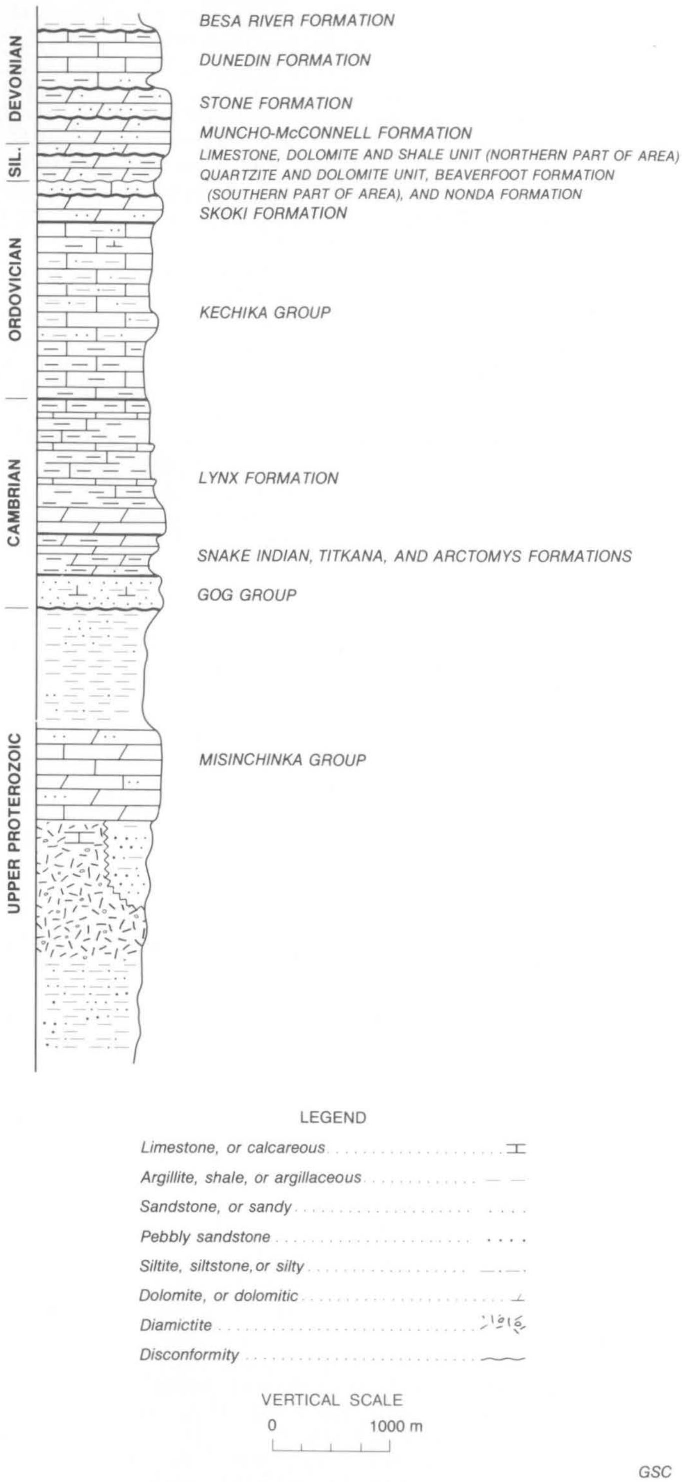

Figure 5. *Generalized stratigraphic column for the Rocky Mountains subprovince, Pine Pass-Peace River area.*

complex chevron or box anticlines (style 'ejective' of Stille, 1917; see also Dahlstrom, 1969b, 1970). Marked changes in the wavelength, amplitude and geometry of folds, and variations in the number of faults from one stratigraphic level to another, suggest that the incompetent strata of the Liard and Toad-Grayling formations form a major zone of detachment between the Upper Triassic-Upper Cretaceous succession and carbonate rocks of the Lower Carboniferous Prophet Formation. Two wells at Pine Pass provide further evidence of this detachment and document marked structural thickening of the Liard/Toad-Grayling interval (normal stratigraphic thickness ~700 m). The Triad B.P. Bush Mountain a-15-A well (Fig. 3, well No. 4) intersected approximately 2000 m of the unit, and the Triad B.P. Bush Mountain b-23-A well drilled 2358 m of the unit before the hole was abandoned. A normal thickness of Upper Triassic strata was drilled in both wells. Within the Upper Triassic-Upper Cretaceous succession, shale of the Fernie Formation appears to act as a local zone of detachment and compensation.

Carbonate strata of the Lower Carboniferous Prophet Formation are exposed in a series of faulted chevron and box folds along the western margin of the Foothills belt in the Pine Pass-Peace River area. The unconformably overlying Carboniferous and Permian strata (Stoddart Group, Kindle and Fantasque formations), deform with the Prophet Formation where they comprise a thin unit (<200 m, south of 55°35'N; see Fig. 3). However, where the Stoddart to Fantasque succession is thick, as seen north of Peace Arm, the strata commonly deform with the overlying Triassic shale and independently of the underlying carbonate unit (see Figure 3; Fitzgerald, 1968).

In surface exposures, faulted chevron and box folds in the Prophet Formation are separated from longer wavelength folds and thrust faults in Upper Proterozoic to Middle Devonian strata of the Rocky Mountain structural subprovince by a major detachment zone in Upper Devonian and Lower Carboniferous shales of the Besa River Formation (Fitzgerald and Braun, 1965; Thompson, 1979). Wells drilled on two major anticlines in Halfway River map area north of Peace River show that Middle Devonian and older strata have not been folded congruently with the overlying Prophet Formation. This suggests that a major zone of detachment also exists in the Besa River Formation beneath the Foothills belt (Thompson, 1979). The absence of Middle Devonian and older strata in the few deep wells drilled in the Foothills of the area, and the presence of flat-bottomed synclines with stratigraphic markers that lie close to the regional slope of these markers, as defined outside the deformed belt, indicate that there probably are no large thrust repetitions of Middle Devonian and older strata under the eastern parts of the Foothills. In the sections of Figure 3, Middle Devonian and older strata are interpreted as forming a nearly undeformed 'pseudobasement' beneath the Foothills subprovince (Thompson, 1979, 1981).* A minimum depth to this 'pseudobasement' was estimated from the Triad B.P. Bush Mountain a-15-A well at Pine Pass (in Triassic Toad-Grayling at -2638 m), from the Quasar et al. Dunlevy a-40-L well (Fig. 3, well No. 1) north of Peace River [top of Lower Carboniferous Banff (Besa River) at -3130.6 m], from CCS et al. Hulcross a-58-I well (Fig. 3, well No. 2) near Mount Hulcross (base of Triassic Charlie Lake at -3000.0 m), and from the depth of Middle Devonian strata in wells immediately east of the locations of the regional sections.

