Geology of the northern Park Ranges and Porcupine Creek Anticlinorium, British Columbia

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Abstract

The northern Park Ranges are underlain by middle and upper Miette Group (+/- 2800 m thick), Gog Group (700 to 1200 m thick) and unnamed Middle Cambrian(?) (> 1000 m thick) strata.

The regional structure is dominated by the southeast-plunging Porcupine Creek Anticlinorium (PCA). The core of the PCA is characterized by large-scale upright folds broken by thrust faults. The west flank of the PCA and the adjacent Baker Syncline (BS) are deformed by steeply southwest-dipping post-metamorphic thrust faults and Eocene (?) normal faults. The Precambrian Hugh Allan Gneiss is faulted against the west flank of the PCA by a post-metamorphic thrust, the Hugh Allan thrust. The Hugh Allan thrust has been correlated with the Purcell thrust of southern British Columbia.

Metamorphic grade increases from greenschist in the east to lower amphibolite in the west adjacent to the Hugh Allan (Purcell) thrust.

Sommaire

Les "Northern Park Ranges" sont hôtes d'une séquence stratigraphique qui comprend: Groupe de Miette moyen et superieur (environ 2800 m d'épaisseur) , Groupe de Gog (700 a 1200 m d'épaisseur) et des strates non definis d'âge Cambrien moyen (> 1000 m d'épaisseur).

Le PCA domine la structure régionale avec un coeur plissé, chevauché et une plongée sud-est. Sur le flanc ouest du PCA et dans le Baker Syncline (BS) adjacent, les roches ont subit une déformation tardive qui consiste en failles de charriage à pendage abrupt vers le sud-ouest et par des failles normales d'age Eocene(?). La faille post-métamorphique Hugh Allan a charrié le gneiss Precambrien Hugh Allan contre le flanc ouest du PCA. La faille Hugh Allan a eté associée avec la faille Purcell de la Colombie Britannique du sud.

Le faciès métamorphiques s'accroît de l'est vers l'ouest, de schiste vert à amphibolite adjacent à la faille Hugh Allan (Purcell).

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CHAPTER I - INTRODUCTION

1.1 Location

The study area is located in the northern Park Ranges in the Western Main Ranges of southeastern British Columbia (Fig.1.1). It lies between Hugh Allan Creek and Dawson Creek and extends eastward to about 5 km west of the Chatter Creek thrust. The western boundary of the study area is the Rocky Mountain Trench (Canoe Reach), a physiographic and structural feature that defines the western limit of the Rocky Mountain Fold and Thrust Belt. Access is by helicopter from Valemount, B.C., located 70 km to the northwest.

1.2 Purpose and objectives

The main purpose of this study was to determine the structural history of the northern Park Ranges and to relate the structures to the regional tectonic framework. This purpose was achieved by: 1) mapping at 1:50,000 scale (Fig. 5.1); 2) collecting structural, stratigraphic and metamorphic data, and 3) integrating and analyzing this data.

More specific objectives of the study were:

Stratigraphy: 1) to define more precisely the major stratigraphic units previously recognized during reconnaissance mapping; 2) to determine the stratigraphic position of; a) strata in the immediate footwall of the Hugh Allan (Purcell) thrust south of Hugh Allan Creek, b) the thick sequence of cliff-forming carbonates south of Baker Creek; 3) to find marker beds in the middle Miette Group and to map their lateral extent; and 4) to compare and correlate the stratigraphic units with other areas.

Structure: 1) to outline the structure at the deepest structural and stratigraphic levels at the northwest end of the Porcupine Creek Anticlinorium (PCA); 2) to construct cross-sections, and 3) to interpret the origin of the PCA and its deeper structure in terms of a regional tectonic model.

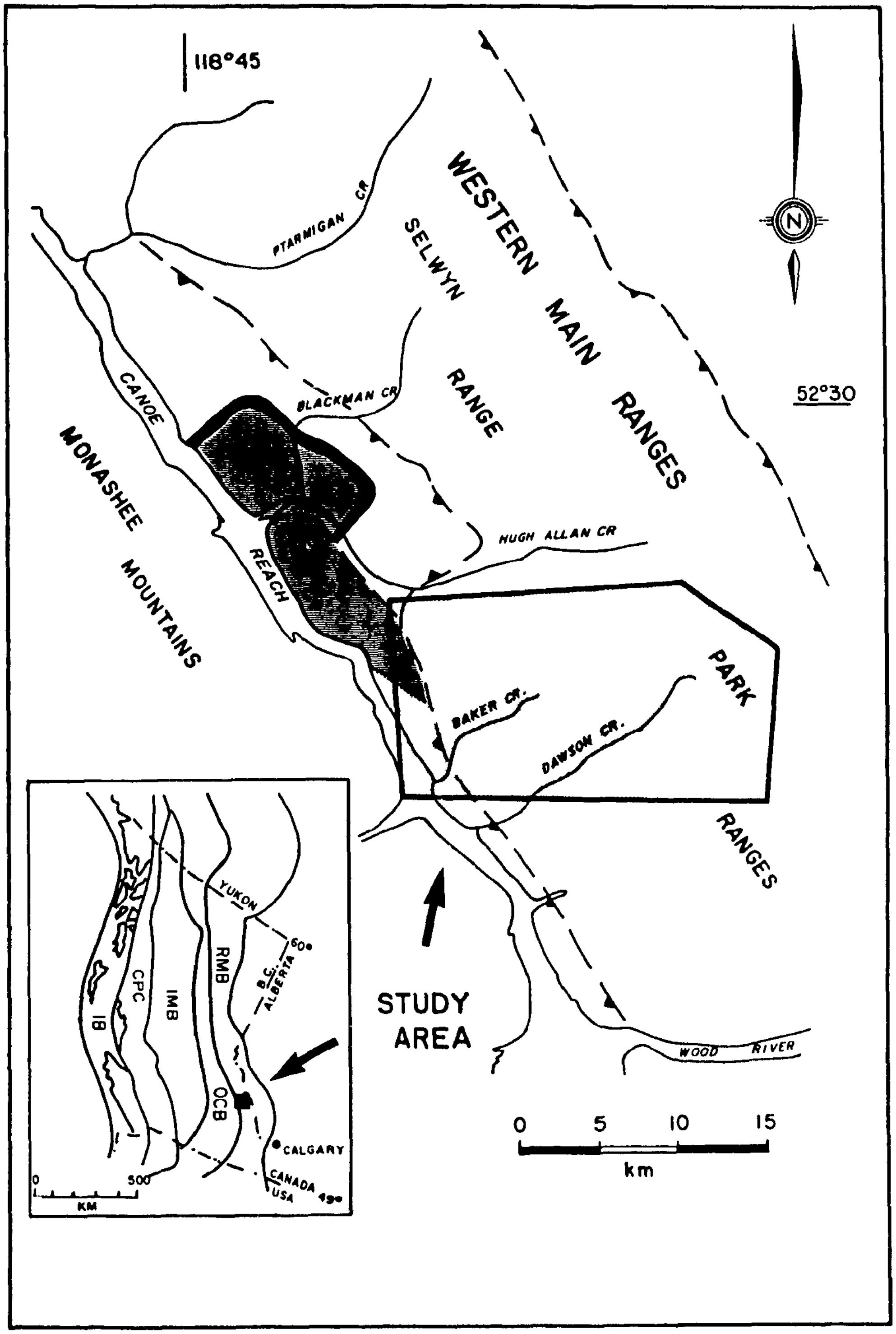


Fig.1.1 Location map, inset shows position of study area with respect to major tectonic belts of the Canadian Cordillera (Monger <u>et al</u>, 1982) ; RMB = Rocky Mountain Belt, OCB = Omineca Crystalline Belt, IMB = Intermontane Belt, CPC = Coast Plutonic Complex, IB = Insular Belt

Metamorphism: to determine the timing relationships between metamorphism and structures based on microtextural relationships.

1.3 Regional tectonic evolution

The Rocky Mountain Thrust and Fold Belt is the easternmost of the five tectonic belts that form the Canadian Cordillera (Fig.1.1). It consists of weakly to moderately metamorphosed mid-Proterozoic to Paleogene sedimentary rocks deposited along the ancient North American continental margin (Monger et al., 1982). The Rockies were shortened by folding and thrust faulting more than 200 km (Bally et al., 1966; Price and Mountjoy, 1970; Monger et al., 1982; among others). LITHOPROBE profiles and seismic sections suggest that deformation in the Rocky Mountain Belt does not involve basement (Bally et al., 1966; Eaton & Cook, 1988). The sedimentary cover was deformed above a décollement at or above the basement-cover contact.

Many different models have been proposed to explain the tectonic history of the Canadian Cordillera. Monger et al. (1982) proposed that the Cordillera was formed during and following the collision of the North American continent with two composite, allochthonous terranes. Terrane I, a collage of several terranes that were amalgamated by latest Triassic to earliest Jurassic, collided with the North American continental margin in mid-Jurassic time. The Omineca Crystalline Belt formed as a result of this collision and overlaps the contact between North America and Terrane I. A second composite terrane, Terrane II, amalgamated by late Jurassic to early Cretaceous, collided with Terrane I and the North American continental margin in the mid-Cretaceous, resulting in the formation of the Coast Plutonic Complex. This collision was followed by the eastward progression of the deformation into the Rocky Mountain Belt.

Both Monger et al. (1982) and Struik (1988), among others have noted the occurrence of strike-slip movements in the Canadian Cordillera. Gabrielse (1985) provided an assessment of these movements for northeastern British Columbia. Chamberlain and Lambert (1985) developed a tectonic model for the Canadian Cordillera that allows for large-scale transcurrent, strike-slip displacement, based on paleomagnetic and paleontological data. They propose that most of the present day western Canadian Cordillera forms a microcontinent named Cordilleria that originated at the latitude of California and has travelled northwards on the Kula plate along strike-slip faults since the mid-Cretaceous. Chamberlain and Lambert suggest that most of the displacement took place along faults in the Rocky Mountain Trench, in their view making it a possible candidate for a major terrane boundary. This model finds little support in the geological community particularly because of the lack of geological evidence for such large-scale strike-slip displacements along the southern Rocky Mountain Trench or elsewhere in the Cordillera (Price and Carmichael, 1986, McDonough and Simony, 1988b).

1.4 Previous work in surrounding areas and regional tectonic setting

The study area was initially mapped on reconnaissance scale by Campbell (1968) and Price and Mountjoy (1970, as a part of the G.S.C.'s Bow-Athabasca Operation). More detailed studies in adjacent areas include M.Sc. thesis research and mapping by Craw (1977), Oke (1982), Forest (1985), Leonard (1985) and Charland (1989) and current research by Dechesne (1990) and Grasby (see Mountjoy and Grasby, 1990, 1991, Grasby and Mountjoy, 1991).

In the region north of Hugh Allan Creek the Blackman anticline (Fig. 1.2), a large, recumbent northeast-overturned anticline cored by the Blackman gneiss, was first mapped by Oke (1982). Oke documented two northeast-verging fold sets in this area and the presence of a shear zone between the Hugh

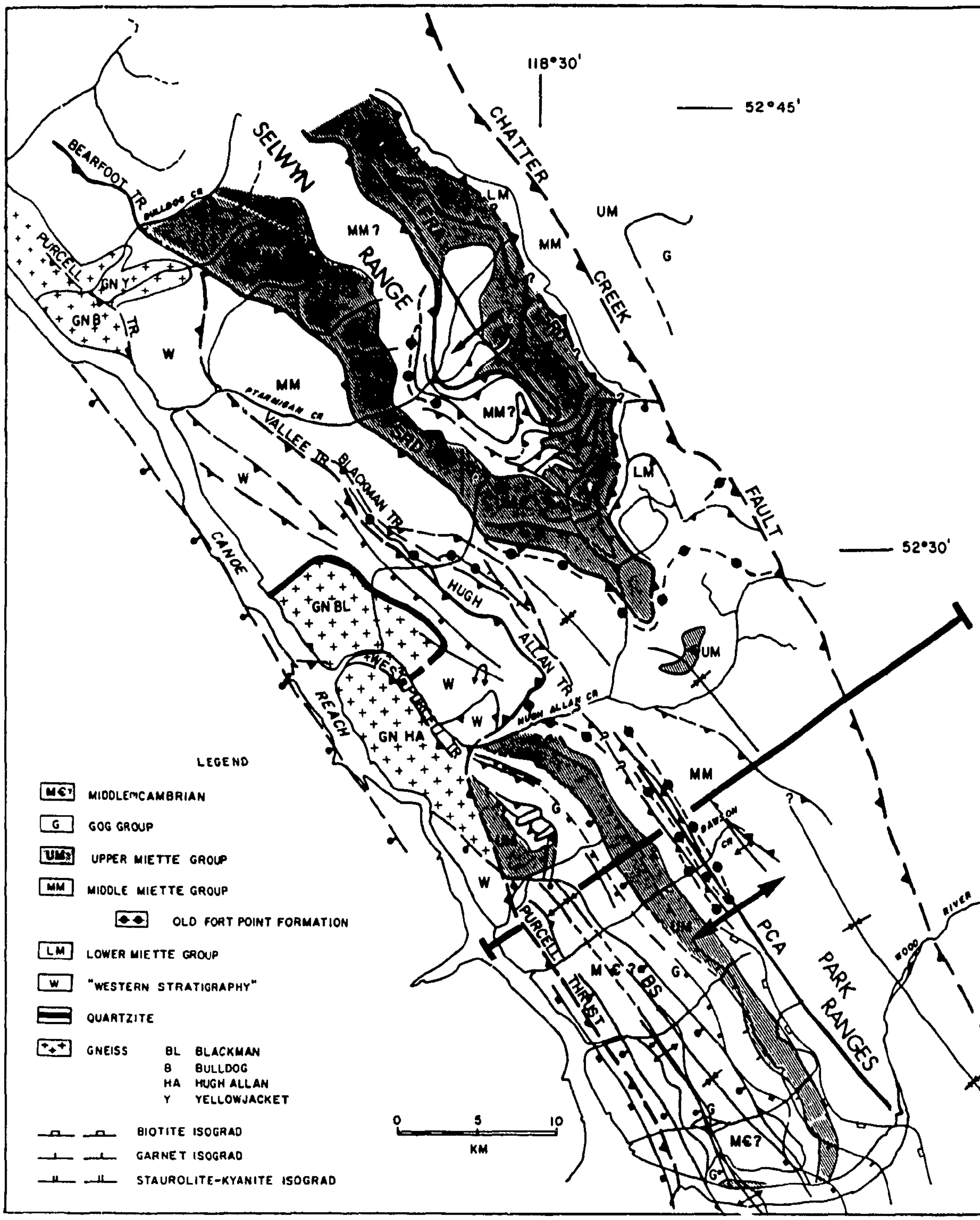


Fig.1.2 Regional compilation map of the Park Ranges and southern Selwyn Range; in part from Charland (1989), Craw (1977), Dechesne (1990a) and Mountjoy and Grasby (1990)

Allan Gneiss and its cover rocks. Leonard (1985) later remapped the Blackman gneiss and anticline and two major thrust faults, the Purcell and Blackman thrusts to the east. He observed significant changes in structural styles and stratigraphy across the Purcell thrust. Strata in the hanging wall, differing from Miette Group strata in the footwall were tentatively assigned to the Horsethief Creek Group. Leonard (1985) also noted the presence of southwest-verging folds in the hanging wall of the Purcell thrust. Mountjoy (1988) found that Leonard's Purcell thrust just north of Hugh Allan Creek was low-angle and renamed it the Hugh Allan Thrust. This fault cuts the Blackman anticline and is folded by upright syn-PCA folds. Mountjoy (1988) reinterpreted hanging wall strata as possible Lower Kaza Group equivalents. The area immediately to the northwest of the area mapped by Leonard (1985) between Blackman and Ptarmigan Creeks was mapped in more detail by Charland (1989). She observed two mylonitic thrust faults (Lower and Upper Vogue thrusts) cutting the overturned limb of the Blackman anticline. Metasedimentary rocks in this area were affected by three folding events: F1 = early southwest-verging, recumbent folds, F2 = northeast-verging, recumbent folds (Blackman Antcline) and F-late = late chevron folds. No major metamorphic break could be documented across faults in that area.

