# STRATIGRAPHY OF THE MIETTE GROUP AND TECTONIC HISTORY OF THE SOUTHERN SELWYN RANGE, WESTERN MAIN RANGES, BRITISH COLUMBIA

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## ABSTRACT

In the southern Selwyn Range, Hadrynian Miette Group strata form a thick conformable sequence. A distinctive carbonate unit in the middle Miette Group is assigned to the Old Fort Point Formation. Facies variations in the middle Miette Group, from grit dominated in the east to pelite dominated in the west, delineate a channel or fan lobe margin.

Structures in the southern Selwyn Range developed during three main phases of deformation. The Fraser River Antiform, the dominant structure, formed during $D_2$. The Selwyn Range Fault cross-cut the earlier Fraser River Antiform during early $D_3$. The Fraser River Antiform tightened during late $D_3$, when the Selwyn Range Fault was reactivated, forming a 100m thick shear zone. The Chatter Creek Fault ($D_3$ or latter) has compressional and dextral motion, both with minor displacement.

Metamorphism was initiated during $D_2$ and peaked during $D_3$.

**RESUMÉ**

Dans la partie méridionale de la chaine Selwyn en Colombie-Britanique, le Groupe Miette d'âge Hadrynian forme une épaisse séquence concordante. Une unité carbonacé apparaissant au milieu du Groupe de Miette et possédant des traits distinctifs a été assignée à la Formation de Old Fort Point. Le milieu du Groupe de Miette est dominé à l'est par une succession de conglomérats immatures et à l'ouest par des pélites. Ces differents facies permettent d'identifier un chenail ou un environment en marge d'un lobe deltaïque.

Les déformations structurales dans le sud de la chaine Selwyn se sont développées en trois phases principales. La structure dominante est l'antiforme de Fraser River. C'est une structure de déformation secondaire ($D_2$). La faille de la chaine de Selwyn a recoupé l'antiforme de Fraser River au début de la déformation tertiaire ($D_3$). Cette déformation a provoqué un reserrement de l'antiforme, ainsi qu'une zone de cisaillement de plus de la 100 m de largueur le long du plan de failles. La faille de Chatter Creek origine d'une déformation tertiaire ($D_3$) ou plus tardive. C'est une faille de compression avec mouvement dextre.

Le métamorphisme régional a débuté durant la période $D_2$ et a atteint son paroxisme durant $D_3$.

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This work was greatly improved by discussions with numerous people: Mike McDonough, Don Murphy, Roland Dechesne, Gabriela Klein, Gouwie Zhang and Andrew Hynes. Mike McDonough and Don Murphy assisted in mapping the Selwyn Range Fault, and analyzing the fabrics in the shear zone on the west flank of the Fraser River Antiform. Linda Roman and Teresa Waller provided assistance and companionship in the field.

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# CHAPTER 1 - INTRODUCTION

## INTRODUCTION

The Selwyn Range lies approximately 45 km southwest of Jasper, just west of the Alberta/British Columbia border (Fig. 1.1). The Selwyn Range comprises part of the western Main Ranges of the southern Canadian Rocky Mountain foreland fold and thrust belt, of the Canadian Cordillera. The Canadian Cordillera was deformed in response to two collisions of allochthonous composite terrains with the rifted margin of western North America in Jurassic and Cretaceous times (Monger et al., 1982; Brown et al., 1986). The Hadrynian Miette Group, that underlies the Selwyn Range, comprises part of the collapsed margin of Proterozoic to Jurassic sediments of western North America. The Miette Group is a turbidite dominated sequence, deposited during initial rifting of the western North American margin.

The structure and stratigraphy of the eastern Main Ranges, Front Ranges and Foothills of the Canadian Rocky Mountains are well constrained by good exposures, well defined stratigraphy, and seismic and borehole data (Price and Mountjoy, 1970; Price 1981; Price and Fermor, 1985). However, until recently, only the shallow structural levels of the western Main Ranges have been studied in detail (Craw, 1977; Gal, et al., 1989; Klein and Mountjoy, 1988; Klein, 1991).

The deepest structural and stratigraphic levels in the western Main Ranges are exposed by the Jasper/Yellowhead culmination that underlies the Selwyn Range (Dechesne and Mountjoy, in press). Work in this area has been hampered by the lack of correlatable units in the Miette Group. As a result, two opposing structural/ stratigraphic interpretations have been proposed for the Selwyn Range, the "thick" stratigraphy of Mountjoy et al. (1985) and McDonough and Simony (1988a, 1988b) and the "thin" stratigraphy of Dechesne (1990a) (see below). These interpretations are examined in Chapter 4.

## GENERAL GEOLOGY

The Selwyn Range is bounded on the west by the southern Rocky Mountain Trench, an extensive linear geomorphic feature (Fig. 1.1) with localised late-stage normal faults, reverse faults and transcurrent faults (Wheeler, 1963; Campbell, 1968; Price and Mountjoy, 1970; Simony et al., 1980; McDonough and Simony, 1988a; Murphy, 1990a). Although the northern Rocky Mountain Trench is thought to have a minimum of 750 km of dextral offset (Gabrielse, 1985), dextral offset at the latitude of Jasper is considered to be minor as, structures and stratigraphy can be correlated across the Trench (McDonough and Simony, 1988a). Minor exposures of basement gneiss (Blackman and Hugh Allan Gneiss) occur in the Selwyn Range, opposite the Malton Gneiss (Morrison, 1982) on the east side

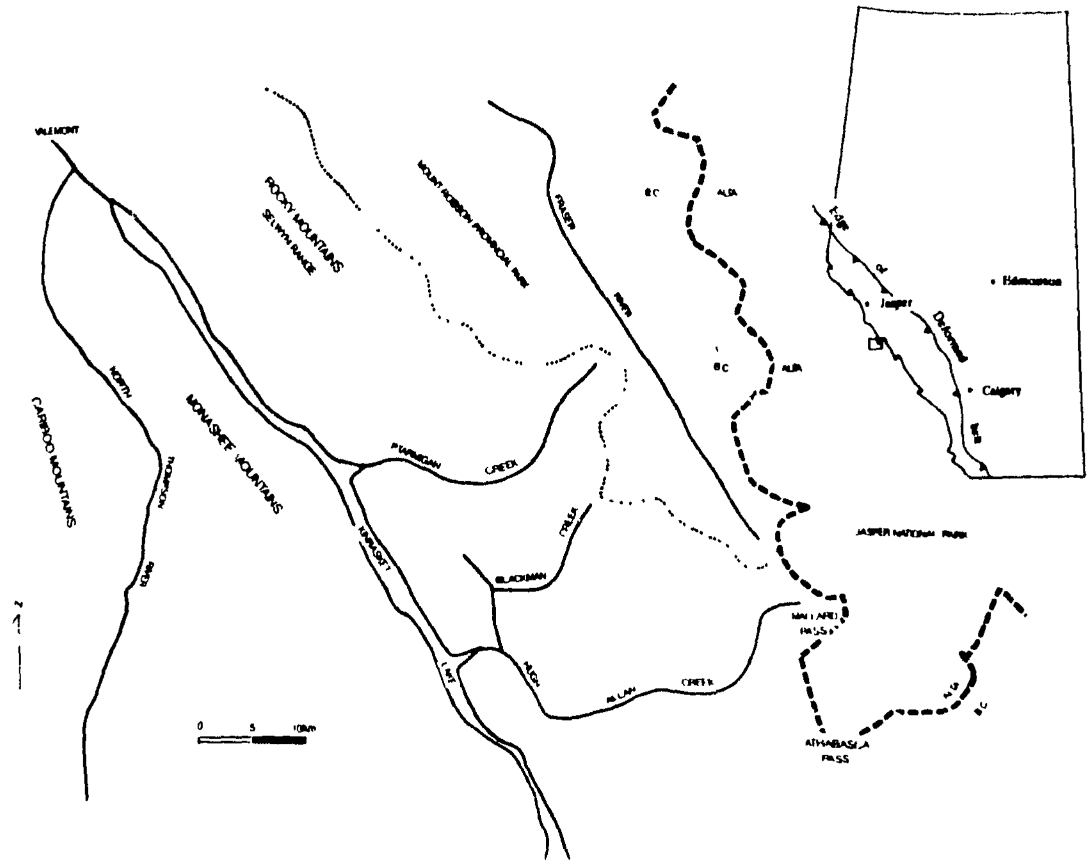



Fig. 1.1. Regional map.

of the Trench (Campbell, 1968; Oke and Simony, 1981) (Fig. 1.1,1.2). The east side of the Selwyn Range is bounded by the Chatter Creek Fault, a near vertical, late-stage fault, with both compressional and dextral motion (Grasby and Mountjoy, 1991).

Three main phases of deformation are recognised in the southern Selwyn Range. The earliest phase of deformation ($D_1$) is west verging, poorly preserved, and restricted to the hanging wall of the Hugh Allan Thrust (Fig. 1.2) (Leonard, 1985; Charland, 1989). Two later phases of northeast-verging deformation ($D_2$ and $D_3$ ) are ubiquitous in the Selwyn Range. Second phase ($D_2$) structures are characterised by low-angle faults and recumbent, isoclinal folds. Third phase ($D_3$) structures are characterised by upright open folds and steep dipping faults. Transverse fabrics of uncertain origin, and late-stage top to the west kinks occur sporadically in the area. Metamorphism increases from greenschist facies in the eastern part of the field area up to amphibolite grade in the western part. Peak metamorphism occurred during $D_3$.

The structure of the map area is dominated by the Fraser River Antiform, a $D_3$, broad, regional scale, doubly plunging antiform (Fig. 1.2). The Fraser River Antiform culminates around Ptarmigan Creek, exposing the Ptarmigan Creek Thrust Zone, a $D_2$ thrust zone (2 to 3 km wide), folded by the Fraser

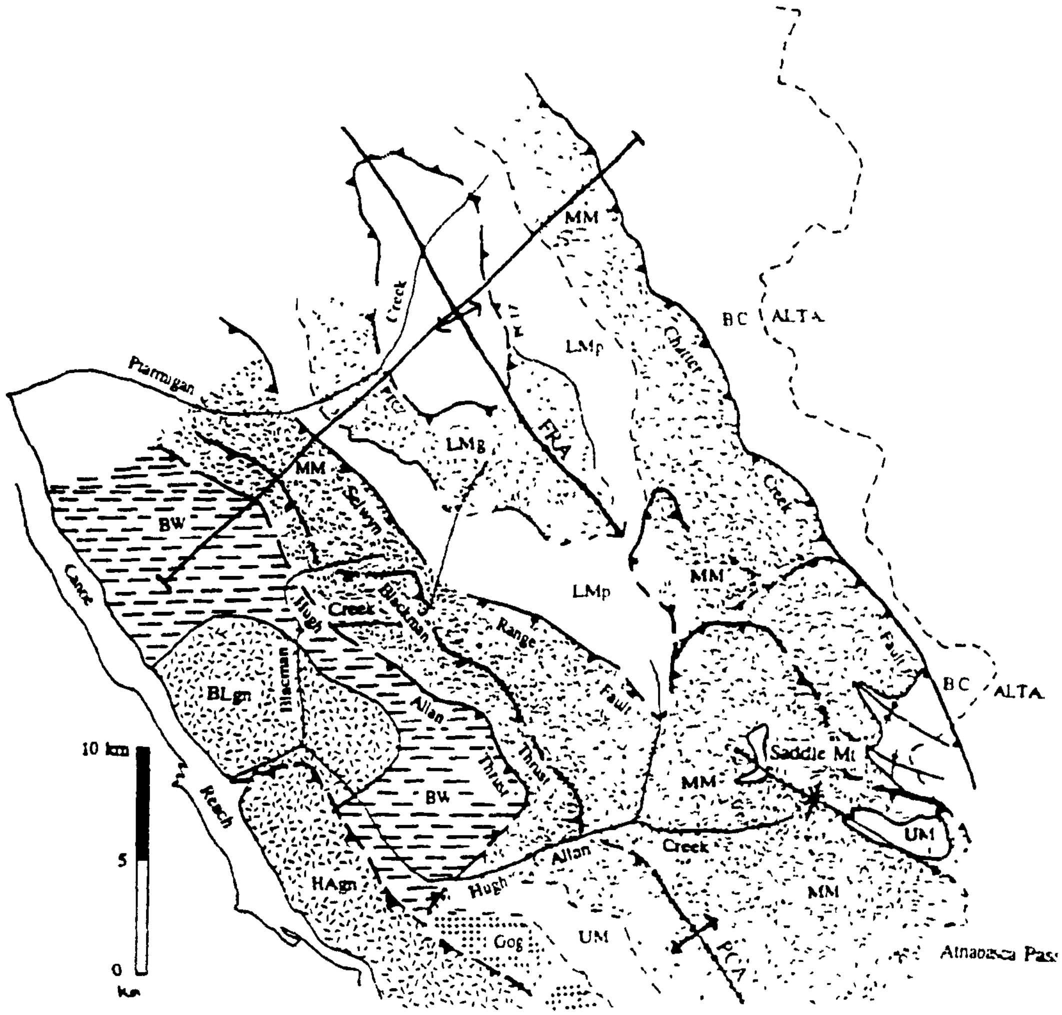



Fig. 1.2. Simplified geologic map of the southern Selwyn Range, showing main stratigraphic and structural features. BW = Basal Windermere, LMg = lower Miette Group grits, LMp = lower Miette Group pelites, MM = middle Miette Group, UM = upper Miette Group, Gog = Gog Group, Blgn = Blackman Gneiss, HAgn = Hugh Allan Gneiss.

River Antiform that crops out as a window in its core (Fig. 1.2). South of Ptarmigan Creek, structures plunge gently to the southeast, where the Fraser River Antiform broadens into a homoclinal, southwest-dipping panel near Hugh Allan Creek (Fig. 1.2).

The Selwyn Range is dominantly underlain by Hadrynian Miette Group stratigraphy. Going up stratigraphic section, the strata in the hanging wall of the Ptarmigan Creek Thrust zone consists of: 2500 m of grit (quartzose feldspathic conglomerates) 2500 m of pelite, 3000 m of grit, and approximately 1500 m of pelite (Fig. 1.2). Two interpretations of this stratigraphic sequence have been proposed, as illustrated in Figure 1.3. McDonough and Simony (1988b) and McDonough (1989) interpret the stratigraphy as a thick, conformable sequence. Whereas Dechesne (1990a) and Dechesne and Mountjoy (in press) have suggested that the stratigraphy is a thin sequence that has been structurally repeated by the Selwyn Range Fault (see Chapter 4), so that the upper grit and pelite correlate with the lower grit and pelite (Fig. 1.3). If the latter interpretation is correct, structural and stratigraphic relations require the Selwyn Range Fault to merge with structures in the eastern Main Ranges (eg. Snaring, Monarch, Simpson Pass, Moose Pass thrusts) (Dechesne and Mountjoy, in press), with a minimum displacement of 100 km. This would greatly increase the

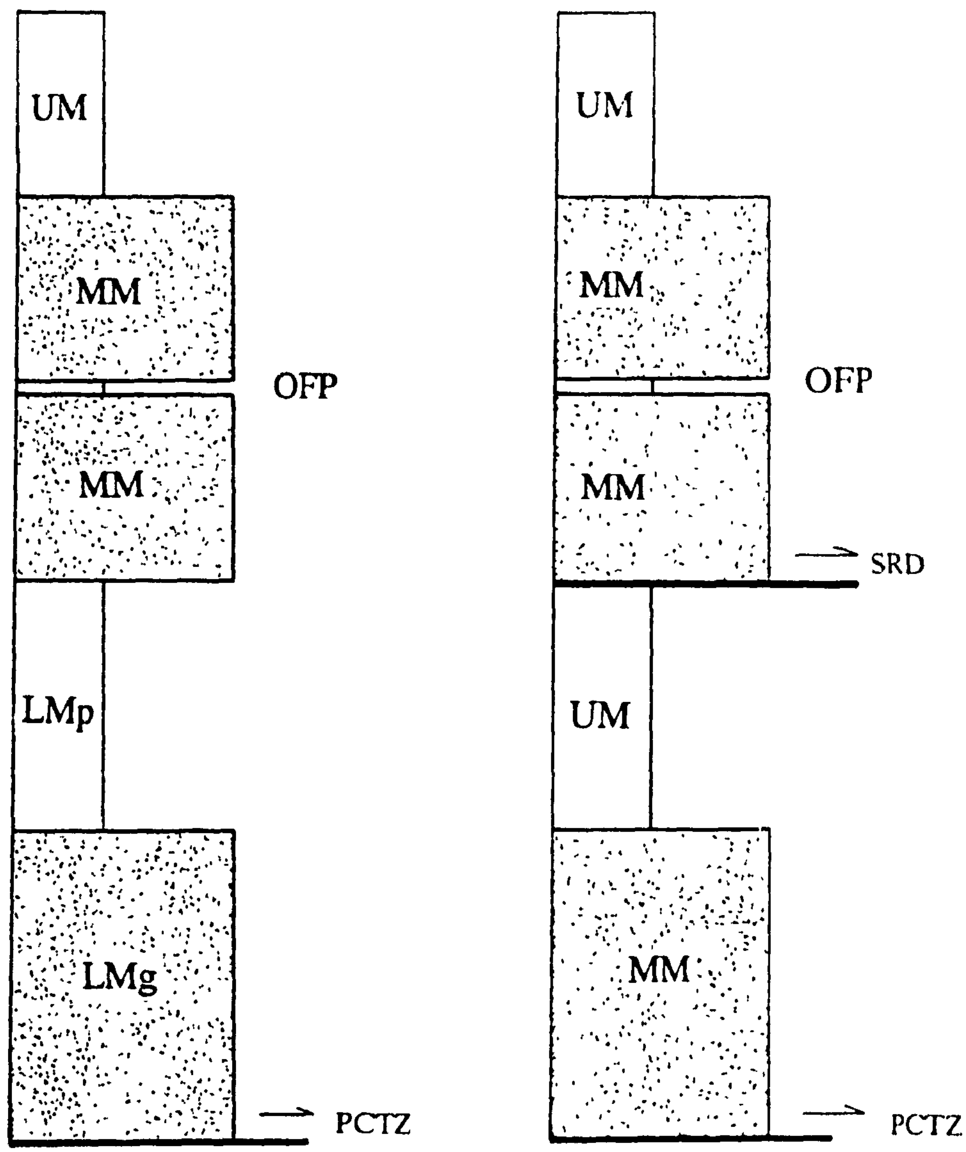



Fig. 1.3. Two structural/stratigraphic interpretations of the stratigraphic sequence in the hanging wall of the Ptarmigan Creek Thrust Zone, in the southern Selwyn Range. PCTZ = Ptarmigan Creek Thrust Zone, SRF = Selwyn Range Fault, LMg = lower Miette Group grits, LMp = lower Miette Group pelites, MM = middle Miette Group, UM = upper Miette Group.

total amount of shortening in the Rocky Mountains at this latitude. Thus the two interpretations have significant implications on how cross-sections are drawn with respect to basement (Fig. 1.4).

## PURPOSE AND METHODS

This study has four main objectives: 1) detailed mapping and correlation of Selwyn Range Fault around the southern plunge of the Fraser River Antiform, to resolve which of the two structural/stratigraphic interpretations of the southern Selwyn Range is most probable, 2) to better define the structure and stratigraphy of the Selwyn Range, by detailed mapping and use of the Old Fort Point Formation (of the middle Miette Group) as a marker, 3) to develop a coherent structural/metamorphic history of the southern Selwyn Range, and 4) to elucidate the nature and timing of the Chatter Creek Fault.

Data were collected during the 1989 and 1990 field seasons. They consist mainly of structural measurements of bedding, foliations, lineations, and fold trends. These data were plotted on equal area projections to discern the overall structural trends and styles in the area. Some areas were mapped in detail by "walking out" faults and stratigraphic units. Detailed stratigraphic descriptions were made at

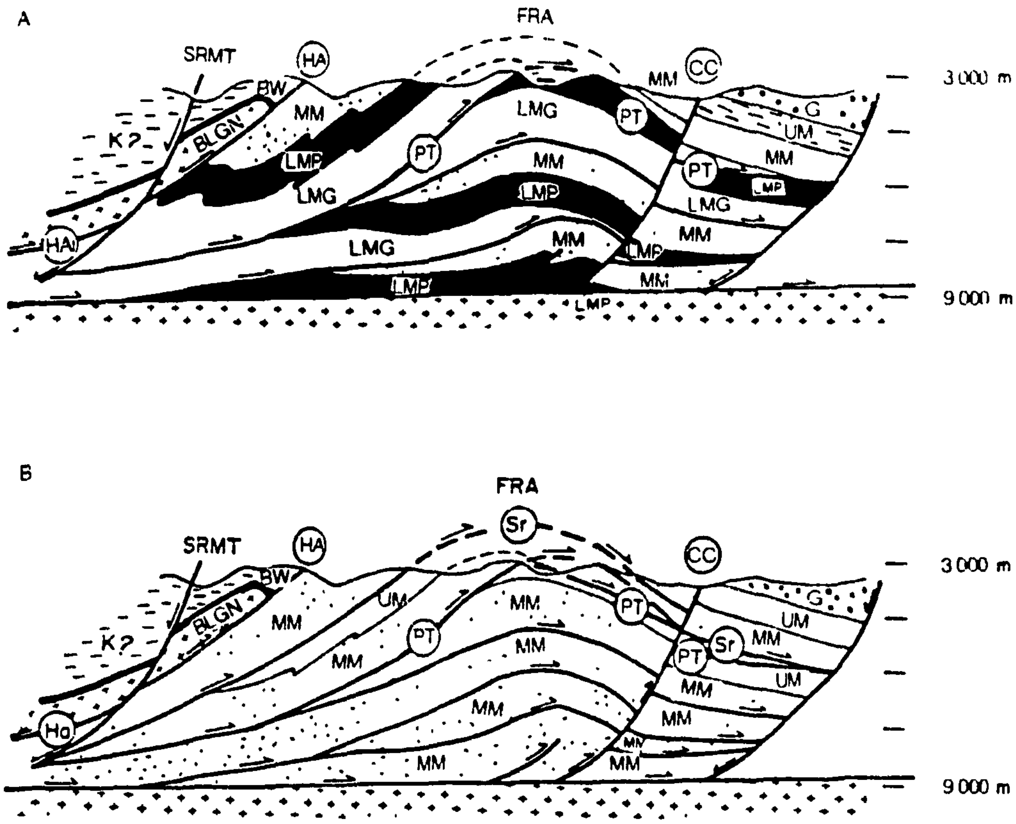



Fig. 1.4 Cross-sections to basement, A. showing thick and B. thin stratigraphy interpretations of strata in the southern Selwyn Range (from Dechesne and Mountjoy, in press). BW = Basal Windermere, LMg = lower Miette Group grits, LMp = lower Miette Group pelites, MM = middle Miette Group, UM = upper Miette Group, G = Gog Group, Blgn = Blackman Gneiss, HA = Hugh Allan Thrust, PT = Ptarmigan Creek Thrust, CC = Chatter Creek Thrust.

a stratigraphy in the southern Selwyn Range. Thin sections were made from characteristic hand samples to better define the Miette Group fabrics and metamorphic textures.

## PREVIOUS WORK

The southern Selwyn Range was originally mapped on reconnaissance scale by Campbell (1968) and Price and Mountjoy (1970). The first detailed mapping of the southern Selwyn Range was completed by Oke and Simony (1981), around Mount Blackman, and Leonard (1985) and Forest (1985), between Hugh Allan and Ptarmigan creeks. Charland (1989) mapped the area northwest of Mount Blackman. Dechesne (1990a) and Dechesne and Mountjoy (1990a) mapped much of the central and northeastern Selwyn Range. McDonough (1984, 1989), McDonough and Simony (1988a, 1988b) and McDonough and Mountjoy (1990) have mapped the northern Selwyn Range. Klein and Mountjoy (1988) and Klein (1991) mapped the area immediately south of Hugh Allan Creek. The northeastern part of the field area (83D/9) has been mapped at 1:50,000 scale by Mountjoy and Price (1989) and the southeastern part (83D/8) by Mountjoy _et al_. (in prep.).

# CHAPTER 2 - STRATIGRAPHY

## INTRODUCTION

The southern Selwyn Range is underlain by Hadrynian Miette Group strata of the Windermere Supergroup (Campbell et al., 1973; Price and Mountjoy, 1970). Lower Cambrian Gog Group, and Middle Cambrian strata, crop out in the footwall of the Chatter Creek Fault, in the eastern part of the field area (Mountjoy and Price, 1989)(Figs. 1.2, 2.1).

The stratigraphic assignment of cover strata of the Blackman Gneiss, in the hanging wall of the Hugh Allan Thrust (Fig. 1.2), is uncertain. Originally these strata where questionably assigned to the Horsethief Creek Group (Mountjoy et al., 1985) and later with the lower Kaza Group (Mountjoy, 1988). In the Cariboo Mountains, west of the southern Rocky Mountain Trench, strata overlying basement rocks are assigned to the Mica Creek Succession by McDonough and Murphy (1990) and the Basal Windermere by Murphy (1990b). These strata are likely equivalents to cover strata of the Blackman Gneiss (McDonough, M.R. 1990, personal communication). The more generic term, Basal Windermere, will be used herein to refer to the cover strata of the Blackman Gneiss.

## BASAL WINDERMERE

Basal Windermere strata only occur in the hanging wall of the

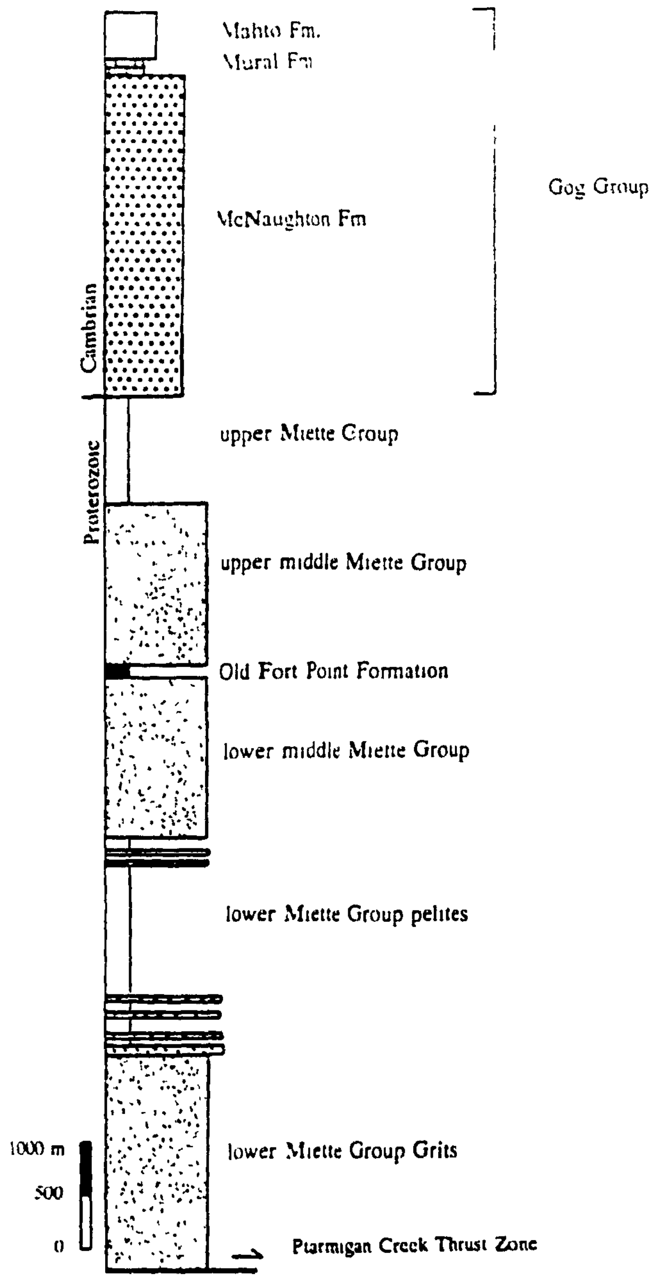



Fig. 2.1 Stratigraphy of the southern Selwyn Range.

Hugh Allan Thrust. The Basal Windermere disconformably overlies the Blackman Gneiss, the two being separated by a mylonitic pelite (Oke and Simony, 1981). The Basal Windermere may be divided here into two units (Leonard, 1985). The lower unit consists of a basal medium grained, grey to white quartzite (250 m thick), a middle 200-900 m thick brown weathering pelite and an upper 1300-3000 m thick sequence of thin bedded (1 m) grits and psammites (60%), and silver coloured pelites (40%). The upper unit consists of 1000 m of brown to green, calcareous pelite, with up to 20% grit beds (1-10 m thick)(Leonard, 1985).

## HADRYNIAN MIETTE GROUP

The Miette Group is divisible into three informal map units (Campbell et al., 1973; Carey and Simony, 1985; Mountjoy and Forest, 1986): 1) lower Miette Group - dominantly dark grey, calcareous pelite, 2) middle Miette Group -amalgamated granule quartzose feldspathic conglomerates (grits) interbedded with green silty pelite, and 3) upper Miette Group - dominantly dark grey to black pelite (Fig. 2.1).

In the core of the Fraser River Antiform, going up stratigraphic section, Miette Group strata consist of: 2500 m of grits, 2500 m of brown to grey weathering dark pelite (structural thicknesses), 3000 m of grits, that contain the Old Fort Point Formation, and 1500 m of black weathering pelites (Figs. 1.2, 1.3). This sequence was originally interpreted as conformable ("thick stratigraphy" interpretation) (Mountjoy et al. 1985; Forest, 1985; Leonard, 1985, McDonough and Simony, 1988b). The lower grit and pelite packages were correlated with the lower Miette Group of the Cushing Creek area (Carey and Simony, 1985), the upper grit package with the middle Miette Group, and the uppermost pelite with the upper Miette Group. However, Dechesne (1990a) proposed that rather than a continuous stratigraphic sequence, the grit and pelite units were repeated by the Selwyn Range Fault (his Selwyn Range Decollement), placing middle Miette Group grits over upper Miette Group Pelites ("thin stratigraphy" interpretation). The two interpretations are illustrated in Figures 1.3 and 1.4.