Stratigraphic markers in synclines near the western margin of the Foothills belt are raised 3 to 4 km above their level in synclines immediately to the east. This relatively abrupt change in level of exposure is interpreted as reflecting the insertion of a major thrust sheet(s) at depth, repeating Middle Devonian and older strata. The thrust that carries this sheet(s) does not splay upward from a basal detachment to intersect the topographic surface, but instead is inferred to merge and flatten into a detachment zone in the Besa River Formation. It is a 'blind' thrust (Thompson, 1979, 1981).

*An alternative (updated) interpretation involving thrust repetition of Middle Devonian older strata under the Central Foothills is presented in McMechan (1985).

The existence of a major thrust sheet(s) carried on a blind thrust under the western Foothills of the Pine Pass-Peace River area, is confirmed by two wells drilled at Pine Pass. The Clark Can Elcan TGS Pine b-23-B well (Fig. 3, well No. 3) was spudded in the Besa River Formation and reached the top of the Middle Devonian carbonate sequence at -1197 m. Eleven kilometres to the east, the Triad B.P. Bush Mountain a-15-A well (Fig. 3, well No. 4) was spudded in the Triassic and was abandoned in the Triassic Toad-Grayling Formation at -2638 m. No major fault occurs between these two wells at the surface. Thompson (1979, 1981) has suggested that shortening across 'blind' thrusts in Middle Devonian and older strata is kinematically linked to shortening by folding and faulting in the overlying strata.

Summary

Contrasts in structural "geometries" indicate that there are three distinct structural levels within the Foothills of the Pine Pass-Peace River area: a lower level (C) of Middle Devonian and probably older rocks, occurring as relatively undeformed 'pseudobasement' or in large 'blind' thrust sheets; a middle level (B) of Upper Devonian to Middle Triassic strata,* characterized by numerous faults and disharmonic folds; and an upper level (A) of Upper Triassic to Upper Cretaceous strata characterized by broad synclines and complex chevron or box anticlines. Major zones of detachment in Lower and Middle Triassic rocks, and in Upper Devonian and Lower Carboniferous shales, permit the more competent Lower Carboniferous carbonates of level B to deform in a structural style independent of levels A and C.

Shortening

Shortening across the Foothills belt in the Pine Pass-Peace River area was calculated for both the Upper Triassic-Upper Cretaceous (level A) and the Upper Devonian-Middle Triassic (level B) structural levels. The amount of shortening for level A was calculated by measuring around marker beds (sinuous bed method). This method is appropriate, because fold geometries are well constrained by surface geology, and sedimentary structures show that the strata have not been penetratively deformed. Thus the present bed length is about the same as the original bed length. The structural geometries in level B are unknown over much of the Foothills belt. Therefore, the area method (see Bucher, 1955; Gwinn, 1970), which is independent of internal structural geometries, was used to estimate shortening. In this method, an excess area of rock is calculated and then restored to an undeformed stratigraphic thickness to give a measure of shortening.

Shortening at the Upper Triassic-Upper Cretaceous structural level (level A) is approximately 13 km on section A-A' and 14 km on section C-C'. That is about half the calculated shortening (28 km on section A-A'; 25 km on section B-B') for the Upper Devonian-Middle Triassic structural level (level B).

Lower estimates of shortening would result for structural level B if: 1) its actual stratigraphic thickness was greater than the best estimate thickness used in the area method calculations, or 2) if the level of the 'pseudobasement' were higher than assumed, or 3) if major thrust sheets repeated Middle Devonian and older strata under more of the Foothills belt. For equivalent shortening of structural levels A and B, the stratigraphic thickness of level B would have to be over 40 per cent thicker than the value used. Such a large difference is improbable because of the multiple sources for stratigraphic data for all formations except the Besa River. Alternatives 2 and 3 could correct the difference; however, each would require marked local structural thinning of incompetent level B strata (to 30%) in order to maintain the observed surface geology. This is considered very unlikely.

An analogous situation of greater shortening of a middle structural level occurs in the Valley and Ridge and Plateau provinces of the Central (Pennsylvanian) Appalachians. In this area, deformed strata lie above a Precambrian and basal Cambrian basement that, according to deep well, seismic and magnetic data, is essentially undeformed (Gwinn, 1970; Root, 1973; Hatcher, 1981). Shortening of the Ordovician to Devonian (upper) level, estimated by measuring bed length around folds mapped at the surface, is probably over 40 km less than shortening of the Cambrian (middle) level, as determined by the area method (see Gwinn, 1970, figures 3, 7; Hatcher, 1981, Figure 5).

In the Foothills of the Pine Pass-Peace River area, Middle Devonian and older strata are interpreted as forming an essentially undeformed autochthonous 'pseudobasement'. In contrast, the overlying strata were deformed and tectonically thickened as they were displaced eastward relative to the craton and 'pseudobasement'. East of the Foothills belt, all strata are essentially undeformed and autochthonous with the craton (Bally et al., 1966; Price and Mountjoy, 1970). Therefore, greater shortening of the Upper Devonian-Middle Triassic structural level (B), as compared to the Upper Triassic-Upper Cretaceous structural level (A), across the Foothills belt, requires that strata of structural level B have moved eastward relative to both the underlying and overlying structural levels (Fig. 6). The sense of relative motion between the three structural levels is the same as in the classical triangle zone (see, for example, sections by Gordy and Frey, in Gordy, Frey and Ollerenshaw, 1975; Price, 1981, Fig. 6). Level B can be viewed as a structurally thickened wedge that raises level A, the upper level of the triangle zone.

Age of deformation

The youngest rocks (Cenomanian, Dunvegan Formation) preserved in the Foothills of the Pine Pass-Peace River area are involved in Foothills structures, implying that the deformation must have occurred after the Cenomanian. Deformation of the thick, Upper Cretaceous [Campanian-Maastrichtian (Stott, 1975)] foredeep deposits preserved south of the Pine Pass-Peace River area indicates that Foothills deformation in northeast British Columbia persisted beyond the Maastrichtian. An upper age limit to the deformation cannot be precisely defined. However, fluviatile foredeep deposits exposed in the central Alberta Foothills (~53°N) imply that the deformation terminated there after the Paleocene (McLean and Jerzykiewicz, 1978). A lower age limit on Foothills deformation in the Pine Pass-Peace River area cannot be directly determined. The absence of pre-Campanian structures within the Jurassic to Upper Cretaceous foredeep deposits suggests that deformation of the Foothills in northeastern British Columbia probably began after the Campanian (Thompson, 1979).

*The Liard Formation at the top of this level consists of Middle Triassic and earliest Late Triassic (Karnian) strata. For purposes of convenience, the Middle Triassic has been used as a break in this classification.