Northwest of Ptarmigan Creek the pre- to synmetamorphic Bear Foot Thrust carries the Bulldog and Yellowjacket gneisses and cover rocks over Miette Group strata of the Western Main Ranges (McDonough and Simony, 1988b). The Bearfoot Thrust may be the continuation of the Vallee and Hugh Allan thrusts (Fig. 1.2). The Bulldog Gneiss is thrust onto the Yellowjacket gneiss by a postmetamorphic thrust considered to be the Purcell thrust by McDonough and Simony (1988b).

The eastern part of the Selwyn Ranges is dominated by a large-scale fold, the Fraser River Antiform (FRA). This doubly-plunging structure exposes the deepest structural and stratigraphic levels of the Western Main Ranges. Parts of the FRA were first mapped in detail by Forest (1985) and Mountjoy and Forest (1986) and more recently by Dechesne (1990) and Mountjoy and Grasby (1990, 1991). The FRA folds a stack of thrust faults and shear zones, two of which are considered to have major displacement, the Ptarmigan and Selwyn Range décollements. The FRA plunges southward and ends north of Hugh Allan Creek.

The southern part of the Porcupine Creek Anticlinorium has been mapped and studied by Fyles (1960), Wheeler (1963), Price and Mountjoy (1970), Balkwill (1972), Craw (1977), Gardner (1977), Mielliez (1972), and Gal et al. (1989), among others. The structure of the PCA immediately south of the study area, in the southern Park Ranges consists of a large-scale anticline (PCA)-syncline pair (Price and Mountjoy, 1970; Craw, 1977). Craw (1977) reported two northeast-verging deformation phases, both related to the formation of the PCA. Peak metamorphic conditions were reached between F1 and F2. Craw inferred pressure differences of 2 to 3 kb across the Purcell thrust and estimated a minimum of 7 km of postmetamorphic movement on this fault.

The Purcell and associated thrusts constitute the boundary between the Main Ranges of the Rocky Mountain Belt and the Omineca Crystalline Belt, which will be referred to in this thesis as the metamorphic core zone. The hanging wall of the Purcell thrust at the latitude of the study area is formed by the northeast flank of the Shuswap metamorphic complex which is characterized by higher metamorphic grades and complex polydeformation (Simony et al., 1980). Immediately west of the study area the large-scale structure is dominated by the Scrip Nappe, an early southwest-verging fold (F1 in core zone terminology, Raeside and Simony, 1983). Simony et al. (1980) recognized three phases of deformation in the Monashee Mountains. Sevigny et al. (1990) dated two metamorphic events at 165 and 100 Ma, and two periods of anatexis (100 Ma and 63 Ma) in the same area. The F2 (recumbent) and F3 (upright) folding events are northeast-verging and have been correlated with F1 and F2, respectively in the Main Ranges (Simony et al., 1980).

1.5 Local geological setting and problematic correlation of Purcell thrust

Rocks of the northern Park Ranges form a single, coherent structural package between the Chatter Creek Fault to the east and faults in or adjacent to the Rocky Mountain Trench to the west (Fig. 1.2). The structure of this area is dominated by the Porcupine Creek Anticlinorium (PCA).

A major thrust fault separates Precambrian basement gneisses and possible Lower Kaza or Horsethief Creek Group strata (hereafter referred to as "Western Stratigraphy"), found normally west of the Rocky Mountain Trench, from middle Miette through Middle Cambrian strata of the Western Main Ranges. This fault has been called the Purcell Fault by Campbell (1968), Price and Mountjoy (1970), Craw (1977), Leonard (1985) and Klein and Mountjoy (1988).

At Hugh Allan Creek this fault branches into three components: 1) the West Purcell Fault, 2) a small unnamed splay of the West Purcell (Mountjoy, 1988, personal comm., 1990) and 3) the Hugh Allan Thrust (Fig. 1.3). The West Purcell places the Hugh Allan Gneiss against the Mount Blackman Gneiss and cover strata. It resembles the Purcell Fault mapped by McDonough and Simony (1984, 1988b) north of Ptarmigan Creek, which faults the Bulldog Gneiss against the Yellowjacket Gneiss. The small splay of the West Purcell carries strata tentatively assigned to the middle marble of the Horsethief Creek Group (Mountjoy, 1988) and shows evidence for both ductile and brittle postmetamorphic deformation (Grasby, 1990, personal comm.).

To the south, the Purcell Fault was first mapped by

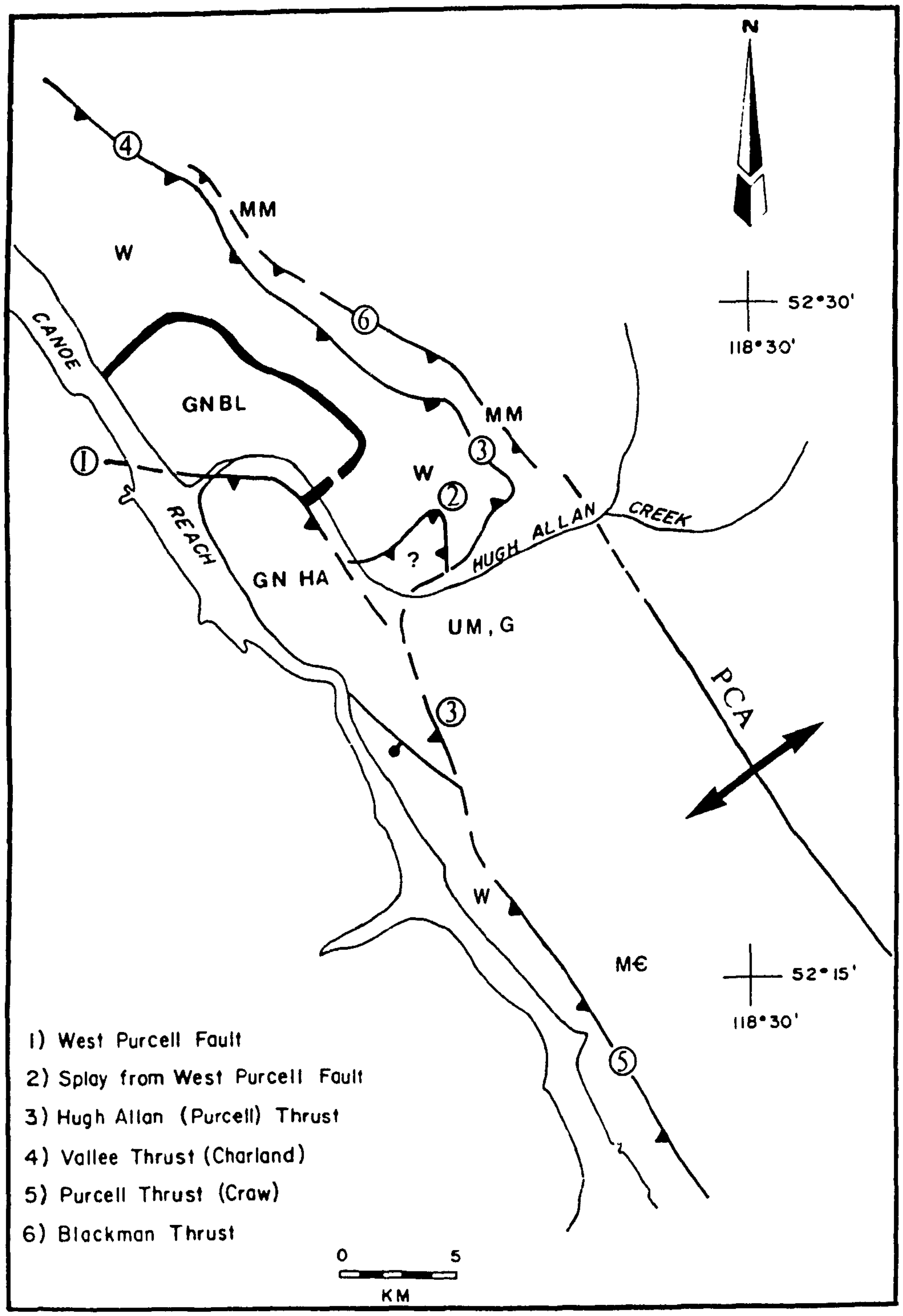


Fig.1.3 Structural relationships in northwestern part of study area; abbreviations as in Fig. 1.2.

Evans (1933), and later by North and Henderson (1954), Wheeler (1963) and Simony and Wind (1970). It was described as a late thrust fault in or near the Rocky Mountain Trench (Simony and Wind, 1970) juxtaposing Precambrian to Lower Cambrian strata of the Purcell and Dogtooth Mountains onto upper Cambrian strata of the Rocky Mountains. Others (Price and Mountjoy, 1970, Simony <u>et al.</u>, 1980) mapped the Purcell Fault as displacing allochthonous gneissic basement and cover strata over Hadrynian to Cambrian strata of the Rocky Mountains.

The use of the term Purcell fault is controversial because different defining criteria have been used by various authors. Charland (1989) therefore recommended that this term should only be applied to faults that can be linked with the original Purcell thrust in the Purcell Mountains. It is the author's opinion (and that of others, Dechesne, personal comm.) that the term Purcell should be redefined by common consensus among those geologists that have worked with this fault or associated faults. One can continue using the term Purcell by following one of the several existing definitions, or one can use different names for faults that can not be shown to be continous with the original Purcell Thrust. The fault that juxtaposes Western stratigraphy onto Rocky Mountain stratigraphy is referred to as the Hugh Allan (Purcell) Thrust in this thesis. It is probably continous with Charland's Vallee thrust.

1.6 Methods of study

1.6A Field Work :

Field work was carried out in the summers of 1986 and 1987. The area was mapped on 1:50,000 topographic sheets (83 D/7, 83 D/8, Fig.5.1). Direct observations were complemented by airphoto interpretation, interpretation of oblique photographs and binocular aided "swiss-hammer" geology. Two accessible ridges north and south of Dawson Creek permitted good observations and sampling of middle and upper Miette Group strata in the PCA, as well as locating the garnet isograd. Access in the western part of the area proved more limited especially north of Baker Creek. Samples were collected systematically for petrographic and possible microprobe analysis. About 100 thin sections were cut for 1) petrographic studies, and 2) microtextural relationships.

1.6B Analytical methods :

For the stereographic plotting of structural data the CONMAP program (ver.1.4-IBM Graphics by P.W. Jeran, J.R. Mashey, U.S. Bureau of Mines Info Circular 8454, adapted to to PC Basic by Andrew Hynes, McGill University) was used.

CHAPTER II - STRATIGRAPHY

2.1 Introduction

The stratigraphic sequence exposed in the northern Park Ranges consists of approximately 5000 m of Hadrynian to Cambrian, Miette Group, Gog Group, and unnamed Middle Cambrian(?) strata (Fig. 2.1). The Miette Group is informally divided into lower (not exposed), middle (grit-dominated) and upper (pelite-sandstone-carbonate)(Campbell et al., 1973). A minimum of 1200 m of middle Miette strata crop out in the core and flanks of the PCA. The upper Miette comprises a 1600 m + thick sequence on the west flank of the PCA. A complete sequence of the Lower Cambrian Gog Group in the western part of the study area thins westward from about 1200 m to about 600 m over a distance of 1 to 2 km, due to thinning of the McNaughton Formation. A minimum of 1000 to 2000 m of cliff-forming carbonates and pelites overlie the Gog Group in the Baker Syncline and are believed to be shallow-water platform equivalents of the Middle Cambrian Chancellor Group. The distribution of stratigraphic units is shown in Figs. 3.1. and 5.1.

2.2 Hugh Allan Gneiss

The Hugh Allan Gneiss has been studied by Oke (1982) and Chamberlain et al. (1985). It is composed of a variety of lithologies including lineated and foliated felsic hornblende gneisses, granitoids, micaceous gneisses, amphibolites and muscovite quartzites. Chamberlain et al. (1985) estimated the metamorphic age of this gneiss at 805 +/- 11 Ma and the approximate crustal age at 900 Ma. Chamberlain et al. (1985) suggested that it is a felsic orthogneiss derived from a peralkaline or alkaline granite protolith.