The "thin stratigraphy" interpretation is inconsistent with structural/stratigraphic constraints discussed in Chapter four. Therefore the lowermost grit and pelite sequence in the southern Selwyn Range are correlated herein with the lower Miette Group.

**Lower Miette Group**

The lower Miette Group can be divided into two units, the basal 'lower Miette Group grits' and the upper 'lower Miette Group pelite'. The lower Miette Group pelite can be further divided into a basal unit characterised by discontinuous lens of quartzites and conglomerates (up to 1 km lateral extent), and an upper unit characterised by more continuous grit units (> 6 km lateral extent) (Fig. 2.2). The upper unit of the lower Miette Group pelites is unfaulted. Below this level, the lower Miette Group is structurally deformed by faulting and folding related to the Ptarmigan Creek Thrust Zone. This makes stratigraphic thicknesses and correlations of the lower part of the lower Miette Group uncertain.

Lower Miette Group Grit

Lower Miette Group grits crop out north of the field area. Mountjoy and Forest (1986) indicate they are superficially similar to the middle Miette Group, in that they consist of amalgamated grit units interbedded with units of green, silty laminated pelites. However, Lower Miette Group grits are distinctly thinner bedded, more calcareous, and contain more abundant brown weathering carbonate units than the middle Miette Group grits (Mountjoy and Forest, 1986; Forest, 1985). The maximum structural thickness of the lower Miette Group grits in the core of the Fraser River Antiform is estimated to be 2500 m.

Dechesne (1990, personal commun.) suggested a carbonate unit observed in this sequence may be correlatable with the Old Fort Point Formation. This would imply this grit sequence was middle Miette Group. This carbonate is highly deformed

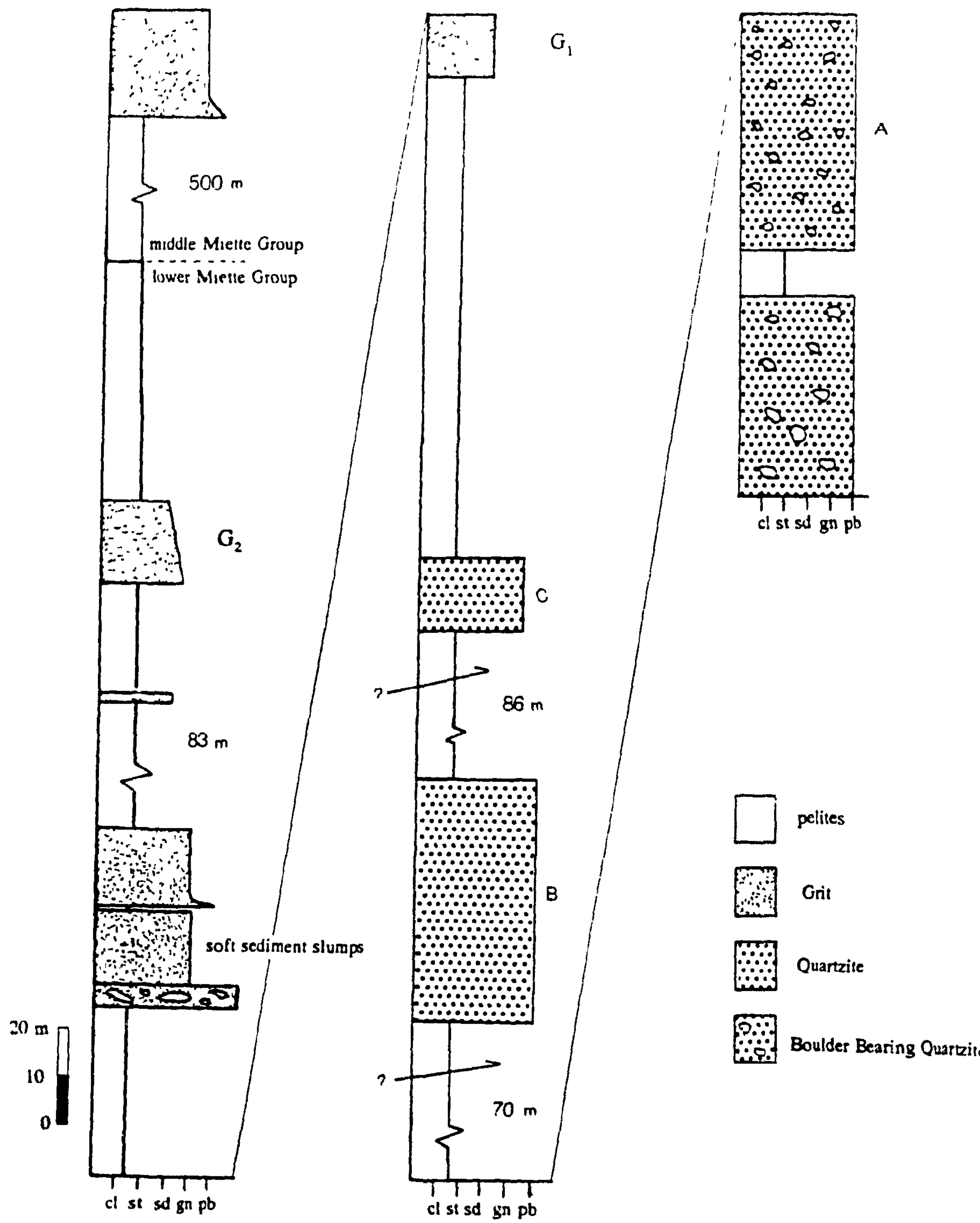



Fig. 2.2 Stratigraphy of the lower Miette Group from the east flank of the Fraser River Antiform. Note that a thick, deformed, pelite occurs below unit A.

by the Ptarmigan Creek Thrust Zone, and can not be positively correlated with the Old Fort Point Formation.

Lower Miette Group Pelite

Lower Miette Group pelites crop out in the northern part of the map area (Fig. 1.2, Appendix I). They consist of dominantly dark grey to black, reddish brown weathering pelite, with common white silty to sandy laminations (mm scale). Framework supported granule to pebble conglomerates are common in the basal unit of the lower Miette Group pelite. Two laterally continuous calcareous grit units ($G_1$ and $G_2$) occur in the upper unit of the lower Miette Group pelites. A maximum structural thickness of the lower Miette Group pelite is estimated at 2500 m on the east flank of the Fraser River Antiform (Fig. 1.2). The lower Miette Group pelites were examined in detail here, and are described below.

Basal Unit of the Lower Miette Group Pelite

A series of discontinuous quartzites occur in the basal unit of the lower Miette Group pelite (Fig. 2.2, A,B & C). These quartzites occur as stacked, or isolated units within the pelite. Typically they have an outcrop length up to 1 km and are 30 to 50 m thick. Along cliff faces, some quartzite units are lens shaped and thin and interfinger with the surrounding pelite. The bedding in pelites, overlying the quartzite units, generally warp down around the edges of the lenses

(Fig. 2.3).

Internally the quartzite units are composed of amalgamated, boulder bearing ( up to 2 m) pebble conglomerates that commonly scour down into underlying units, in channels up to 1 m deep and 5 m across (Fig. 2.4). The well rounded clasts (1-5 cm) are dominantly white and blue quartz (20%) and white quartzite (70%). Abundant carbonate clasts (up to 10%) generally consist of laminated carbonates and sandy carbonates. The quartzite units are dominantly clast supported, with rare feldspar. Pelites adjacent to the quartzites are generally greenish grey, with green silt laminations, as compared to the predominant black pelites that dominate the lower Miette Group pelite.

Some of these quartzite units appear to be isolated, stacked channels, based on: 1) the lensoid shapes of the structures, similar to channel forms, 2) the lateral thinning, fining and interfingering of some quartzites with the surrounding pelites, indicating they are sedimentary structures, and 3) the warping of pelites around the edges of the quartzites, consistent with differential compaction around a preexisting sedimentary feature. Originally, the discontinuous quartzite units, in the basal unit of the lower Miette Group pelite, were interpreted by Mountjoy and Forest (1986) and Mountjoy and Price (1989) as dismembered fault slices of a regionally correlatable unit (their $G_1$). This interpretation was based on the occurrence of the quartzites below G1, and the associated structural deformation. However, the quartz pebble, framework supported, feldspar poor lithology of the quartzites is very distinct from the calcareous, feldspathic, granule conglomerates of $G_1$, making the correlation of the units unlikely.

The extrapolation of faults from the west flank of the Fraser River Antiform, and deformation of some of the quartzite lens, indicate these units have been faulted. It is not certain whether the quartzites are structural repeats of the same unit (i.e. unit A may be equivalent to unit B), a series of stacked channels, or a combination of both. In any case, the quartzites are distinct unit(s) that underlie $G_1$.

### Upper Unit of the Lower Miette Group Pelite

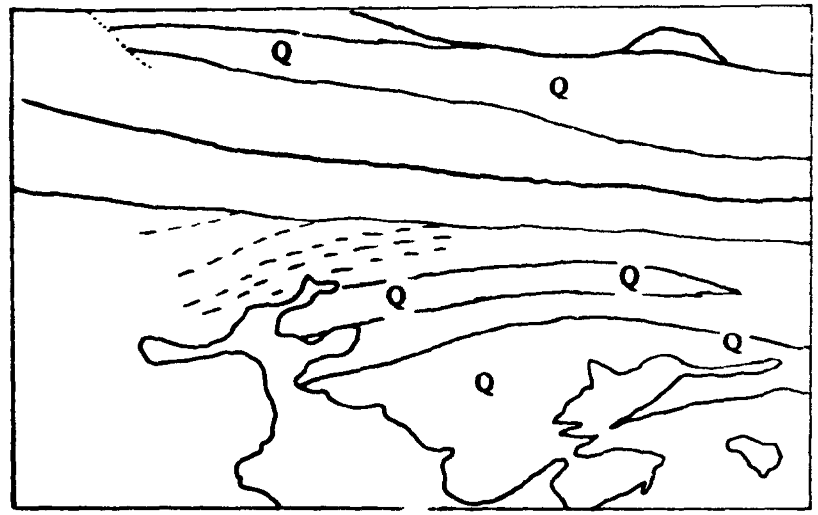
The upper unit of the lower Miette Group pelite is dominated by dark grey to brown weathering pelite as in the basal unit, however, isolated quartzite units are absent. Two grit units ($G_1$ and $G_2$, originally mapped by Mountjoy and Forest (1986)) that occur in the upper unit are laterally continuous for at least 6 km on the east Flank of the Fraser River Antiform (Appendix I). The $G_1$ and $G_2$ units are generally grey to brown weathering, depending on the carbonate content, and consist of well rounded granule quartz, and quartzite clasts, with feldspar up to 15%. Elongate clasts of pelite up to 40 cm long are common. The supporting matrix is dominantly a brown weathering carbonate.

In one locality, (52°32′39″, 118°26′24″) (Appendix I), a 30 m thick composite unit of coarse grained, sand to pebble conglomerate, has a basal 5 m boulder-bearing pebble conglomerate that occurs between $G_1$ and $G_2$. Unique to this boulder conglomerate are abundant cobbles of black pelite, brown weathering, finely laminated carbonate, and boulders of dark grey limestone, up to 2.5 m long (Fig. 2.5). Limestone blocks are finely laminated and some contain abundant spherical carbonate grains (2-4 mm) that are generally recrystallized, but rarely show concentric layers. These spherical grains suggest derivation from a shallow carbonate platform. The coarse sandstone to granule conglomerates overlying the boulder conglomerate are deformed into large (10 m amplitude) isoclinal folds, interpreted as soft sediment slumps, because the bedding immediately surrounding these structures are undeformed (Fig. 2.6). This boulder bearing conglomerate is only exposed for approximately 4 km (Appendix I), pinching out into a shale dominated section to the north. Although it is lithologically similar, it occurs at a higher stratigraphic level than the boulder conglomerate described by Dechesne and Mountjoy (1990b) at the base of their upper Miette Group (referred to here as lower Miette Group pelite).

Fig. 2.3 A. Quartzite lens (resistive cliff forming units) in the basal unit of the lower Miette Group pelite on the east flank of the Fraser River Antiform (52°34′00″, 118°28′10′). The quartzite in the background gradually thins to the northwest, and pelites overlying the quartzite in the foreground drape over the left margin. B. Sketch of A. Q = quartzite.

Fig. 2.4 A. Boulder bearing conglomerate scouring down into underlying coarse sandstone and pelite, in a quartzite lens near the base of the lower Miette Group, 5 km northwest (52°36′30″, 118°30 50 ) of those shown in 2.3. Note the large boulder in the right hand side of the photo. B. Close-up of the channel margin on the left hand side of the channel shown in A.

2.3a




2.3b

2.4a

2.4b

On the west flank of the Fraser River Antiform, the lower Miette Group pelite is dominantly brown, rusty weathering, silt laminated pelite. Brown weathering beds of grit to quartzite (10-20 cm thick) are common. Two (sometimes three) thick mappable quartzite units occur approximately 1000 m above the base of the lower Miette Group pelite (Appendix I). These units consists of relatively pure, fine to coarse grained, finely laminated to cross-bedded quartz sandstones. Quartz pebble conglomerates, 2 to 5 cm thick with some white angular feldspar (up to 1 cm), locally occur at the base of these quartzites. The closest equivalent to these units in the lower Miette Group pelites on the east flank would be the quartzite units (Fig. 2.2, A,B & C) of the basal unit. If this correlation is correct the upper part of the lower Miette Group pelites (containing $G_1$ and $G_2$) is absent. This may be explain by a stratigraphic pinch out, or more likely, structural truncation of the upper part of the lower Miette Group by the Selwyn Range Fault (see Chapter 4).

**Middle Miette Group**

The middle Miette Group is divisible into three stratigraphic units, a lower grit dominated sequence (about 1500 m), a middle, regionally distinctive, Old Fort Point Formation (50-100 m) (Ross and Murphy, 1988; McDonough and Simony, 1988b; Dechesne and Mountjoy, 1990a; Kubli, 1990), and an upper grit

Fig. 2.5 Boulder-bearing conglomerate in the upper unit of the lower Miette Group pelites (52°32′39″, 118°26′24″).

Fig. 2.6 A loose block of isoclinal soft sediment folds, that immediately overlie the boulder conglomerate in Fig. 2.5.

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dominated section (1500 m). A reliable thickness for the middle Miette Group (3000 m) was obtained from a composite section of relatively undeformed strata on the east flank of the Fraser River Antiform and at Saddle Mountain (Appendix 1).

The two grit dominated sequences are designated as upper and lower middle Miette Group. They consist of dominantly composite-bedded grit units 10-100 m thick, interbedded with thick (10-40 m) pelites. Individual grit beds (10-30 cm) are poorly sorted, and grade upward from pebble to granule-conglomerate, into coarse sandstones (Bouma $T_{aa}$, $T_{ab}$, $T_{ae}$). Clasts are angular and dominantly consist of white, smoky, and blue quartz, in order of decreasing abundance. Feldspar is common, ranging from 3-15%. Clasts are supported in an argillaceous to calcareous matrix. The Middle Miette grit beds have a much lower carbonate content, and are thicker bedded than in the lower Miette Group (Mountjoy and Forest, 1986). Interbedded with the composite grit units are distinctive grey-green, chloritic pelite units with abundant green silty laminations. The pelite units (10-40 m-thick) generally show sharp contacts with underlying and overlying grit units.

The Old Fort Point Formation is correlated from its type area near Jasper, westward to Mount Robson and then to the Fraser River Antiform west of the Chatter Creek Fault (Dechesne and

Mountjoy, 1990a; McDonough and Simony, 1988b). The Old Fort Point Formation consists of a distinctive tripart sequence of green pelite overlain by a banded carbonate and capped by a black pelite (Ross and Murphy, 1988; Charlesworth et al., 1967; McDonough and Simony, 1988b; Dechesne and Mountjoy, 1990a; Mountjoy and Grasby 1990). The Old Fort Point Formation has been instrumental in elucidating the structural and stratigraphic relations of the southern Selwyn Range (Mountjoy and Grasby, 1991).

The use of the Old Fort Point Formation as a marker unit is dependent on the assumption that such a lithologically distinctive tripart sequence occurs only once in the Miette Group. A tripart sequence occurs only once, at the base of an unfaulted stratigraphic section at Saddle Mountain (Fig. 1.2), underlying the upper 1500 m of the middle Miette Group. It does not occur in the overlying upper Miette Group. North to the Lucerne Map area (McDonough and Simony, 1988a, Dechesne and Mountjoy, 1990a), on the east flank of the Fraser River Antiform (Fig. 1.2), the lower middle Miette Group and the underlying lower Miette Group are exposed. Here again, only one tripart carbonate sequence occurs, approximately 1500 m above the lower/middle Miette Group contact (Mountjoy, personal comm.). In the southern Selwyn Range, the marked similarity in the facies of the tripart carbonate bearing sequences, wherever exposed in the field area, strongly suggests that this marker represents the same stratigraphic unit. Thus it is assigned to the Old Fort Point Formation.

Lower middle Miette Group

The lower middle Miette Group crops out in two areas, the east flank of the Fraser River Antiform and the hanging wall of the Blackman Thrust. The lower middle Miette Group is estimated to be 1.5 km thick on the east flank of the Fraser River Antiform. The lower middle Miette Group consists of amalgamated grit units (15-20 m), consisting of beds up to 1.3 m thick. Beds grade upwards from pebble to granule to coarse sand (Bouman $T_{ab}$, $T_{ae}$ sequences). Clasts are dominantly quartz and white quartzite, with less abundant clasts of brown laminated carbonate, rusty weathering carbonate and green silty pelite (10-40 cm). Feldspar is common, making up to 15% of the grits. Grit sequences are interbedded with units of green weathering, silty pelite up to 20 m thick. The basal 500 m of the lower middle Miette Group, on the east flank of the Fraser River Antiform, is dominated by green pelite. Unique to these pelites (and the shaled out facies of the upper middle Miette Group) are isolated thin beds (cm-to dm-scale) of calcareous, brown weathering, coarse to fine-grained sandstone. Less common are isolated ripple-laminated lenses of fine sandstone or siltstone inferred to be starved ripples.

## Old Fort Point Formation

The Old Fort Point Formation at Saddle Mountain is notably thinner, 98 m compared to 120 m in the northern Selwyn Range (McDonough, 1989), 305 m at Waddington Peak (Dechesne, 1990b), and 365 m in the type area at Jasper (Charlesworth et al., 1967). This thickness variation is due to a thinner basal green pelite than noted by McDonough (1989), and the absence of a 138 m thick green pelite, overlying the black pelite cap, in the Waddington Peak section. In the southern Selwyn Range there is a slight westward thickening trend of the basal pelite (member I) and overlying carbonate (member II)(Fig. 2.7).

A complete section of the Old Fort Point Formation (98 m) was measured at Saddle Mountain (Fig. 2.8). Five units are recognised in this section. Using the terminology proposed by Dechesne (1990b), they are the lower and upper units of member I, the lower and upper units of member II and member III. These units always occur in the same stratigraphic order. Dechesne's (1990b) members IV (debris flow) and V (thick green pelite) are not present at Saddle Mountain.

### Member I

This member is divisible into a lower sandstone and upper green silty pelite. The contact of the lower unit of member I with the underlying 40 m thick grit unit (of the lower

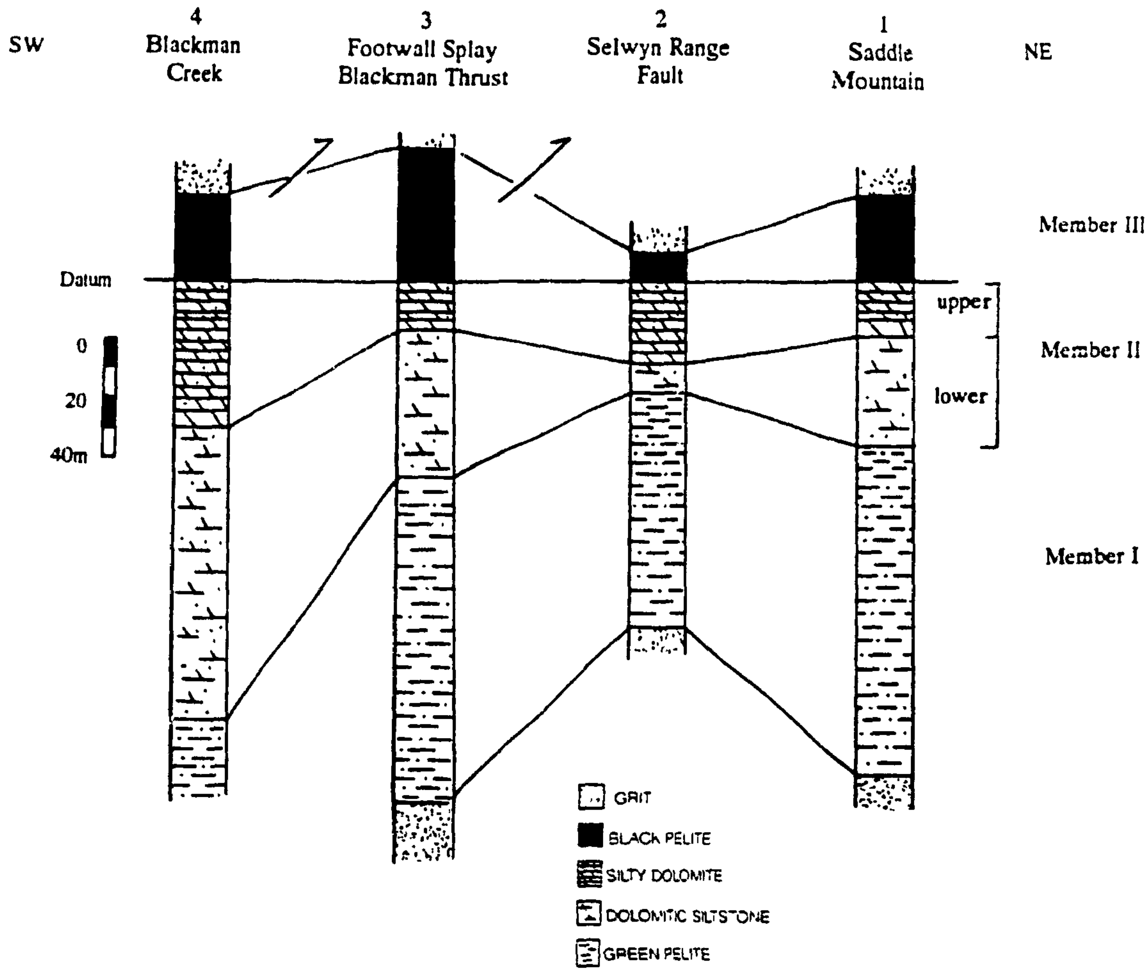



Fig. 2.7 Correlation of the Old Fort Point Formation from four localities (west to east) in the field area (see Fig. 2.10 for locations).

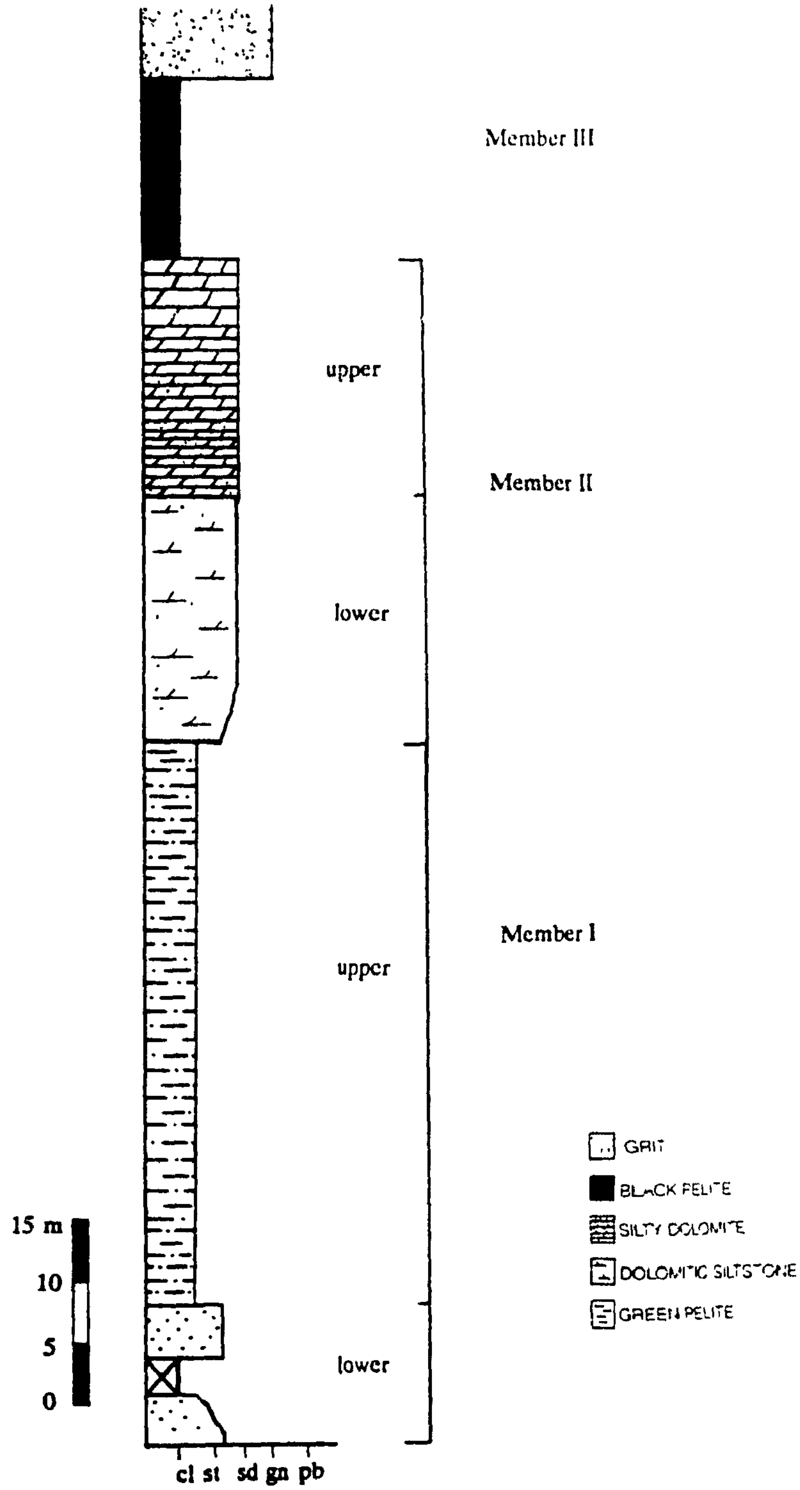



Fig. 2.8 Stratigraphic section of the Old Fort Point Formation at Saddle Mountain (location 1 Fig. 2.10)

middle Miette Group), is gradational and is marked by a fining and thinning upward sequence of granule conglomerate to interbedded light grey to brown calcareous sandstone (10-15 cm thick) and olive green, silty laminated, pelite. The lower contact of this unit is arbitrarily placed at the last thick (>1 m) grit bed. Sandstone beds, in the lower unit of member I, have sharp bottoms and generally grade up from planar laminated to crossbedded sands, and then into the overlying pelite layer. These beds generally exhibit Bouman $T_{bcde}$ sequences. The lower unit of member I grades into the upper unit and the contact is placed at the last siltstone bed < 20 cm. The upper unit is dominantly silty, bright green, thin bedded to laminated pelite. Sandstone beds are absent, and siltstone beds (1 cm) are rare.

Member II

This member represents the banded carbonate in the middle of the Old Fort Point Formation, and is divisible into a lower dolomitic siltstone and upper white carbonate. The contact of the lower unit with the underlying member I is gradational, and is placed at the first occurrence of laminated, brown weathering siltstone. The lower unit consists of laminated brown, dolomitic siltstone, olive green pelite, and interspersed, white, cross laminated carbonate layers (5-20 cm thick). Dolomitic siltstone dominates the facies, with carbonate layers becoming more abundant upwards. Pyrite is abundant.

The contact of the upper and lower units of member II is gradational. The contact is placed where the white, cross laminated carbonate units dominate the section (> 50%). The white carbonate layers (5-20 cm thick) are massive to cross laminated, with climbing ripples. The carbonate layers weather orange brown and are interbedded with dark brown weathering, dolomitic, siltstone and laminated green pelite (1-5 cm). Carbonate beds become thicker and more abundant upwards (>95%). Pelites form millimetre-scale laminae.

Member III

Member III abruptly overlies member II. It consists of dark grey to black, graphitic pelite, with disseminated pyrite. This facies is sharply overlain by a 30 m thick grit unit.

Upper middle Miette Group

In much of the region, the upper middle Miette Group consists of a sequence of interbedded grit and pelite units, typified by the section at Saddle Mountain (described below). From east to west, across three thrust sheets, a gradual facies change from normal coarse grits and silty pelites (at Saddle Mountain) to pelites lacking grits (on the west flank of the Fraser River Antiform) can be demonstrated in the upper middle Miette Group in the southern Selwyn Range (Fig. 2.9). To illustrate these lateral variations, the upper middle Miette Group is described from four locations in the southern Selwyn Range, from east to west: (1) the hanging wall of the Selwyn Range Thrust at Saddle Mountain (locality 1, Fig. 2.10), (2) hanging wall of the Selwyn Range Fault on the west flank of the Fraser River Antiform (locality 2, Fig. 2.10), (3) hanging wall of the lower unnamed thrust (locality 3, Fig. 2.10), and (4) hanging wall of Blackman Thrust (locality 4, Fig. 2.10). A similar facies change is inferred from oblique and air photos near Canoe and Athabasca passes (Mountjoy and Grasby, 1991) (Figs. 2.11,12).

Saddle Mountain

A complete stratigraphic sequence of the upper middle Miette Group is exposed at Saddle Mountain, on the southern plunge of the Fraser River Antiform (Fig. 1.2). Amalgamated grit units range from 10-40 m-thick. Individual beds (10-30 cm-thick) are poorly sorted, grading upwards from basal granule-to pebble-conglomerate to a coarse-grained sandstone. Interbedded with the grit units are green pelites with silty laminations (10-20 m-thick).