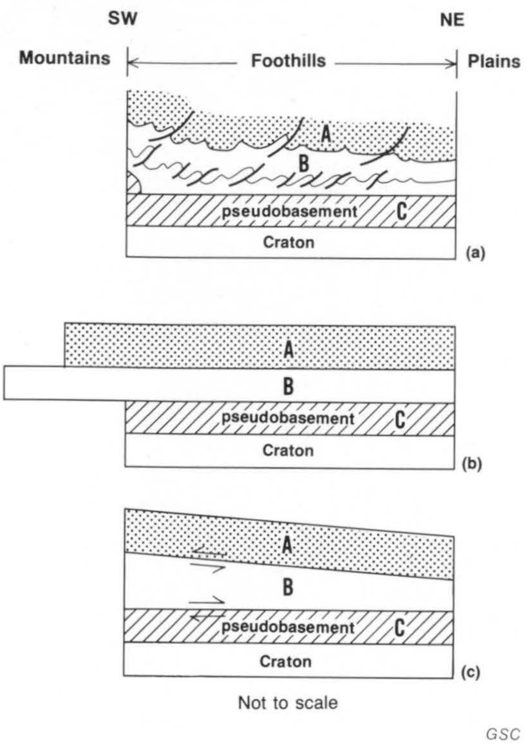

Figure 6. *Schematic diagrams illustrating the relationships between structural levels in the Foothills of the Pine Pass-Peace River area. A - Upper Triassic to Upper Cretaceous; B - Upper Devonian to Middle Triassic; C - Upper Proterozoic(?) to Middle Devonian.*

a. *Schematic section across the Foothills belt. The strata at the northeast end are undeformed and have not moved with respect to the North American craton.*

b. *Schematic palinspastic restoration of units underlying the Foothills belt.*

c. *Simplified block diagrams showing the relative sense of motion (indicated by arrows) required to deform units shown in Figure 6b to their present configuration (Fig. 6a).*

Rocky Mountains segment

Structural geometry

The Rocky Mountains structural subprovince in the Pine Pass-Peace River area can be subdivided into three structural domains that are relatively homogeneous with respect to the orientation of bedding, or folds outlined by bedding (Fig. 7).

Domain 1 comprises west-dipping, thrust faulted panels of Proterozoic to Cambrian strata. Major strike-slip faults within the Rocky Mountain Trench delineate the western

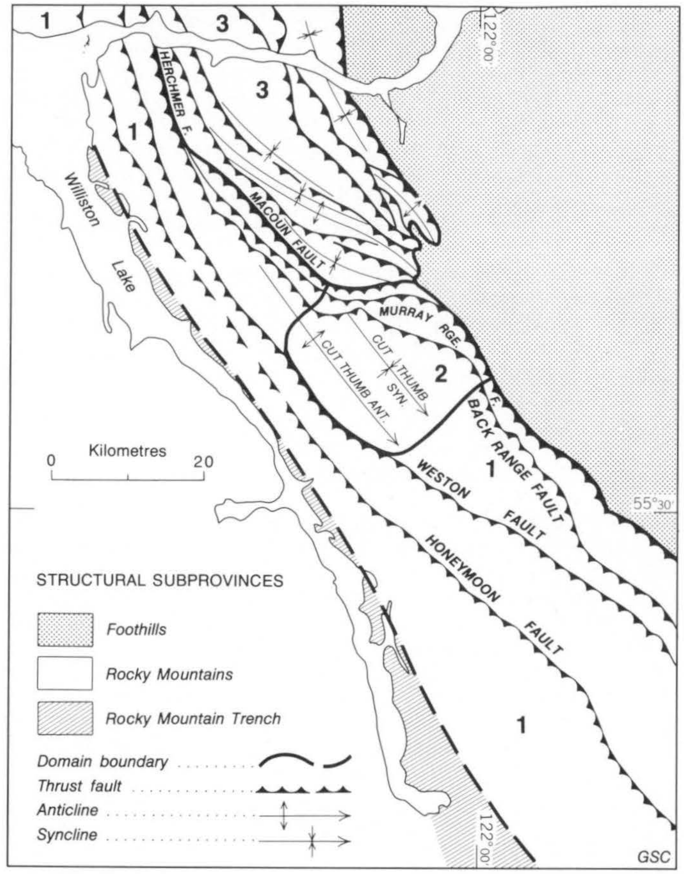

Figure 7. *The three structural domains (1, 2, 3) in the Rocky Mountain subprovince, Pine Pass-Peace River area.*

boundaries of Domain 1 and the Rocky Mountains structural subprovince. Domain 2 is characterized by south-dipping Proterozoic and Cambrian strata and south-dipping thrust faults. Its structures are continuous with those of Domain 1. Domain 3 comprises a series of faulted folds in Upper Cambrian to Middle Devonian strata. It is separated from domains 1 and 2 by the Macoun or Herchmer faults.

The Murray Range Fault forms the boundary between the Foothills and the Rocky Mountains structural subprovinces south of latitude 55°40'N. To the north, the fault steps west from the mountain front, and the faulted folds of Domain 3 make up the eastern part of the Rocky Mountains structural subprovince. Changes in the ages of rocks exposed suggest that the 'blind' thrust sheet inferred to underlie the westernmost part of the Foothills subprovince probably extends 15 to 20 km under the eastern part of the Rocky Mountains subprovince (Fig. 3). Shales of the Besa River Formation, at the top of this 'blind' thrust sheet, are interpreted as forming an extensive bedding glide zone for the overlying (Hidden) fault (see cross-sections A-A', B-B', Fig. 3).

Four main thrust sheets separated by major west-dipping thrust faults (Honeymoon, Weston, Back Range and Murray Range) constitute Domain 1. The Upper Proterozoic to Cambrian strata within the thrust sheets are predominantly west-dipping, except for an area above a major step in the hanging wall of the Back Range Fault, where they dip south or east (see Figure 3, section B-B'). North of latitude 55°40'N, a faulted panel of Cambrian strata occurs along the footwall of the Murray Range Fault. This panel is included in Domain 1, and the underlying Macoun Fault forms the eastern boundary of the domain. Structure sections (Fig. 3) indicate that these strata are part of the faulted west limb of the Scott Creek Syncline exposed along the western edge of Domain 3. Near Mount Selwyn, the Macoun, Murray Range and Back Range faults merge into a single fault that separates domains 1 and 3. This (single) fault is the southeastern continuation of the Herchmer Fault, a major fault, which brings basement rocks up to the surface 140 km northwest of the Mount Selwyn area (Evenchick, 1983). The trend of bedding and thrust faults within Domain 1 gradually changes from south-southeast near the Peace River, to southeast near latitude 55°30'N. This is part of the regional swing in the orientation of structures across the entire Rocky Mountain fold and thrust belt at this latitude, the underlying cause of which is unknown.

Domain 2 occurs along the structural salient in the Murray Range and related faults. It is characterized by an easterly structural trend that is divergent from the regional south-southeast or southeast trend of structures within the northern Rocky Mountain fold and thrust belt. The Upper Proterozoic and Cambrian strata that comprise Domain 2, occur in four, south-dipping, fault bounded panels. Within the highest panel, a large, open, anticline-syncline pair is outlined by the carbonate unit of the Misinchinka Group (Cut Thumb Anticline and Syncline). These structures are included in Domain 2 because the map pattern shows that the shared east-dipping limb formed above a major step in the hanging wall of the Back Range Fault (see also section C-C'). If the hanging wall step were not there, then the anticline would be absent, and the map pattern would be similar to that for the other structural panels of Domain 2. Only one of the four fault bounded panels that make up Domain 2 does not extend beyond the domain. The other three panels can be traced to the north and/or south into Domain 1, where they and their bounding faults have the regional south-southeast or southeast trend. This change in orientation of the same fault panel clearly indicates that the panels have been folded about a southeast plunging structure. In order to understand the nature and origin of this southeast plunging structure, it is necessary to examine the structure of Domain 3.