Several isolated outcrops located in the southern part of the Hugh Allan gneiss (lat. 52°21', long. 118°34-35') were visited. The most common lithology in these outcrops is a

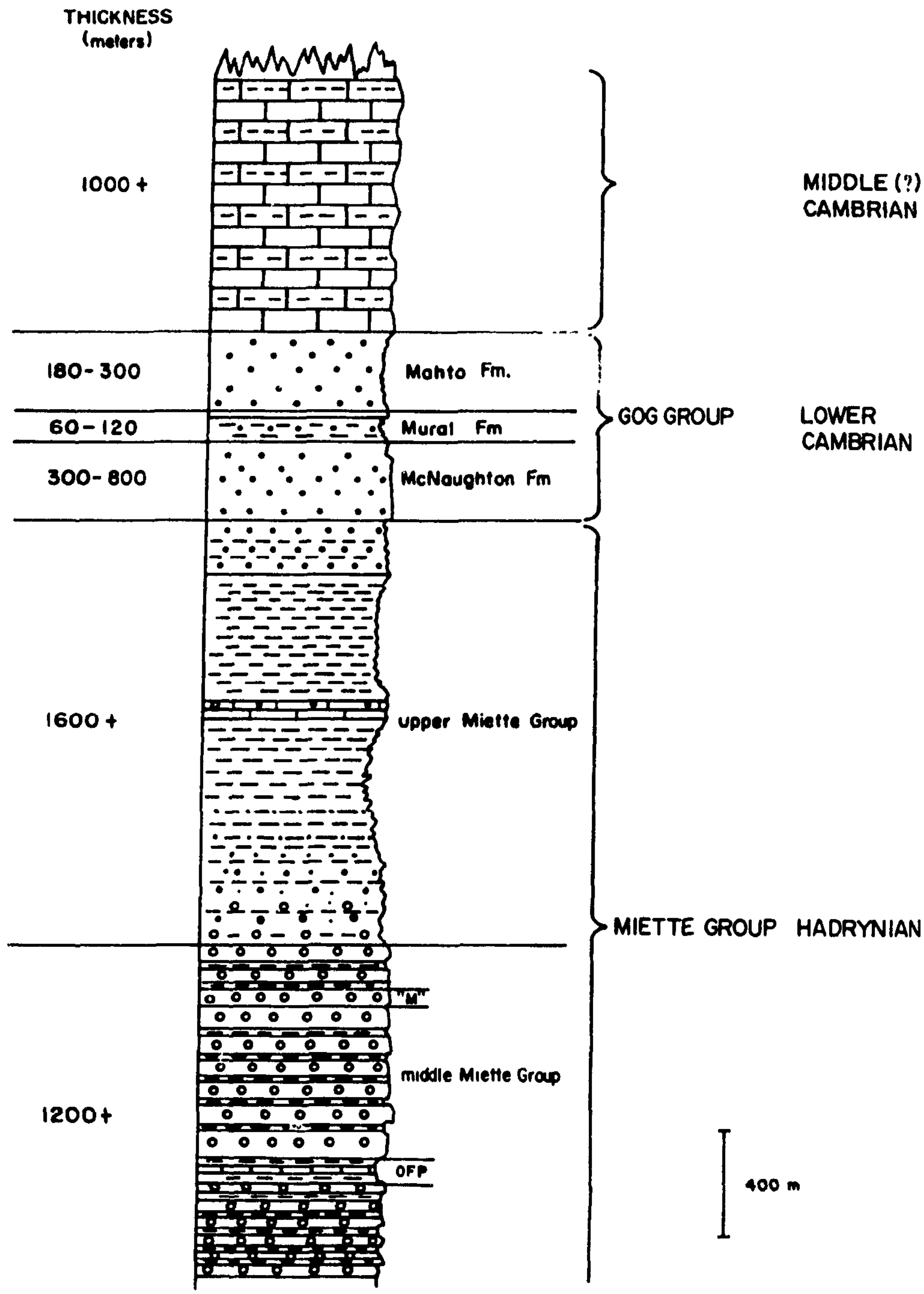


Fig.2.1 Generalized stratigraphic section for core and west flank of PCA

white to pinkish, coarse grained quartzo-feldspathic granite gneiss with variable amounts of biotite and hornblende (from 10 to 40%). These gneisses are weakly to moderately foliated or massive and often show a mineral lineation defined by the alignment of biotite and hornblende. Feldspar augen textures and garnet prophyroblasts are locally present. In one outcrop migmatitic gneisses were observed consisting of mafic (biotite-rich) lenses and pods in leucocratic gneisses and leucocratic lenses in biotite schists (Plates 1.1, 1.2).

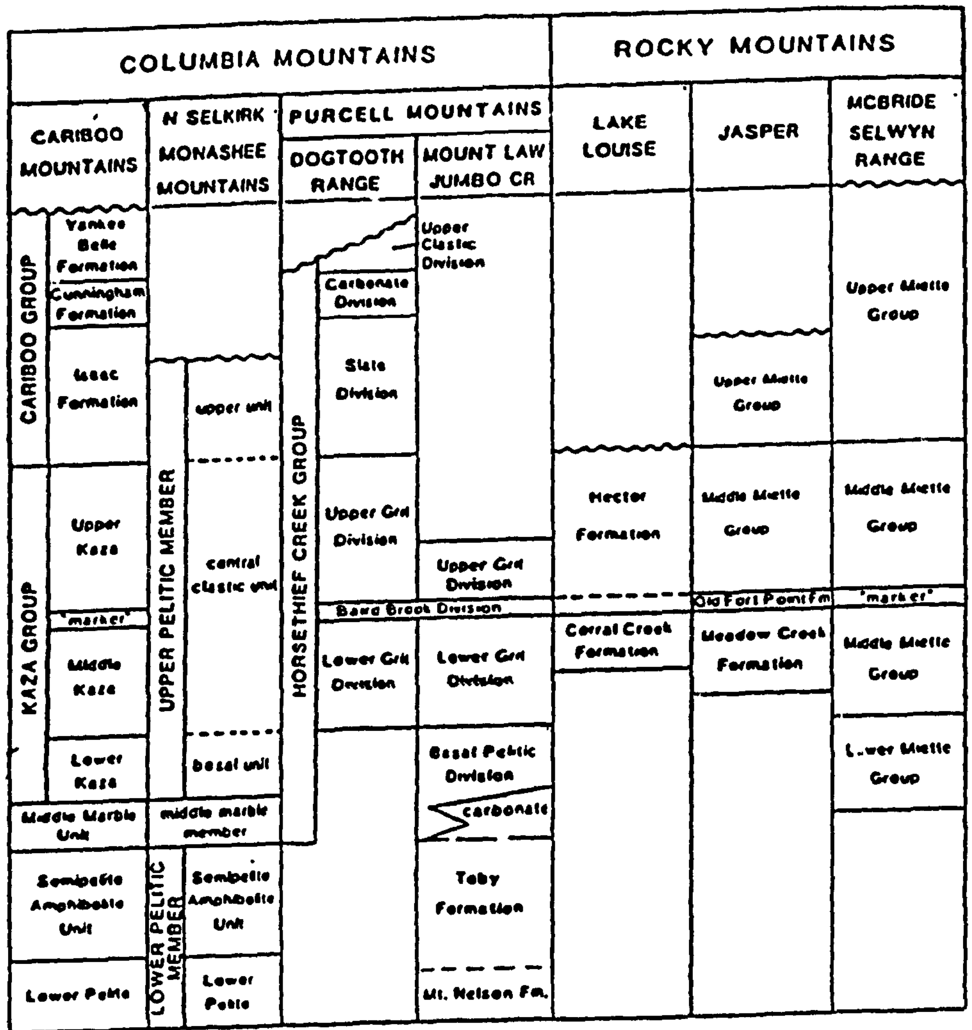
2.3 Middle Miette Group

Approximately 1200 m of middle Miette Group strata are exposed in the core and on the flanks of the PCA, occupying most of the eastern part of the study area.

The middle Miette Group is characterized by alternating sequences of composite grit units and predominantly green pelites and subordinate psammites, semipelites and carbonates. Middle Miette Group grits have been traditionally interpreted as turbidite flows deposited along the Upper Proterozoic passive margin. It is thought that deposition of the middle Miette Group took place during a rifting event, but recent studies (see Ross, 1990) may indicate otherwise. The middle Miette Group has been correlated with other Windermere turbidite sequences west of the Rocky Mountain Trench such as the middle and upper Kaza Group and the lower and upper Grit divisions of the Horsethief Creek Group (Fig. 2.2).

The middle Miette Group can be divided into three parts: a lower grit-dominated part, the Old Fort Point Formation (OFP) and an upper grit-dominated part. In the study area only the uppermost 250 m of the lower part of the middle Miette Group are exposed. Structural problems and lack of good markers other than the OFP make estimates of thicknesses difficult. The OFP and the upper part of the middle Miette Group are estimated to be 100 m and 800 m thick respectively.

Immediately to the northwest, a complete section of the



Stratigraphic correlation chart for the Windermere Supergroup.

Fig.2.2 Regional Windermere correlations from Kubli, 1990a middle Miette Group is exposed around the southern plunge of the Fraser River Antiform (FRA) where it reaches thicknesses between 2500 and 3000 m (Forest,1985; Mountjoy and Grasby, 1990).

2.3A Lower middle Miette Group

About 250 m of lower middle Miette Group strata were observed north and south of Dawson Creek in the core of the PCA. They comprise 35 to 50 m-thick, massive and coarse grits separated by green or grey, 20 to 35 m-thick pelites.

2.3B Old Fort Point Formation

The Old Fort Point Formation (OFP) is a distinct tripart marker that crops out in the core and on the flanks of the PCA. It is typically characterized by a lower green pelite-semipelite member, a middle carbonate member and an upper black pelite member. Significant lithological variations were observed within the study area. Three sections of the OFP were studied, two north of Dawson Creek (sections A, B, Fig. 2.2), and one south of Dawson Creek (section C, Fig. 2.2).

Section A occurs on the eastern flank of the PCA and is 145 m to 215 m thick. It consists of, from bottom to top 1) 50 - 100 m of strongly recessive, fissile, green pelites with brown sandy carbonate beds and lenses in its upper part; 2) approximately 50 m of alternating grits and pelites; 3) 40 to 60 m of black pelite characterized by the presence of abundant pyrite cubes with a 5 m-thick dark-grey to black limestone in its lower part. This sequence is overlain by thick, massive grits and psammites separated by a few thin pelites.

Section B on the west flank of the PCA is approximately 150 m thick, strongly recessive and partly faulted. It consists of a lower sequence of alternating red, orange weathering carbonate rich psammites and semipelites and green, chloritic semipelites and pelites. These are overlain by a 10 m-thick black pelite which in turn is overlain by a thick

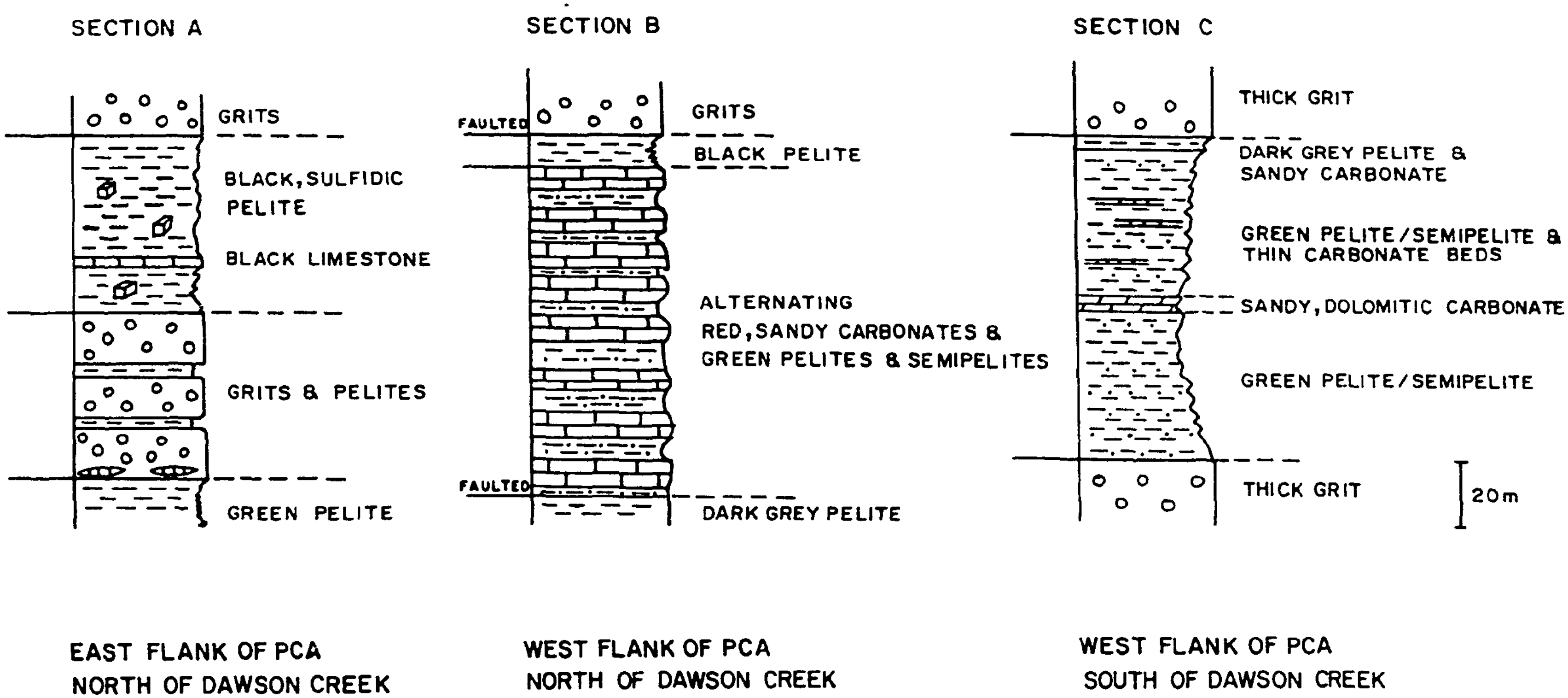


Fig. 2.3 Old Fort Point Formation stratigraphic sections along core of PCA

package of composite grits.

Section C on the west flank of the PCA consists of a 100 m-thick green pelite-carbonate unit. The lower 40 to 50 m of this unit are made up of green, fissile pelites and semipelites with a few, thin, brown carbonate rich-beds. Near the middle of the unit a 5 m-thick sandy, dolomitic carbonate marker was observed. The upper 50 m of the unit consist of rhythmically interbedded green pelites and semipelites and thin (2 to 10 cm) brown carbonate layers. The sequence is topped by a 5 m-thick dark grey pelite.

The characteristic lithologies of this marker, its thickness and stratigraphic position permit a strong correlation with the OFP tripartite marker to the north in the Selwyn Range and to the south in the southern Park Ranges. A similar carbonate marker was mapped in the Selwyn Range by Forest (1985), Dechesne (1990), Mountjoy and Grasby (1990, 1991) and by McDonough and Simony (1988a) near the middle of the middle Miette Group, and recently by Lickorish and Simony (1991) south of Wood River. Equivalents of the OFP occur at the top of the middle Kaza Group west of the Rocky Mountain Trench in the Cariboo Mountains (Pell and Simony, 1987; Ross and Murphy, 1988) and between the Lower Grit division and Upper Grit division of the Horsethief Creek Group in the Purcell Mountains (Kubli, 1990a,b). The lithologies of the OFP are suggestive of a eustatic sealevel rise. Lithological and facies variations within this unit can be attributed to basin topography (Ross and Murphy, 1988), and proximity to the continental margin.

2.3C Upper middle Miette Group

Approximately 600 to 800 m of upper middle Miette Group strata are exposed on the west flank of the PCA, north and south of Dawson Creek (Fig. 2.1). They are characterized by massive 30 to 100 m-thick grits separated by a few, thin (<20 m) green pelites. About 200 m below the top of the middle

Miette a carbonate marker is found. It consists of 20 to 40 m of reddish calcareous grits and psammites but has no black pelites associated with it. This carbonate was not observed on the east flank of the PCA.

Typical strata observed in the upper part of the middle Miette Group consist of alternating 10 to 100 m-thick, composite, resistant, grit-dominated units and recessive green, black or grey, 5-50 m thick pelites (Plate 1.3). Individual grit beds vary in thickness between 5 and 50 m. A typical grit package is characterized by basal, unsorted, 2 to 10 m-thick pebble conglomerates, grading upwards into medium- to coarse-grained psammites and semipelites. Graded grit and psammite beds are common and provide useful facing criteria. Grit units are often laterally discontinous and pinch out, as was observed in the upper part of the middle Miette section exposed at the head of Dawson Creek.

Middle Miette grits are texturally immature quartz wackes composed mostly of white quartz clasts with subordinate plagioclase, feldspar and igneous or metamorphic clasts and fragments. Most clasts are subrounded to subangular. The predominant matrix minerals are muscovite and chlorite. Quartz clasts range in size from 0.5 to 3 cm (long axis) and are either grey, white, blue or black (in order of decreasing abundance). Other constituents are opaques, sericite and zircon. Orange or reddish grits have carbonate cements, while green grits have chloritic matrices. Grits are predominantly matrix-supported. Sorting is generally poor to moderate. Argillaceous grits are poorly schistose. Mud clasts and dolomitic fragments are present in coarse, basal, conglomeratic units and debris flow units (Plates 1.4, 1.5). Long axes of clasts or fragments vary in length from a few cm up to 0.5 m. Pelites are predominantly green or light grey. Dark grey or black pelites are rare.