Hanging wall of the Selwyn Range Thrust

Much of the hanging wall of the Selwyn Range Thrust comprises a thick (1,000 m) unit of green, silty pelites. Originally assigned to the upper Miette Group, by Leonard (1985), this

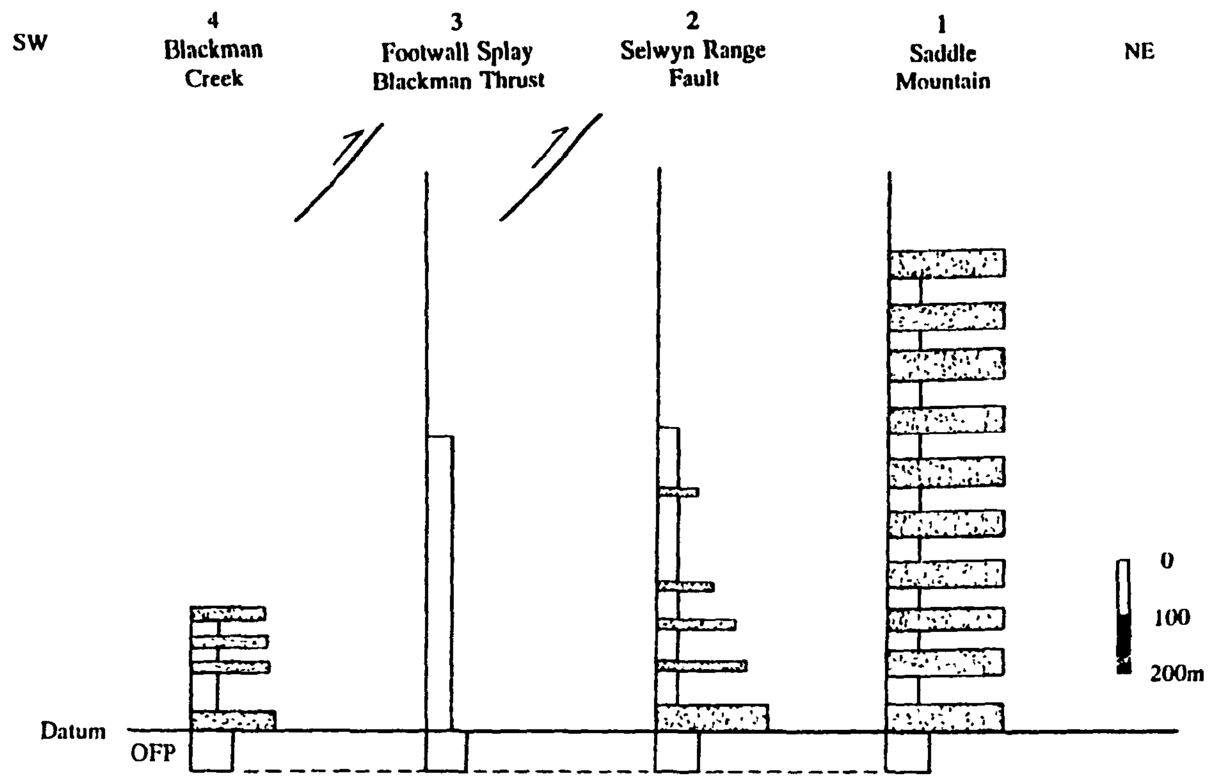



Fig. 2.9 Schematic diagram illustrating facies variations in the middle Miette Group. See Figure 2.10 for location of sections.

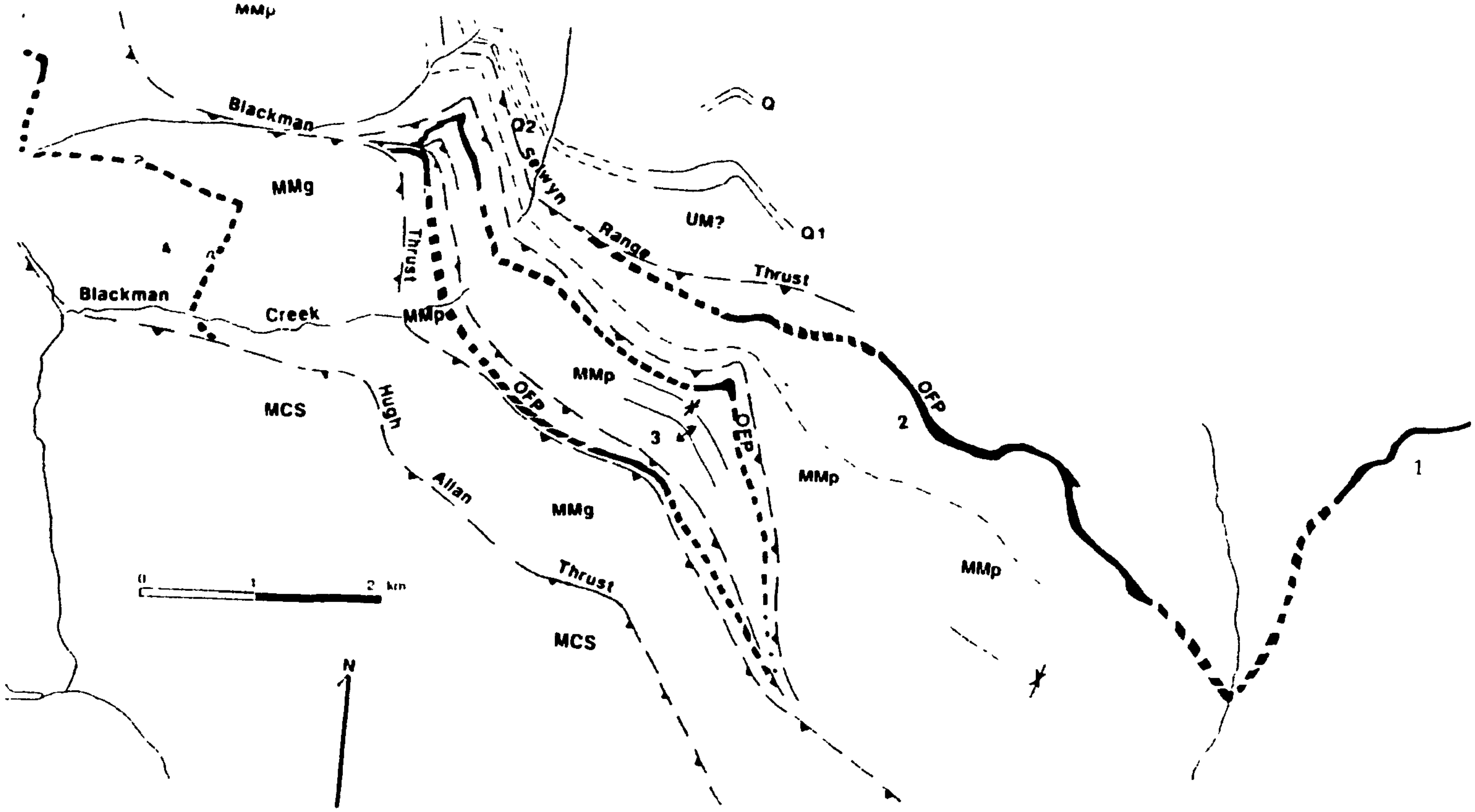



Fig. 2.10 Simplified geologic map of the area between Hugh Allan Thrust and the Selwyn Range Fault, in the western part of the field area. Numbers 1,2,3,4 are locations discussed in text and in Figs. 2.7 & 2.9.

Fig. 2.11 Sketch from photographs showing facies change of composite grit units to pelite in the upper most 300 m of the middle Miette Group strata at the head of Iroquois Creek, 5 km northwest of Athabasca Pass (see Fig. 2.12 for location). Vertical exaggeration is approximately 2 times.

Fig. 2.12 Generalised geological map of Canoe and Athabasca passes showing rapid facies change of top of the middle Miette Group grits into pelites

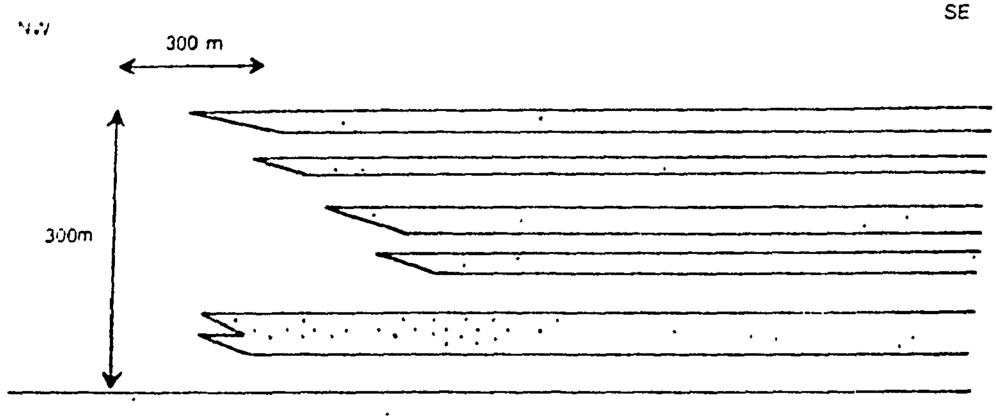



Fig 2.11

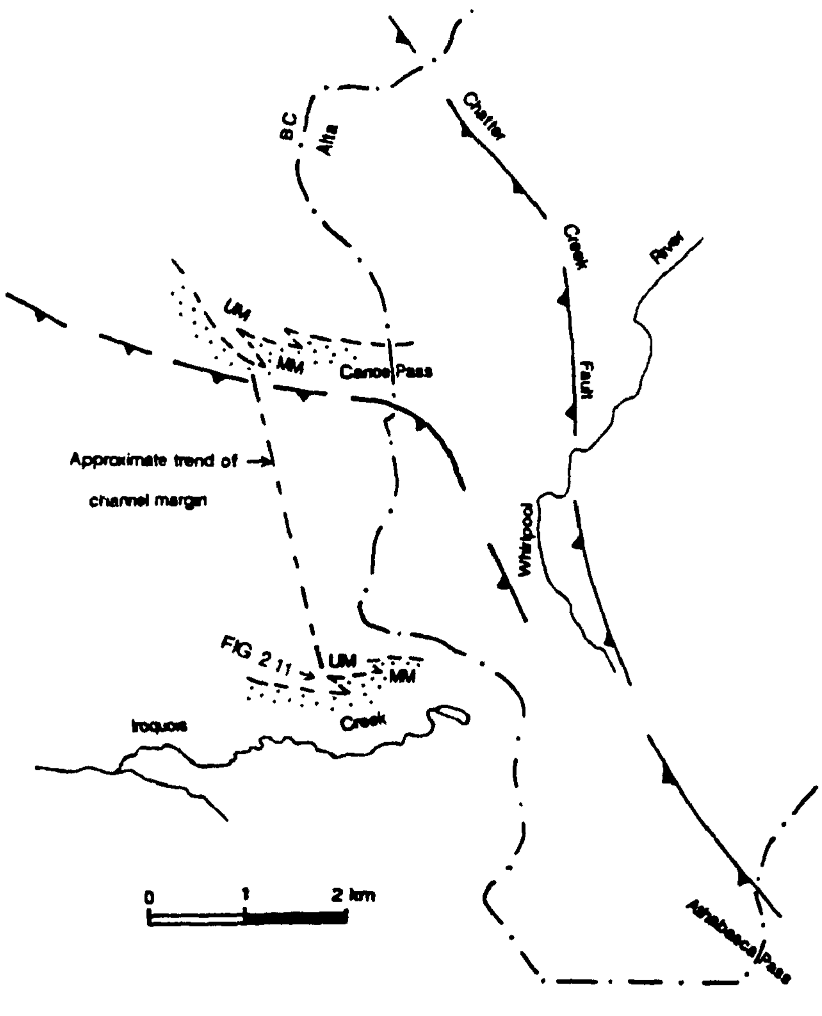



Fig 2.12

unit is now considered to be middle Miette Group, due to the presence of the Old Fort Point Formation conformably beneath it. Above the Old Fort Point Formation, grit packages are notably thinner (10-15 m-thick), more widely spaced, and finer-grained than on Saddle Mountain to the southeast. About 200 m above the Old Fort Point Formation, grits are absent and silty green pelite becomes predominant, with only minor units of coarse-grained, calcareous sandstone (up to 6 m-thick) present (Fig. 2.9). Pelites are greyish-green, chloritic, and contain the abundant silty laminations that are characteristic of pelites in the middle Miette Group. This sequence appears to be transitional to the pelite lacking grits in the unnamed thrust slice to the southwest.

Footwall splay of Blackman Thrust

Strata in this thrust slice are almost entirely silver-grey to green pelite with abundant green, silty laminations characteristic of the middle Miette Group. However, unique to this facies are isolated thin beds (cm- to dm-scale) of calcareous, brown weathering coarse to fine-grained sandstone. Less common are isolated ripple-laminated lenses of fine sandstone or siltstone inferred to be starved ripples. Occasionally sandstone beds occur in composite units up to 5 m-thick. These strata are estimated to be over a kilometre thick. The presence of the Old Fort Point Formation in this sequence indicates that it is part of the middle Miette Group.

Blackman Thrust Sheet

Only 100 to 200 m of upper Middle Miette Group strata are exposed in the Blackman Thrust Sheet, north of Blackman Creek (Fig. 2.10). These strata are predominately pelites, containing a few grit units up to 5-10 m thick. This may represent part of the middle Miette Group pelite (see below).

**Middle Miette Group contacts**

The upper and lower middle Miette Group contacts have traditionally been placed at the first and last thick mappable grit units (Campbell, et al., 1973; Carey and Simony, 1985; Mountjoy and Forest, 1986; Mountjoy and Grasby, 1990). Working in the northern Selwyn Range, McDonough and Simony (1988b), McDonough (1990 - personal commun.) noted there is a distinct change from grey/black pelite in the lower Miette Group to silty green pelite in the middle Miette Group. They also noted a similar change from silty green pelite to black pelite at the upper/middle Miette Group boundary. They defined the basal middle Miette Group contact as the base of the first thick-bedded grit unit, above which silty green pelite is most common. The upper middle Miette Group contact was defined as the last grit above which silty green pelite is rare to absent. McDonough and Simony (1988b) consider that the change in pelite character is as important as the presence or absence of grits, in mapping the middle Miette Group contacts.

Using only the presence of grits to map the middle Miette Group contacts would include silty green pelite dominated strata, that contain the Old Fort Point Formation (described above), in either the lower or upper Miette Group pelite. However the presence of the Old Fort Point Formation indicates that the silty green pelite strata are a lateral equivalent of the grit dominated sections of the middle Miette Group and therefore should be included in the middle Miette Group. Since middle Miette Group generally refers to a litho-stratigraphic unit dominated by grit bearing strata, the silty green pelite facies is referred herein as the "middle Miette Group pelite". This term refers to a silty green pelite facies that can occur in either the upper or lower middle Miette Group.

### Lower/middle Miette Group Contact

On the east flank of the Fraser River Antiform, the lower middle Miette Group is characterised by a thick sequence of interbedded grit units and pelites. These grits are underlain by a 500 m sequence of green silty pelites (middle Miette Group pelite). A sharp change (over 2 m) occurs at the base of the middle Miette Group pelite, to black, reddish brown weathering pelites, typical of the lower Miette Group. This change defines the lower/middle Miette Group contact (Appendix 1).

Middle/upper Miette Group Contact

The "last grit" criteria is difficult to use in mapping the middle/upper Miette Group contact, due to the facies variations of the middle Miette Group. The change from silty green pelites (middle Miette Group pelite), to the dark grey to black pelites of the upper Miette Group, is used to map the contact in pelite dominated sections of the middle Miette Group (McDonough and Simony, 1988b; Mountjoy and Grasby, 1991). The silty green pelite dominated sections containing the Old Fort Point Formation (middle Miette Group pelite), on the west flank of the Fraser River Antiform (originally mapped as upper Miette Group, Leonard (1985)) are classified herein as middle Miette Group.

**Middle Miette Group pelite**

The rapid facies change of upper middle Miette Group grits to middle Miette Group pelite, delineates a facies margin running approximately northeast-southwest in the southern Selwyn Range. To the north this margin must either die out or occur west of the upper middle Miette Group grit units mapped by McDonough (1989), McDonough and Mountjoy (1990). The upper/middle Miette Group boundary is difficult to continue south of Hugh Allan Creek, although pelite dominated sections of the upper middle Miette Group are locally important in the northern Park Ranges (Klein, 1991; Lickorish, H. 1991 - personal communication). In the northern Cariboo Mountains an eastward facies change to pelite dominated strata has also been mapped in the Kaza Group (middle Miette Group equivalents)(Ferguson and Simony, 1991).

Paleocurrent data from the Miette Group in the Rocky Mountains give a broad range of transport directions, however the dominant direction is towards the northwest, suggesting middle Miette Group grits were deposited in a basin trending northwest-southeast, with longitudinal transport of sediments towards the northwest (Ross et al., 1989). McDonough (1990) suggested that stacked channels in the middle Miette Group (up to 100 m thick and 10 km wide) delineated a longitudinal trough (the Selwyn Trough) in the northern Selwyn Range. Similar canyon fill features have also been described to the south at Redoubt Mountain, in the Lake Louise area. The facies variation mapped in the field area may represent the margin of a similar canyon fill feature, trending approximately parallel to tectonic strike, in the southern Selwyn Range. Alternatively, the facies variation may represent a distal equivalent to the clastic dominated portion of a deep sea fan (i.e. the grit dominated portion of the middle Miette Group to the east). One difficulty with the latter interpretation is the extensive deposits of middle Miette Group equivalent grits further to the west. Clearly, detailed work on the stratigraphy of this area is needed to better elucidate the nature of these facies changes.

**Upper Miette Group**

Some of what was previously mapped as upper Miette Group in the southern Selwyn Range has been reassigned as "middle Miette Group pelite" middle Miette Group (see above). Upper Miette Group strata crop out at two localities in the map area, at Saddle Mountain and near Canoe Pass (Fig. 1.2). Only the lower 330 m are exposed. More complete sections occur to the south on the west limb of the Porcupine Creek Anticlinorium (Klein and Mountjoy, 1988; Klein, 1991). Upper Miette group strata are dominantly dark grey to black pelites with thin (2-3 cm thick) ripple laminated, white siltstone layers, weathering brown to rusty red. Ripple laminated silt layers generally have sharp bottoms and grade up into the overlying pelite (Bouma $T_{de}$ sequences). Isolated units of grit (1-10 m thick) occur in the lower upper Miette Group. These units tend to become more quartz rich and are dominantly quartzites higher in the section. Just south of Canoe Pass (Fig. 1.2) a 10 m thick dark grey to black, finely laminated carbonate occurs approximately 250 m above the base of the upper Miette Group. A distinctive boulder bearing conglomerate and carbonate that occurs near the base of strata Dechesne and Mountjoy (1990b) assigned to the upper Miette Group, is absent in strata assigned to the upper Miette Group in the southern Selwyn Range. As well, the carbonate unit in the upper half of the upper Miette Group, on the west limb of the Porcupine Creek Anticlinorium south of Hugh Allan Creek

(Klein and Mountjoy, 1988; Gal et al., 1989; Lickorish and Simony, 1991), is absent.

## LOWER CAMBRIAN GOG GROUP

The Gog Group only occurs in the southeast portion of the map area, in the footwall of the Chatter Creek Fault. The Gog Group is divided into three formations: a lower McNaughton Formation of coarse grained, quartz sandstone (about 3000 m thick), a middle Mural Formation of light grey carbonate interbedded with shales and siltstone (about 165 m thick), and an upper Mahto Formation of fine-grained, quartz sandstone (about 450 m thick) (Mountjoy and Price, 1989).

### McNaughton Formation

The McNaughton Formation, where observed near Mallard Peak, is dominantly a clean, white to pink, coarse sand to granule quartzite with planar crossbedding. Composite beds are 10-30 cm thick with occasional thin partings of green pelite (up to 5 cm). Quartzite clasts consist of green and red quartz. White quartzite pebbles up to 1 cm occur at the bases of some quartzite beds. Feldspar is rare (<3%), both pebbles and feldspar are more abundant near the base of the formation.

### Mural Formation

The Mural Formation was observed in scattered outcrops in the footwall of the McGillivray Thrust, east of Mallard Peak. The

Mural Formation consists of massive, finely crystalline, grey, micritic limestone containing archaeocyathid and olenellid fragments. Often massive carbonates occur at the top and bottom of the formation with the middle portion consisting of silty to calcareous shales.

**Mahto Formation**

The Mahto Formation consists of brown weathering, thin to medium bedded, crossbedded, fine to medium grained sandstones with interbeds of siltstone and silty shales.

**MIDDLE CAMBRIAN**

**Snake Indian Formation**

The Snake Indian Formation is dominantly a recessive weathering unit between the Gog Group and the overlying resistant Eldon Formation (Mountjoy and Atkien, 1978). It consists of alternating grey, argillaceous limestone, and sandy dolomite and recessive, calcareous, grey shales. In the adjacent Amethyst Lakes area it is approximately 1000 m thick (Mountjoy and Price, 1989).

# CHAPTER 3 - STRUCTURE

## INTRODUCTION

This chapter gives a detailed description of structural elements in the southern Selwyn Range. A summary of the structural/metamorphic evolution of the southern Selwyn Range is given in Chapter 6.

Three main phases of deformation are recognised in the southern Selwyn Range. The earliest phase of deformation ($D_1$) is southwest-verging, poorly preserved and restricted to the hanging wall of the Hugh Allan Thrust (Leonard, 1985; Charland, 1989). Two post $D_1$ phases of deformation ($D_2$ and $D_3$) are northeast-verging and ubiquitous in the southern Selwyn Range. Second phase ($D_2$) structures are characterised by recumbent isoclinal folds with an associated pervasive micaceous cleavage ($S_2$), and low angle thrusts. Third phase structures are characterised by upright open folds, with near vertical crenulation cleavages ($S_3$), and steeply dipping faults. Third phase folds coaxially fold second phase folds and fold the $S_2$ foliation. The $S_3$ foliation crenulates $S_2$ foliations.

Post $D_3$ fabrics are observed sporadically throughout the field area, they include a crenulation transverse to regional structural trends, and late, west-verging, minor kink folds. The

Chatter Creek Fault, Hugh Allan Thrust and an unnamed fault (in the hanging wall of the Hugh Allan Thrust) were reactivated by $D_3$ or later dextral motion.

The dominant structure of the Selwyn Range is the broad regional scale, doubly-plunging Fraser River Antiform. The antiform is characterised by gently southwest and northeast dipping limbs. The antiform folds both bedding and the $S_2$ cleavage, indicating it is a $D_3$ structure. Towards the north, the Fraser River Antiform culminates around Ptarmigan Creek and changes plunge direction to the northwest.

## FAULTS

Faults in the field area are described below, from west to east are: unnamed thrust, Hugh Allan Thrust, Blackman Thrust, Ptarmigan Creek Thrust, Chatter Creek Fault, and McGillivray Fault (Appendix I). The Selwyn Range Fault (which occurs in the middle of the field area) is described and discussed in chapter 4.

### UNNAMED FAULT WEST OF HUGH ALLAN THRUST

Thick grey to brown weathering marble calcsilicate of uncertain affinity are juxtaposed against Basal Windermere stratigraphy, in the hanging wall of the Hugh Allan Thrust, by an unnamed fault (Leonard, 1985; Mountjoy, 1988) (Appendix I). Rocks in the immediate hanging wall of the unnamed fault are characterised by elongate pods of quartz, and crushed garnet (Fig. 3.1). Vertical shear planes adjacent to the fault trend north-south. Two sets of slickenlines occur on these surfaces. The first set plunge 10° to the north, with steps showing dextral offset, and the second set plunge 65° to the south, with steps indicating west side up motion.

**HUGH ALLAN THRUST**

The Hugh Allan Thrust is a low-angle fault placing Basal Windermere stratigraphy, over middle Miette Group rocks, in the western portion of the field area. The fault cuts up section, in the footwall and hanging wall, at a low angle to bedding (Mountjoy, 1988). The hanging wall is dominated by the early $D_2$ northeast-verging, recumbent, Blackman Anticline, cored by the Blackman Gneiss (Oke and Simony, 1981; Leonard, 1985; Charland, 1989). Hanging wall strata of the Hugh Allan Thrust have a distinctive well developed biotite foliation in grit bands, that helps distinguish hanging wall from footwall rocks.

Just north of Hugh Allan Creek (52°26′, 118°30′), the Hugh Allan Thrust is characterized by a 50 cm shear zone of highly deformed pelite, with a penetrative fabric parallel to the shear zone boundaries. Splays subparallel to the main shear zone slice grits into lens shaped pods 50 cm by 1 m. These splays are infilled with quartz and carbonate. A penetrative

($D_2$) fabric in grits below the main shear zone is progressively rotated into parallelism with the shear zone, with a top to the northeast sense of vergence. At a second locality, north of Blackman Creek (52°32′50 , 118°41′00″), Charland (1989) observed $D_2$ orogen parallel lineations in the footwall of the Hugh Allan Thrust (her Vallee Thrust), similar to those in the Bearfoot Thrust, observed by McDonough and Simony (1988a, 1989). Also at this locality, northeast-trending vertical shear planes are well developed next to the fault. Slickenlines on these surfaces plunge at 55° to the south, with steps indicating oblique, dextral slip.

On the ridge north of Hugh Allan Creek, the Hugh Allan Thrust can be "walked out" around the hinges of a series of upright $F_3$ folds. A synmetamorphic crenulation cleavage associated with the $F_3$ folds (see Chapter five) clearly cross cuts the penetrative fabric of the fault zone. The fault's low angle nature, relative timing to $D_3$ structures, and northwest vergence are all consistent with the Hugh Allan Thrust being a $D_2$ structure.

Leonard (1985) correlated the Hugh Allan Thrust with the late stage Purcell Thrust of (McDonough, 1984). Mountjoy (1988) demonstrated that the Hugh Allan Thrust was an early fault, making the correlation with the late stage Purcell Thrust unlikely. North of Blackman Creek, the Vallee Thrust of

Charland (1989), places basal Windermere strata on middle Miette Group strata. This fault occurs along strike and can be traced into the Hugh Allan Thrust (Fig. 1.2), suggesting these two faults are correlatable. The Hugh Allan Thrust likely correlates with the Bearfoot Thrust, in the northern Selwyn Range (Mountjoy et al., 1985; Mountjoy and Forest, 1986; McDonough and Mountjoy, 1990; Murphy, 1990b).

**BLACKMAN THRUST**

The Blackman Thrust is a low-angle fault placing lower middle Miette Group strata over upper middle Miette Group strata (Fig. 1.2). The fault is difficult to map, hcwever it can be recognised by the truncation of grit units and the Old Fort Point Formation (Fig. 1.2), and by an increase in finite strain in hanging wall and footwall rocks near the fault zone. In thin section, pelites near the fault have well developed S-C fabrics (Berthé et al., 1979), indicating top to the northeast-vergence (Fig. 3.2).

At least two unnamed faults occur as splays in the footwall of the Blackman Thrust following a detachment horizon just below the Old Fort Point Formation, along the ridge north of Blackman Creek, (Figs. 1.2, 2.10, 3.3). These faults must merge with the Blackman thrust to the north as they do not continue across the unnamed creek 2.5 km northwest of Blackman Creek. The southern extent of these faults is difficult to constrain, however they do not occur in the east limb of the Porcupine Creek Anticlinorium (Mountjoy and Grasby, 1991; Klein and Mountjoy, 1988; Klein, 1991) suggesting that they merge with the Blackman Thrust to the south as shown in Figure 2.10. The low angle nature of the Blackman Thrust, and associated faults in the footwall, is consistent with these faults being related to $D_2$.

The Blackman Thrust can be correlated across Hugh Allan Creek with a fault or faults that occur in the core of the Porcupine Creek Anticlinorium (Klein, 1991; Mountjoy, unpublished data), suggesting shortening of the Porcupine Creek Anticlinorium is taken up by the Blackman Thrust north of Hugh Allan Creek.

**PTARMIGAN CREEK THRUST ZONE**

The Ptarmigan Creek Thrust zone is a $D_2$ fault that is folded by the Fraser River Antiform (Forest, 1985; Mountjoy and Forest, 1986). It crops out as a window in the core of the antiform just north of the field area. The zone is characterised by highly deformed grit units that are faulted, and folded into isoclinal folds with attenuated, overturned limbs. The total shortening in the zone is estimated to be about 18 km (Dechesne and Mountjoy, in press).

**CHATTER CREEK FAULT**

The Chatter Creek Fault juxtaposes Miette Group strata against

Fig. 3.1 Photomicrographs of crushed pods of garnet in the Canoe Fault zone (SEG89-199A).