Faulted folds of Upper Cambrian to Middle Devonian strata with planar limbs and narrow hinge zones characterize Domain 3. They are chevron or box folds. Each major fold can be traced southward from Williston Lake across the domain until it plunges underneath or is faulted against the Foothills structural subprovince, or, in the case of the Scott Creek Syncline, it plunges under Domain 2 structures. In general, the trend of these folds changes from south-southeast in the northern part, to east-southeast in the central part, to southeast in the southern part of the domain. The folds have little plunge in the northern and central parts of the domain, but plunge up to 20° to the southeast in the southern part of the domain. Because of this change in plunge, the northeast limb of the Scott Creek Syncline has rotated from moderately southwest-dipping in the north, to moderately south-southwest dipping in the south (along Macoun Creek). Looking only at this northeast limb gives the erroneous impression that the Scott Creek Syncline trends east-southeast rather than southeast. Domain 3 is in the hanging wall of the Hidden Fault. Structure sections (Fig. 3) indicate that Upper Proterozoic to Middle Cambrian strata are involved in Domain 3 structures under most of the northern and central parts of the domain, but are restricted to structures along the western edge of the domain in the south. This implies that across most of the domain there is a transverse step in the hanging wall of the Hidden Fault that cuts out the Upper Proterozoic to Middle Cambrian strata to the south. Juxtaposition of this hanging wall step with the nearly horizontal Besa River bedding glide zone, in the footwall of the fault, can explain the plunge of folds in the eastern part of the domain, part of the plunge of the westernmost anticline in the domain, but little of the plunge of the Scott Creek Syncline, the most westerly fold in the domain. Before the origin of plunge on the Scott Creek Syncline and the east-southeast trend of folds in Domain 3 are discussed, it is appropriate to evaluate the limitations on shortening estimates across the entire Rocky Mountains structural subprovince in the Pine Pass-Peace River area.

Shortening

Two main factors affect estimates of shortening across the Rocky Mountain structural subprovince in the Pine Pass-Peace River area: 1) Misinchinka Group strata exposed within approximately 10 km of the physiographic Rocky Mountain Trench have been penetratively deformed; and 2) data on the locations of footwall and hanging wall cutoffs along the major thrust faults carrying Misinchinka strata are limited, so that estimates have a wide margin of error.

Flattened clasts, deformed calcite crystals in limestone (Pl. 8), and the penetrative cleavage (Pl. 9) indicate that the length of beds in the deformed state is significantly less than the original length of beds in the undeformed state. Folding of the cleavage about the Cut Thumb Anticline (see section on cleavage) suggests that the penetrative deformation and associated metamorphism predate most, if not all, the thrust faulting in the Mount Selwyn area. Because no mappable folds related to this penetrative deformation are outlined by the middle carbonate unit of the Misinchinka Group, a reliable estimate of nonpenetrative shortening, due to faulting and related folding, can be made by measuring around this carbonate unit. However, the accuracy of this estimate depends on factor 2.

Although a spaced solution cleavage that is axial planar to the folds of Domain 3 occurs in strata of the Kechika Group over much of Domain 3, the interstratal penetrative strain appears to be low* and shortening has been accomplished mainly by folding and related thrust faulting. Cleavage is absent in the overlying Ordovician to Middle Devonian strata, and shortening can be reliably estimated by measuring around marker beds.

The sections of Figure 3 were drawn assuming that significant displacement occurred on both the Honeymoon and Weston faults, and that this displacement increased to the north, as is suggested by the long strike length of these faults and their termination to the south. Shortening across the Back Range Fault was assumed to decrease gradually to the north from the relatively well constrained estimate for section C-C'. From these sections, the nonpenetrative shortening of the Upper Proterozoic-Middle Devonian structural level in the Pine Pass-Peace River area is estimated to be approximately 70 km [68 km, section A-A', 38 km east of Macoun Fault; 70 km, section section B-B', 38 km east of Macoun Fault; 71 km** section C-C', 28 km east of (below) Murray Range Fault].

*Suggested by the lack of shortening by folding or faulting across uncleaved beds within the unit, the spacing (0.5-5 cm) of the cleavage, and the thinness of the cleavage selvages.

**Displacement across Murray Range Fault is estimated at be 11 km.

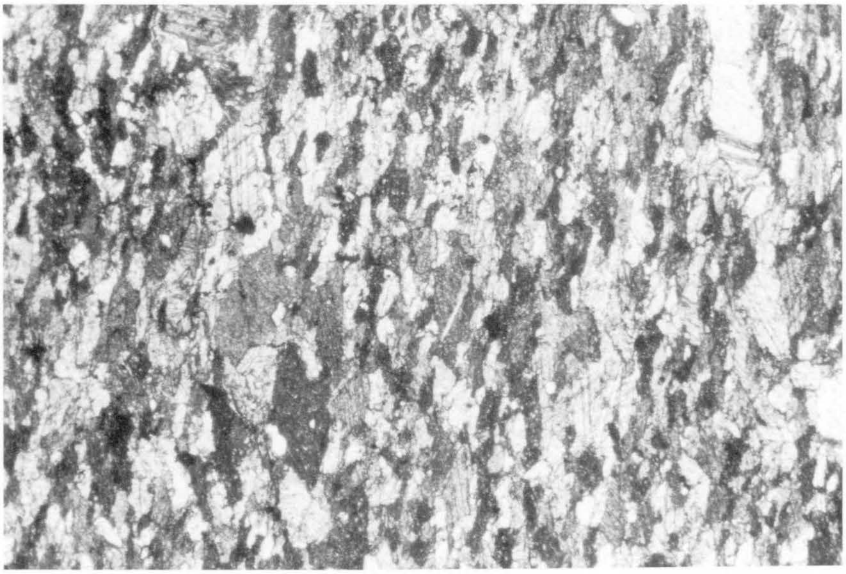

Plate 8. *Photomicrograph of elongated calcite crystals in limestone, middle unit of Misinchinka Group, Weston thrust sheet. ISPG photo 1820-19.*

Plate 9. *Penetrative cleavage in silty diamictite, lower unit of Misinchinka Group, Back Range thrust sheet. Pencil on left of photograph is 15 cm long. Q - quartzite clast. ISPG photo 1820-12.*

Origin of Domain 3 structures and the more easterly structural trends in Domains 2 and 3

Examination of the three structure sections and the geological map (Fig. 3) reveals that the folds and faults of Domain 3 occur in a wedge that widens rapidly to the northwest, from zero kilometres in width south of section C-C', to over twenty kilometres at section B-B'. In all sections, the estimated shortening below the Back Range Fault and above and across the Hidden Fault is approximately the same. However, the sections indicate that there is a rapid decrease in shortening across the Murray Range Fault, and an equivalent increase in shortening across Domain 3 structures going northwestward from section C-C' to B-B'. This and the wedge shape of the domain suggest that the structures of Domain 3 probably formed in a zone where displacement was transferred from the Murray Range Fault to underlying folds and faults.