2.3D Middle Miette-upper Miette Group boundary

The change from the grit-dominated middle Miette Group to the pelite-dominated upper Miette Group is reflected by a gradual upward increase in the proportion and thickness of pelites and semipelites and corresponding decrease in the proportion and thickness of grits. This contact has traditionally been arbitrarily placed at the uppermost thick grit unit. McDonough and Simony (1988) noted that a change from green colored to black colored pelites does appear to represent a good mapping criterium for the middle Miette-upper Miette Group contact in the northern Selwyn Range. In the study area, south of Dawson Creek the transition from green to black or dark grey pelites is sharp and coincides with a distinct increase in the abundance and thickness of pelites. North of Dawson Creek there were difficulties in mapping the change from green or light grey pelites to dark grey to black pelites on the west flank of the PCA. The middle-upper Miette Group had to be chosen arbitrarily there and could be placed anywhere in a 50 - 100 m interval. It was placed where grits are thinner than 20 m and pelites, psammites and semipelites are the predominant lithologies.

2.4 Upper Miette Group

Approximately 1600 to 2000 m of the upper Miette Group crop out in an elongated SE-NW trending belt on the west flank of the PCA. Farther west more than 800 m of the uppermost upper Miette are exposed beneath Gog Group strata, in the Baker Glacier Syncline (Fig. 3.1).

Two complete upper Miette Group sections on the west flank of the PCA were studied (Fig. 2.4). They are about 5 km apart. The upper Miette Group just south of Hugh Allan Creek (Section B in Fig. 2.4, Lat. 52°21',long. 118°26') is relatively undeformed. It is 1600 m-thick and divisible into four major units which are from bottom to top : 1) lower pelite unit; 2) carbonate-grit-pelite unit); 3) upper pelite unit, and 4) upper clastic unit.

The lower pelite unit consists of 580 m of monotonous pelites. These pelites are predominantly medium to dark grey when fresh and weather to a brown color. They locally contain chloritoid, biotite and/or garnet porphyroblasts. Towards the top, a few interbeds of semipelites, psammites and sandy carbonates are found.

The carbonate-grit-pelite unit is about 440 m-thick and grey limestones, sandy dolomitic carbonates, grits and calcareous pelites predominate. It is divisible into four subunits: 1) a 80 m-thick lower carbonate subunit, 2) a 124 m-thick lower grit-pelite subunit, 3) a 124 m-thick upper carbonate subunit and 4) a 122 m-thick upper grit-pelite subunit. The lower carbonate subunit consists of 1-12 m-thick beds of black or grey, micritic or dolomitic limestones which commonly contain shale clasts . Stromatolitic laminations and beef calcite textures (calcite growth parallel to layers) were observed in some of these limestones. The rest of the carbonates are yellow, grey or brown, generally sandy carbonates varying in thickness between 3 and 22 m. Thin pelites (generally < 1 m thick) are interbedded with the carbonates. The lower grit-pelite subunit (Fig. 2.4) consists of about 17 m of grey to green pelites at its base, overlain by 30 m of alternating grit beds (2-7 m thick) and pelites, and topped by about 38 m of pelites with minor calcareous psammite beds. The lower 65 m of the upper carbonate subunit are formed by a sequence of strongly folded, brown weathering, sandy carbonates and calcareous pelites, containing chloritoid and or plagioclase porphyroblasts (Plate 1.6). Bed thickness is variable ranging from a few cms to a few meters. The upper 60 m consist of alternating thin beds of grits, pelites, carbonates and two debris flow beds (Plate 1.6). Bed thicknesses vary between 2 and 10 m. This sub-unit is topped by a 2 m-thick white marble. The uppermost 122 m-thick upper pelite-grit subunit consists of 3 to 30 m-thick chloritoid-

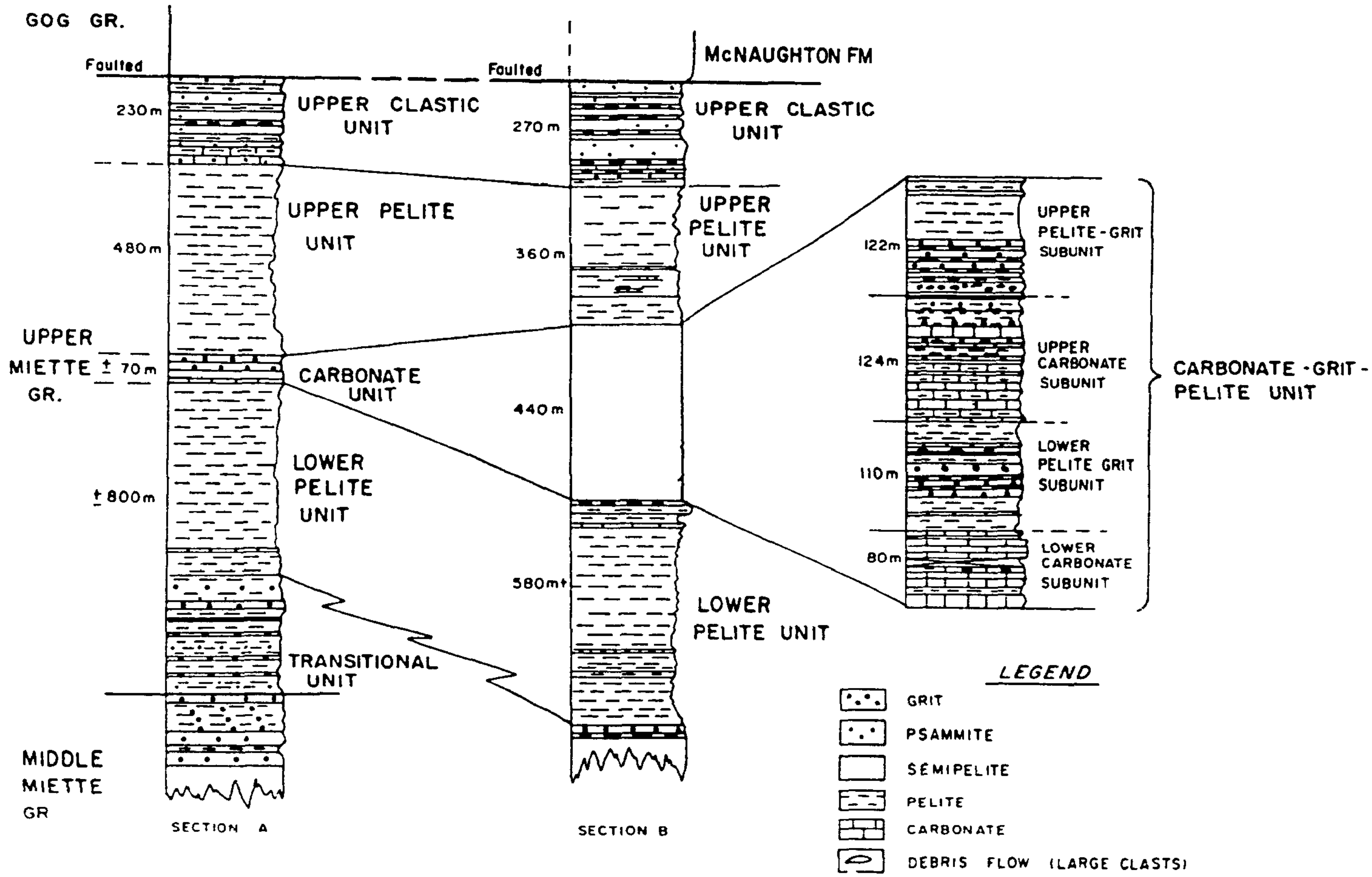


Fig.2.4 Upper Miette Group stratigraphic sections, measured on west flank of PCA; Section A located on ridge north of Dawson Creek, Section B located between Hugh Allan Creek and Baker Creek headwaters; sections are about 5 km apart

or garnet-bearing pelites interbedded with 4 to 13 m-thick grits.

The upper pelite unit consists of 360 m of grey or green, generally brown-weathering chloritoid and/or garnet-bearing pelites with minor silty, sandy or carbonate interbeds (Section B, Fig. 2.4). These pelites are overlain by 270 m of beige and brown quartzites and pelites of the upper clastic unit. The lower 60 m of this unit are formed by alternating 4 to 15 m-thick, well sorted, clean quartz sandstones and thin pelites. Some beds show cross-bedding. In the upper 200 m the quartz sandstones are more massive, medium- to coarse-grained, have variable bed thicknesses, and contain only minor thin pelite and carbonate interbeds. They are very similar to basal McNaughton quartzites, which are generally lighter colored and coarser grained.

The upper Miette Group exposed on the ridge north of Dawson Creek (Section A, Fig. 2.4) has a minimum thickness of 1600 m. Five units were observed in this section. The lowermost 300 m-thick grit-psammite-pelite unit is transitional between the grit-dominated middle Miette Group and the pelite-dominated lower upper Miette Group. It consists of 5-10 m-thick, interbedded grits, psammites and semipelites with minor sandy carbonates. It is overlain by 500 m of monotonous dark grey to black pelites and semipelites of the lower pelite unit, characterized by their brown weathering aspect.

A 70 m-thick carbonate unit overlies the lower pelite unit. It contains a single black limestone marker, overlain by brown sandy carbonates and a 30 m-thick, quartz pebble conglomerate with a yellow carbonate cement (pebble size varies between 1 to 3 cm). Thus the carbonate unit thins dramatically southwards probably in conjunction with thickening in the lower and upper pelite units.

The upper pelite unit is about 480 m thick and resembles the lower pelite unit. The upper Miette Group in this section is topped by 230 m of interbedded quartz sandstones, pelites and minor carbonate.

The uppermost 800 m of the upper Miette Group are exposed on the west flank of the Baker Syncline (BS, Fig.3.1.). They comprise from bottom to top, a more than 500 m-thick pelite unit, a 200 to 300 m-thick unit consisting of alternating quartz-rich pelites and quartzites, and a 50 m-thick carbonate-dominated sequence overlain directly by the McNaughton Formation. The pelite and the quartzite units can be correlated with the upper pelite and upper clastic units of sections A, B (Fig.2.4), respectively. The carbonate sequence which was not observed elsewhere at the top of the upper Miette may be an equivalent of the Cunningham Formation of the Cariboo Mountains and the Yellowhead platform of the Selwyn Range.

Quartzites in the upper Miette Group sequence exposed on the west flank of the BS are variably colored, ranging from white, to light and dark grey to brown. They vary from being relatively pure to containing variable amounts of muscovite and biotite in thin layers or seams. Bed thickness of quartzites and pelites varies from a few cm to about 1 m. The carbonate-rich sequence consists of calcareous siltstones and sandstones, grey limestones with small dolomitic nodules and thin quartz-pebble conglomerate beds.

In summary, the upper Miette Group in the study area can be divided into five, possibly six distinct units, of which one (carbonate unit) thins significantly (by more than 300 m) southwards over a small distance. A newly recognized carbonate sequence tops the upper Miette Group on the west flank of the BS and may represent a Cunningham or Yellowhead equivalent.

2.4A Basal upper Miette Group conglomerate

South of Dawson Creek a 20 m-thick grit unit containing several 2-4 m-long elongated and lense-shaped boulders, occurs in the lower part of the upper Miette Group (Plate 1.7) about 100 m above the middle/upper Miette Group contact. The boulders are light brown and consist of carbonate-rich psammites and semipelites. They occur in the upper 5 m of a grit bed and are aligned parallel to the bedding. This marker was not observed elsewhere and does not appear to be laterally continous.

A boulder and conglomerate unit has been reported by Forest (1985), Dechesne (1990a), and Mountjoy and Grasby (1990) in the Selwyn Range and by Ross and Murphy (1988) in the Cariboo Mountains. It has been assigned to the basal upper Miette Group but its stratigraphic assignment is still uncertain (personal comm., Mountjoy, 1990). Whether these conglomerates can be correlated with the one in the study area is uncertain.

2.4B Upper Miette Group - Gog Group contact

In the Main Ranges and in the southern Western Main Ranges the upper Miette Group-Gog Group contact has been described as an unconformity (Aitken, 1969, Mountjoy, 1962; McDonough and Simony, 1984, Teitz and Mountjoy, 1985, Gal et al., 1989). Craw (1977) described it as a gradational contact in the southern Park Ranges and did not observe any evidence for an unconformity. He noted an up-section increase in quartzites in the upper part of the upper Miette Group and placed the contact at the first appearance of massive, light-colored quartzites.

The upper Miette Group-Gog Group contact on the west flank of the PCA is a tectonic one. The Gog Group is downdropped against the upper Miette Group by a steeply southwest-dipping normal fault. An unfaulted upper Miette Group-Gog Group contact was observed on the west flank of BS and appears to be conformable.

2.4C Upper Miette Group correlations :

Craw (1977) divided the upper Miette Group (1350 m thick) in the southern Park Ranges into three divisions, from bottom to top: 1) a 1000 m-thick slate division, 2) a less than 200 m-thick carbonate division of variable thickness, and 3) a 150 m-thick upper clastic division (section B, Fig. 2.5). The slate division consists predominantly of pelites with minor quartzites. The carbonate division is made up of marbles and sandy carbonate. The upper Clastic division is composed of interbedded quartzites and pelites.

Southward from the study area the upper Miette Group thins by about 300 m into Craw's area. If the correlations shown in Figure 2.5 are correct, this thinning appears to be due to the southward erosion of the upper pelite unit of the study area, perhaps corresponding to a sub-Gog unconformity.

South of the Wood River the upper Miette Group is made up entirely of slates and reaches maximum thicknesses of up to 500 m but is completely absent in places (Fig.2.5, Lickorish and Simony, 1991, Gal, et al., 1989, Fig. 2.5). Lickorish and Simony (1991) recognized an up to 700 m-thick quartzo-feldspathic sequence between upper Miette slates and the McNaugthon Formation and assigned it to the Jasper Formation. Lithologies in this sequence are similar to the ones observed in the upper clastic unit on the west flank of BS in the study area.

2.5 Gog Group

A 650 to 1200 m-thick sequence in the central and western parts of the study area is assigned to the Lower Cambrian Gog Group on the basis of its characteristic threefold lithological division, relative thicknesses, and stratigraphic position above the upper Miette (Fig. 2.6, Plate 1.8). Neither fossils nor bottom markings were found, probably in part due to metamorphism and deformation.