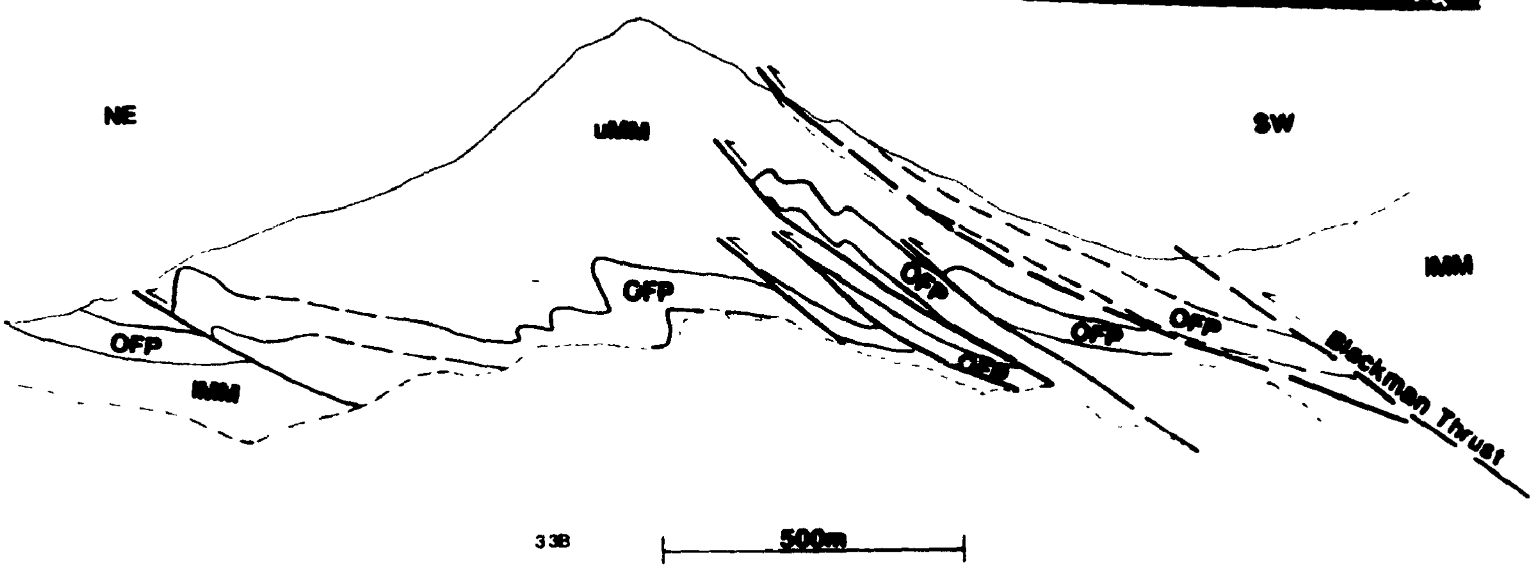
Fig. 3.2 S-C fabrics from the Blackman Thrust fault zone, indicating top to the east vergence (SEG90-18).

Fig. 3.3 Photograph (A) and sketch (B) of deformation in the footwall of the Blackman Thrust.


3.1

3.2

33A




33B

Lower Paleozoic and upper Proterozoic strata (mostly Gog Group) along its length between Mount Robson and the Wood River. Near Mallard Peak (Fig. 3.4), the Chatter Creek Fault crops out as a discrete zone, easily recognised by the juxtaposition of brown weathering upper Miette Group pelites against the resistant, near vertical cliff face of Gog Group quartzites (Fig. 3.5). Just north of Mallard Peak the vertical dip of the Chatter Creek Fault can be seen in a steep valley with over 500 m of vertical relief. In outcrop immediately west of Mallard Peak (Fig. 3.4) the fault is defined by a zone (up to 1 m thick) of highly deformed upper Miette Group brown pelite and calcareous sandstone, with abundant chlorite and carbonate-bearing quartz veins.

Two sets of folds (10-20 cm amplitude) are observed within the fault zone. One set is characterised by shear folds, defined by rotation of the vertical fault zone fabric on the long limbs, to horizontal on the short limbs, with subhorizontal northwest-trending fold axes, similar to the regional $D_3$ folds. The second set of folds are vertical (fold axes plunge 90°), and show a dextral shear sense. No overprinting of folds was observed, so their relative ages are uncertain. Footwall rocks contain a set of north-south trending vertical shear planes next to the Chatter Creek Fault. The spacing between shear planes decreases from 10 cm next to the fault zone, to 1-2 m, 120 m away from the zone. The shear plane

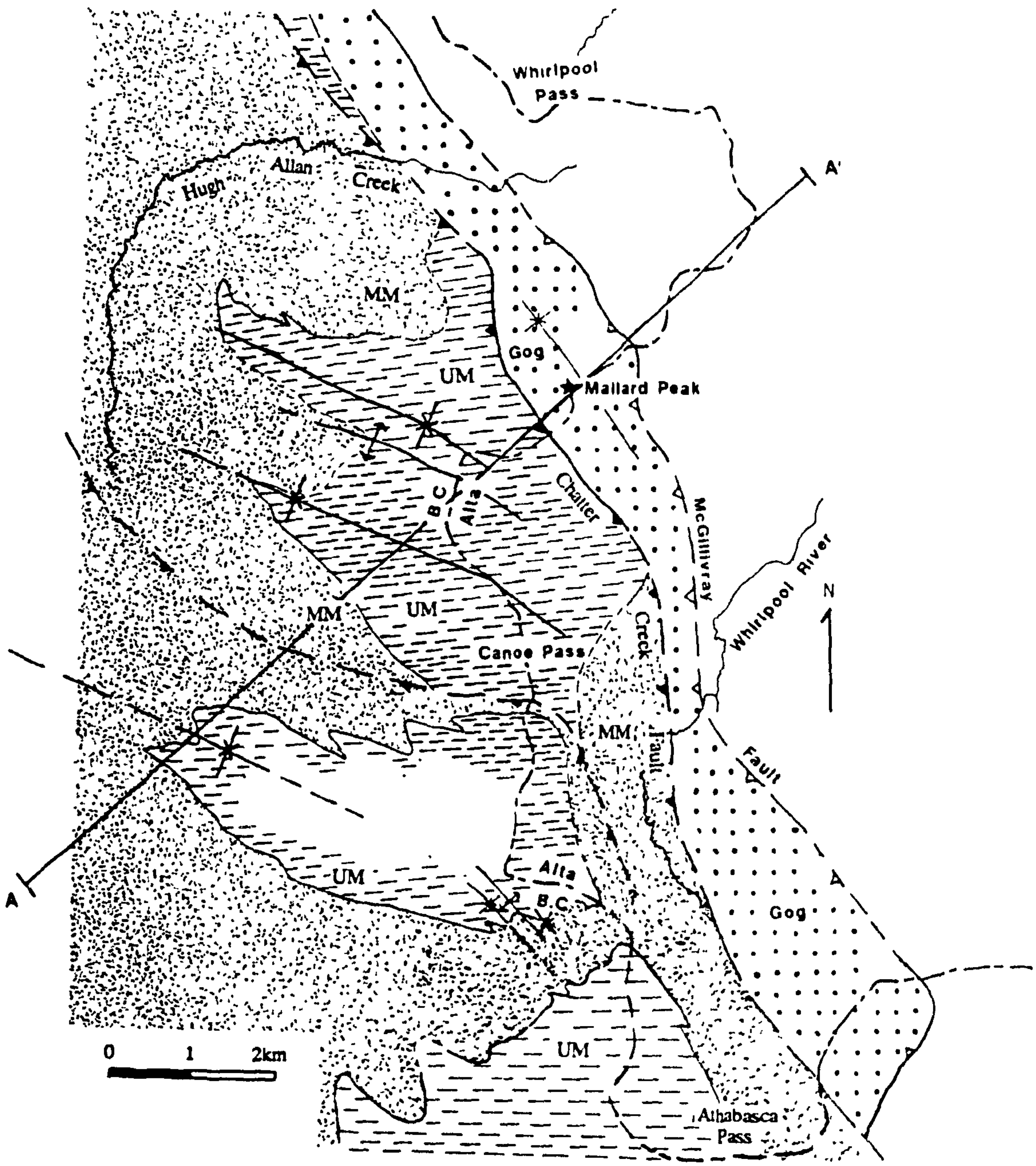


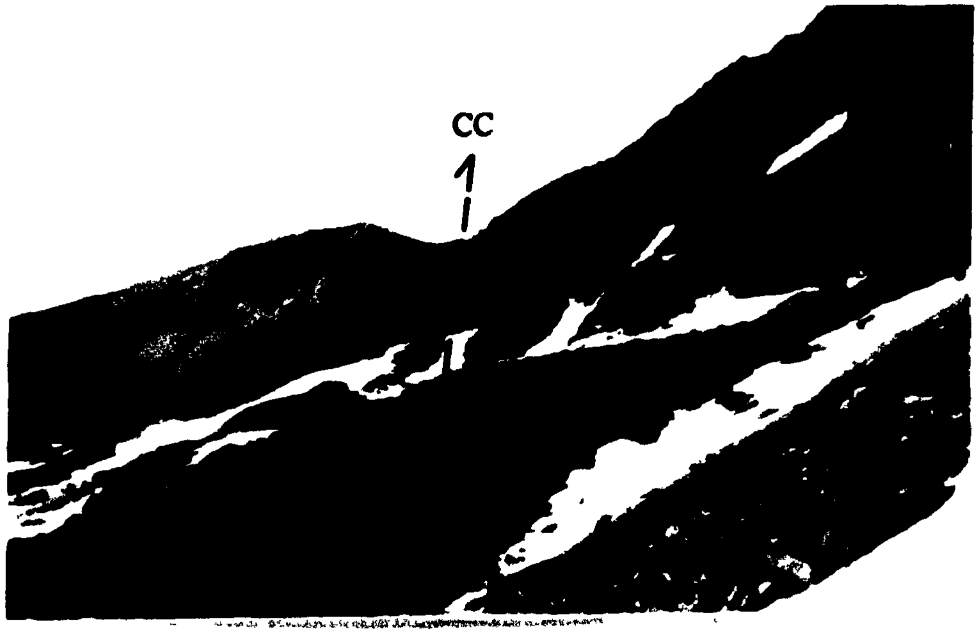

Fig. 3.4 Geologic map of the Mallard Peak/Athabasca Pass area, in the southeastern portion of the field area.

surfaces contain horizontal slickenlines that consistently trend north-south, all showing steps in quartz fibres indicating dextral slip (Fig. 3.6, 3.7). Near the fault, steeply dipping bedding planes contain slickenlines with similar orientation and shear sense. Rarely, bedding has slickenlines trending northeast, indicating a top to the northeast compressional motion. The angular relation of the shear planes with the strike of the Chatter Creek Fault (30°), suggest that they are R Riedel shears related to the dextral motion along the Chatter Creek Fault (Fig. 3.8). The gold bearing discordant veins at McGillivray (Shaw and Morton, 1990) trend roughly east west and may represent R' Riedel shears.

Two distinct phases of motion (compressional and dextral) are indicated by the two fold domains and slickenlines in the Chatter Creek Fault zone, but their relative timing with respect to each other is uncertain. The Chatter Creek Fault may be mapped along strike to the northwest into the Moose Lake Fault. Just west of Moose Lake McDonough (1989) reported evidence for dextral motion along the Klapperhorn Thrust that was interpreted to be late to post $D_3$. These regional relations, together with the observed structural relations in the map area, make it reasonable to suggest that the dextral motion on the Chatter Creek Fault in the Mallard Peak - Athabasca Pass area may be post $D_3$.

Fig. 3.5 View looking northwest at the Chatter Creek Fault places the recessive upper Miette Group (left) against the more resistant, east-dipping Gog Group (right), in the pass just west of Mallard Peak.

Fig. 3.6 Looking east at a surface of a shear plane in McNaughton Formation quartzites, approximately 10 m east of the Chatter Creek Fault on the east side of pass in Figure 3.5. The horizontal slickenlines and steps show dextral offset. Arrow points north.

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3.6

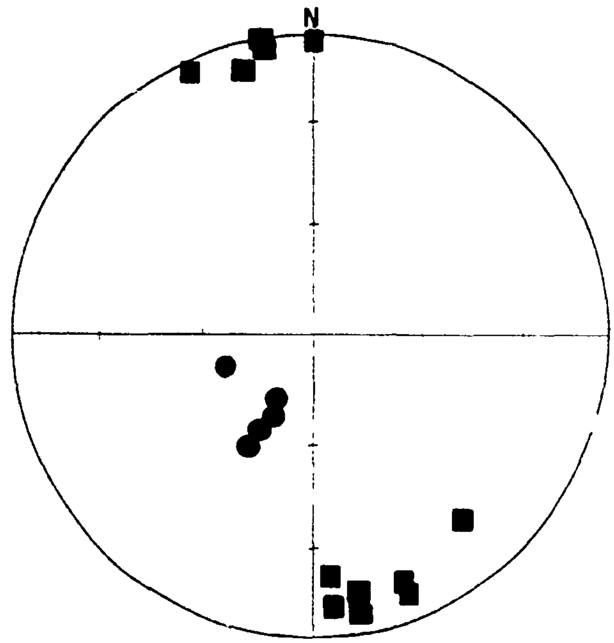



Fig. 3.7 Stereographic projection of slickenlines (squares) and poles to associated shear plane surfaces (circles).

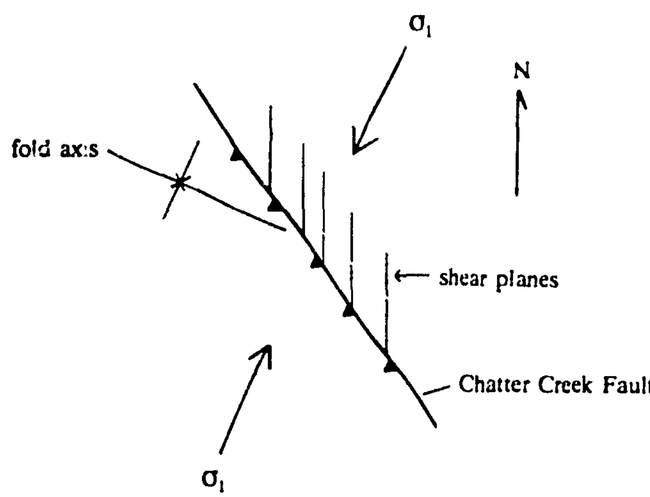



Fig. 3.8 Schematic diagram indicating relations of the Chatter Creek Fault, and associated shear planes, with the assumed regional stress field during dextral motion.

**MCGILLIVRAY FAULT**

The McGillivray Fault crops out immediately east of the Chatter Creek Fault in the eastern Main Ranges (Fig. 3.4). The fault is a low-angle thrust (20-30°) placing Gog Group quartzites over Middle Cambrian carbonates at McGillivray Ridge, and at Mallard Peak along strike to the northwest. East of Mallard Peak the fault zone is covered. However, at Athabasca Pass, Shaw and Morton (1990) observed a 2 m quartz rich mylonite along the McGillivray Fault. They inferred that a series of west-dipping surfaces are hanging wall splays, of the McGillivray Fault, and sheared thinned limbs of recumbent folds in the Gog Group quartzite (Shaw and Morton, 1990, their Fig. 7). These relationships do not occur at Mallard Peak. The steeply dipping surfaces in their Figure 7 are apparently joints with little or no displacement, since bedding can be traced continuously across these structures in McGillivray Ridge.

Shaw and Morton (1990) interpret the McGillivray Fault to be a footwall splay of the Chatter Creek Fault. South of Athabasca Pass, the near vertical Chatter Creek Fault cuts the shallow dipping McGillivray Fault at a high angle, making such a correlation unlikely (Figs. 3.4,3.9). The Chatter Creek Fault appears to be an out-of-sequence thrust with respect to the McGillivray Fault. There are no obvious features to indicate whether McGillivray Fault is a $D_2$ or $D_3$ structure.

The fault's low angle suggests it may be related to $D_2$.

## STRUCTURAL RELATIONSHIPS BETWEEN THE CHATTER CREEK AND MCGILLIVRAY FAULTS

Thrust displacement on the Chatter Creek Fault is approximately 3.5 km (Fig. 3.9a). When this displacement is restored (Fig. 3.9b), the McGillivray Fault appears to connect with a unnamed fault at Canoe Pass. This unnamed fault is correlated with a fault to the northwest, that is interpreted to be a splay of the Selwyn Range Fault (Fig. 1.2). If this correlation is correct, it suggests the McGillivray Fault is a $D_3$ structure (see Chapter 4). The minimum displacements along the McGillivray and unnamed faults, near Mallard Peak, are about 1500 m (Fig. 3.9). If the correlation of McGillivray Fault with the unnamed fault is correct, dextral motion on the Chatter Creek Fault would be minor, as the two faults lie opposite each other on either side of the Chatter Creek Fault. The cut-offs of the McGillivray Fault, in the footwall of the Chatter Creek Fault, can not be used to determine total dextral displacement, as Gog stratigraphy has been eroded in the hanging wall of the Chatter Creek Fault. The near vertical dips of the Chatter Creek Fault constrain it to cut the shallow dipping McGillivray Fault at a steep angle (Fig. 3.9a), indicating that the Chatter Creek Fault is an out-of-sequence fault (relative to the McGillivray Fault). This cross cutting relation indicates that the Chatter Creek Fault is a $D_3$, or later, structure.

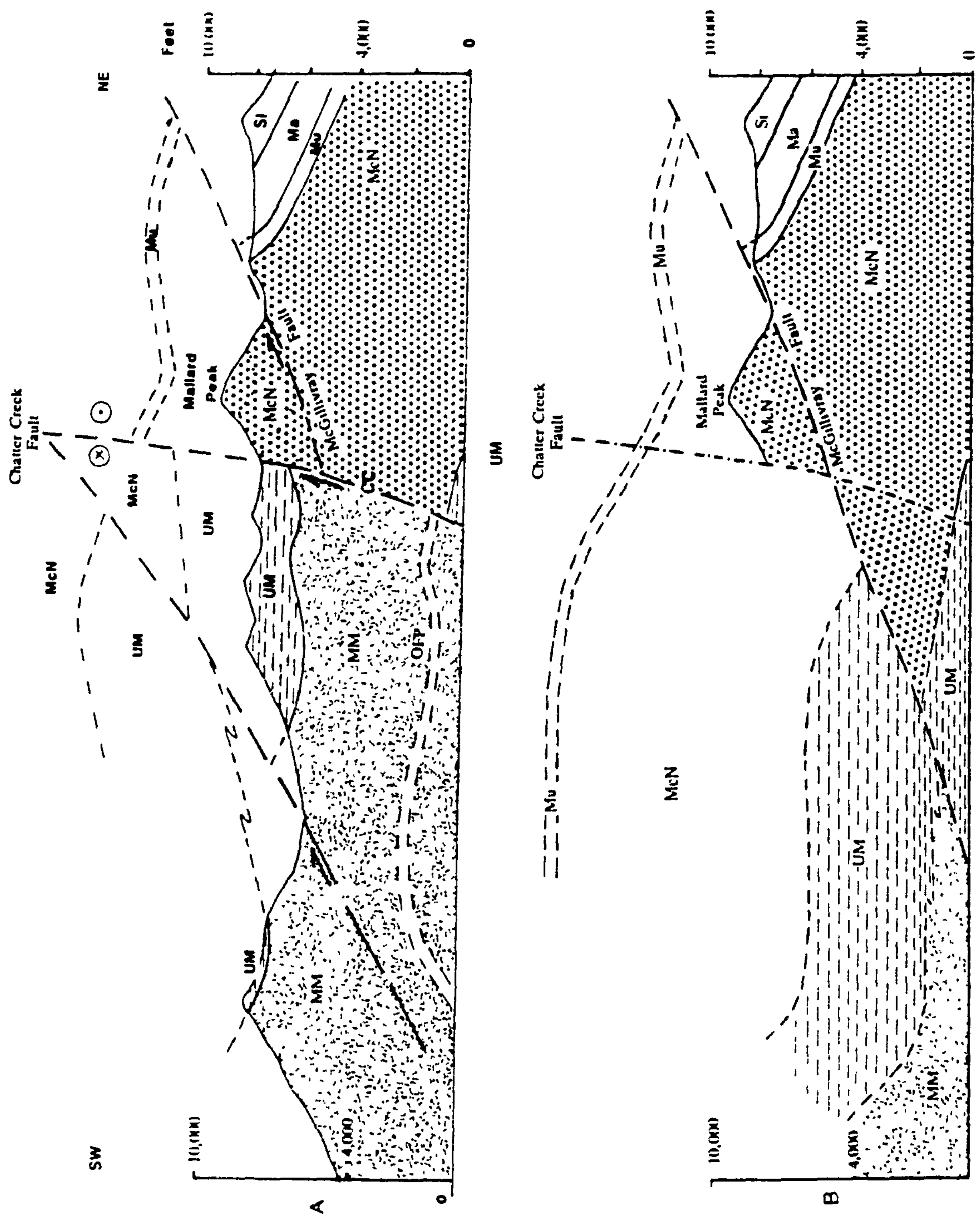



Fig. 3.9 A. Cross-section north of Canoe Pass through Mallard Peak, showing structural relations of the Chatter Creek and McGillivray Faults. B. Compressional motion on the Chatter Creek Fault restored, showing the McGillivray Fault connecting with a thrust west of the Chatter Creek Fault. (see Fig. 3.4 for location).

## FOLDS

High amplitude (200 m), upright folds related to $D_3$ dominate the area, forming localised fold trains in competent grit stratigraphy on the flanks of the larger scale Fraser River Antiform, as well as further to the west in the hanging wall of the Hugh Allan Thrust (Figs. 1.2, 3.10). Folds related to $D_2$ are less common, and occur as minor folds in pelite and as large recumbent folds in the Ptarmigan Creek Thrust Zone. Coaxial interference patterns between $F_2$ and $F_3$ folds are rare, being best developed in the banded carbonates of the Old Fort Point Formation (Fig. 3.11). Folds possibly related to $D_1$ are rare, southwest-verging and restricted to the hanging wall of the Hugh Allan Thrust; they are not discussed further.

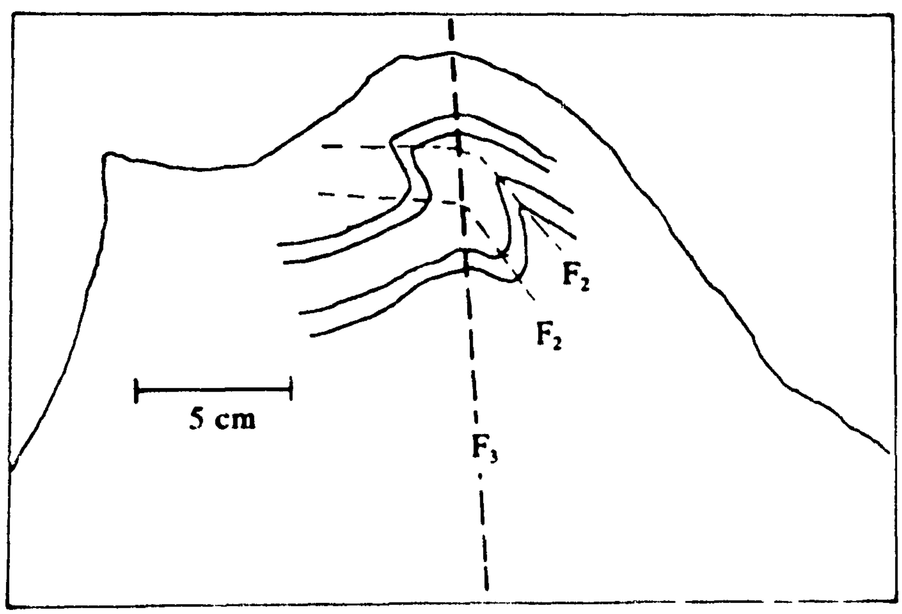
### FRASER RIVER ANTIFORM

The dominant structure in the field area is the Fraser River Antiform, a broad, upright, doubly plunging antiform, with an approximate wavelength of 15 km. The Antiform plunges gently to the southeast (10 to 15°) in the southern Selwyn Range, culminates around Ptarmigan Creek, and reverses plunge to the northwest in the northern Selwyn Range. In the central Selwyn Range the Fraser River Antiform has a rounded nose, which flattens out to the south, where the antiform is characterised by moderately east and west dipping limbs (Appendix 2). The southernmost plunge of the Fraser River Antiform widens into a homoclinal panel, just north of Hugh Allan Creek, with

Fig. 3.10 Fold train in competent middle Miette Group grits, west flank of the Fraser River Antiform, in hanging wall of the Selwyn Range Fault. Viewed to the northwest.

Fig. 3.11 Schematic diagram of an outcrop of a coaxial interference pattern of $F_2$ and $F_3$ folds in the upper unit of member II of the Old Fort Point Formation.

3 10




3 11

bedding and $S_2$ cleavages dipping gently to the southwest (Fig. 3.12a).

Bedding and the $S_2$ foliation are folded by the Fraser River Antiform (Figs. 3.12b,c), whereas the $S_3$ crenulation cleavage fans across the antiform (Fig. 3.12d). This indicates that the Fraser River Antiform is a $D_3$ structure. However structural/stratigraphic relationships discussed in Chapter four, suggest that the antiform was initiated during $D_2$.

The southern termination of the Fraser River Antiform occurs east of and overlaps the northern termination of the Porcupine Creek Anticlinorium (Fig. 1.2, Appendix I). The northern Porcupine Creek Anticlinorium developed during two stages of deformation (Klein, 1991). The first stage characterised by low angle structures, and the second stage characterised by more upright structures (Klein, 1991). The two phases of deformation are similar to $D_2$ and $D_3$ in the southern Selwyn Range, suggesting the two antiforms formed at similar times as en echelon structures, typical of regional scale structures in the Rocky Mountains.

**$F_2$ FOLDS**

Second phase ($F_2$) folds are generally seen on a mesoscopic scale, however, macroscopic $F_2$ folds are observed near and in the Ptarmigan Creek Thrust Zone. Mesoscopic and macroscopic

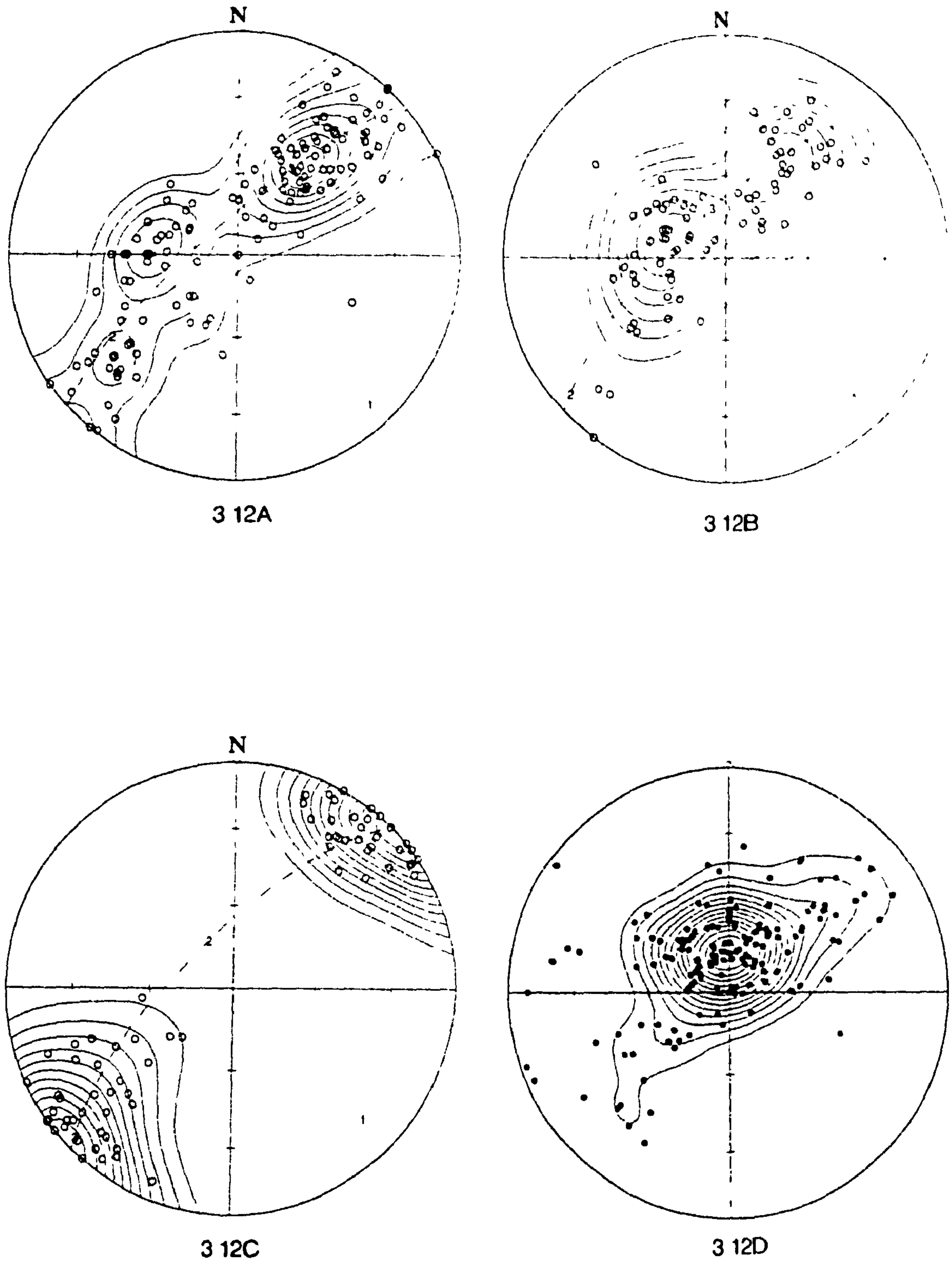



Fig. 3.12 Equal area plots of poles to: a) bedding and $S_2$ in the southern plunge of the Fraser River Antiform, b) bedding, c) the $S_2$ cleavage, and d) the $S_3$ cleavage, across the Fraser River Antiform.

$F_2$ folds are isoclinal, recumbent, and strongly asymmetric, northeast-verging folds. Mesoscopic $F_2$ folds are common in pelite dominated stratigraphy, and are rare in grit dominated stratigraphy. A pervasive cleavage ($S_2$) is axial planar to $F_2$ folds. Generally $F_2$ fold axes plunge gently to the southeast.

**$F_3$ FOLDS**

Third phase folds ($F_3$) occur on microscopic, mesoscopic and macroscopic scales. Macroscopic $F_3$ folds occur most frequently in coarse clastic dominated sequences of the middle Miette Group and have an associated steeply-dipping, axial planar crenulation ($S_3$). The folds are generally upright, open, symmetrical folds. Their geometry is controlled by buckling of competent clastic units. Disharmonic $F_3$ folding occurs in strata were pelite units are thicker than interbedded grit units (in the facies transition from grit to pelite dominated stratigraphy of the middle Miette Group) in the hanging wall of the Selwyn Range Sear Zone (Fig. 3.13, Appendix I). On the southern plunge of the Fraser River Antiform, near Saddle Mountain (Fig. 1.2), $F_3$ folds are tight and slightly inclined to the northeast. Mesoscopic and Macroscopic $F_3$ folds are cylindrical and have fold axes that generally plunge gently southeast.