Along both the Murray Range and Hidden faults a deep bedding glide zone in the Misinchinka Group is connected to a higher bedding glide zone in the Besa River Formation by a steep ramp or series of ramps, where the fault cuts rapidly through the stratigraphic section (figs. 3, 8a). The horizontal separation between the ramp in the footwall of the Murray Range Fault and those in the footwall of the Hidden Fault appears to widen rapidly to the northwest from near zero kilometres in width southeast of section C-C' to tens of kilometres northwest of section B-B' (Fig. 8a); continuing in a northwestward direction, this horizontal separation probably remains nearly constant. As motion occurred along the Murray Range and Hidden faults, the folds and faults of Domain 3 apparently formed in the zone between the two faults, and the zone itself moved up and along the Hidden Fault (Fig. 8b). The plunge of folds in the southern part of Domain 3 and the east-northeast trends of the faults and bedding in Domain 2 can be explained by the juxtaposition of the southeastward-narrowing wedge in the hanging wall of the Hidden Fault with the nearly horizontal Besa River bedding glide zone in the footwall of the Hidden Fault. This juxtaposition, combined with increased structural thickening of the wedge to the northwest, resulted in a southeastward-thinning (in the vertical sense) wedge of folded and faulted strata above the Hidden Fault and below the Murray Range Fault (Fig. 8b). The faults of domains 1 and 2 are folded around this southeast-facing wedge (Fig. 8c) and the folds, which were initiated as horizontal southeast-trending structures within the wedge, became southeast-plunging.

Comparison of sections A-A' and B-B' (Fig. 3) suggests that the change in the trend of folds in Domain 3 from south-southeast in the northern part, to east-southeast in the central part, can be explained by a net southward increase in shortening across the faults in the eastern part of the domain and across the Hidden Fault. In the southern part of Domain 3, there is little change in net shortening across the Hidden and the eastern faults, and the folds have a southeast trend that is consistent with the regional trend of structures in the southern part of the Pine Pass-Peace River area.

Age of deformation

The kinematic link between movement on 'blind' thrust faults (carrying Middle Devonian and older strata) and the deformation of Upper Devonian to Cretaceous strata exposed in the Foothills belt (Thompson, 1979, 1981), and the apparent transfer of displacement from the Murray Range Fault to the underlying 'blind' thrust fault (Hidden Fault) suggest that the

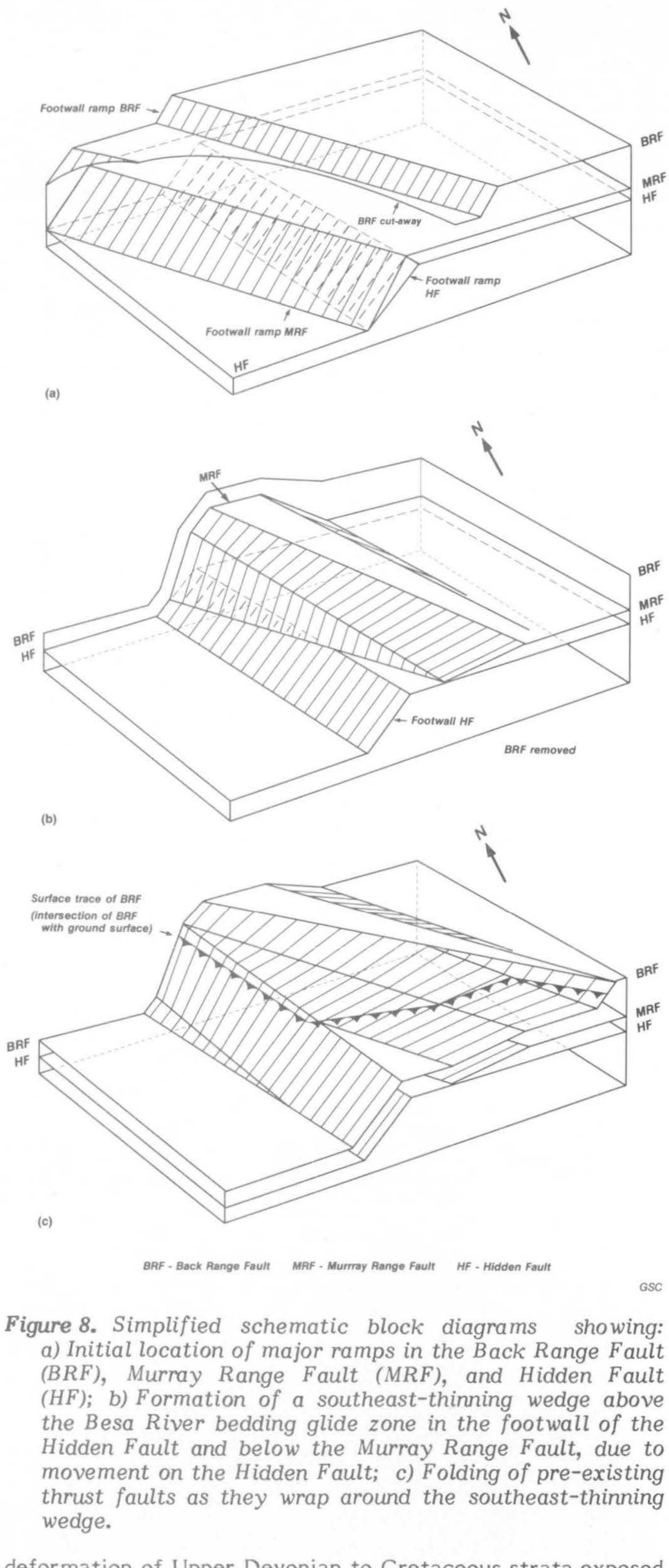

Figure 8. *Simplified schematic block diagrams showing: a) Initial location of major ramps in the Back Range Fault (BRF), Murray Range Fault (MRF), and Hidden Fault (HF); b) Formation of a southeast-thinning wedge above the Besa River bedding glide zone in the footwall of the Hidden Fault and below the Murray Range Fault, due to movement on the Hidden Fault; c) Folding of pre-existing thrust faults as they wrap around the southeast-thinning wedge.*

displacement on faults east of the Back Range Fault probably occurred in the Late Cretaceous and Early Tertiary, at the same time as the deformation of the Foothills. Folded cleavage (see section on cleavage) suggests that movement on the Back Range fault postdates Late Jurassic or earlier metamorphism and penetrative deformation and probably occurred in the Late Cretaceous. The presence of clasts of weakly metamorphosed Misinchinka Group strata in the Late Cretaceous-Paleocene Sifton Formation suggests that movement on the Honeymoon and Weston faults probably occurred prior to deposition of the Sifton Formation. Whether or not this movement is as old as Late Jurassic is unknown.