The basal unit of the Gog Croup consists primarily of quartzites and is assigned to the McNaughton Formation. It is overlain by carbonates, pelites and quartzites of the Mural

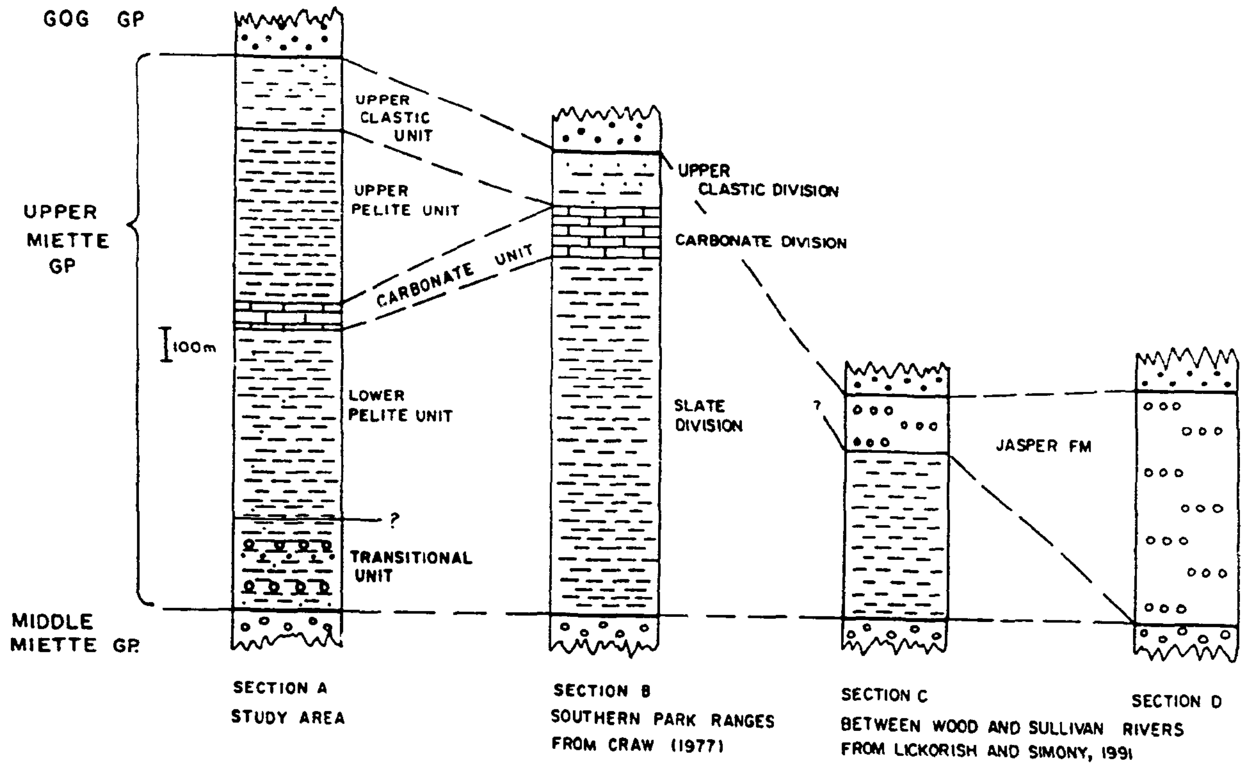


Fig.2.5 Upper Miette Group correlations from study area to south of the Wood River

Formation. In turn the Mural Formation is overlain by quartzites and sandy carbonates of the Mahto Formation.

2.5A McNaughton Formation

The McNaughton Formation crops out in a NW-trending belt in the western and central parts of the study area forming a series of massive, rugged and near vertical peaks. Near Baker Creek headwaters it is estimated to be about 800 m thick, whereas on the west flank of the BS it is estimated to be only 300 m thick.

Anomalously thin sequences of the McNaughton Formation and of its western equivalent the Hamill Group have been attributed to "highs" or positive elements within the sedimentary basin. Young (1979) inferred a high in the McBride area that could account for thinner McNaughton sequences (+/- 400 m-thick) and two troughs, one to the east (Robson Trough, minimum of 2000 m) and another to the west (Cariboo Trough, +/- 2500 m). Kubli (1990b) found evidence for two similar highs, a northern extension of the Windermere High in the Dogtooth Range (Purcell Mountains) and another east of the Rocky Mountain Trench referred to as the "Easterly High". The Dogtooth High is interpreted as a fault block. It may extend northwards and connect with the McBride High. Southwestward thinning of the McNaughton Formation in the study area may reflect approaching either the northern continuation of the Dogtooth High or the Easterly High.

Reported thicknesses of the McNaughton Formation to the southeast range from 200 to 500 m (Mielliez, 1972; Craw, 1977; Ferri, 1984; Gal et al., 1989; Lickorish and Simony, 1991).

The McNaughton Formation in the map area consists predominantly of cliff-forming, massive to cross-bedded light colored quartz sandstones (Fig. 2.6). The quartz sandstones are generally white to creamy colored when fresh and black weathering, due to an abundant lichen cover. Some quartzites are pure, others contain thin, reddish or orange siderite or

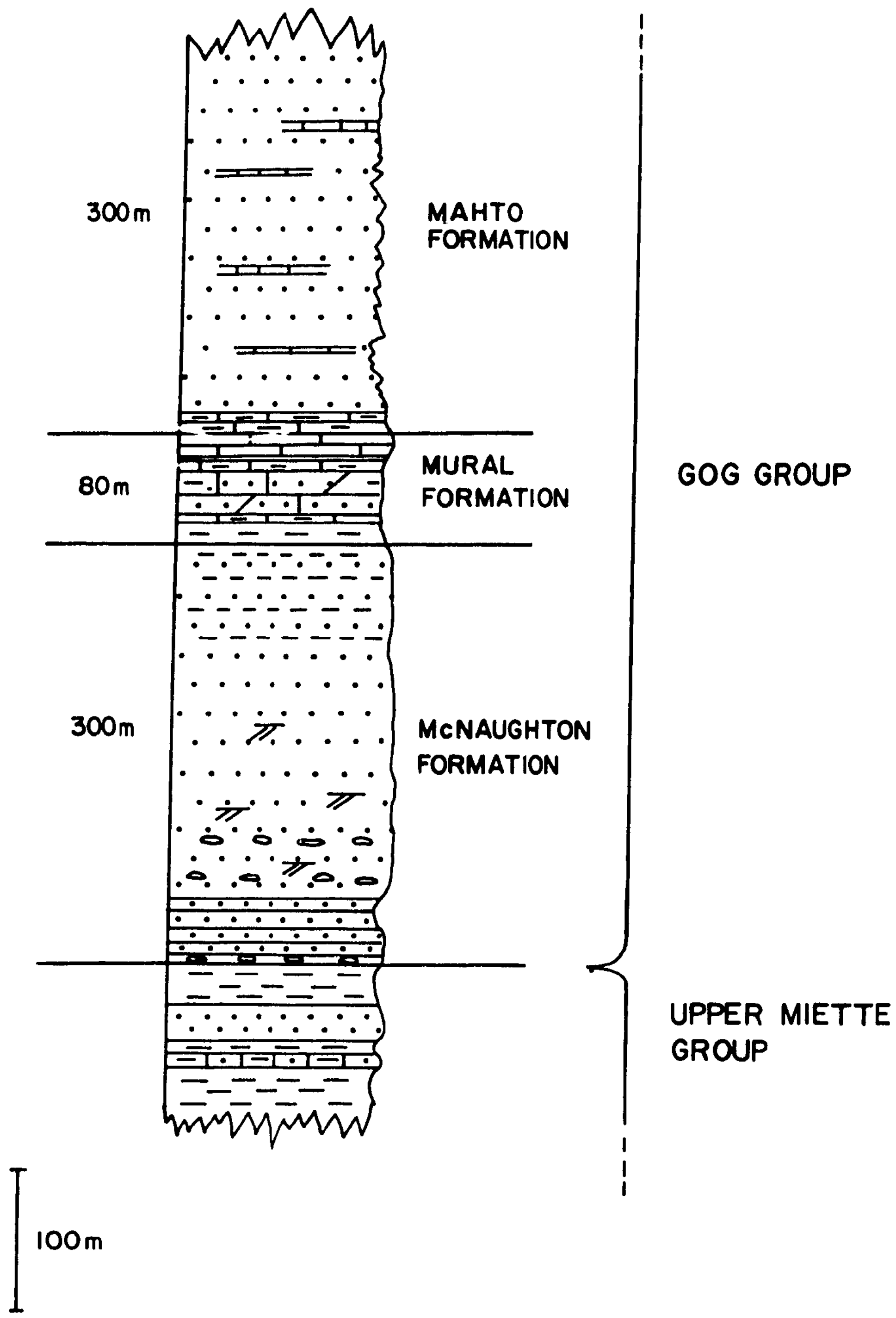


Fig.2.6 Stratigraphic column of the Gog Group on west flank of the BS

hematite rich layers; black, magnetite rich seams and layers, or muscovite rich layers. Green, pink and beige colored quartzite beds are common. In outcrops near the base of the McNaughton Formation north of Baker Creek thin conglomeratic beds with stretched quartz pebbles were observed. Bedding thickness varies between a few cms to a few m.

The upper 50 to 100 m of the McNaughton Formation consist of interbedded thin pelites and sandy carbonates intercalated with thin quartzites. The contact with the overlying Mural Formation is gradational.

Typically McNaughton quartzites are medium- to coarse-grained, moderately sorted, with subangular to angular quartz grains and a mica content varying between 1-5 %. In most thin sections metamorphic fabrics overprint sedimentary textures. Quartz grains are commonly weakly to strongly undulose. They occur as single or composite, lensoidal grains. Grain boundaries are commonly crenulated. These textures suggest that the rock was sheared or strained and that original rounding of quartz grains has been obliterated. Some grains show syntaxial overgrowths. Feldspar is notably rare in most McNaughton quartzites. This contrasts with feldspar being abundant in the basal McNaughton in the Main Ranges east of the Chatter Creek Fault (Mountjoy, 1962; pers. commun., 1990).

2.5B Mural Formation

The Mural Formation is a relatively incompetent, ductile unit sandwiched between two competent quartzite units. Almost everywhere it is strongly deformed and as a result its thickness varies considerably. In the least deformed section north of Baker Glacier, it is about 60 m-thick which appears to be close to true thickness. South of Baker Glacier the Mural Formation is tectonically thickened to more than 100 m by folding and thrusting. Locally it appears to have acted as a detachment horizon (see section 3.2.E, Plates 2.10, 2.11).

North of Baker Glacier the Mural Formation is exposed both in the hanging wall and footwall of the Crevasse thrust (Fig. 3.2, Plate 2.11). The lower 40 to 50 m in these localities comprise recessive, brown-black weathering interbedded calcareous and non-calcareous quartzites and pelites, sandy dolomitic carbonates and grey marbles. In the hanging wall, carbonates become more abundant stratigraphically upwards, whereas in the footwall carbonates are distributed uniformily throughout the sequence. The Mural Formation is capped by 1) a 4 to 10 m-thick, black biotite schist, and overlain by 2) a distinct 10 to 20 m-thick, white-yellow marble. The marble is coarsely crystalline and relatively pure except for muscovite-rich partings and lenses of sandy brown dolomite. This marble is similar to an archeocyathid-bearing marble observed at the top of the Mural Formation by Craw (1977), Gal et al. (1989) and Ferri (1984). South of Baker Glacier two such marble units were observed (Marbles "A","B" in Fig. 3.3). It was not possible to determine with certainty whether they are structural repeats of the same marble or two separate units.

2.5.C Mahto Formation

The Mahto Formation is about 300 m-thick and crops out in the BS north of Baker Creek (lat. 52°21-22',long. 118°30') and in the hanging wall and footwall of the Hallam Normal Fault (lat. 52° 19-20',long. 118°28-32). At a distance it can be distinguished from the underlying Mural Formation by its distinct brownish weathering color, uniform layering and slightly recessive character. Predominant lithologies are brown, and less abundantly beige and green, calcareous, and non-calcareous sandstones and fine- to medium-grained quarztites. Bedding thickness varies from a few cm to about 15 cm. The contact with the overlying Middle(?) Cambrian sequence was inaccessible or covered and appears to be tectonic (see section 3.2.F).

2.6 Middle(?) Cambrian strata

A thick carbonate sequence occurs above the Gog Group south of Baker Creek in the Baker Syncline. It is assigned to the Middle Cambrian following all previous workers (Campbell, 1968; Price and Mountjoy, 1970; Craw, 1977). No fossils have yet been found in this unit to confirm this assignment.

The section south of Baker Creek is estimated to be more than 1000 m-thick using topographic maps (Fig. 3.1) and is overlain by at least an additional 1000 m of massive, cliff-forming, light brown or grey carbonates that are exposed south of Dawson Creek.

The stratigraphic sequence south of Baker Creek consists of alternating; 1) brown weathering, recessive bands of interbedded sandy dolomitic or black micritic carbonates and calcareous and non-calcareous pelites, and 2) massive grey or yellow marbles and limestones (Fig. 2.7, Plates 1.9, 1.10). Thickness of the pelite-carbonate bands and marbles is variable ranging between 10 and 70 m. Individual beds vary in thickness from a few mm to several cm in the interbedded carbonates and pelites. Carbonate layers are generally thicker than pelite layers. The marbles are massive, and coarsely crystalline, locally containing sandy dolomitic lenses and muscovite-rich beds and lenses.

2.6A Middle(?) Cambrian correlations

In the southern Park Ranges, Craw (1977) divided strata conformably overlying the Gog Group into a basal argillite unit (200 m-thick) and an 800 m-thick upper mixed carbonate sequence consisting of sandy carbonates, calcareous and non-calcareous psammites and pelites and large bodies of grey marble. He correlated these units with the Tsar Creek Argillite and the Kinbasket Formation respectively. These units were originally named by Fyles (1960) in the Blackwater and Solitude Ranges.