**FOLD TRAIN BETWEEN HUGH ALLAN CREEK AND WHIRLPOOL RIVER**

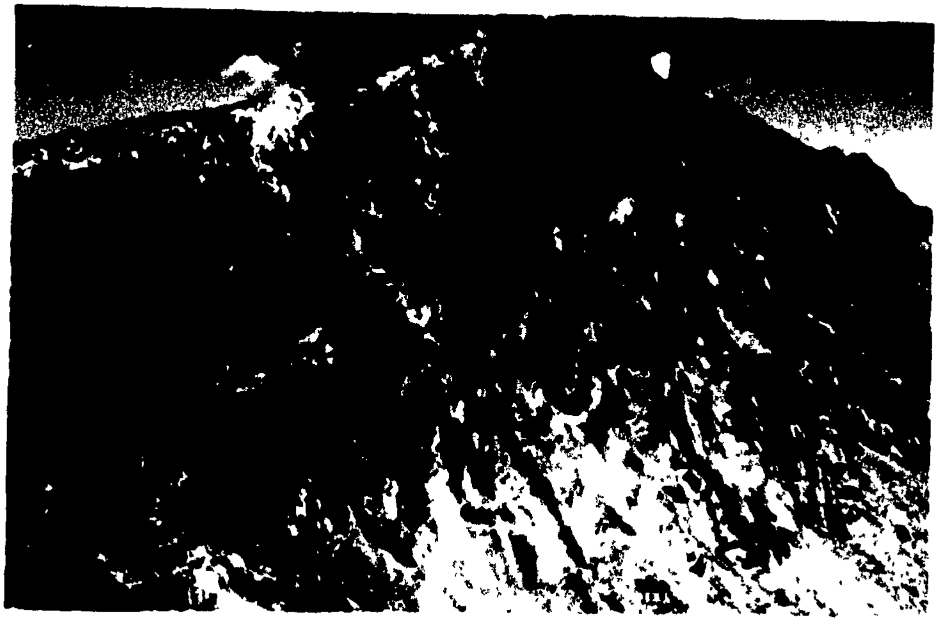
Broad, southeast-plunging, open folds between Hugh Allan Creek and the Whirlpool River (Fig. 1.2) all trend about 295°, as compared to regional $D_3$ fold trends of 330° in the southern Selwyn Range and 315° in the Eastern Main Ranges (east of the Chatter Creek Fault). This suggests that they have an origin unrelated to the regional $D_3$ event, however no interference relations were observed to support this. These anomalous trends are unlikely related to paleo basin-geometry because they are isolated in an area of Miette Group that does not show marked thickness changes and they are surrounded by regional folds consistently trending 20-35° more northerly.

These folds make about a 35° angle with respect to the trace of the adjacent more northerly-trending Chatter Creek Fault (Fig. 1.2). The fold train's angular relation with the Chatter Creek Fault is consistent with folds formed in a transpressional regime (Sanderson and Marchini, 1984), indicating they may be related to dextral motion along the Chatter Creek Fault.

## FOLIATIONS

A poorly preserved foliation, restricted to the hanging wall of the Hugh Allan Thrust, is the earliest observed fabric in the southern Selwyn Range. Two later foliations, an early pervasive foliation sub-parallel to bedding and a later upright crenulation cleavage, are ubiquitous in the southern Selwyn Range. In the northern Selwyn Range, McDonough (1989)

Fig. 3.13 A) Disharmonic folds in pelite dominated section of the middle Miette Group on west flank of the Fraser River Antiform in hanging wall of the Selwyn Range Fault. Cliff is approximately 150m high. B) Sketch of A.



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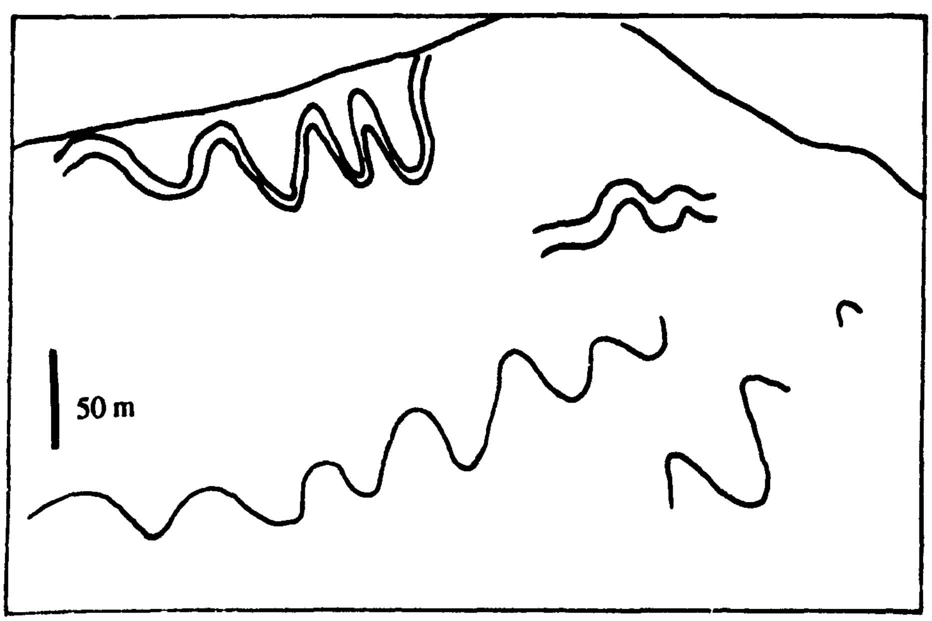



3 13B

termed the earliest, poorly preserved foliation, $S_n$, and the two ubiquitous foliations $S_1$ and $S_2$. Charland (1989), Klein (1991) and Dechesne (1990a) termed the poorly preserved foliation $S_1$ and the two ubiquitous foliations $S_2$ and $S_3$. The latter terminology is used herein. Using this terminology, the earliest foliation generally seen in the field area is the pervasive foliation subparallel to bedding ($S_2$). Figure 3.14 shows the relation of foliations to the dominant structures in the field area.

**$S_1$ FOLIATION**

The $S_1$ foliation is only observed in thin sections from rocks in the hanging wall of the Hugh Allan Thrust. The foliation generally occurs as microlithons between septa of the $S_2$ foliation (Charland, 1989). The $S_1$ foliation is crenulated and transposed by the pervasive $S_2$ foliation (McDonough and Simony, 1988a). The bedding cleavage relations suggest that $S_1$ is related to southwest-verging deformation (Charland, 1989).

**$S_2$ FOLIATION**

The $S_2$ foliation is defined by the alignment of white mica, chlorite, chloritoid, biotite and elongate quartz. The foliation is pervasive and ubiquitous in pelites. Coarse clastic units rarely show $S_2$ as a weak alignment of micas in the matrix. The foliation is generally parallel to subparallel to bedding, except in the hinges of isoclinal $F_2$ folds. The $S_2$ foliation generally dips slightly steeper than southwest-dipping bedding, and slightly shallower than northeast-dipping bedding. The $S_2$ foliation is folded by $F_3$ folds (Fig. 3.12c) and crenulated by the $S_3$ cleavage. The bedding/cleavage intersections and facing data indicate the southern Selwyn Range is underlain by an upright panel of a $D_2$ northeast-verging structure.

## $S_3$ FOLIATION

The $S_3$ foliation is a steeply dipping cleavage that intersects bedding at a high angle and crenulates $S_2$. In the hanging wall of the Hugh Allan Thrust, $S_3$ is a solution cleavage (Gray, 1979) defined by a strong alignment of synkinematic mica on the limbs, and quartz in the hinges, of microscopic folds (Fig. 3.15a). In the eastern part of the map area, $S_3$ is defined by a weak to strong crenulation of micas aligned with $S_2$ (Fig. 3.15b). The $S_2$ micas here exhibit sweeping extinction around the hinges of microfolds, indicating that they were crenulated after metamorphism. Solution cleavages are not developed in the eastern part of the field area.

Occasionally a low angle, southwest-dipping crenulation is associated with $S_3$. The two crenulation cleavages generally have a dihedral angle of 52°, and show mutual cross cutting

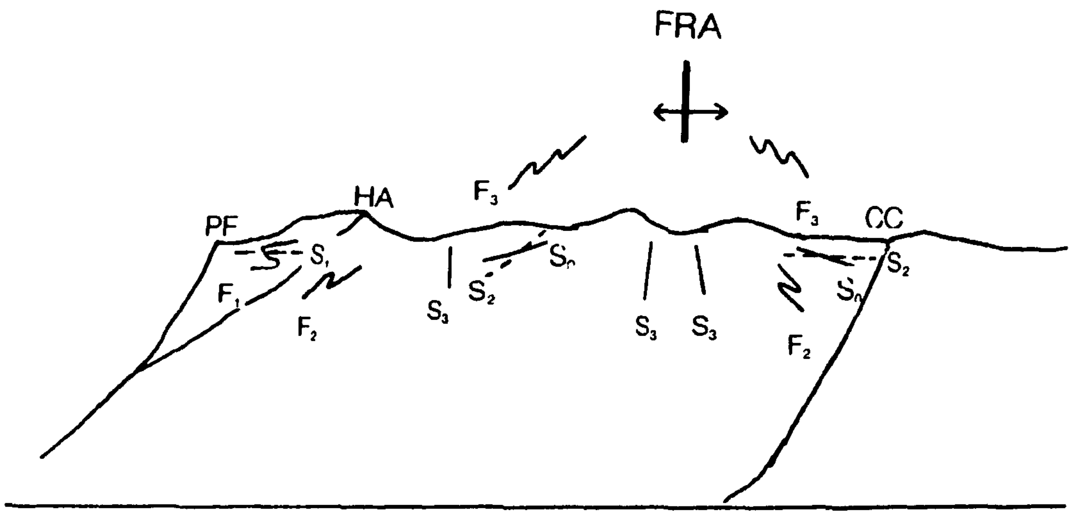



Fig. 3.14 Schematic cross-section of the southern Selwyn Range showing spacial relations of the dominant fabrics and structures.

relations (Fig. 3.16). These are interpreted as conjugate cleavages (see Williams and Price, 1990) that formed coevally,similar to those described by McDonough (1989) in the northern Selwyn Range. The conjugate cleavages may be found together or individually, the steeply dipping one being more common.

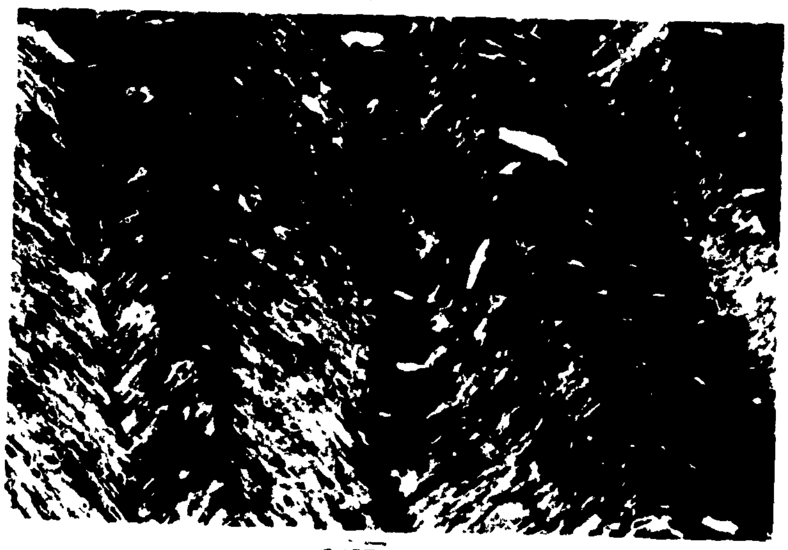
**TRANSVERSE CRENULATION**

A crenulation transverse to the regional structure occurs sporadically throughout the field area. The crenulation is steeply dipping and is generally restricted to pelitic units in the western part of the field area. Similar transverse structures have been recognised over a large part of the western Main Ranges (Carey and Simony, 1985; McDonough and Simony, 1988a; Leonard, 1985; Forest, 1985; Charland, 1989; Klein, 1991). The transverse crenulations are postmetamorphic, however their origin is uncertain. They may be related to the late stage dextral motion observed on a number of faults in the field area.

Fig 3.15 Microphotograph of a) $S_3$ discrete solution cleavage from the hanging wall of Hugh Allan Thrust (SEG89-170B), and b) weak $S_3$ crenulation from the east flank of the Fraser River Antiform. Both fold an earlier pervasive foliation ($S_2$) defined by the alignment of micas and quartz (SEG90-96).

Fig. 3.16 Upright $S_3$ crenulation and the low angle conjugate crenulation showing mutual cross-cutting relations. Scale 5 cm.

3 15A



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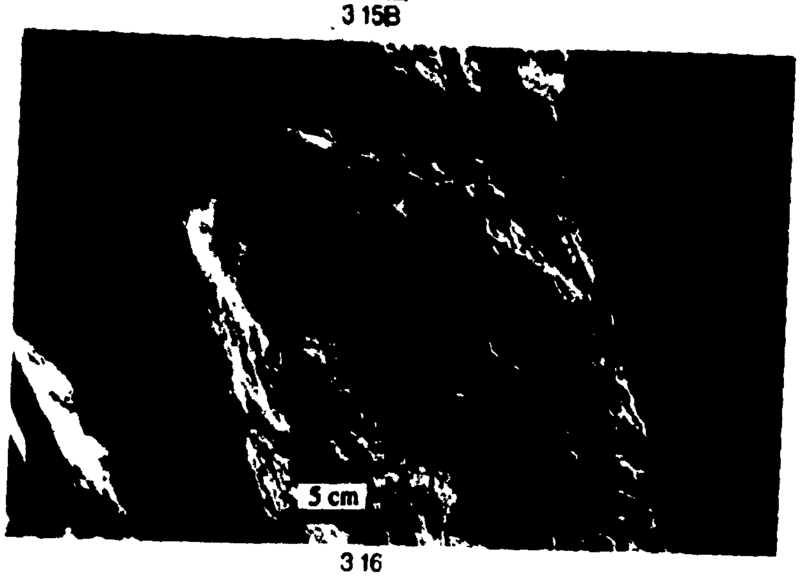


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## CHAPTER 4 - THE SELWYN RANGE FAULT AND SELWYN RANGE SHEAR ZONE

### INTRODUCTION

Early mapping in the southern Selwyn Range (Leonard, 1985) indicated the presence of a fault at the level of the Old Fort Point Formation, on the west flank of the Fraser River Antiform (Fig. 1.2) (herein called the Selwyn Range Fault). Leonard (1985) originally interpreted this as a normal fault, dropping middle Miette Group strata in the hanging wall against a thick sequence of pelite, he correlated with the lower Miette Group, in the footwall. North, along strike of the Selwyn Range Fault, Dechesne (1990a) noted a 100 m wide shear zone. He indicated the shear zone (herein called the Selwyn Range Shear Zone), has top to the northeast displacement, and suggested it was related to movement on the Selwyn Range Fault. He correlated the shear zone, across the Fraser River Antiform, to a strain zone he observed on the east flank, at the base of the middle Miette Group. Dechesne (1990a) suggested that the shear zone represented a $D_2$ structure (his Selwyn Range Decollement), similar to the Ptarmigan Creek Thrust Zone, that was folded by the Fraser River Antiform (Fig. 1.4b). He interpreted the stratigraphy to be a thin sequence repeated by the Selwyn Range Fault.

In the northern Selwyn Range, McDonough (1989) observed a fault (his Packsaddle Detachment) at about the same structural position as the Selwyn Range Fault, on the west flank of the Fraser River Antiform. He did not observe a high strain zone on the east flank, at the base of the middle Miette Group. McDonough interpreted the stratigraphy in the northern Selwyn Range as being a thick conformable sequence.

The two interpretations have significant implications on the stratigraphy, structural style and total shortening in the western Main Ranges at this latitude. The interpretation of Dechesne (1990a) suggests displacement on the Selywn Range Fault is over 100 km, and that the Windermere Supergroup is a thin sequence (about 4.5 km), consisting of only the upper and middle Miette Group (Dechesne and Mountjoy, in press). Whereas the interpretation of McDonough (1989a) suggests movement on the Selywn Range Fault is minor and that the Miette Group is a thick conformable sequence (about 9.5 km structural thickness). The two structural/stratigraphic interpretations are shown in Figures 1.3 and 1.4.

The southern Selwyn Range was mapped to determine which of the two interpretations is more plausible. This was done by: 1) examining the mesoscopic and macroscopic fabrics of the Selwyn Range Shear Zone exposed on the west flank of the Fraser River Antiform, 2) determining the relationship of the Selwyn Range Shear Zone to the Selwyn Range Fault, 3) examining the east flank of the Fraser River Antiform for the presence of a east dipping shear zone, and 4) examining possible correlations of the Selwyn Range Fault.

## SELWYN RANGE SHEAR ZONE

The Selwyn Range Shear Zone is best exposed on the west flank of the Fraser River Antiform (Appendix 1). The shear zone is characterised by a progressive development of finite strain over 50 m of stratigraphic section, to a maximum, and then decreasing over another 50 m (Fig. 4.1). The shear zone occurs in dominantly pelitic strata of the middle Miette Group, just below the Old Fort Point Formation (Fig. 1.2). The shear zone is overlain by a train of open, symmetric folds. Total shortening of these folds is approximately 20%.

Along strike to the south, the shear zone can be correlated with a fold train on the southwestern flank of Saddle Mountain (Fig. 1.2, Appendix 1). These folds are a localised, low amplitude, $D_3$ fold train, and are not extensive. They likely represent the southern extent of the shear zone. To the north, shear zone fabrics occur along strike as far north as Ptarmigan Creek (Appendix I), however the fold train is not as evident. Approximately 20 km north of Ptarmigan Creek, the Selwyn Range Fault appears to merge with the Packsaddle Fault; which occurs at about the same structural level. The Selwyn Range Shear Zone's relation to the Packsaddle Fault is uncertain and complex. More mapping is needed to trace the fault from the head of Bulldog Creek to Yellowjacket Creek.

## Shear Zone Fabrics

Fabrics of the Selwyn Range Shear Zone are described from the exposure on the west flank of the Fraser River Antiform. A pervasive schistosity ($S_2$) sub-parallel to bedding is the dominant fabric in unstrained pelitic rocks, in the footwall of the Selwyn Range Shear Zone. Upright $S_3$ crenulations are sporadic and poorly developed. The base of the shear zone is defined by the development of asymmetric, periodic, minor folds, outlined by silty and sandy layers, and the $S_2$ cleavage (Fig. 4.2). A zonal crenulation cleavage (Gray, 1977), axial planar to these folds, intersects bedding at a high angle and crenulates the pervasive $S_2$ fabric (Fig. 4.3). The crenulation cleavage is developed preferentially in the hinge and short limbs of the minor folds, giving it a spaced distribution (Fig. 4.2).

Towards the centre of the shear zone, minor folds become more prominent and the crenulation cleavage in the hinges and short limbs becomes more strongly developed (Fig. 4.3). The long limbs of minor folds become progressively enriched in insoluble material (mica, opaques, etc.). In contrast, the short limbs of minor folds become progressively enriched in quartz. Where quartz is concentrated between extended $S_2$ folia.

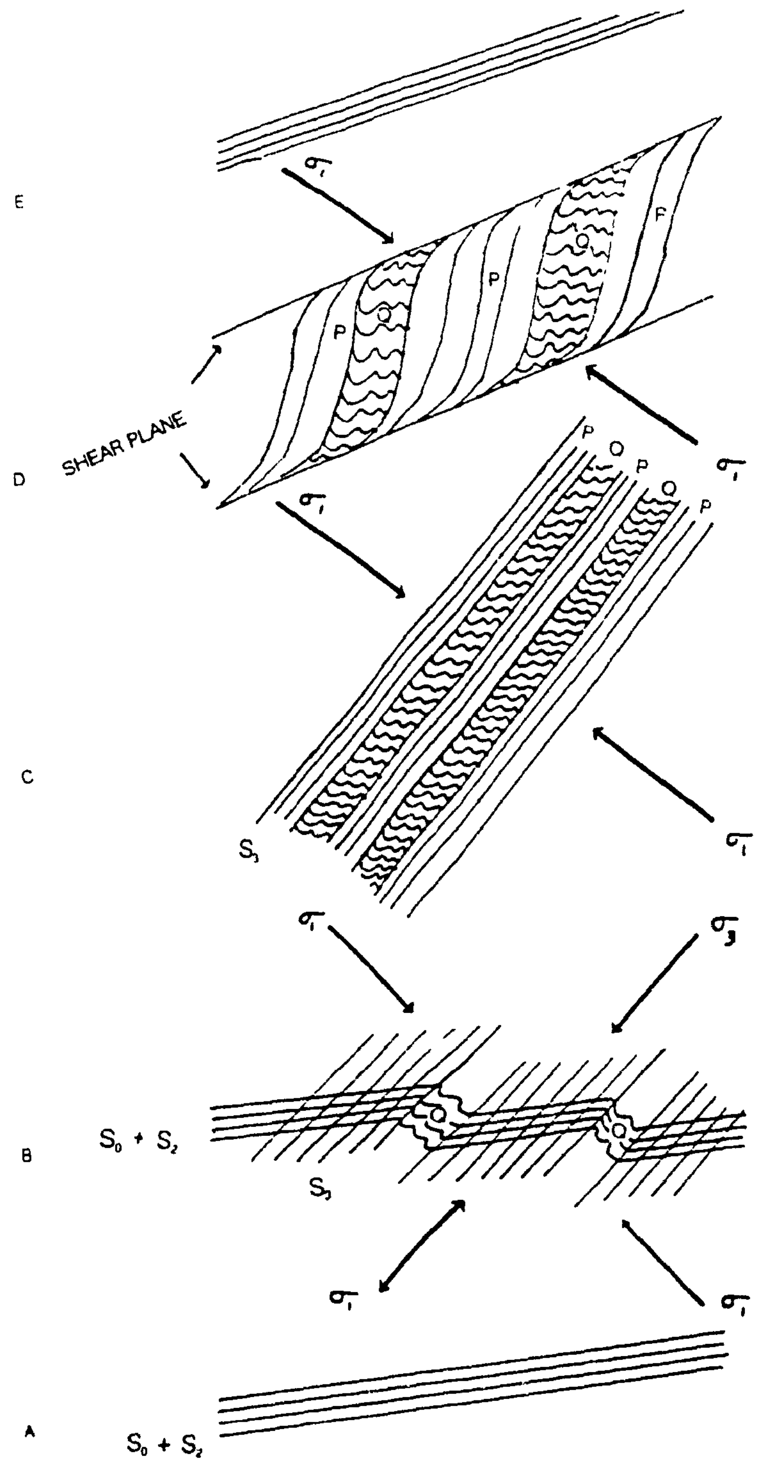



Fig. 4.1 Schematic diagram showing progressive development (from bottom to top) of fabrics in the shear zone on the west flank of the Fraser River Antiform. A. $S_2$ cleavage at the base of the shear zone. B. Development of spaced $S_3$ crenulations. C. Development of incipient layers. D. Development of through going shear planes. E. Transposed cleavage in the centre of the shear zone.

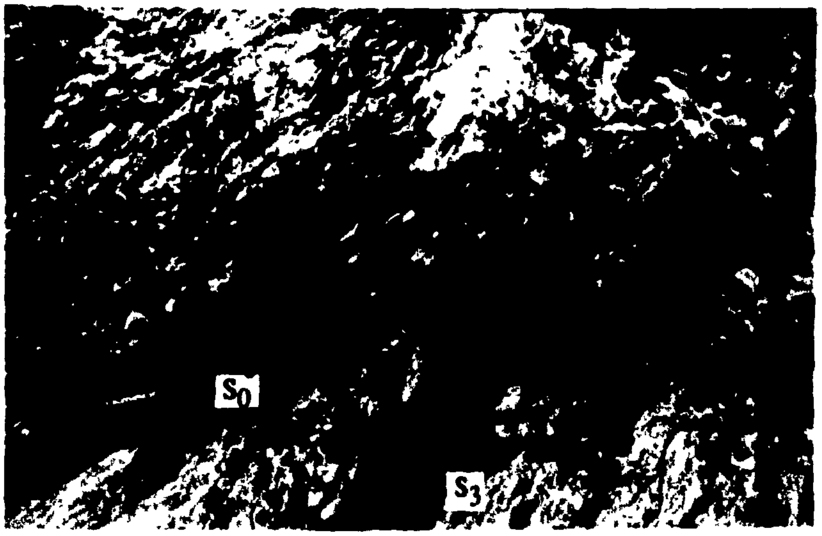
Further towards the centre of the shear zone, a metamorphic differentiation develops, with incipient quartz rich and insoluble rich layers forming at a high angle to relic bedding (Figs. 4.4, 4.5). The incipient layers are parallel to the crenulation cleavage, with quartz rich layers localised along short limbs, and insoluble rich layers along long limbs of minor folds (Figs. 4.4, 4.5). Bedding is still observed, even where the incipient layers are highly developed (Fig. 4.5).

Closer to the centre of the shear zone, a through-going foliation develops at a lower angle than, and truncates the incipient layering and crenulation cleavage. The incipient layers are deformed into sigmoids by shear along these through-going foliations. Incipient layers are rotated towards the shear planes, giving a top to the northeast sense of vergence (Fig. 4.6). Towards the centre of the shear zone, the amount of rotation of the incipient layers into the shear plane progressively increases. Eventually decimetre scale features, analogous to 'foliation fish' (Hamner, 1986), develop. These are defined by pods of sigmoidal incipient layers surrounded by the through-going foliation. As the foliations are rotated into parallelism with the through-going shear plane, they are reactivated and transposed. Eventually the through-going foliation becomes the dominant fabric in the rock, with only occasional relic sigmoids of the incipient layering present. This represents the highest developed

Fig. 4.2 The $S_3$ cleavage in the short limb of a minor fold in Selwyn Range Shear Zone, west flank of Fraser River Antiform. View looking northwest.

Fig. 4.3 The $S_3$ cleavage developing preferentially in the hinges and short limbs of minor folds, giving it a spaced character, from the Selwyn Range Shear Zone, west flank, Fraser River Antiform. View looking northwest.

Fig. 4.4 Well developed incipient layers in pelitic rocks in Selwyn Range Shear Zone. The solid grey bands are insoluble rich, whereas the layers with a spotty white appearance are quartz rich.



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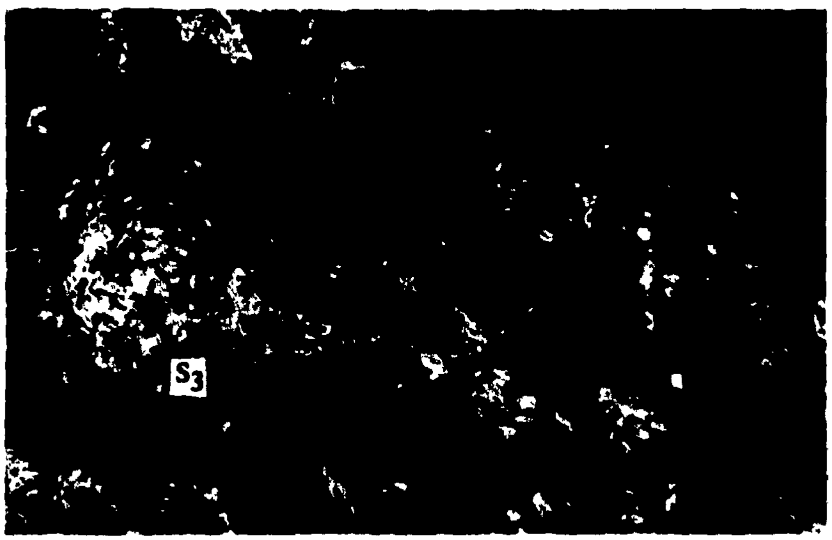

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strain, occurring approximately 50 m above the base, in the centre of the shear zone.

Above this level, strain progressively decreases, with structures occurring in the reverse order as just described, creating a mirror image of these fabrics. The top of the shear zone is where the incipient layers are no longer developed, but a strong crenulation cleavage is still present. The crenulation cleavage in the upper part of the shear zone steepens from dips of 70° to near vertical above the shear zone. This crenulation is axial planar to symmetric, open folds, in a fold train of middle Miette Group strata overlying the shear zone (Fig. 3.10). Both bedding and $S_2$ foliations in the fold train are folded and crenulated by the upright cleavage, indicating the folds are related to $D_3$. The association of the folds with the Selwyn Range Shear Zone suggest the shear zone is also $D_3$.

**Interpretation of Shear Zone Fabrics**

The fabrics described above represent a progressive development of strain within a shear zone. Using a simple shear model, the crenulation cleavage and incipient layers are considered to form parallel to the infinitesimal flattening plane, and the through-going foliation parallel to the shear plane (similar to S-C fabrics (Berthé et al., 1979; Lister and Snoke, 1984). With increasing strain the incipient layers were progressively rotated towards the shear plane, deforming them into sigmoids.

The incipient layers that formed in the hinges and long limbs of minor folds appear to have developed by a solution/precipitation process. The long limbs of minor folds lying in the compressional field would have had a higher chemical potential than the short limbs in the extension field (Gray, 1979, Robin, 1979). This caused pressure dissolution of quartz in the long limbs, which then diffused along the chemical potential gradient to the short limbs. Quartz was deposited in the interstitial area of the extended $S_2$ folia (Fig. 4.7).

The timing of the shear zone ($D_3$), and the geometry of the minor folds, are both consistent with the shear zone being related to interlimb slip on the $D_3$ Fraser River Antiform. As mentioned above, $D_2$ fabrics are folded and crenulated by fabrics developed in the shear zone. As well, the crenulation developed in the shear zone is axial planar to $D_3$ folds overlying the shear zone. Both these features indicate the shear zone is a $D_3$ structure. Minor folds in the shear zone are generally periodic, asymmetric "Z" type (northeast-vergent), equally spaced, and have constant amplitude. These features are characteristic of parasitic folds formed by interlimb slip on the flank of a larger scale antiform. By contrast, if the shear zone was related to a fault with large displacement, as interpreted by Dechesne (1990a), non-periodic, less uniform shear folds would usually be expected (P. Williams, 1991, personal communication).