Rocky Mountain Trench

The northern Rocky Mountain Trench is the locus of a major right lateral strike-slip fault system. The fault system was active in the Late Cretaceous and early Tertiary and had hundreds of kilometres of displacement (Tempelman-Kluit, 1977). The outcrop of vertically dipping, Eocene or younger(?) strata at the entrance to Scott Creek (Pl. 7) is consistent with deformation along a strike-slip fault zone.

Minor structures

Cleavage

A penetrative cleavage or schistosity (Pl. 9), defined by the preferred orientation of metamorphic mica minerals, occurs in strata of the Misinchinka Group exposed near the Rocky Mountain Trench. The cleavage strikes north to northwest and dips west to southwest, except around the nose of the Cut Thumb Creek Anticline, where it strikes west and dips to the south. The cleavage appears to have been folded about this south-plunging anticline, which formed above a major step in the hanging wall of the Back Range Fault (sections B-B', C-C', Fig. 3) and must predate the main movement on the Back Range Fault. K-Ar dates (Leech et al., 1963; Wanless et al., 1979) indicate that the metamorphism and associated cleavage development occurred prior to the latest Jurassic.

A spaced solution cleavage (0.5-5 cm spacing) that is axial planar to folds of Domain 3 occurs in strata of the Kechika Group. A more intense cleavage, which is locally developed in the lowest unit of the Kechika Group between the fault splays at the western edge of Domain 3, probably results from the transfer of displacement from these faults to the intervening rock mass. A closely spaced solution cleavage (~0.5 mm spacing) occurs at least locally in shales of the Besa River Formation. This cleavage is probably a result of the deformation that formed the Foothills structural subprovince during the time when the Besa River Formation was a detachment zone between the overlying Lower Carboniferous carbonate and the underlying Middle Devonian and older carbonate.

Faults

Faults, with a few metres to over a hundred metres of stratigraphic separation, are recognized in well exposed sections of Lower to Middle Cambrian and Upper Ordovician to Middle Devonian strata. The faults strike northwest, northeast, or north, and vary from moderately dipping normal faults to vertical faults. A horst-graben sense of displacement is locally observed. Some of these faults offset thrust faults and clearly postdate the thrust faulting (e.g., the 8 km long fault extending north from Macoun Creek), whereas other faults terminate against a thrust fault and clearly predate at least some of the thrust faulting (Pl. 10; some of the small faults on the ridge north of Macoun Creek). In many cases, the relationship between these minor faults and thrust faulting cannot be directly determined. A few steep, east- or northeast-trending faults terminate against underlying and overlying thrust faults (e.g. the faults cutting Cambrian strata in the footwall of the Murray Range Fault west of Scott Creek). These faults have predominantly strike-slip displacement and are probably tear faults.

Folds

Minor folding of bedding is common in quartzite interlayered with cleaved argillite in the upper unit of the Misinchinka Group, in Kechika Group strata exposed near reverse faults or their terminations, and in the Toad-Grayling Formation. Minor folding occurs locally in the limestone unit of the Misinchinka Group, in Middle Cambrian strata, and in the Dunedin Formation. Kink style minor folds with steeply dipping axial planes are locally abundant in thinly interbedded strata adjacent to reverse faults in Domain 1 and the western part of Domain 3.

Minor folds of schistosity occur in Misinchinka Group strata exposed within the physiographic Rocky Mountain Trench. East of the Trench, kink bands (Pl. 11) deform the cleavage in phyllitic rocks along narrow (20-30 m) zones adjacent to the major reverse faults. The kink bands are subvertical, with limbs up to 2 cm long. They define a crenulation cleavage.

Poles to the axial planes of kink-style minor folds of bedding and cleavage that developed adjacent to faults in the Mount Selwyn area are plotted in Figure 9. Comparison with kink fold and crenulation cleavage orientations from areas along the Rocky Mountain Trench near 53°N (Murphy and Journeay, 1981; two subvertical sets striking 025° and 110°, probably conjugate), and latitude 51°N (Simony and Wind, 1970; two subvertical sets striking 030° and 100°, conjugate; and one other moderately dipping set), suggests that the kink-style minor folds in the Mount Selwyn area probably form two steeply dipping sets (strikes 035° and 085°) that are conjugate to each other. This conjugate system indicates NNW-SSW shortening, that is, approximately parallel to the trend of the reverse faults that these minor folds are localized along, and suggests that strike-slip rather than dip-slip was the last motion along these faults. The restriction of these minor kink folds east of the Rocky Mountain Trench to reverse fault zones that run into the Rocky Mountain Trench suggests that the strike-slip motion along these reverse faults probably occurred during major Late Cretaceous-Early Tertiary strike-slip displacement along the Northern Rocky Mountain Trench fault system.

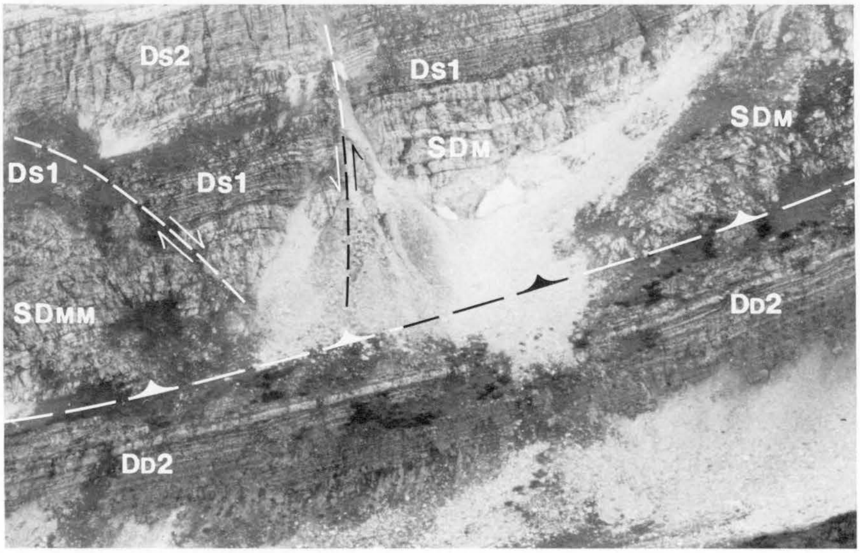

Plate 10. *Minor faults that predate movement on underlying thrust fault, ridge north of Macoun Creek.* SDM - *Muncho-McConnell Formation;* DS1 - *Stone Formation (lower unit);* DS2 - *Stone Formation (upper unit);* DD - *Dunedin Formation. ISPG photo 1820-1.*