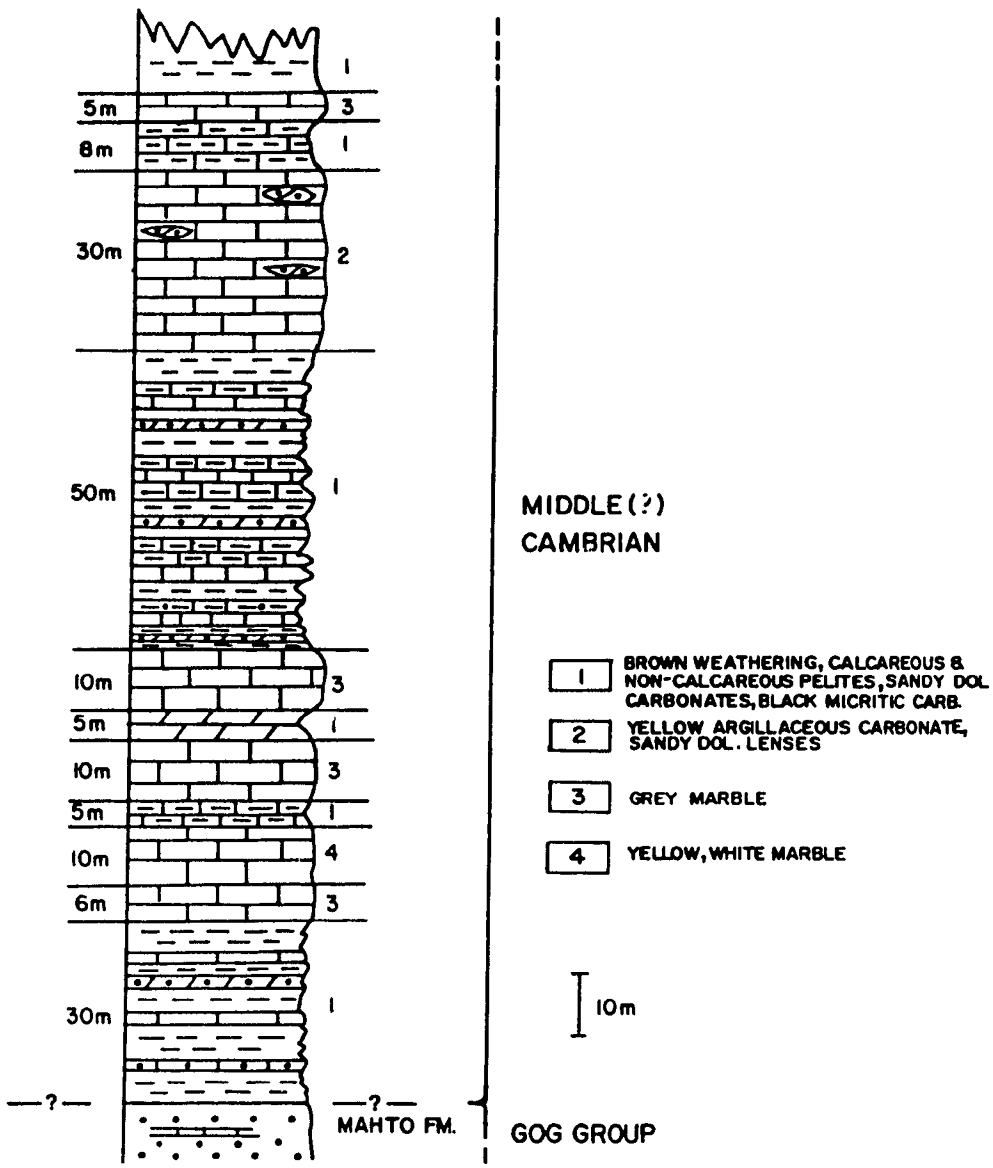


Fig.2.7 Stratigraphic column of basal Middle(?) Cambrian strata south of Baker Creek

The basal 200 m of Middle(?) Cambrian strata observed south of Baker Creek (Fig.2.7), could be correlated with the Tsar Creek Formation due to its position above the Mahto Formation and presence of pelitic lithologies. However there is a strong similarity between these strata and the Kinbasket Formation as described by Craw (1977), especially the presence of grey marbles. Craw himself noted that the Tsar Creek and Kinbasket Formations can often not be clearly separated. For this reason the Middle Cambrian(?) sequence in the study area is not assigned to a particular formation.

In the Eastern Main Ranges the Gog Group is overlain by massive, shallow water Middle and Upper Cambrian carbonates. In the southern Western Main Ranges it is overlain by deeper water equivalents of these carbonates assigned to the Chancellor Group (Mielliez, 1972, Ferri, 1984, Gal et al., 1989). The eastward change from carbonate to shale dominated facies corresponds to the western margin of an extensive Cambrian platform termed the Kicking Horse Rim (Aitken, 1989). The carbonate sequence overlying the Gog Group in the study area resembles more closely the Middle Cambrian rocks of the Eastern Main Ranges than Chancellor Group strata to the south, because of their massive, well-bedded, and cliff-forming character, the predominance of carbonate lithologies and the presence of grey marbles which may represent small reefs or carbonate shoals. This implies that a facies change from massive carbonates change to deeper water Chancellor facies occurs somewhere south of the Wood River (Craw, 1977; Gal et al., 1989).

2.7 Carbonate breccia

An unusual local carbonate boulder breccia occurs at lat. 52°18-19'lat. and long. 118°28-29'long. along Dawson Creek (B on Fig. 3.1.). It is more than 300 m-thick and crops out on a strongly eroded terrace located topographically below Middle(?) Cambrian strata exposed in the BS. It is formed by angular boulders and clasts ranging in size from a few cm to several m (4-5 m) (Plates 1.11,12). These consist predominantly of interbedded yellow and brown carbonates, pelites and calcareous pelites, very similar to the lithologies observed in the Middle(?) Cambrian sequence. The breccia is predominantly clast-supported and cemented by a yellow to pink, coarsely crystalline carbonate cement. This cement is very soluble explaining the presence of large solution holes and depressions.

The probable provenance of boulders and clasts of the breccia is from Middle(?) Cambrian strata. The angularity of boulders and clasts, and unsorted character of the breccia point to a short distance of transport. It may represent cemented Tertiary talus deposits.

2.8 Sheared quartz-pebble conglomerate

Several outcrops of strongly sheared quartz-pebble conglomerates were observed about 1 km east of the Hugh Allan (Purcell) thrust on the west flank of the BS (A in Fig. 3.1). These conglomerates are characterized by a strong mineral lineation defined by 0.2. to 1 cm-long elongated quartz grains. In thin section elongated quartz grains are either composite grains or single grains showing strong undulose extinction. They are set in a matrix consisting predominantly of quartz and mica flakes and with small amounts of biotite, chlorite and zircon. Muscovite flakes define a weak schistosity in some thin sections that parallels the plane of elongation of quartz grains.

Most textures observed in these rocks, such as the presence of well-preserved quartz grains point to a sedimentary origin. They may represent a strongly sheared upper Miette Group sandstone. Alternatively they may be cover rocks to the Hugh Allan Gneiss.

Plates

W

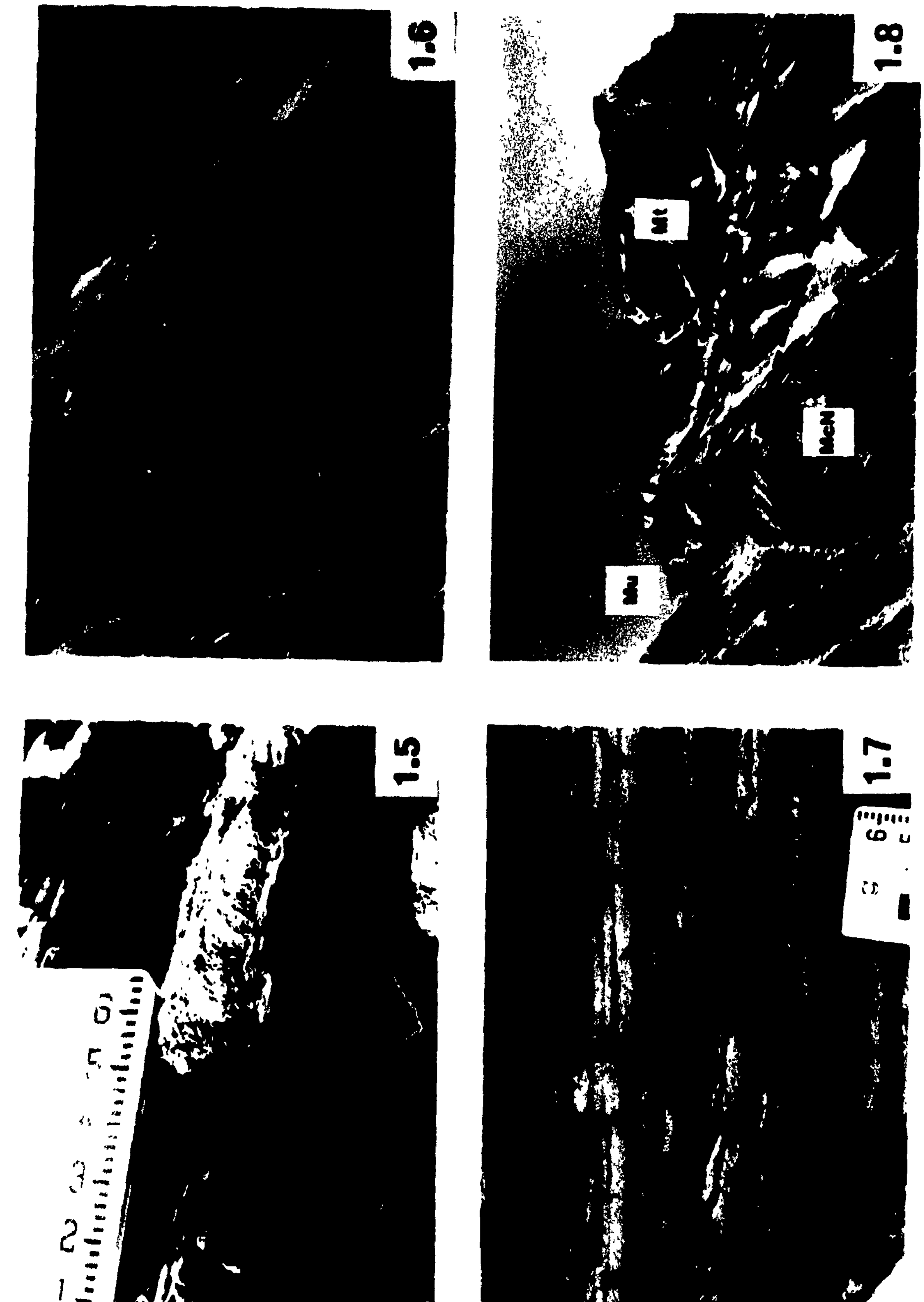

E

1.5 Shale clast in upper middle Miette Group grit on east flank of PCA, on ridge north of Hugh Allan Creek

1.6 Basal, upper Miette Group boulder conglomerate on west west flank of PCA, on ridge south of Dawson Creek

1.7 Folded pelites and calcareous pelites with ubiquitous amphibole porphyroblasts (shown by arrows) in upper Miette Group carbonate division on west flank of PCA, north of Baker Creek headwaters

1.8 Conformable stratigraphic sequence of McNaughton (McN), Mural (Mu), about 100 m thick and Mahto (Ma) Formations in Baker Syncline, north of Baker Creek, view looking north


1.5
1.6
1.7
1.8
Mt
McN
Mu

1.9 View south of Middle(?) Cambrian strata in BS south of Baker Creek

1.10 View southwest of Middle(?) Cambrian strata in BS south of Baker Creek

1.11 Large boulders in carbonate breccia of unknown origin, stratigraphic position and age, south of Baker Creek; largest boulder about 3 m in diameter

1.12 Boulders in carbonate breccia, south of Baker Creek; hammer for scale in upper part of picture

1.9

1.10

1.11

1.12

CHAPTER III - STRUCTURE

3.1 Introduction

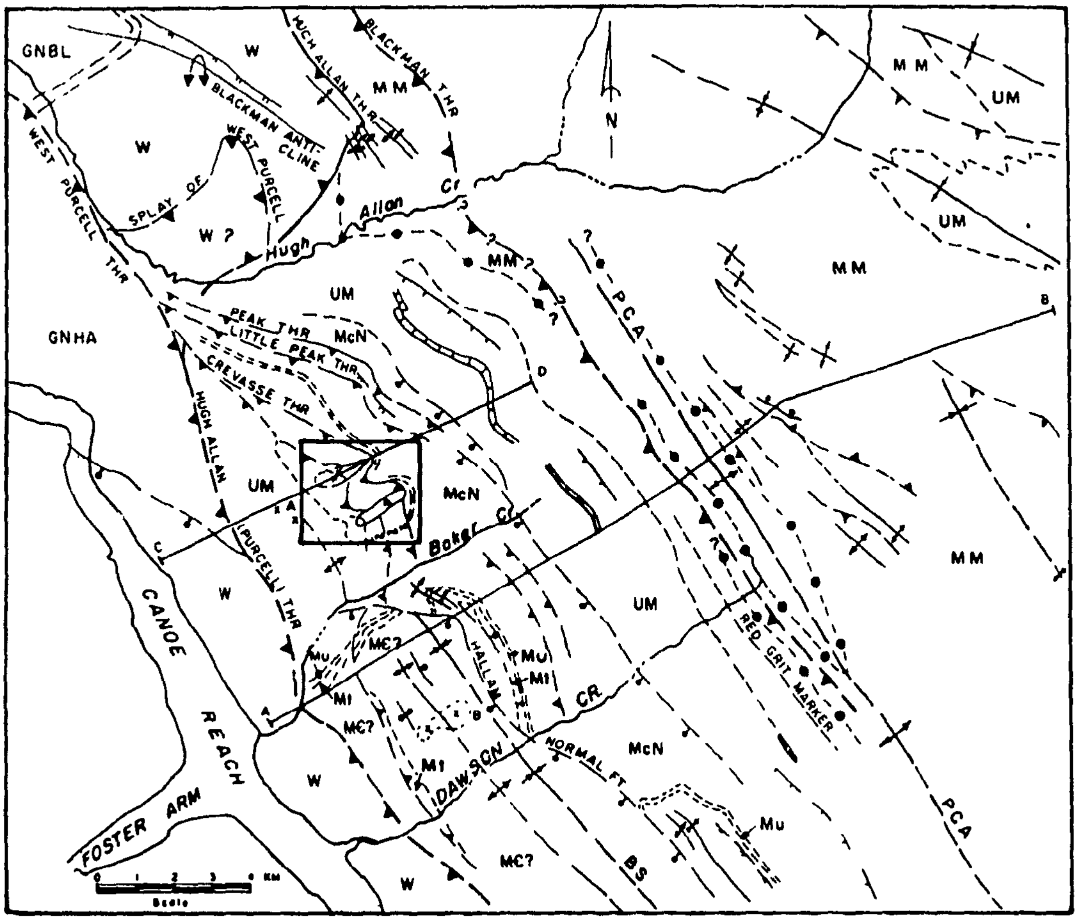
The structure in the study area is dominated by two large-scale upright structures, the PCA and the associated Baker Syncline (BS) to its southwest (Figs.3.1, 5.1). The core and the east flank of the PCA are characterized by folded and faulted middle Miette Group strata and a relatively undeformed panel of upper Miette Group and Gog Group strata forms its west flank. North of Baker Creek three late, steeply southwest-dipping thrust faults break the common limb of the PCA and the BS within the Gog Group (Figs. 3.3, 3.4). South of Baker Creek a southwest-dipping normal fault, the Hallam Fault, cuts the BS.

Megascopic and mesoscopic structures in the area include an early schistosity (S-early), northeast-verging recumbent and upright folds (F2) and associated axial planar foliations (S2), three late crenulation cleavages, four generations of thrust faults, as well as Early Tertiary normal faults.

3.2 Megascopic structures

3.2A Porcupine Creek Anticlinorium

The PCA is a regional fold structure that extends from the study area, over a distance of more than 400 km, to south of Golden, where it is known as the Porcupine Creek Fan structure (Price and Mountjoy, 1970; Balkwill, 1972; among others). Overall the regional plunge of the PCA is about 1° southeast. In the northern Park Ranges the deepest structural and stratigraphic levels of the PCA are exposed. Mapping north of Hugh Allan Creek (Mountjoy, 1988; Mountjoy and Grasby, 1991) suggests that the PCA is faulted there. The east flank has been overridden by its west flank carried on the Blackman thrust. The Blackman thrust probably extends across Hugh Allan Creek into the core of the PCA, losing displacement southwards.



LEGEND

MC? — Middle (?) Cambrian

Mt = Mahto Fm.
Mu = Mural Fm. — Lower Cambrian Gog Gp.
McN = McNaughton Fm.
UM = upper Miette Gp.
= basal conglomerate unit
= carbonate unit — Hadrynian Miette Gp
MM = midle Miette Gp.
◆◆ = Old Fort Point Fm
W = Western stratigraphy — Hadrynian
GN = basement gneiss — Precambrian
BL = Blackman
HA = Hugh Allan

Location of outcrops .
A = sheared quartz pebble congl.
B = carbonate breccia

SYMBOLS

stratigraphic contact
thrust fault
normal fault
anticline (overturned)
syncline
garnet isograd
staurolite isograd

Fig.3.1 Geology of the study area; area in box is shown enlarged in Fig.3.2.