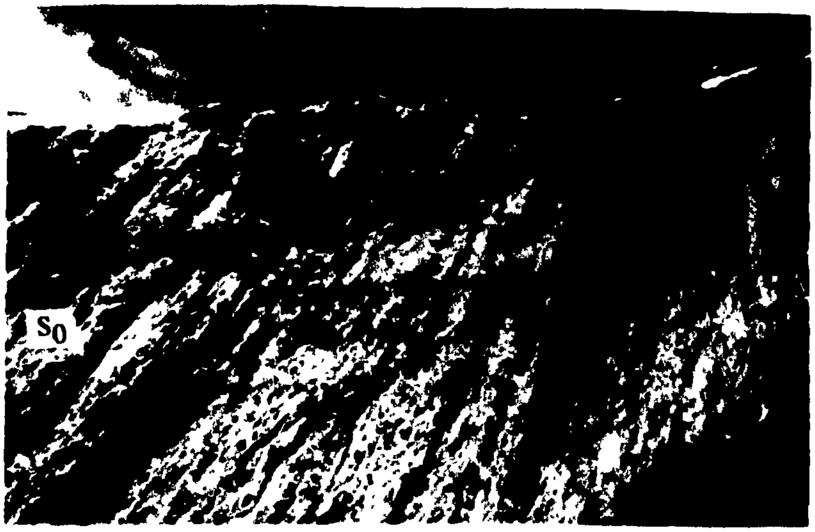
If the Selwyn Range Shear Zone is related to interlimb slip as a result of the development of the Fraser River Antiform, the shear zone would have only minor displacement. A problem with this interpretation is that such minor displacement does not adequately explain the juxtaposition of middle Miette Group strata against lower Miette Group on the west flank of the Fraser River Antiform. This requires the existence of a structure earlier than the Selwyn Range Shear Zone ($D_2$ or early $D_3$), at the same level as the shear zone (i.e. the Selwyn Range Fault). This implies that the Selwyn Range Fault is a $D_2$ or early $D_3$ structure that was reactivated by the Selwyn Range Shear Zone.

The Selwyn Range Fault may be one of two types: 1) a normal fault as originally suggested by Leonard (1985), or 2) a compressional fault. If the Selwyn Range Fault had normal displacement, as proposed by Leonard (1985), the offset would be a minimum of 1500 m, as the lower middle Miette Group is absent in the hanging wall. Presumably this offset would be observed along strike to the south, across the north arm of Hugh Allan Creek near Saddle Mountain (Fig. 1.2). This area

Fig. 4.5 Well-developed, steep dipping, incipient quartz and insoluble rich layers cross-cutting low angle bedding. Note that quartz rich layers are localised in the short limbs of minor folds.

Fig. 4.6 Incipient quartz and insoluble rich layers cut by a through-going foliation.

Fig. 4.7 Schematic diagram of pressure solution, and migration of quartz (arrows) from the insoluble rich limbs (P) to the quartz rich hinges (Q) of minor folds in the shear zone on the west flank of the Fraser River Antiform.

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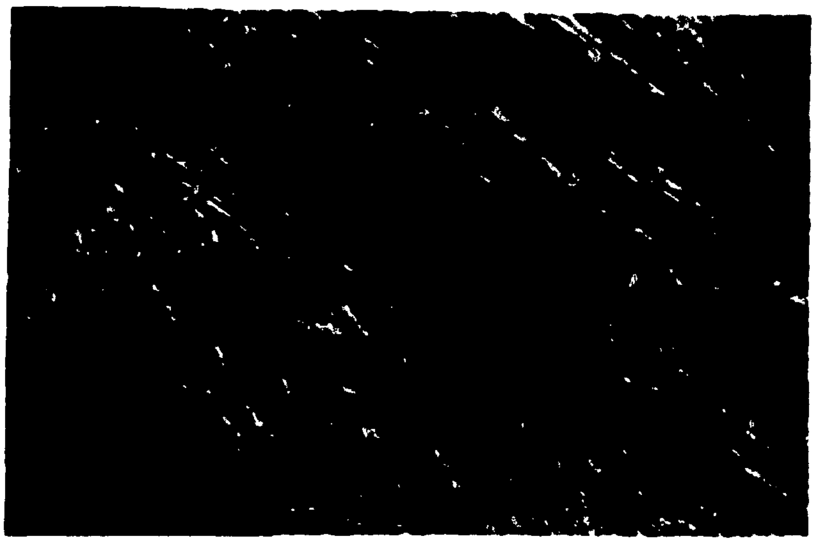

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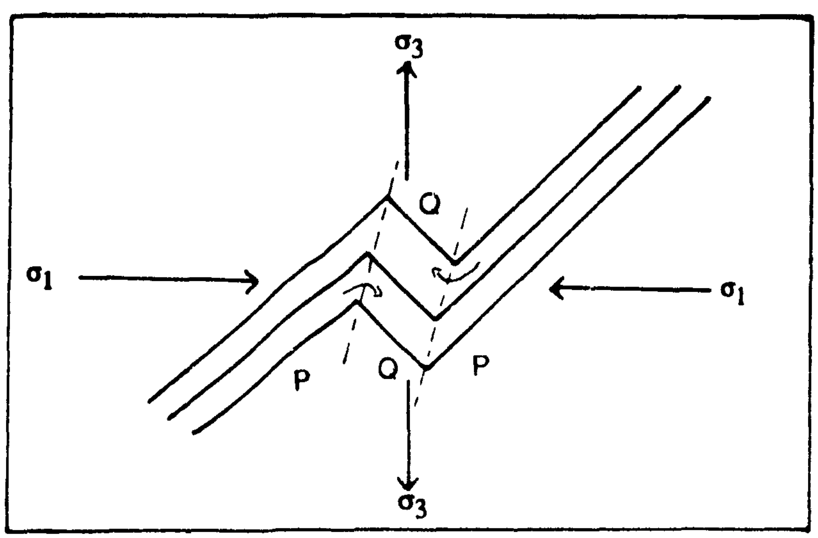


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is characterised by a gently southwest-dipping homoclinal panel. There are no obvious extension faults or offsets present. Further south along strike, north of Mount Brown (Appendix I), only compressional structures are observed.

The absence of a normal fault along strike, suggests that the Selwyn Range Fault is a compressional structure. Based on this presumption the possible correlations of Selwyn Range Fault are discussed below.

## CORRELATIONS OF THE SELWYN RANGE FAULT

Three interpretations of the continuation of the Selwyn Range Fault, from where it is mapped on the west flank of the Fraser River Antiform, are examined (Fig. 4.8). The first interpretation is that the fault continues along strike to the south (southwest of Saddle Mountain) (Fig. 4.8a). This implies the thick pelites in the footwall are upper Miette Group. The second interpretation is that the fault wraps around the southern plunge of the Fraser River Antiform, and occurs at the base of the middle Miette Group on the east flank of the Fraser River Antiform. This requires the contact between the middle Miette Group and the underlying thick pelites to be tectonic. As well, this interpretation requires the fault to be folded by the Fraser River Antiform and crop out as a window in it's core (making the fault a $D_2$ structure placing middle Miette Group grits over upper Miette Group pelites) - "thin stratigraphy interpretation" (Dechesne and Mountjoy, in press) (Fig. 4.8b). The third interpretation is that the fault wraps around the southern plunge of the Fraser River Antiform, and occurs somewhere within the middle Miette Group, so that the base of the middle Miette Group lies confor ably on the underlying thick pelites. This implies that the underlying pelites are lower Miette Group ("thick stratigraphy" interpretation).

The first interpretation, that the fault continues along strike to the south, would require the Old Fort Point Formation to be thrust over the upper Miette Group, a minimum throw of 2500 m. As discussed above, no faults with large displacements were observed along strike near Saddle Mountain, making this interpretation improbable. If the Selwyn Range Fault does not continue along strike to the south, it must wrap around the southern plunge of the Fraser River Antiform. This is supported by correlations of the Old Fort Point Formation around the southern plunge of the Fraser River Antiform, with no offset, restricting the Selwyn Range Fault to occur underneath it (Appendix I).

The second interpretation ("thin stratigraphy") requires that the fault be a $D_2$, east-dipping thrust, riding under the middle Miette Group on the east flank of the Fraser River Antiform, as proposed by Dechesne (1990a). Three ridges on

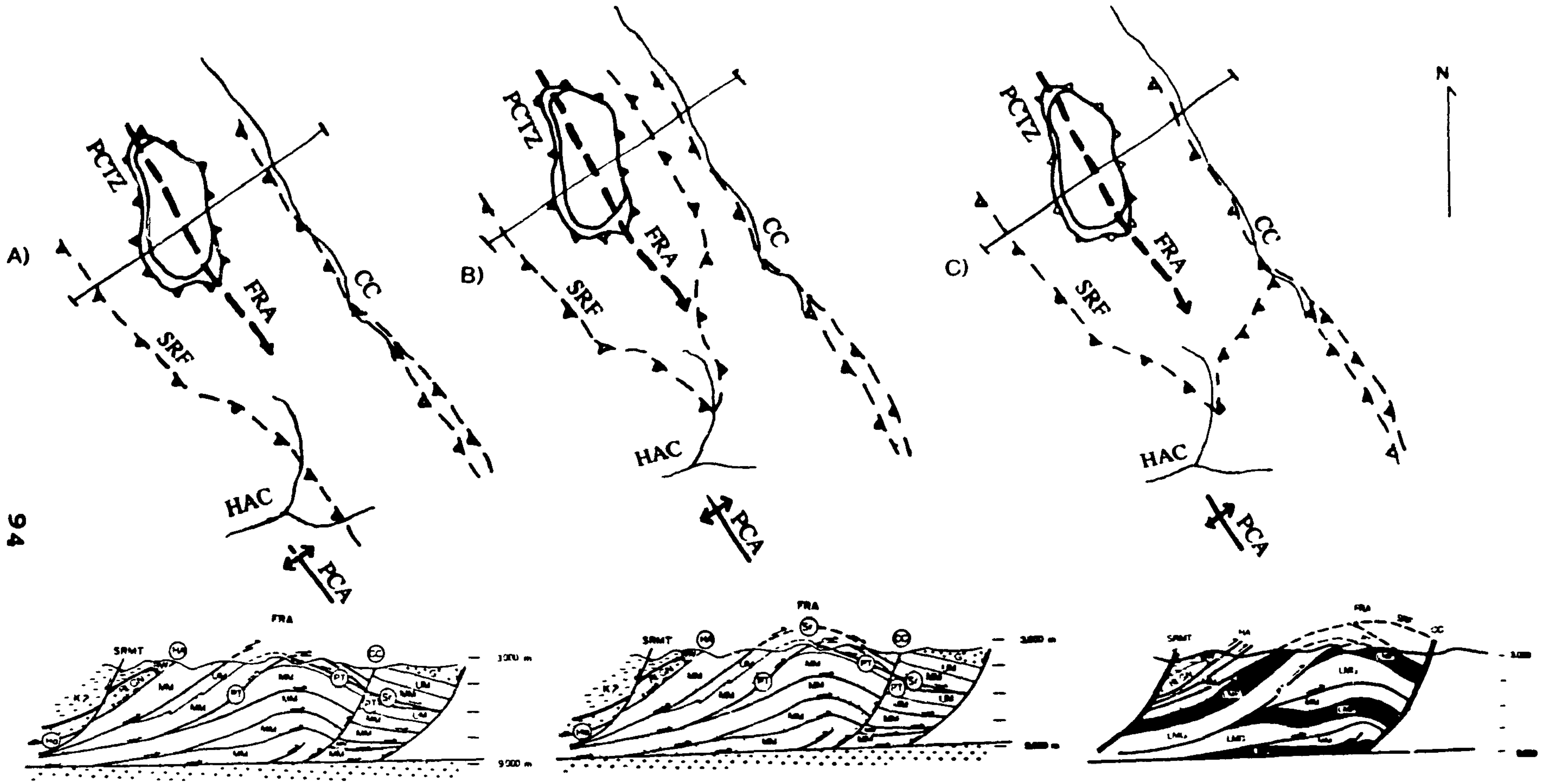



Fig. 4.8. Maps and related schematic cross-sections, illustrating three interpretations of the continuation of the Selwyn Range Fault from the west flank of the Fraser River Antiform. See text for discussion.

the east flank of the Fraser River Antiform were traversed, from the middle Miette Group down section into the core of the antiform, to see if a $D_2$ fault was present. Overall the east flank is characterised by an essentially homoclinal east-dipping panel with mincr $D_2$ east dipping faults (less than 100 m displacement), and associated thin zones (1-2 cm) of highly strained pelite crenulated by $S_3$. The east limb is locally folded by $D_3$ folds. A shear zone was not observed at the base of the middle Miette Group (as defined in Chapter 2).

The second interpretation requires the Selwyn Range Fault to cut down section in the direction of transport. On the west flank of the Fraser River Antiform the fault rides at the Old Fort Point Formation level, whereas on the east flank of the Fraser River Antiform, the fault must ride at the base of the middle Miette Group (Mountjoy and Grasby, 1990). This would require the Selwyn Range Fault to cut down section 1500 m in the hanging wall, contrary to the "foothills rules" outlined by Dahlstrom (1970). This relation may be explained if the Selwyn Range Fault is an out-of-sequence $D_2$ fault that cross-cuts an earlier, large scale, $D_1$ structure (Mountjoy and Grasby, 1990). However, there is no direct evidence for $D_1$ structures east of the Hugh Allan Thrust. The earliest structures observed are $D_2$. The lack of pre-$D_2$ structures, and the absence of a major $D_2$ fault and/or shear zone on the east flank of the Fraser River Antiform, makes the second interpretation improbable.

The third interpretation ("thick stratigraphy"), again requires the fault to cut down section (Fig. 4.8c). On the west flank of the Fraser River Antiform, the fault places the Old Fort Point Formation against strata interpreted to be lower Miette Group (Appendix I). This requires the Selwyn Range Fault to cut down-section in the footwall a minimum of 1500 m. Again, this relationship may be explained if the Selwyn Range Fault is an out-of-sequence fault. As discussed above, the Selwyn Range Fault may be either a $D_2$ or early $D_3$ structure. If the fault is a $D_3$ structure, it could have cross-cut an earlier $D_2$ structure. This structure must be an antiform to explain the down-cutting relation. A $D_2$ antiform (Fraser River Antiform) may have formed in response to thrust stacking in the Ptarmigan Creek Thrust Zone and lower structures during $D_2$, similar to duplexes described by Boyer and Elliot (1982) (Fig. 4.9). Unlike the second interpretation, this interpretation is plausible since there is evidence for structures earlier than $D_3$.

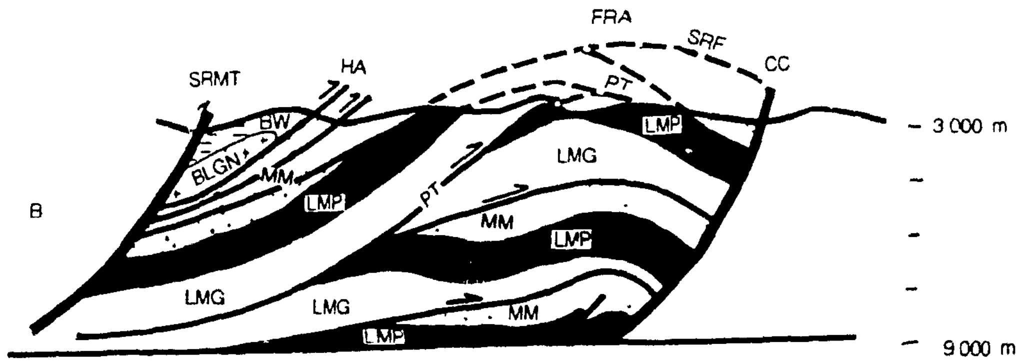
If the above interpretation is correct, the Selwyn Range Fault must occur somewhere on the east flank of the Fraser River Antiform. Strata above the Old Fort Point level, northeast of Saddle Mountain (Appendix I), are deformed into tight, slightly inclined, west-dipping $D_3$ folds, with approximately

50% shortening. However strata to the north, across the northeast arm of Hugh Allan Creek, are characterised by the homoclinal east-dipping limb of the Fraser River Antiform. This necessitates a fault to separate the highly shortened rocks northeast of Saddle Mountain from the relatively undeformed rocks to the north. This fault occurs below the Old Fort Point Formation (Appendix I), at about the same stratigraphic position as the Selwyn Range Fault on the west flank of the Fraser River Antiform. This fault is correlated herein around the southern plunge of the Fraser River Antiform with the Selwyn Range Fault (Fig. 1.2, Appendix I). To the east, the fault intersects the Chatter Creek Fault at a high angle, and is presumably cut by it.

This interpretation implies that lower Miette Group strata should occur somewhere in the hanging wall of the Selwyn Range Fault on the east flank of the Fraser River Antiform (Fig. 4.9a). Within the study area, the Selwyn Range Fault always contains middle Miette Group in the hanging wall. The portion of the Selwyn Range Fault, with lower Miette Group in its hangingwall, likely occurs east of the Chatter Creek Fault. This implies the Selwyn Range Fault has a minimun of 7 km displacement

**SUMMARY**

Fabrics associated with the shear zone on the west flank of



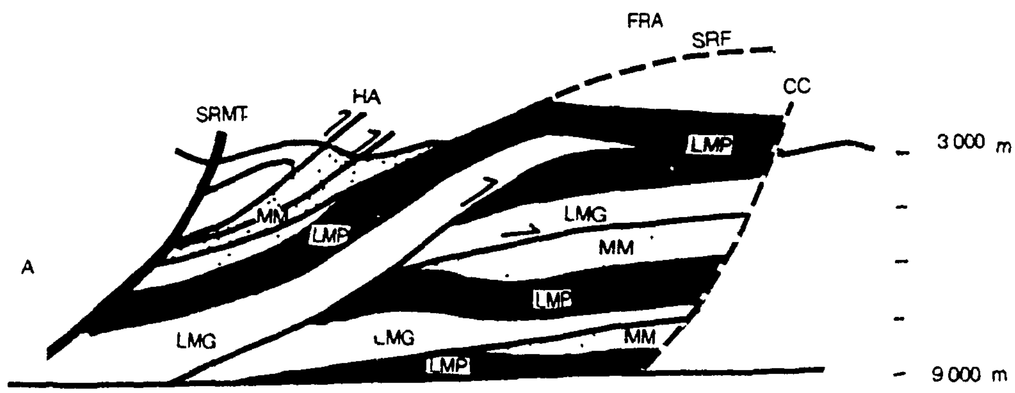




Fig. 4.9 Schematic diagram showing the Selwyn Range Fault cross-cutting the $D_2$ Fraser River Antiform A) and being warped by $D_3$ tightening of the Fraser River Antiform B). BW = Basal Windermere, LMg = lower Miette Group grits, LMp = lower Miette Group pelites, MM = middle Miette Group, UM = upper Miette Group, G = Gog Group, Blgn = Blackman Gneiss, HA = Hugh Allan Thrust, PT = Ptarmigan Creek Thrust, CC = Chatter Creek Thrust. See Fig. 1.2 for line of section

the Fraser River Antiform suggest that the shear zone is related to interlimb slip on the developing antiform, rather than to major faulting. This shear zone occurs at the same level, and likely reactivates an earlier fault (the Selwyn Range Fault) that juxtaposes middle Miette Group stratigraphy against a thick pelite sequence (lower Miette Group). The Selwyn Range Fault must be an out-of-sequence fault that cross-cuts an earlier structure, as it cuts down stratigraphic section in the direction of transport. The earliest deformation event east of the Hugh Allan Thrust is $D_2$. The "thin stratigraphy" interpretation requires the Selwyn Range Fault to be a $D_2$ structure. This interpretation is not plausible since there are no observed earlier $D_1$ structures for this fault to cross-cut. As discussed above, tectonic fabrics indicate the Selwyn Range Shear Zone is a $D_3$ structure. As the shear zone reactivates the Selwyn Range Fault, the fault must be a $D_2$ or early $D_3$ structure. Since the Selwyn Range Fault is out-of-sequence it must cut an earlier structure. The earliest structures east of Hugh Allan Thrust are $D_2$, suggesting the Selwyn Range Fault is early $D_3$.

# CHAPTER 5 - METAMORPHISM

## INTRODUCTION

Metamorphism in the field area increases westwards from greenschist facies to amphibolite facies, consistent with Barrovian regional metamorphism (Miyashiro, 1973). Previous workers in the area (Forest, 1985; Leonard, 1984, 1985; Charland, 1989) have shown that garnet zoning profiles are normal for prograde metamorphism (Hollister, 1966; Tracy, 1978), with Mg increasing and Mn decreasing from the core to the rim. Biotite shows variability in Mg/Mg + Fe, with slightly Mg rich cores (Charland, 1989). Peak metamorphic conditions in the western part of southern Selwyn Range were reached at pressures of 5.3 to 6.3 Kb and temperatures of 550°C to 640°C (Leonard, 1985; Charland, 1989). Whereas peak metamorphic conditions in the eastern part were reached at pressures of 4.5 Kb and temperatures of 400°C to 440°C (Forest, 1985).

Sporadic first occurrences of metamorphic minerals have made it difficult to accurately locate and determine the geometry of isograds in the field area. Isograds on the field map (Appendix I) indicate the easternmost position where metamorphic assemblages commonly occur. Charland (1989) suggested isograds, near Mt. Blackman (in the northwest part of the map area) were steeply west-dipping, with increasing metamorphic grade to the west. To the south, in the Park Ranges, Craw (1978) suggested isograds were east dipping with increasing grade to the west. Although isograds in the field area are difficult to map, they appear to be moderately to steeply dipping as metamorphic grade generally varies east-west. There is insufficient control to determine if grade varies vertically.

## PETROLOGY

The dominant metamorphic minerals in the area are: chlorite, white mica, chloritoid, biotite and garnet. Staurolite and kyanite have been reported west of the field area (Charland, 1989; Leonard, 1985). Chlorite, muscovite and chloritoid tend to be aligned with the $S_2$ fabric, whereas garnet and biotite show syntectonic relations with $D_3$. These relations are consistent with metamorphism beginning during $D_2$ and peaking during $D_3$, as suggested by Klein (1991). Charland (1989) did not recognise the $D_3$ event and places the peak of metamorphism during $D_2$.

Chlorite and muscovite are the dominant minerals in pelitic rocks and are found throughout the field area. They usually occur as small laths aligned in the $S_2$ cleavage (Fig. 5.1). They are commonly kinked and crenulated by the $S_3$ cleavage, and exhibit sweeping extinction around the hinges of $F_3$ microfolds. In the higher grade, western part, of the field area, the $S_3$ cleavage is a zonal to discrete crenulation with a strong alignment of muscovite and chlorite (Fig. 3.15). Chlorite also occurs as a retrograde mineral replacing garnet and biotite. Chloritoid occurs sporadically throughout the field area as euhedral twinned crystals. Generally chloritoid is aligned in the $S_2$ foliation. However chloritoid occasionally overgrows $S_3$ fabrics.

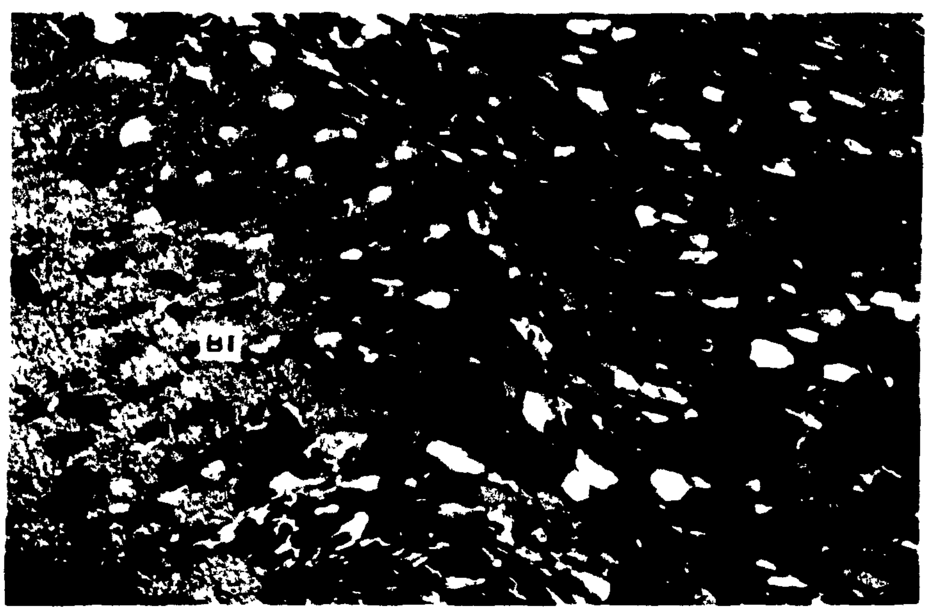
Biotite is generally restricted to the western part of the field area. However, a few small crystals were observed in samples from the east flank of the Fraser River Antiform. Biotite occurs as large porphroblasts with poorly defined inclusion trails. Generally Si appears to be continuous with Se (Fig. 5.2). Biotite usually overgrows the $S_3$ foliation, however biotite is commonly kinked by the $S_3$ crenulation cleavage (Fig. 5.3). Biotite is occasionally observed as laths aligned in the $S_2$ foliation.

Garnet only occurs in association with biotite in the areas sampled. The low grade zone of garnet without biotite, in the hanging wall of the Ptarmigan Creek Thrust Zone (Forest, 1985; Hynes and Forest, 1989), was not observed. Three types of garnet are observed within the biotite + garnet zone: Type I garnets have weakly crenulated inclusion trails that are continuous with a more strongly crenulated Se (Fig. 5.4). The axial traces of inclusion trail crenulations, from different

Fig. 5.1 Muscovite and chlorite laths aligned in the $S_2$ cleavage.

Fig. 5.2 Biotite porphroblast overgrowing the $S_2$ cleavage (SEG90-32-1).

5.1




5.2

porphroblasts, tend to be parallel with each other and the external crenulation. In type II garnets Si is discontinuous with, and at a high angle (up to 90°) to the matrix foliation (Fig. 5.5). Type III garnet overgrow the $S_3$ foliation and do not contain inclusion trails (Fig. 5.6). There is no apparent spacial or stratigraphic distribution of the three garnet porphroblast types.

## RELATIVE TIMING OF METAMORPHISM

A number of data indicate metamorphism peaked during $D_3$. Type I garnets overgrow the crenulated fabric of the $D_3$ episode of deformation. However the crenulations of the internal inclusion trails are usually less developed than the external crenulation. This fabric relation suggests garnet grew during the $D_3$ deformation (Bell, 1985; Spry, 1969). Type II garnets, where the external foliation is highly oblique to the internal foliation, indicate $D_3$ continued after garnet growth. Type III garnets indicate some garnet growth occurred late in $D_3$. The three types of garnet may be interpreted to represent either different metamorphic episodes, or different timing of growth within the same metamorphic event. The latter interpretation is preferred as there is no evidence of two stages of garnet growth within a single thin section. Metamorphism ended before the end of $D_3$ as evidenced by kinked

Fig. 5.3 Biotite porphroblast overgrowing, and kinked, by the $S_3$ foliation (SEG90-35B).

Fig. 5.4 Weakly crenulated inclusion trails of the garnet porphroblast continuous with the external foliation (SEG90-15B).

Fig. 5.5 Inclusion trails in garnet porphroblast at a high angle to the external foliation.

Fig. 5.6 Garnet porphroblast overgrowing the $S_3$ crenulation cleavage (SEG89-186B).

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and crenulated micas that exhibit sweeping extinction.

# CHAPTER 6 - STRUCTURAL EVOLUTION AND CONCLUSIONS

The structural/metamorphic history of the southern Selwyn Range is summarised in Table 1. The first phase, west-verging, deformation in the southern Selwyn Range is restricted to the hanging wall of the Hugh Allan Thrust and represents the easternmost expression of west-verging deformation in the Cordillera.

The major structures in the southern Selwyn Range developed during $D_2$ and $D_3$. The first main phase of deformation ($D_2$) was characterised by low-angle thrusting and recumbent, isoclinal folding. Second phase thrust sheets (Hugh Allan, Blackman, Ptarmigan Creek thrusts) propagated from west to east, forming an imbricate thrust stack, typical of foreland fold and thrust belts (Boyer and Elliot, 1982). During $D_2$, imbricate stacking within the Ptarmigan Creek Thrust Zone, and lower structures, formed an antiformal stack of thrusts (the Fraser River Antiform).

During early $D_3$ a low angle fault (Selwyn Range Fault), cross-cut the Fraser River Antiform, cutting down section in the direction of transport. The Fraser River Antiform then tightened during late $D_3$, warping the Selwyn Range Fault. Interlimb shear associated with this tightening reactivated the Selwyn Range Fault, developing a 100 m thick shear zone on the west flank of the Fraser River Antiform. Third phase tightening of the Fraser River Antiform, folded earlier $D_2$ structures.

Originally Mountjoy and Forest (1985) interpreted the shortening associated with the Fraser River Antiform to be accommodated by motion on the Chatter Creek Fault. However the steep nature of the fault, and its minor displacement make such a relation unlikely. Dechesne and Mountjoy (in press) suggest that shortening is accommodated along a lower, unexposed detachment, that feeds into structures of the eastern Main Ranges.

A number of faults in the area (unnamed fault, Hugh Allan, Chatter Creek) were reactivated by late stage ($D_3$ or later), post metamorphic dextral motion. Similar late stage dextral motion has also been reported in the northern Selwyn Range along the Klapperhorn Thrust (McDonough, 1989), in the Mount Robson area along the Resplendant Fault (Mountjoy, 1964;1980) and near the Trans-Canada Highway to the southeast along the Stephen-Cathedral and Cataract Brook normal faults (Cook, 1975). These occurrences suggest that dextral strike slip motion (with relatively minor displacement) has occurred over a large area of the southern Rocky Mountain Main Ranges. If the Cathedral and Cataract Brook normal faults are related to Eocene extension in the Cordillera, dextral motion would have occurred up to this time.