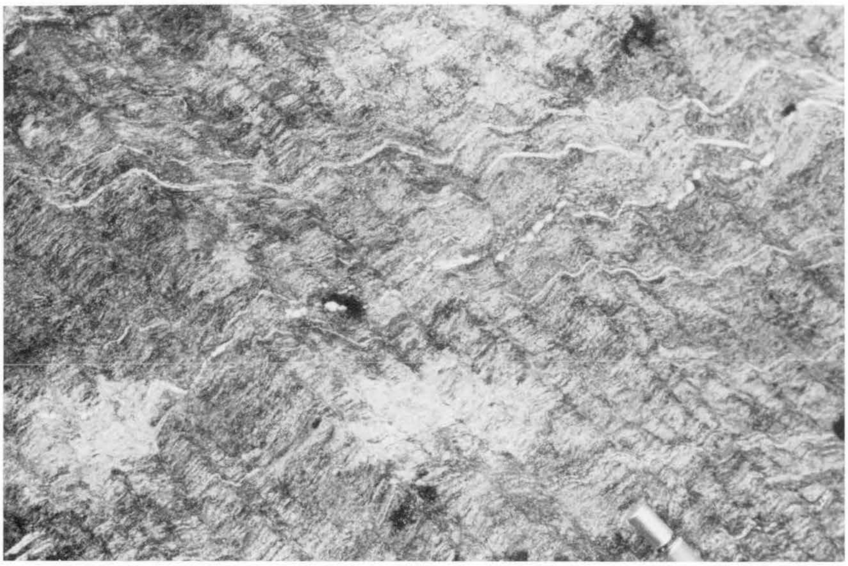

Plate 11. *Kink folds deforming cleavage, lower unit of Misinchinka Group adjacent to Back Range Fault. The pencil in lower right of photograph is 0.7 cm in diameter. ISPG photo 1820-13.*

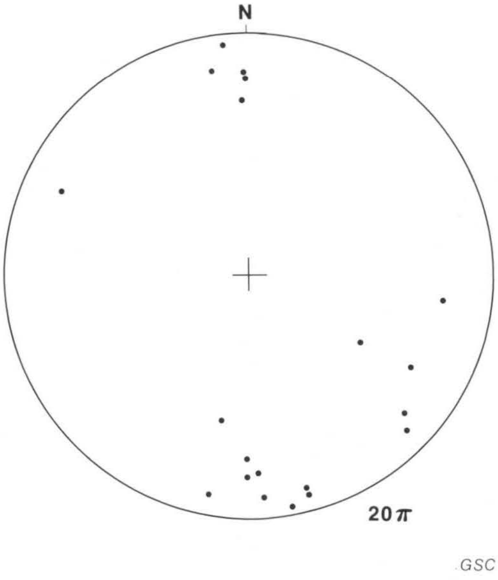

Figure 9. *Poles to axial planes of kink folds of bedding and cleavage, Mount Selwyn area (equal-area projection from the lower hemisphere).*

ECONOMIC GEOLOGY

Mineral deposits are rare in the Mount Selwyn area. Stratabound, fine grained magnetite and hematite occur within the Misinchinka Group eight kilometres northeast of the junction of Six Mile Creek and Williston Lake (B.C. Ministry of Energy, Mines and Petroleum Resources, 1977, 1978), and minor lead-zinc mineralization occurs at the fault contact between limestones of the Kechika Group and dolomites of the upper unit of the Stone Formation on the southeast flank of Mount Selwyn (B.C. Ministry of Energy, Mines and Petroleum Resources, 1976; this study).

In the 1920's and early 1930's, an alleged gold deposit on the northwest spur of Mount Selwyn generated considerable excitement and interest (see B.C. Ministry of Mines, 1924, 1929, 1934, 1936). The gold was said to occur in quartzite beds that extended from Peace River to just north of the Mount Selwyn area (in NTS 94-B/4E) providing vast tonnages and great potential for development. Assaying published by the B.C. Ministry of Mines consistently showed an absence of gold values, and in 1935 after extensive sampling, finally put an end to the Mount Selwyn gold promotion.

Minor coal occurs within Eocene and younger(?) sediments exposed along the Rocky Mountain Trench. Poor exposure, seam thinness and structural complications make its exploitation unlikely.

No wells have been drilled to test the petroleum potential of the Mount Selwyn area. The leading edges of 'blind' thrust sheets that probably underlie the western part of the Foothills belt are prospective structures. Middle Devonian limestones could form suitable reservoir rocks within these sheets, especially if dolomitized or fractured. Carbonates in the upper part of the Lower Carboniferous Prophet Formation locally have good porosity. Structural traps in faulted anticlines of the Prophet Formation (Debolt Formation to the east) probably occur under most of the Foothills belt. However, those underlying the northern Mount Selwyn area are probably water saturated, because their up-plunge continuations are exposed immediately north of Williston Lake.

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APPENDIX

Fossil collections*

The following fossil collections were made by the author from various parts of the map area and were identified by paleontologists of the Geological Survey of Canada.

GSC loc. no. Rock unit Identified by	Location Fauna/flora Age
C-89657 Lynx Formation, upper unit G.S. Nowlan	55°47.5'N, 123°22.3'W Conodonts: *Proconodontus* cf. *P. muelleri* Miller Age: Late Cambrian
C-89684 Lynx Formation, upper unit G.S. Nowlan	55°43.5'N, 123°08.3'W Conodonts: *Eoconodontus notchpeakenis* (Miller) *Cambrooistodus cambricus* (Miller) Age: Late Cambrian (Trempealeauan)
C-89678 Kechika Group, lower unit G.S. Nowlan	55°51.5'N, 123°23.3'W Conodonts: *Acontiodus iowensis* Furnish s.f. *A. propinquus* Furnish s.f. *Cordylodus angulatus* Pander s.f. *C. rotundatus* Pander s.f. *Cornuodus* sp. *Drepanodus* sp. s.f. *Drepanoistodus* n. sp. *Juanognathus* ? n. sp. "*Paltodus*" n. sp. cf. "*P.*" *bassleri* Furnish *Scolopodus rex* Lindström Age: Early Ordovician early to mid-Canadian (Tremadoc-early Arenig)
C-89554 Kechika Group, upper unit G.S. Nowlan	55°48.5'N, 123°12.8'W Conodonts: "*Acodus*" *russoi* Serpagli *Bergstroemognathus extensus* (Graves and Ellison) *Cornuodus longibasis* (Lindström) *Oepikodus intermedius* Serpagli ? *O. evae* (Lindström) *Oistodus* sp. 1 Serpagli s.f. *Paltodus*? *sweeti* Serpagli s.f. *Paracordylodus* sp. *Paroistodus parallelus* (Pander) *Protopanderodus gradatus* Serpagli *Scandodus americanus* Serpagli s.f. *Scolopodus rex* Lindström *Walliserodus australis* Serpagli Age: late Early Ordovician late Canadian mid-Arenig)
C-89611 Besa River A.W. Norris	55°50.7'N, 123°08.4'W *Schizophoria* sp. cf. *S. athabaskensis* Warren Age: early Late Devonian, early Frasnian "*Stropheodonta costata*" Zone
C-89656 unnamed clastic unit A.R. Sweet	55°42.8'N, 123°35.2'W *Alnus verus* (R. Potonié) Martin and Rouse 1966 (abundant) ?*Carya* sp. (rare) *Diervilla echinata* Piel 1971 (rare) *Micrhystridium fraseri* Piel 1971 (rare) *Nyssa* sp. (common) *Pterocarya stellatus* (R. Potonié) Martin and Rouse 1966 (scarce) *Tilia crassipites* Wodehouse 1933 (scarce) tetracolpate pollen (smooth) (rare) *Ulmus* sp. (rugulate) (common) Age: late Paleocene or younger, most probably Eocene or younger.