3.2B East flank of PCA

The middle Miette Group on the east flank of the PCA dips 20° to 40° east and is characterized by broad and open, generally large-scale, parallel, concentric folds and southwest-verging thrust faults that appear to be related to the large scale folds (Plate 2.1). Offsets of the Old Fort Point Formation indicate that fault displacements are small (Fig. 3.3). These folds are associated with a vertical to steeply northeast- or southwest-dipping axial planar cleavage (see section 3.3). Two late-stage, steeply northeast-dipping normal faults of small displacements locally offset the southwest-verging thrust faults.

3.2C Core of PCA

A faulted, double anticline forms the core of the PCA. Megascopic folds are generally tight and are locally overturned to the southwest. They are broken by minor steep southwest and northeast-dipping thrust faults with minor displacements (Fig. 3.3, Plates 2.3, 2.5).

3.2D West flank of PCA north of Baker Creek

Upper Miette Group strata on the west flank of the PCA form a relatively homogenous, southwest-dipping pelite-dominated panel, in which megascopic folds and thrust faults are not apparent.

The Gog Group on the west flank of the PCA is duplicated by the steeply southwest-dipping Peak, Little Peak and Crevasse thrusts (Figs. 3.2, 3.4). They have relatively small displacements not exceeding 3 to 4 km total displacement. Thus the PCA and the BS are linked by a common, slightly deformed limb. The Baker Syncline is a regional-scale upright structure like the PCA that continues south to the Wood River (Fig.1.2, Plate 2.8; Price and Mountjoy, 1970, Craw, 1977).

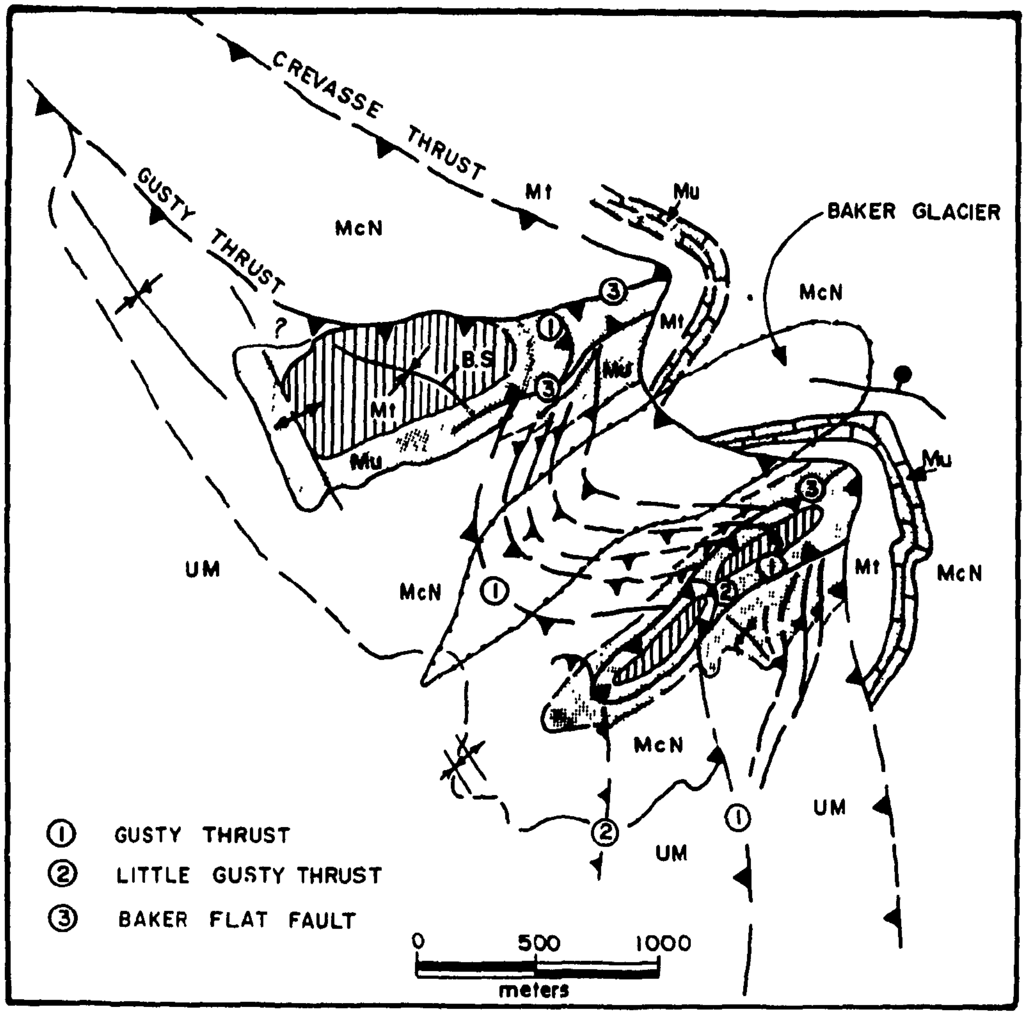


Fig.3.2 Detailed geology of Baker Glacier area; for symbols see Fig. 3.1

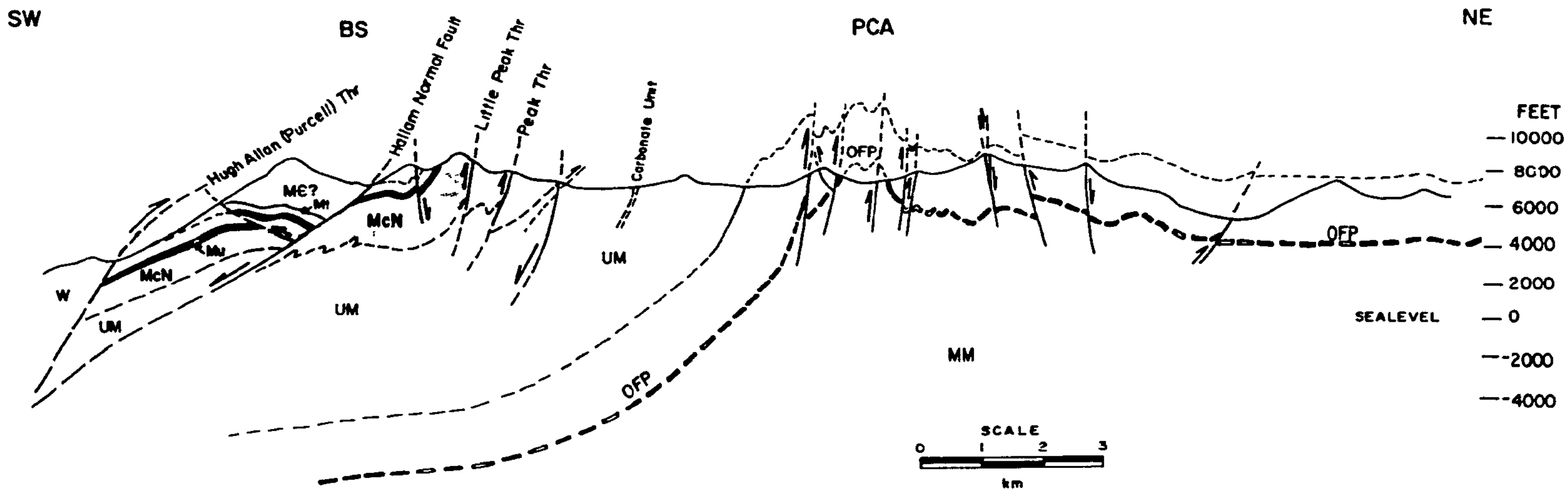


Fig.3.3 Cross-section south of Baker Creek, for location of line of section (A-B) and symbols see Fig.3.1

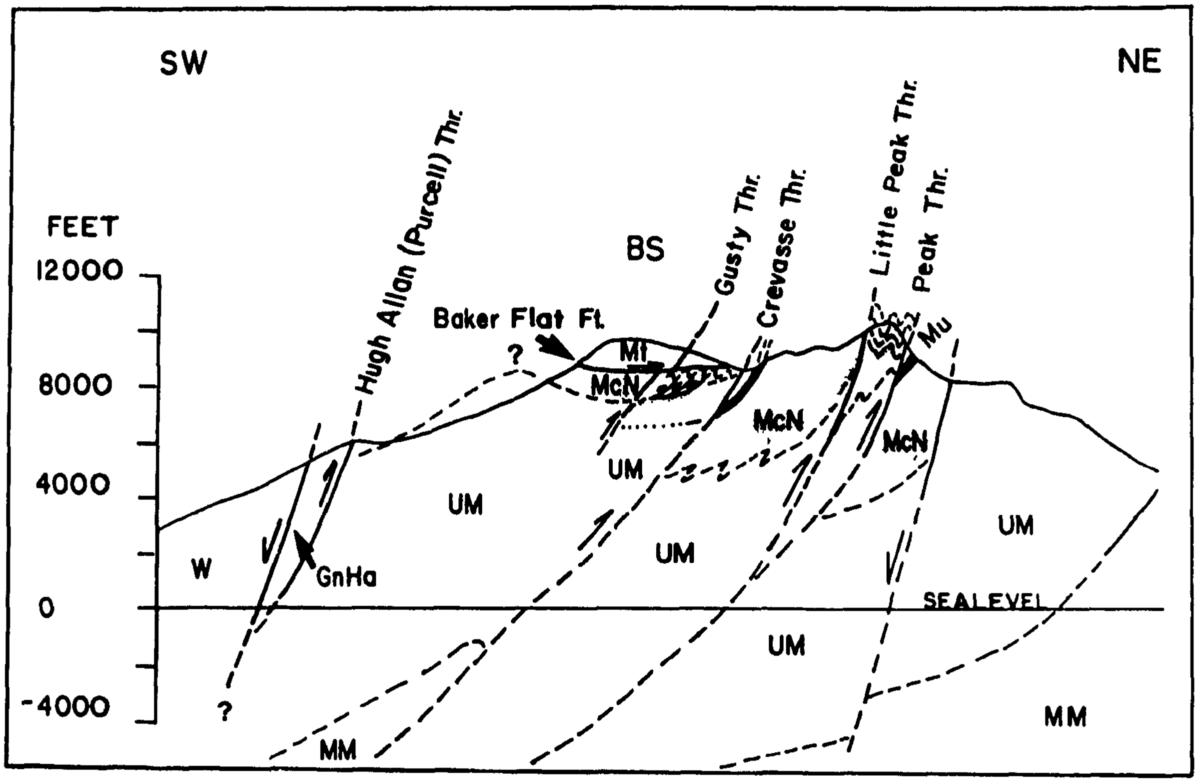


Fig.3.4 Cross-section north of Baker Creek, for location of line of section (C-D) and symbols see Fig.3.1.

The easternmost Peak Thrust juxtaposes a structurally complex slice of McNaughton Formation quartzites over relatively undeformed, southwest-dipping Mural and McNaughton strata. Displacement is about 2 km as calculated from the cross-section (Fig. 3.3). Binocular observations indicate three types of structures in the hanging wall of the Peak Thrust (Plate 2.7): 1) Several large-scale, upright and tight folds (F2 folds as documented later) in McNaughton Formation quartzites; 2) two southwest-dipping detachment surfaces thought to be thrust faults which truncate the folds, possibly small splays of the Peak Thrust; 3) a very strongly developed, nearly horizontal joint set.

To the west, the Crevasse Thrust underlies the BS with complexly faulted and folded McNaughton, Mural and Mahto strata (Figs. 3.2, 3.4). Displacement is about 1 km. Two small, steeply southwest-dipping thrust faults (Gusty and Little Gusty thrusts) occur in the western part of the Crevasse thrust sheet. Offsets on these faults are on the order of a few tens of meters. Both faults appear to be truncated by the Baker Flat fault which dips eastward at a low angle (Fig.3.5).

The eastern part of the Crevasse thrust sheet (Figs. 3.2, 3.5) consists of a series of small, southwest-dipping (50° to 70°) thrusts spaced about 50 m apart with offsets of roughly 10 to 30 m (Plate 2.9). These faults involve the uppermost part of the McNaugnton Formation and the lower part of the Mural Formation and some appear to merge upwards into the Baker Flat fault. They are overlain by upright and recumbent, northeast-verging folds of a distinctive upper Mural Formation marble (Marker "B" in Fig. 3.5). Downwards these faults probably merge with a floor or basal thrust (not observed). The markedly different structural styles observed in the Mural and McNaughton Formations reflect the contrast in competency between these two units. The Mural Formation deformed more ductily by folding, than the underlying more

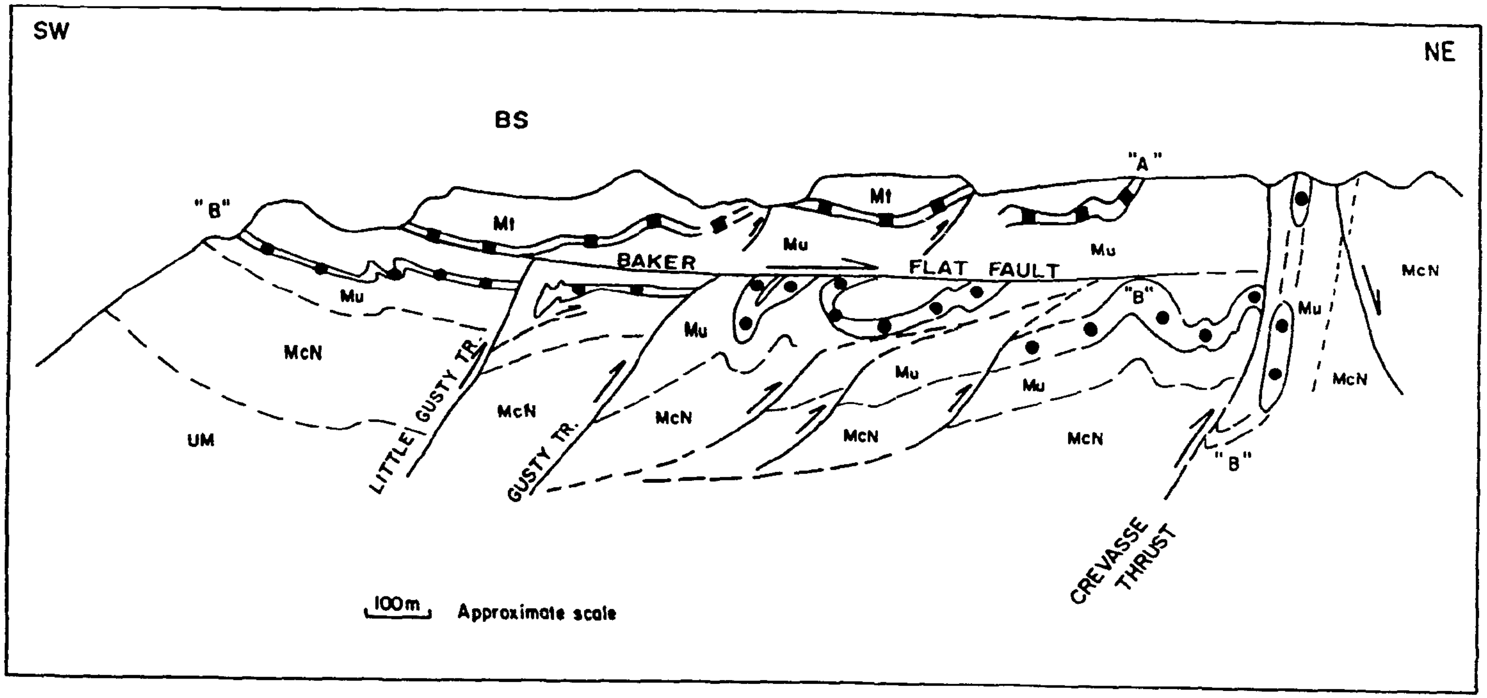


Fig.3.5 Schematic cross-section of Crevasse Thrust Sheet, Baker Glacier area, on south side of glacier; for symbols see Fig. 3.1

brittle McNaughton Formation quartzites which deformed predominantly by thrusting.