Metamorphism was initiated during $D_2$, indicated by alignment of micas, biotite, and chloritoid in the $S_2$ foliation. Metamorphism was prograde, and peaked during $D_3$ (at garnet grade in the western part and greenschist grade in the eastern part of the Selwyn Range). Third phase deformation outlasted metamorphism.

The relative timing of metamorphism, and similar structural histories, suggest that the Fraser River Antiform formed at the same time as the Porcupine Creek Anticlinorium. The two folds are en echelon, with total shortening in the Fraser River Antiform increasing northward and the shortening in the Porcupine Creek Anticlinorium increasing southward of Hugh Allan Creek. Shortening associated with the Porcupine Creek Anticlinorium is transferred across Hugh Allan Creek to the Blackman Thrust, which disappears southward into the core of the Porcupine Creek Anticlinorium.

## CONCLUSIONS

1) The Miette Group in the southern Selwyn Range is interpreted to consist, from the base up, of 2500 m of lower Miette Group grit, 2500 m of lower Miette Group pelite, 3000 m of middle Miette Group grit and 1500 m of upper Miette Group pelite. All units have been tectonically thickened.

2) The Old Fort Point Formation is a distinctive tripart sequence in the middle Miette Group, that was used for stratigraphic correlations and mapping structure.

3) The presence of the Old Fort Point Formation in pelite dominated sequences, delineates a facies change, westward across the map area, from a grit dominated to a pelite dominated succession in the middle Miette Group.

4) Three main phases of deformation are observed in the southern Selwyn Range. The first phase is west-verging and restricted to the hanging wall of the Hugh Allan Thrust. The second and third phases of deformation are east-verging and ubiquitous in the field area.

5) The Fraser River Antiform is a broad, open fold, en echelon with the Porcupine Creek Anticlinorium. This antiform formed during $D_2$, and tightened during $D_3$.

6) The Selwyn Range Fault is interpreted to be a $D_3$ out-of-sequence fault, cutting down section in the direction of transport (from west to east) in the footwall and hanging wall. The fault cross-cuts the earlier ($D_2$) Fraser River antiform.

7) The Selwyn Range Fault was reactivated by a 100 m thick

shear zone (the Sewlyn Range Shear Zone) on the west flank of the Fraser River Antiform. The shear zone is related to interlimb slip during $D_3$ tightening of the Fraser River Antiform.

8) The Chatter Creek Fault is a $D_3$ or latter, steeply dipping, out-of-sequence fault with approximately 3.5 km of throw, and unknown, but apparently minor dextral displacement. The fault cross-cuts the McGillivray Ridge Fault.

9) Late-stage dextral motion reactivated the unnamed fault in the hanging wall of the Hugh Allan Thrust, the Hugh Allan Thrust and the Chatter Creek Fault during $D_3$ (or later).

10) Metamorphic grade increases from greenschist in the east to amphibolite facies in the west. Metamorphism was initiated during $D_2$ and peaked during $D_3$. Deformation outlasted metamorphism.

**TABLE 1**

**TIMING OF DEFORMATION IN THE SOUTHERN SELWYN RANGE**

| | | |
|---|---|---|
| $D_1$ | West-verging structures | - restricted to the hanging wall of the Hugh Allan Thrust |
| $D_2$ (early) | Hugh Allan Thrust<br>Blackman Anticline | - Pre to synmetamorphic |
| $D_2$ | Ptarmigan Creek Thrust Zone<br>Blackman Thrust<br>Porcupine Creek Anticlinorium<br>Fraser River Antiform | - Synmetamorphic |
| $D_3$ (early) | Selwyn Range Fault | |
| $D_3$ | Fraser River Antiform<br>Porcupine Creek Anticlinorium<br>Selwyn Range Shear Zone | - Peak to postmetamorphic |
| $D_3$ (late) | Chatter Creek Fault<br>Dextral Strike slip motion<br>Trench Faults | - Postmetamorphic |
| $D_4$ | Normal Faulting | |

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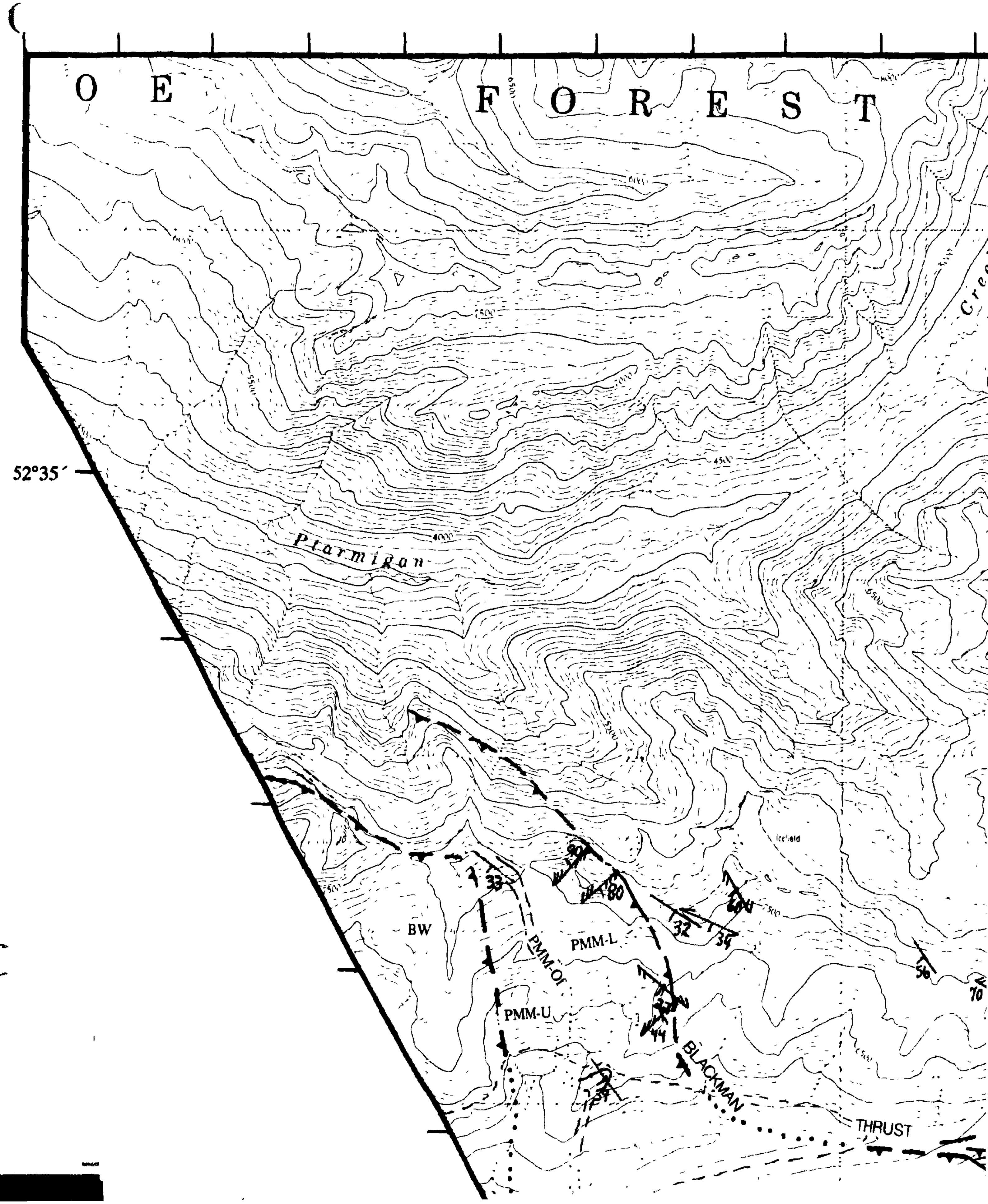
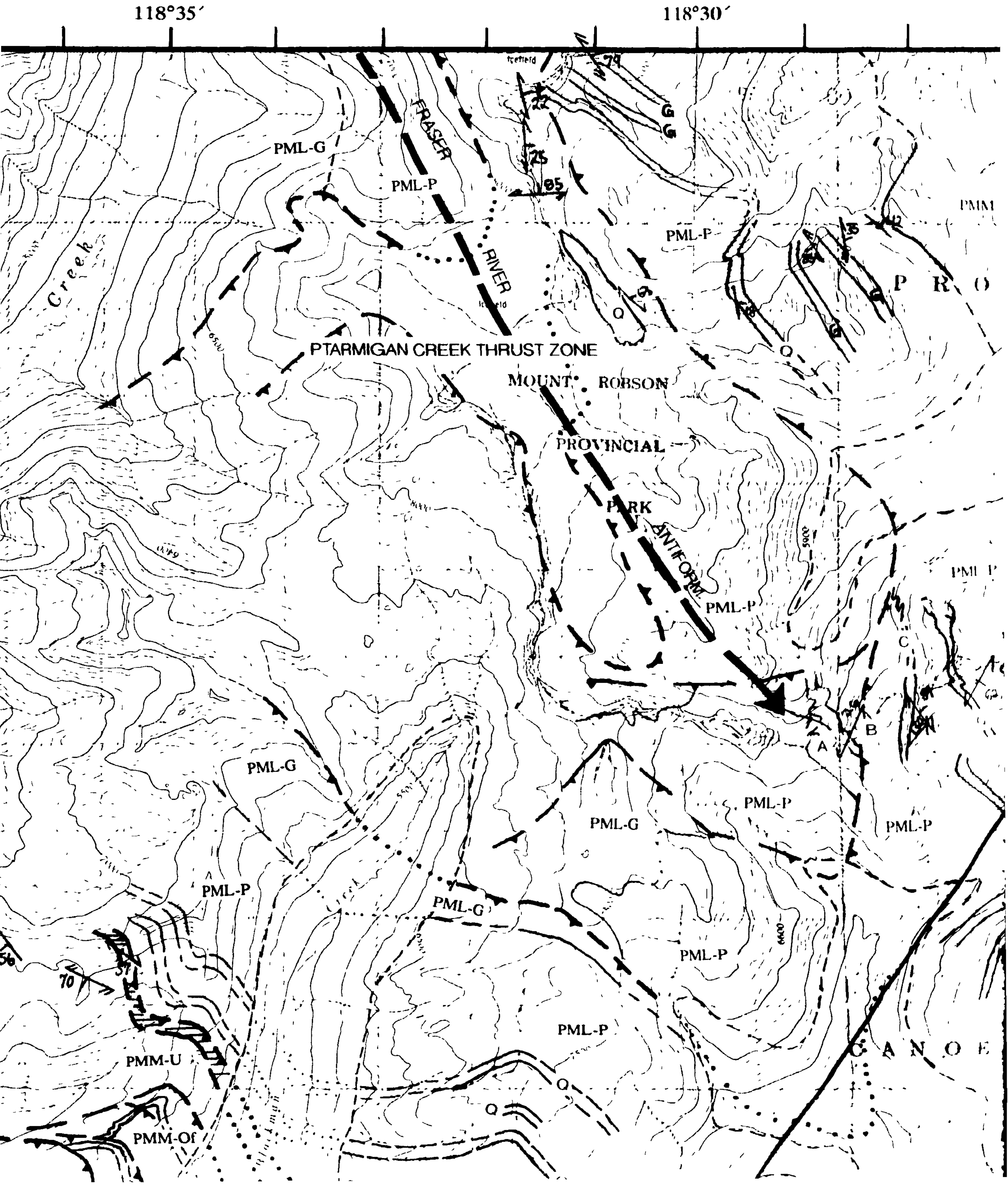

O E
F O R E S T
Ptarmigan
52°35′
BW
PMM-L
PMM-Of
PMM-U
BLACKMAN
THRUST
Icefield



118°35′
118°30′
PML-G
PML-P
FRASER
RIVER
Creek
PTARMIGAN CREEK THRUST ZONE
MOUNT ROBSON
PROVINCIAL
PARK
ANTIFORM
PML-P
PMM
P R O
Q
G
PML-P
C
B
A
PML-G
PML-G
PML-P
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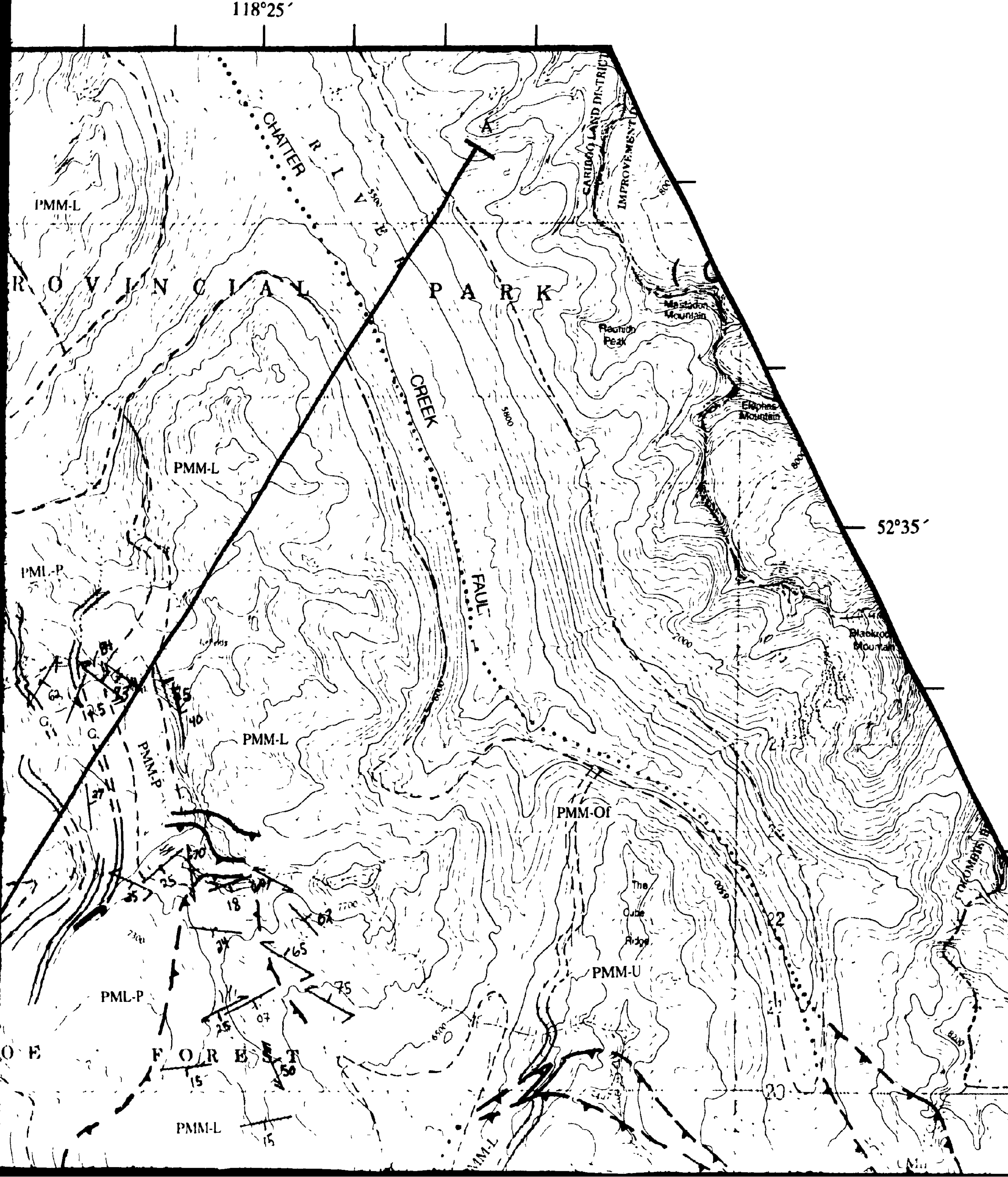
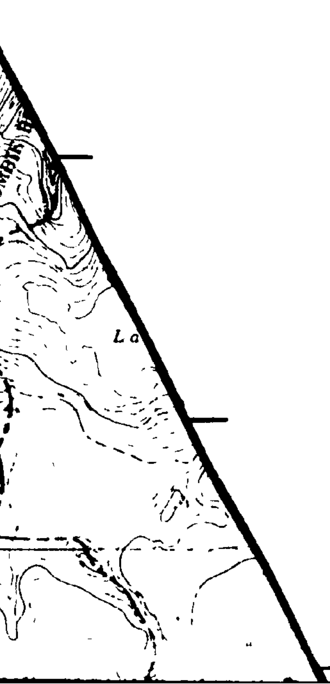
PML-P
PML-G
PML-P
PML-P
PMM-U
PMM-Of
Q
Q
C A N O E



118°25′
52°35′
CHATTER
CREEK
FAULT
R I V E R
P R O V I N C I A L P A R K
F O R E S T
CARIBOO LAND DISTRICT
IMPROVEMENT
Mastadon Mountain
Raurich Peak
Elaphes Mountain
Blackrock Mountain
The Cube Ridge
A
PMM-L
PML-P
PMM-P
PMM-Of
PMM-U



## STRATIGRAPHIC UNITS

MIDDLE CAMBRIAN

**CSi** SNAKE INDIAN FORMATION: alternating units of limestone and calcareous shale; limestone, micritic, partings, grey and resistant; silty shales and siltstone at base

LOWER CAMBRIAN

GOG GROUP

**CMa** MAHTO FORMATION sandstone, quartzose, crossbedded; alternating with thinner beds of siltstone and silty shales

**CMu** MURAL FORMATION. limestone, micritic; dolomite, finely crystalline; grey; archaeocyathid fragments

**CMn** McNAUGHTON FORMATION: sandstone, quartzose, crossbedded, massive; pebble conglomerate and feldspathic sandstone at base

HADRYNIAN

WINDERMERE SUPER GROUP

MIETTE GROUP

**PMU** UPPER MIETTE GROUP. pelite, silty, dark grey to brown, finely laminated; rare sandstone and grit beds near base; local black carbonate near base

**PMM-U** UPPER MIDDLE MIETTE GROUP: alternating, cliff forming, composite grit units up to 100 mn thick, and recessive silty, green, pelite units up to 50 m thick.

**PMM-Of** OLD FORT POINT FORMATION: tripart sequence; basal green pelite; middle silty orange to brown weathering dolomite; upper black, graphitic pelite

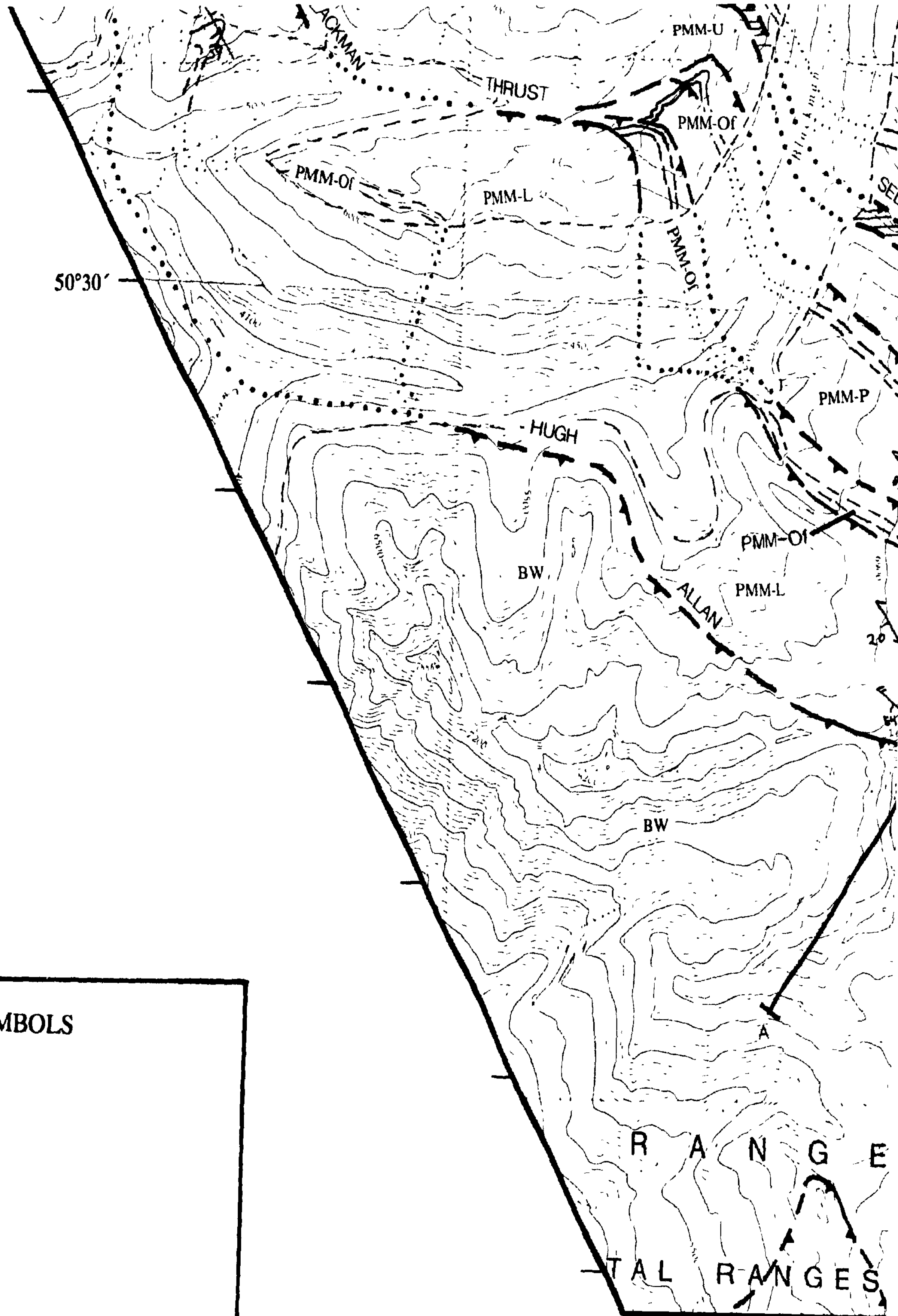
**PMM-L** LOWER MIDDLE MIETTE GROUP: same as upper middle Miette Group

**PMM-P** MIDDLE MIETTE GROUP PELITE: pelite, silty, green; common beds of sandstone, calcareous, brown weathering, cross bedded, rare beds of grit, up to 5 m

**PML-P** LOWER MIETTE GROUP PELITE: shale and pelite, dark reddish grey to black; occasional interbeds of siltstone and sandstone, two continuous grit units in upper part (G1 & G2); discontinuous, chanalised quartzites (Q) in lower part

**PML-G** LOWER MIETTE GROUP GRIT: grit unit; thin composite units (5 to 20 m thick) of grit and poorly sorted sandstone, calcareous, alternating with thicker pelite units, siltstone

**BW** BASAL WINDERMERE basal quartzite, grey to white, middle pelite, brown and grits, thin bedded (1 m), upper pelite, calcareous, brown, up to 20% 1-10 m grit beds




Contour Interval = 100ft

## MAP SYMBOLS

BEDDING

$S_1$

$S_3$

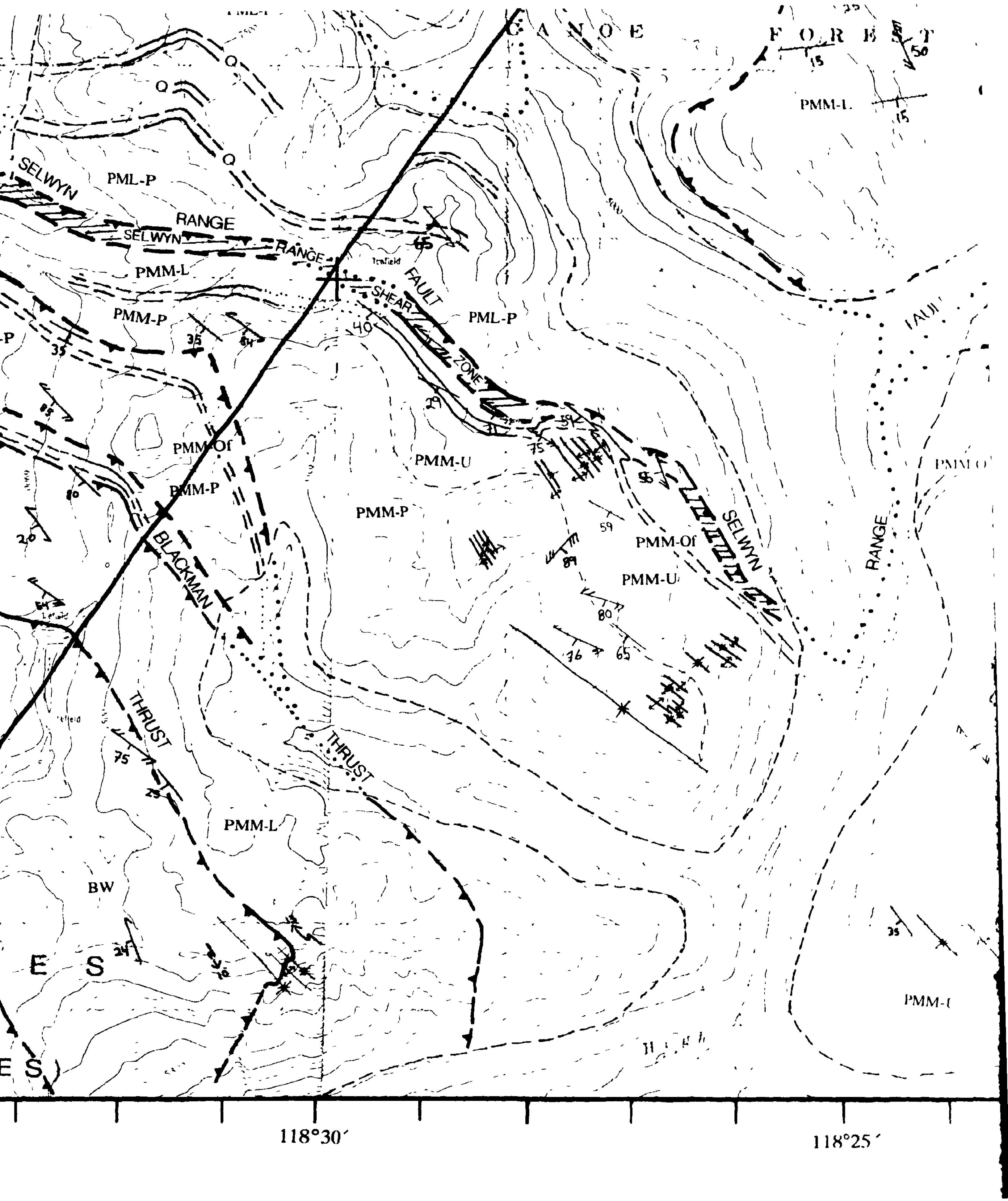
TRANSVERSE CLEAVAGE

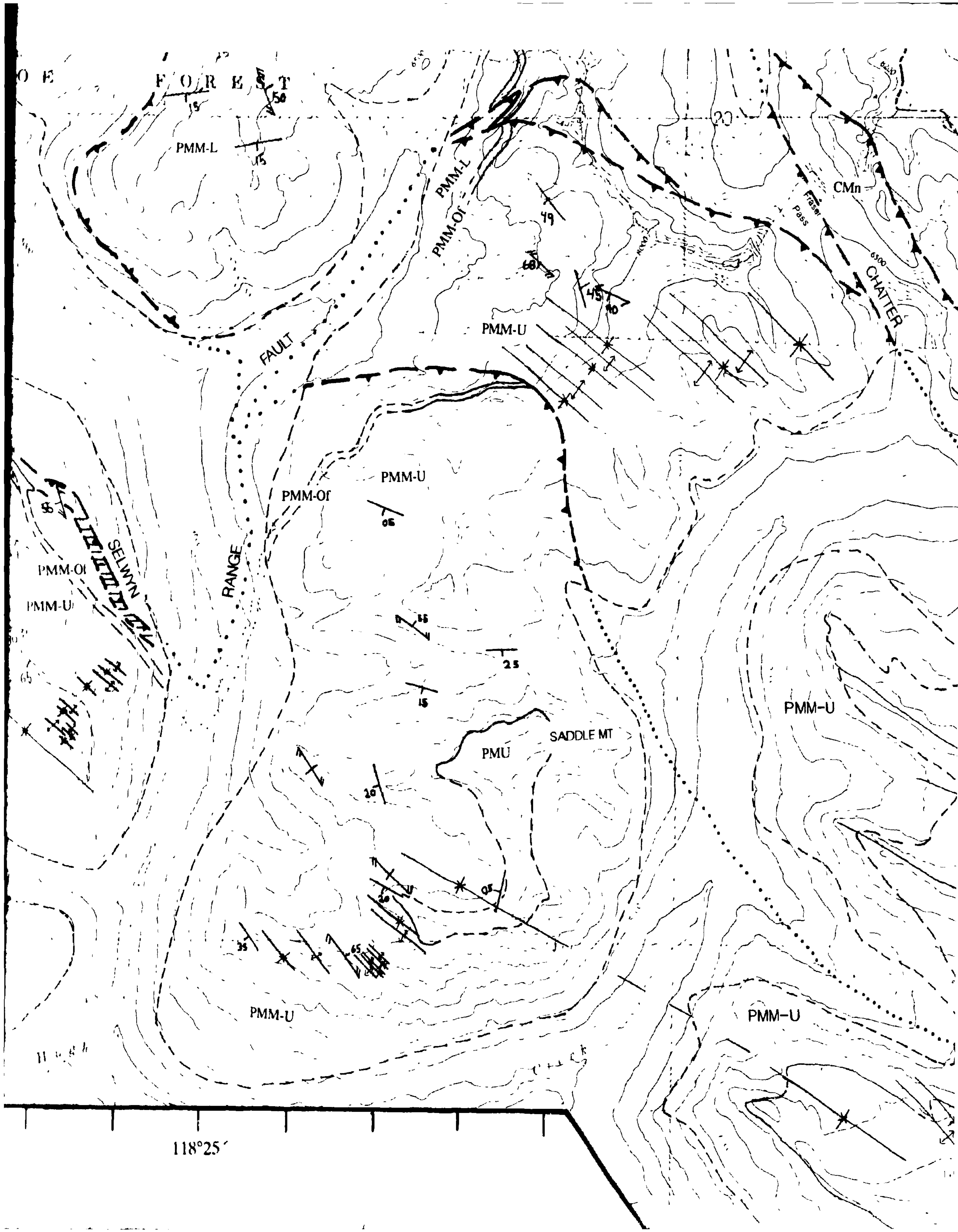
JOINT

MINOR FOLD

FOLD AXIS (TREND/PLUNGE)