The following fossil collections were made by B.S. Norford of the Geological Survey of Canada from an Ordovician to Devonian section exposed on the ridge north of Macoun Creek, starting at 55°49'N, 123°15'W, and were identified by paleontologists of the Geological Survey of Canada. The lowest 400 feet (120 m)** of strata are better exposed at 55°49.3'N, 123°13.3'W and were measured there. This section is the Clearwater section of Norford et al. (1966).

GSC loc. no. Rock unit Identified by	Fauna/flora Age
45516 Kechika Group, top of upper unit B.S. Norford	orthid brachiopod planispiral gastropod trilobite fragments Age: probably Late Cambrian or Ordovician
45565 Skoki, 345-350 feet** (105-106.5 m) above base B.S. Norford	orthid brachiopod new genus aff. *Orthidiella* *Orthambonites* cf. *O. marshalli* (Wilson) Age: early Middle Ordovician, Whiterock, probably *Orthidiella* Zone

*The location and stratigraphic assignment of fossil collections made by J.E. Muller of the Geological Survey of Canada in 1959 and 1960 are poorly known and, therefore, excluded from this list.

**As the section was measured in feet, these units are given first, their metric conversion to the nearest half metre is given in parentheses.

45517 unnamed quartzite and dolomite unit, 421-423 feet (128-129 m) above base of Skoki B.S. Norford	bryozoan solitary coral brachiopods *Catenipora* sp. Age: Ordovician	
45564 and 45561 Beaverfoot, 591-622 feet (180-189.5 m) above base of Skoki B.S. Norford	brachiopods ?*Hesperorthis* sp. ?*Onniella* sp. *Rhynchotrema* sp. *R. increbescens occidens* Wilson *Bighornia* sp. ?*Grewingkia* sp. *Lobocorallium* aff. *L. trilobatum* (Whiteaves) ?*Paleophyllum* sp. ?*Catenipora* sp. *Paleofavosites* sp. ?*Sarcinula* sp. ?*Tollina* sp. auloporid coral bryozoan Age: Late Ordovician, *Bighornia-Thaerodonta* fauna	
45562 Nonda, 921-941 feet (280.5-287 m) above base of Skoki B.S. Norford	stromatoporoid solitary coral halysitid coral *Favosites* sp. Age: Silurian	
45613 Nonda, 988-1003 feet (301-305.5 m) above base of Skoki B.S. Norford	halysitid coral *Coenites* sp. ?*Favosites* sp. *Favosites* aff. *F. biloculi* Hall Age: Silurian, probably late Llandovery	
45567 Nonda, 971-1031 feet (296-314 m) above base of Skoki B.S. Norford	solitary, tabulate and halysitid corals *Columnaria columbia* Norford ?*Columnaria* sp. ?*Favosites* sp. Age: Early Silurian, late Llandovery	
45614 Nonda, 1016-1031 feet (309.5-314 m) above base of Skoki B.S. Norford	stromatoporoid solitary and tabulate corals *Columnaria columbia* Norford *Favosites* aff. *F. biloculi* Hall *Favosites* spp. Age: Early Silurian, late Llandovery	
45566 Nonda, 1151-1191 feet (351-363 m) above base of Skoki B.S. Norford	brachiopod solitary coral bushy auloporoid coral tuberose tabulate corals *Favosites* spp. Age: probably Silurian	
45304 Dunedin, lower unit, 2971-2996 feet (905.5-913 m) above base of Skoki M.J. Copeland	*Richina* sp. *Kloedenella* sp. A Age: probably Devonian	
45293 Dunedin, lower unit, 3046-3071 feet (928.5-936 m) above base of Skoki M.J. Copeland	?*Dizygopleura* sp. charophytes Age: probably Devonian	
45623 Dunedin, lower unit, 3071-3081 feet (936-939 m) above base of Skoki D.J. McLaren and A.W. Norris	*Emanuella* sp. Age: probably Middle Devonian	
45295 Dunedin, lower unit, 3071-3096 feet (936-943.5 m) above base of Skoki M.J. Copeland	*Bollia* cf. *B. disjuncata* Kesling and Kilgore *Kloedenella* sp. A ?*Barychilina* sp. Age: probably Middle Devonian	
45624 Dunedin, lower unit, 3117-3118 feet (950-950.5 m) above base of Skoki D.J. McLaren and A.W. Norris	pelecypod fragment *Warrenella* sp. - elongate form Age: probably early Middle Devonian	
45303 Dunedin, lower unit, 3221-3246 feet (982-989.5 m) above base of Skoki M.J. Copeland	auloporoid coral ostracode indet. Age: indeterminate	

45621 Dunedin, lower unit, 3229-3236 feet (984-986 m) above base of Skoki D.J. McLaren and A.W. Norris	*Plasmophyllum* sp. Age: probably Middle Devonian
45619 Dunedin, lower unit, 3236-3246 feet (986-989.5 m) above base of Skoki D.J. McLaren and A.W. Norris	*Hexagonaria* ex gr. *H. arctica* (Meek) *Spinatrypa* cf. *S. coriacea* Crickmay *Favosites* sp. *Atrypa* sp. ?*Schizophoria* sp. Age: probably early Middle Devonian
47298 Dunedin, lower unit, 3296-3321 feet (1004.5-1012 m) above base of Skoki M.J. Copeland	auloporoid coral ?*Kloedenella* sp. B *Phelobythocypris* sp. Age: probably Middle Devonian
45620 Dunedin, lower unit, 3316-3336 feet (1010.5-1017 m) above base of Skoki D.J. McLaren and A.W. Norris	cup coral fragment *Favosites* sp. *Schizophoria* sp. *Cypricardinia* ? sp. *Michelinoceras* ? sp. *Desquamatia* cf. *D. perfimbriata* (Crickmay) *Spinatrypa* cf. *S. lata* (Warren) *Hadrorhynchia intermissa* Crickmay trilobite tail Age: late Middle Devonian (early Givetian)
45294 Dunedin, lower unit, 3371-3396 feet (1027.5-1035 m) above base of Skoki M.J. Copeland	*Phelobythocypris* sp. Age: indeterminate
45306 Dunedin, lower unit, 3396-3421 feet (1035-1042.5 m) above base of Skoki M.J. Copeland	*Rozhdestvenskayites*? sp. Age: possibly Middle Devonian
45622 Dunedin, upper unit, 3436-3446 feet (1047-1050 m) above base of Skoki D.J. McLaren and A.W. Norris	*Alveolites* sp. *Favosites* sp. ?*Stringocephalus* sp. Age: late Middle Devonian (Givetian)

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