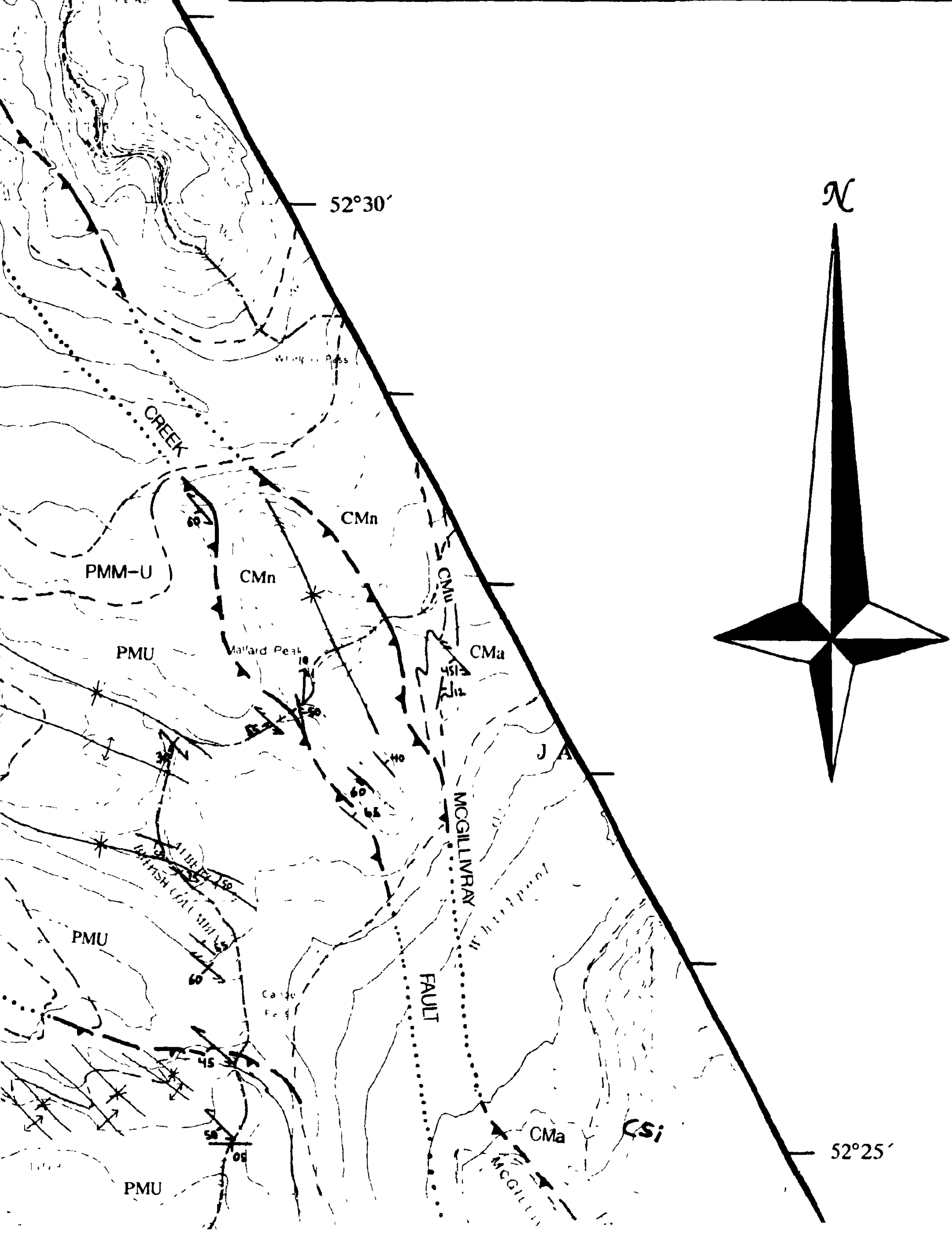
STRATIGRAPHIC CONTACT


CANOE
FOREST
PMM-L
SELWYN
PML-P
RANGE
SELWYN
RANGE
PMM-L
FAULT
SHEAR
ZONE
PML-P
PMM-P
PMM-Of
PMM-U
PMM-P
PMM-P
PMM-Of
PMM-U
SELWYN
RANGE
FAULT
BLACKMAN
THRUST
THRUST
PMM-L
BW
E S
E S
PMM-L
118°30′
118°25′



FOREST
PMM-L
PMM-L
PMM-Of
CMn
Fraser Pass
CHATTER
PMM-U
FAULT
PMM-U
PMM-Of
SELWYN
PMM-Of
PMM-U
RANGE
SADDLE MT
PMU
PMM-U
PMM-U
PMM-U
118°25′

| | |
|---|---|
| PML-G | LOWER MIETTE GROUP GRIT grit unit, thin composite units (5 to 20 m thick) of grit and poorly sorted sandstone, calcareous, alternating with thicker pelite units, siltstone |
| BW | BASAL WINDERMERE basal quartzite, grey to white; middle pelite, brown and grits, thin bedded (1 m), upper pelite, calcareous, brown, up to 20% 1-10 m grit beds |



## MAP SYMBOLS

BEDDING

$S_1$

$S_2$

TRANSVERSE CLEAVAGE

JOINT

MINOR FOLD

FOLD AXIS (TREND/PLUNGE)

STRATIGRAPHIC CONTACT

DEFINED

APPROXIMATE

ASSUMED

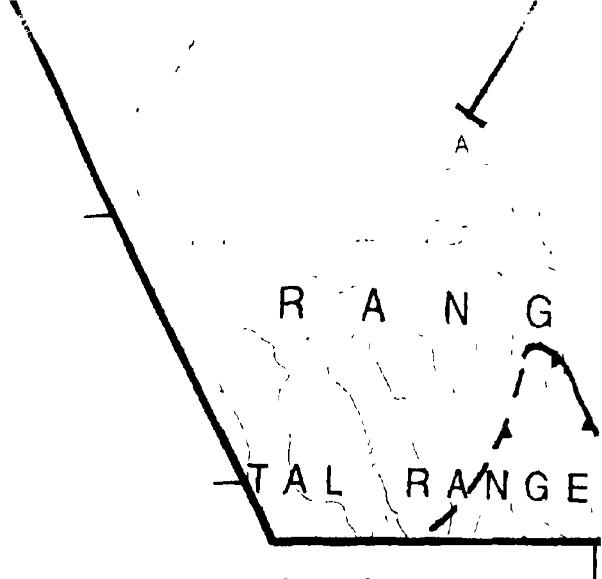
FAULT

DEFINED

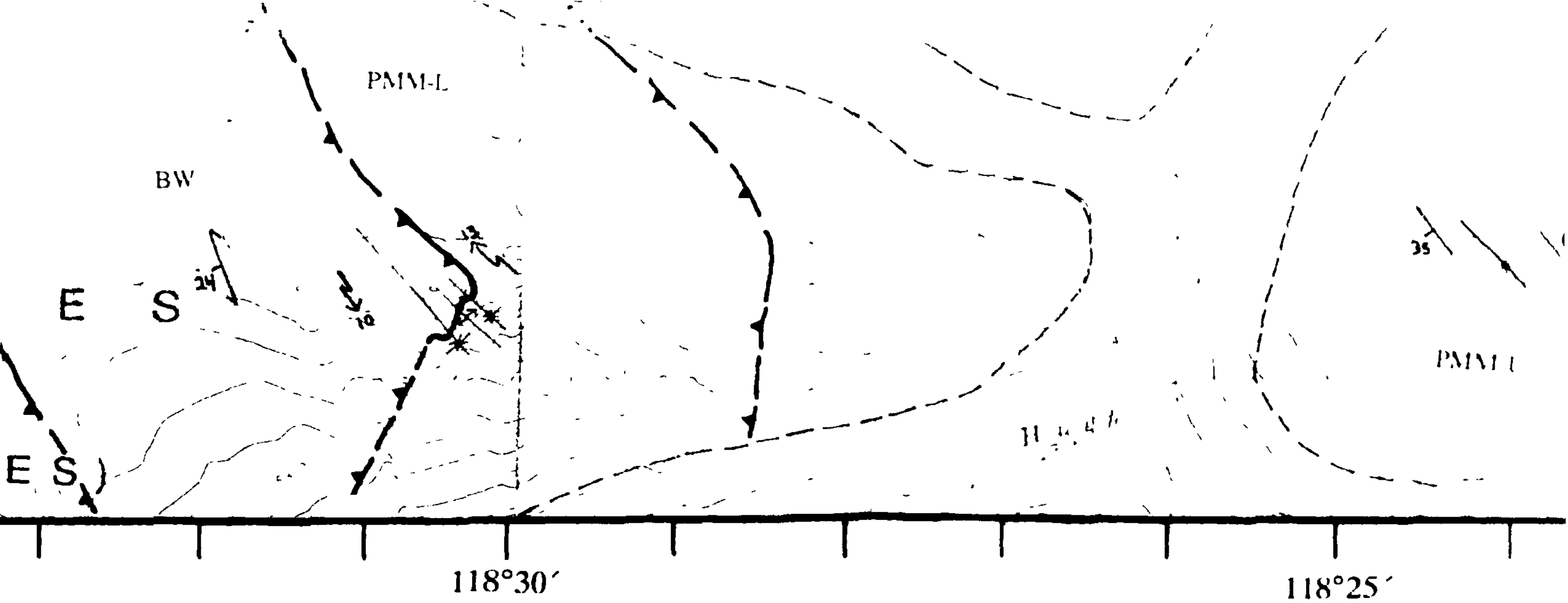
APPROXIMATE

ASSUMED

SELWYN RANGE SHEAR ZONE




Contour Interval = 100ft



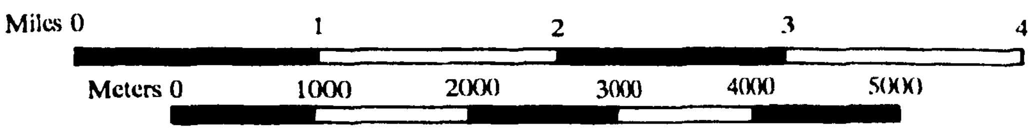

# GEOLOGY

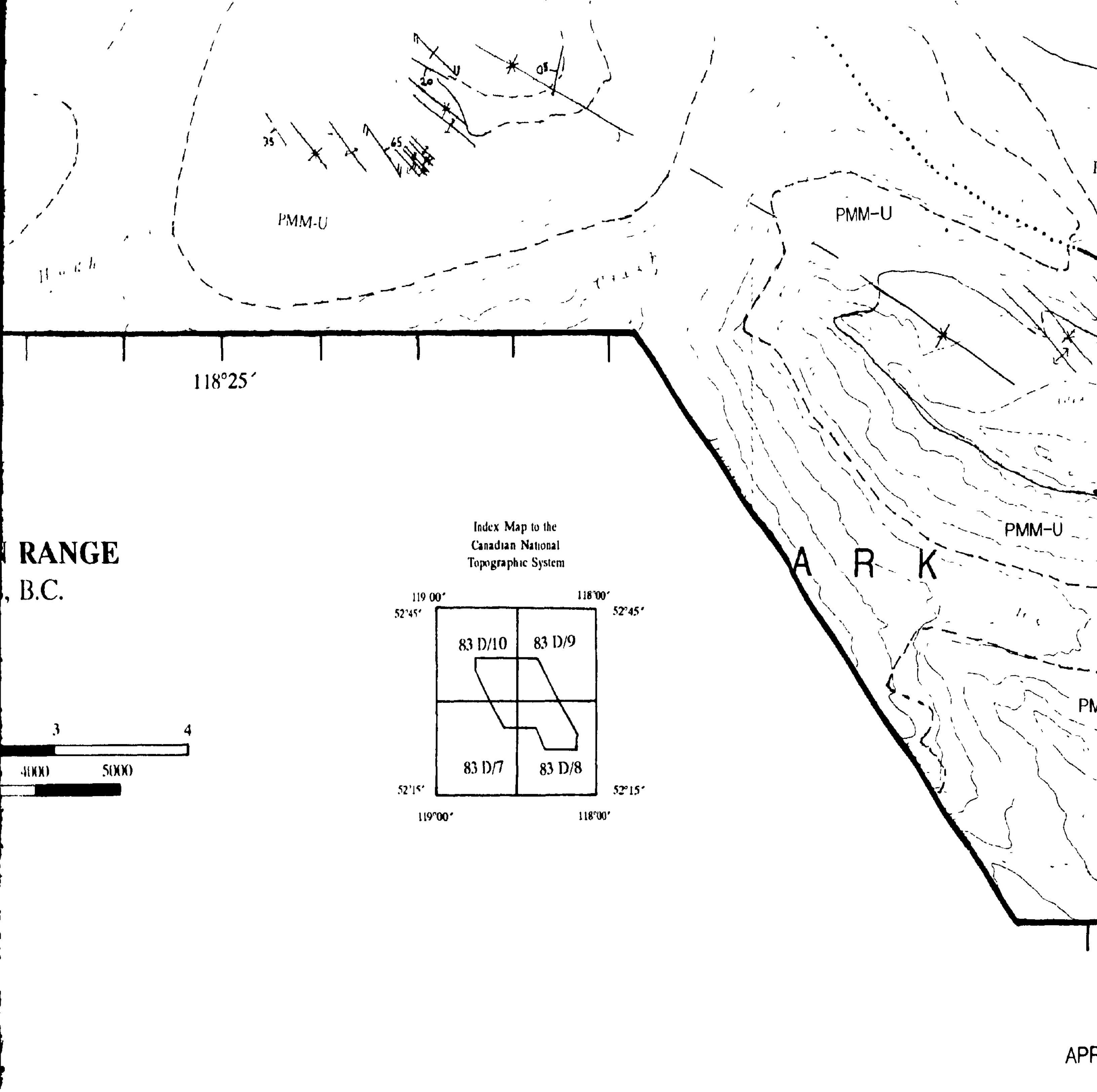
*of the*

# SOUTHERN SELWYN RANGE

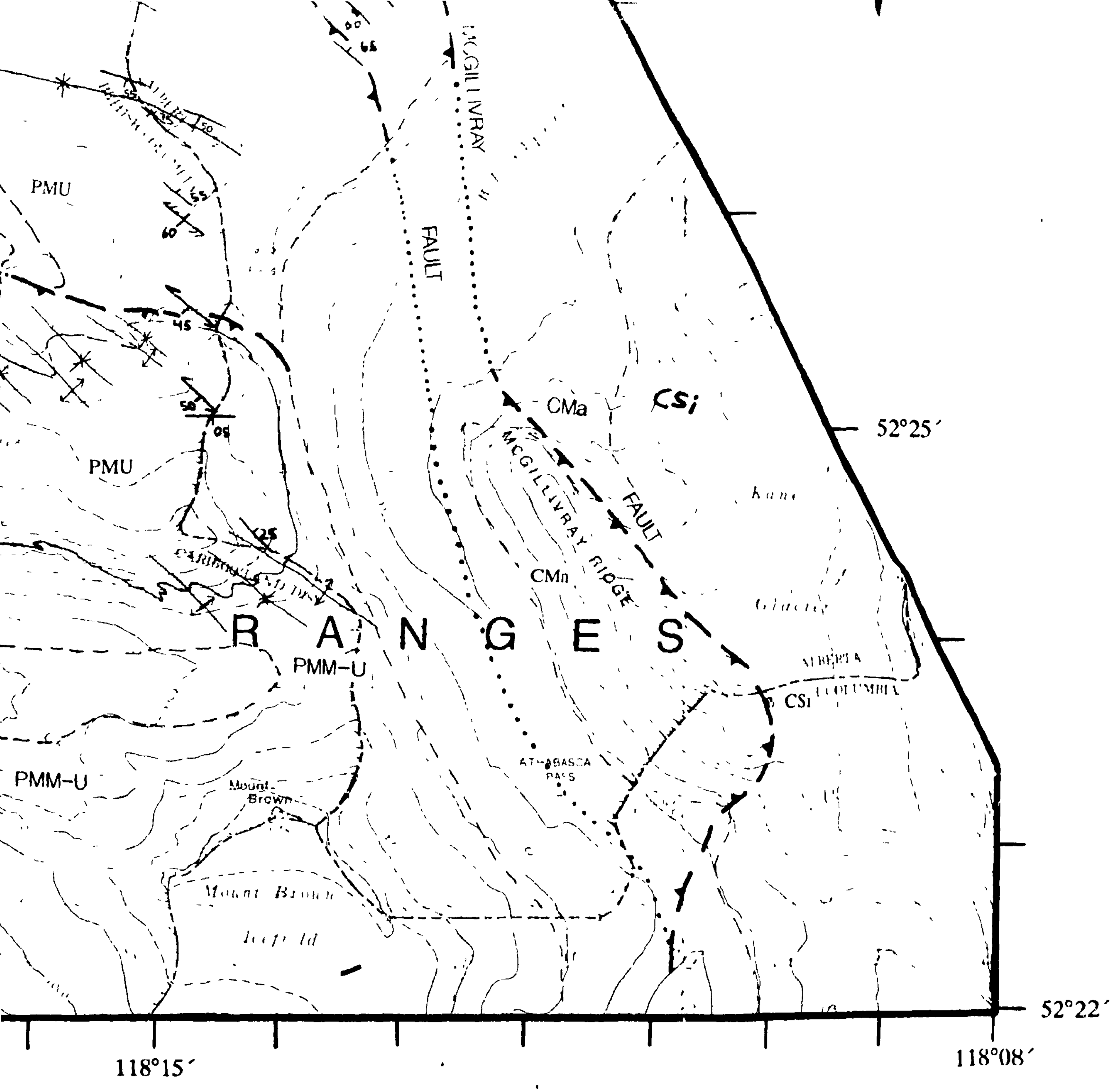
Western Main Ranges, B.C.

Scale 1:50 000

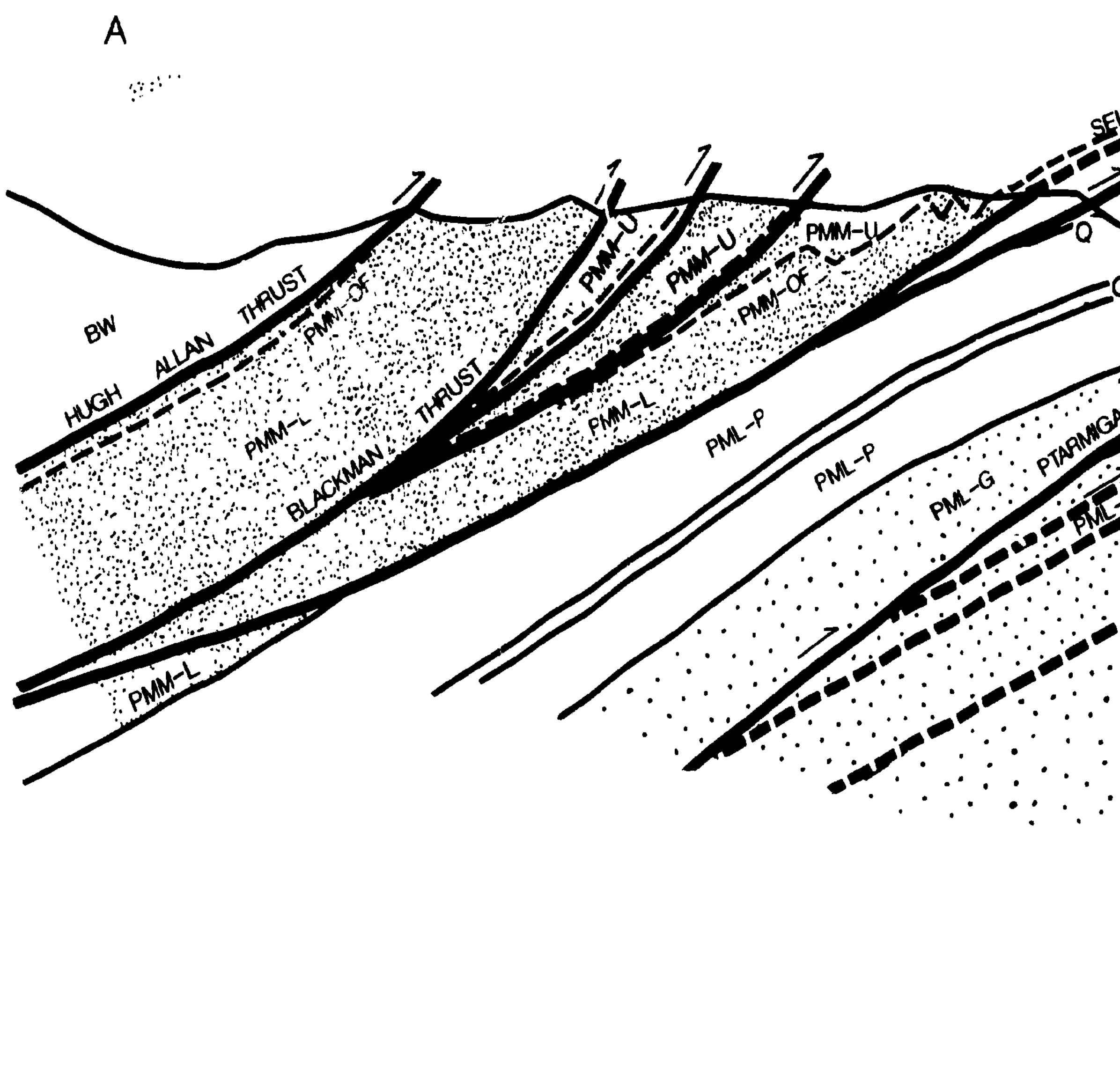




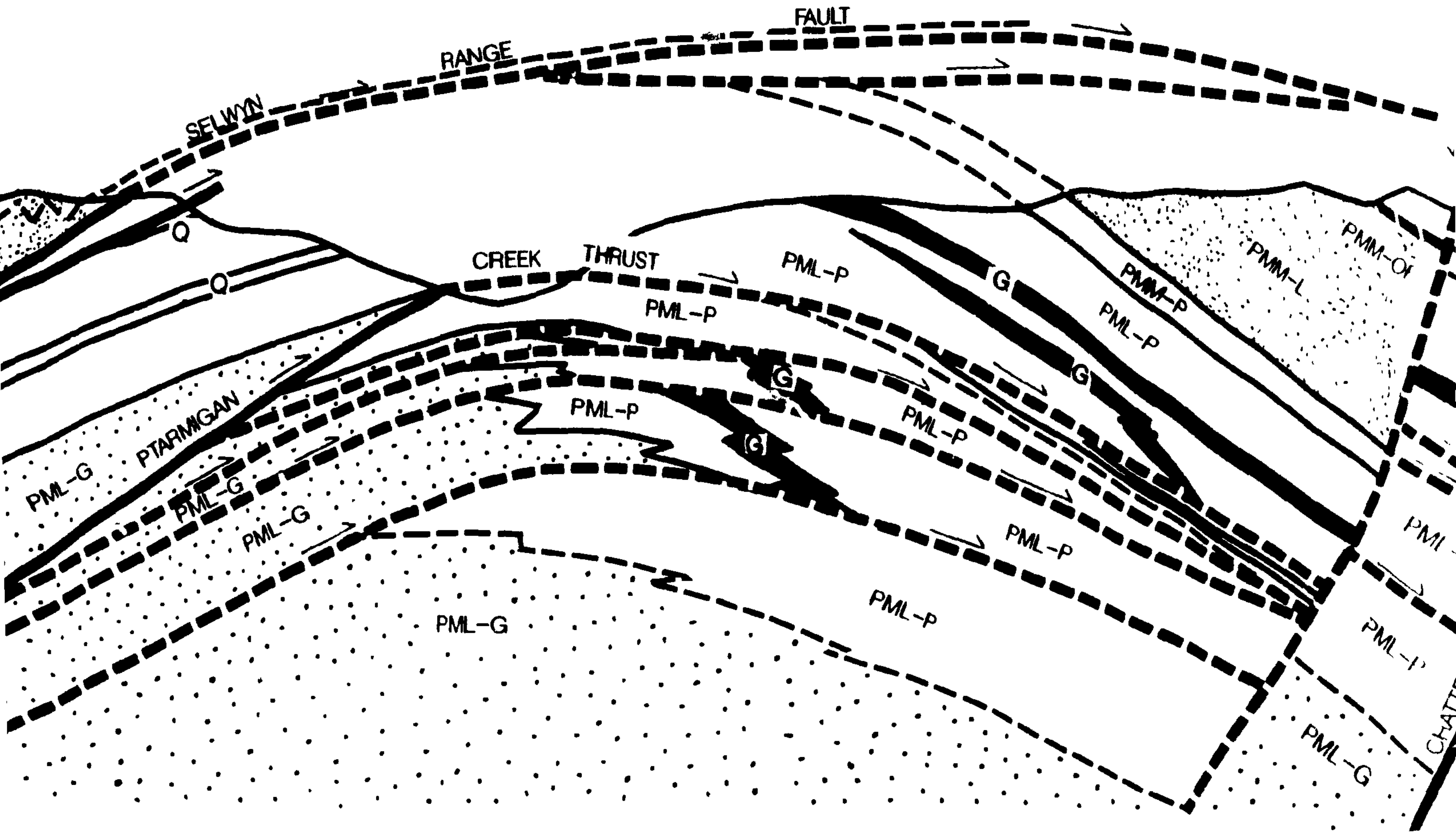
PMM-U
PMM-U
PMM-U
118°25′
RANGE
, B.C.
A R K
3
4
4000
5000
Index Map to the
Canadian National
Topographic System
119 00′
118°00′
52°45′
52°45′
83 D/10
83 D/9
83 D/7
83 D/8
52°15′
52°15′
119°00′
118°00′
APP


PMU
PMU
PMM–U
PMM–U
McGILLIVRAY
FAULT
CMa
CSi
McGILLIVRAY RIDGE
FAULT
CMn
R A N G E S
ATHABASCA PASS
Mount Brown
CSı
ALBERTA
52°25′
52°22′
118°15′
118°08′

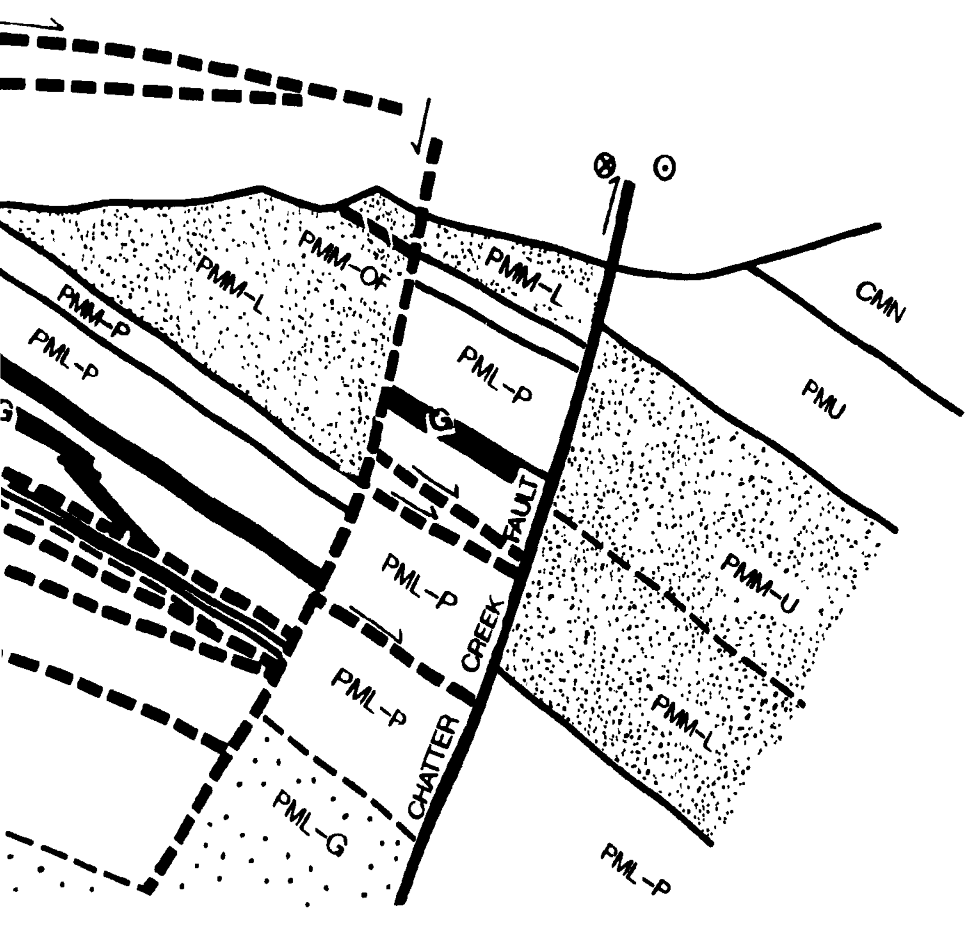
APPENDIX I


A
BW
HUGH ALLAN THRUST
PMM-OF
PMM-L
BLACKMAN THRUST
PMM-U
PMM-U
PMM-U
PMM-OF
PMM-L
PML-P
PML-P
PML-G
PTARMIGA
PMM-L
Q

FRASER RIVER ANTIFORM



A'


PMM-OF
PMM-L
PMM-P
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G
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CMN
PML-P
PMU
G
PMM-U
PML-P
PML-P
PMM-L
PML-G
PML-P
CHATTER CREEK FAULT

APPENDIX 2