3.2E Baker Flat Fault

The Baker Flat fault is a very low-angle fault within the Crevasse thrust sheet, that cuts the large, northeast-verging recumbent and upright folds in the Mural marble and the southwest-dipping Gusty and Little Gusty thrusts (Fig. 3.5, Plates 2.10-12). Sense and magnitude of displacement on this fault were difficult to determine due to intensive folding and faulting. It is possible that it developed in a zone of weakness, following a pelitic horizon in the Mural Formation, and that two large, recumbent synclines in the footwall are drag folds of this fault (Fig.3.5, Plate 2.13). The Baker Flat fault appears to have offset the Gusty and Little Gusty thrusts eastwards by about 450 m and is in turn folded by late upright folds (Plate 2.13) and truncated by the Crevasse thrust (Plates 2.11,12). It may however be a southwest-verging backthrust as indicated by the cut-off angle of layering.

3.2F West flank of PCA south of Baker Creek

South of Baker Creek the predominant structure is the southwest-dipping Hallam normal fault (with dips ranging between 45° and 60°), which cuts the core of the BS (Fig. 3.3). On the west side it downdrops by about 800 m a thick section of Middle(?) Cambrian carbonates. Smaller normal faults with displacements in the order of several tens of meters are common in both hanging wall and footwall of this fault (Plate 2.14). In its hanging wall a shallow northeast-dipping thrust fault with about 300 m of displacement duplicates parts of the Gog Group. It is the only observed southwesterly verging fault on the west flank of the PCA.

Airphoto interpretation and binocular observations suggest that thrust faults similar to the Peak, Little Peak and Crevasse faults and large scale upright folds are present south of Baker Creek in the footwall of Hallam Fault (Fig. 3.1). Also the Gusty Thrust can also be traced southward across Baker Creek where it appears to be truncated by the Hallam Fault. The Hallam Fault possibly reutilized an earlier thrust fault, accounting for its uncharacteristic low dip. Middle Cambrian strata in the BS and an adjacent anticline are folded by large-scale recumbent isoclinal northeast-verging folds. Similar folds were observed in the footwall of Hallam Fault, but not in underlying Gog Group strata, indicating disharmonic folding and the possibility of a detachment surface or zone between these stratigraphic units.

3.2G Sequence of thrust faults

Four generations of thrust faults occur in superposition in the study area. The earliest thrust fault is the Hugh Allan (Purcell) Thrust that bounds the northwestern corner of the study area. The second generation of thrust faults consists of small northeast- and southwest-verging thrusts found on both flanks of the PCA and BS (ie. Gusty and Little Gusty thrusts). These faults appear to be related to the formation and possibly tightening of PCA-related folds. The Baker Flat Fault is the only example of a third generation thrust in the study area and appears to be a local response to marked competency contrasts of a highly deformed stratigraphic package. The Crevasse, Peak and Little Peak thrusts are fourth generation thrusts that may have formed at the same time as the West Purcell thrust and unnamed splay north of Hugh Allan Creek.

3.2H Normal faults

Several generally steeply, southwest-dipping normal faults occur throughout the study area, in addition to the Hallam Fault discussed in section 3.2.F. Displacements on these faults are relatively small and do not exceed 1 km. They postdate all other structures and are thought to have formed during regional widespread Eocene extension and/or during transcurrent transtensional deformation.

3.3 Structural analysis: fold morphology and mesoscopic fabrics

Three predominant types of folds were observed in the study area (Fig. 3.6., Table 3.1): type 1 = southwest-verging folds; type 2 = recumbent northeast-verging folds, and type 3 = upright northeast-verging folds.

Upright to reclined southwest-verging type 1 folds were observed in the western part of the study area. Their timing with respect to northeast-verging structures is not clear.

Type 2 folds (F2?) are northeast-verging, recumbent and generally tight to isoclinal. They occur on all scales, being common throughout the western part of the study area, but were not observed in the core and on the east flank of the PCA. They occur predominantly in pelitic and carbonate units of the Gog Group and in Middle(?) Cambrian strata. These folds are associated with an axial planar schistosity (S2?) that is bedding-parallel or is inclined at small angles to the bedding. Microscopically this schistosity is defined by the alignment of muscovite, chlorite, ilmenite, rutile and elongated quartz grains (see Chapter 4). At one locality on the west flank of BS, in Middle(?) Cambrian calcareous pelites, northeast-verging recumbent type 2 folds fold an earlier foliation. This foliation (S-early), a bedding-parallel schistosity defined by micas and calc-silicate porphyroblasts, is crenulated in fold noses. On fold limbs both foliations are parallel and form a composite schistosity.

Upright and generally open type 3 folds of all scales are abundant throughout the entire study area. They are thought to be parasitic folds of the PCA based on the similarity of fold style and attitudes. They plunge

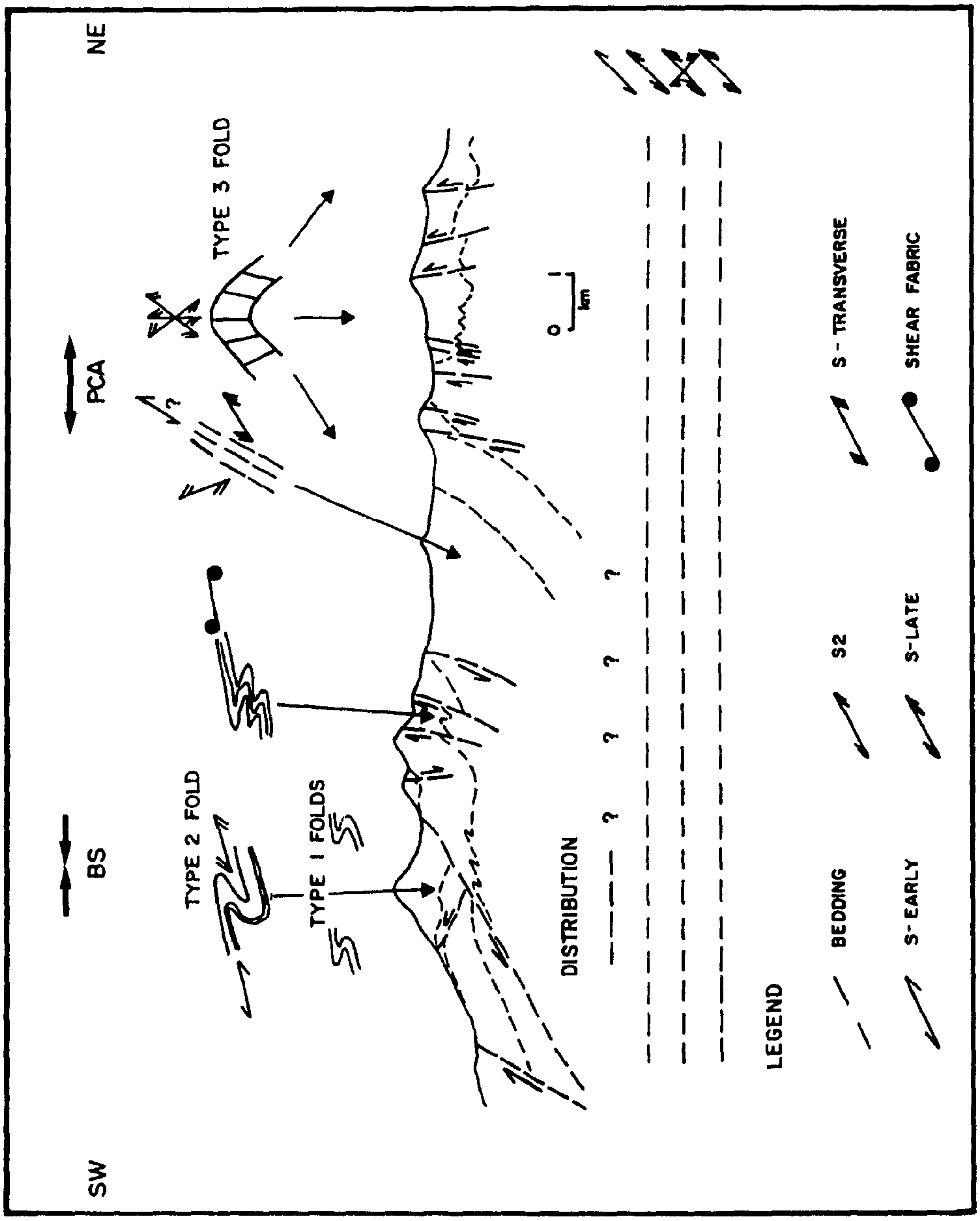


Fig.3.6 Distribution of mesoscopic fabrics

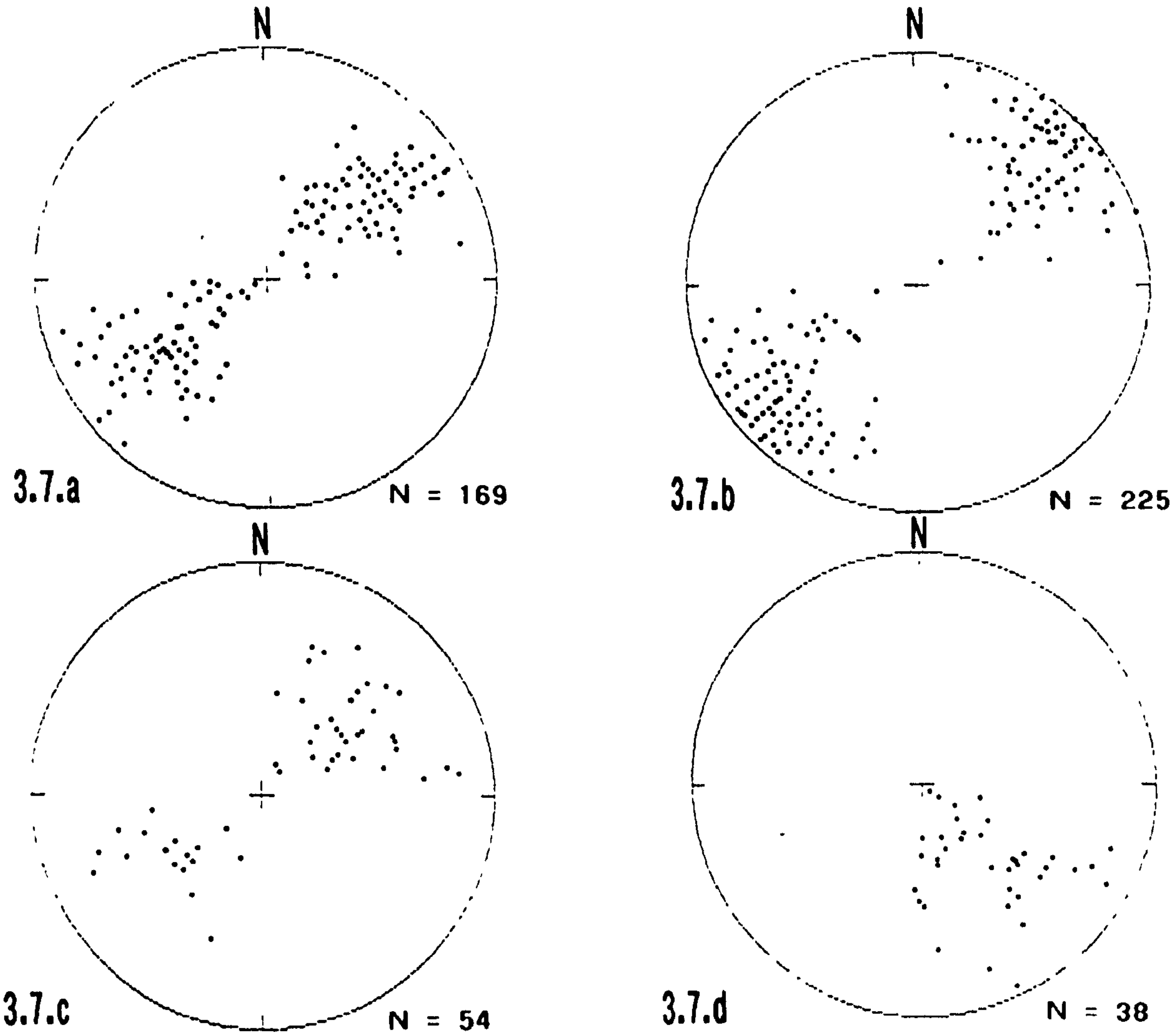


Fig.3.7 Stereonet projections for entire study area of poles to
3.7a bedding
3.7b S2 schistosity and cleavage
3.7c S-late crenulations
3.7d transverse crenulations
plotted on Schmidt equal area nets

predominantly to the southeast, parallel to the regional plunge of the PCA (Fig. 3.8), and are colinear with type 2 fold axes. Most of these upright folds are concentric, although thickening occurs in incompetent pelitic sequences. They are characterized by a vertical to steeply southwest- or northeast-dipping axial planar foliation (S2). S2 occurs as a pervasive slaty cleavage or schistosity in pelites and semipelites, and as a fracture cleavage in competent grits and psammites (Plates 2.15, 2.16) on the east flank and in the core of the PCA. It was also observed as a crenulation in outcrop and thin section on the west flank of the PCA in upper Miette Group strata, where they overprint an earlier cleavage (S-early ?) that occurs at small angles to bedding. Refraction of the S2 cleavage through beds of different competencies is common. Locally in upper Miette pelites and calcareous pelites late stage offsets occur along the steep S2 cleavage (Plate 2.15).

On both flanks and in the core of the PCA, late, southwest- or northeast-dipping crenulations (S-late) were observed (Fig. 3.6c). They form small kinks of earlier S2 foliations, locally defining conjugate crenulation sets. These crenulations also deform metamorphic porphyroblasts (Plate 3.7), indicating that they are postmetamorphic.

Rare, late, northeast-verging kink folds occur in upper Miette Group pelites on the west flank of the PCA. These small-scale folds are tight and inclined to the northeast producing southwest-dipping (45° to 65°) axial planar kink surfaces (Sk) that crosscut S-late crenulations.

Two mesoscopic structures occur in quartzites of the McNaughton Formation in the hanging wall of the Peak thrust that are not observed elsewhere and are not easily correlated with other foliations. The earlier fabric is a strongly developed bedding-parallel foliation, possibly a tectonic shear fabric (Plates 2.17,18). This fabric is spaced at intervals of 0.2 to 0.5 cm and produced significant stretching

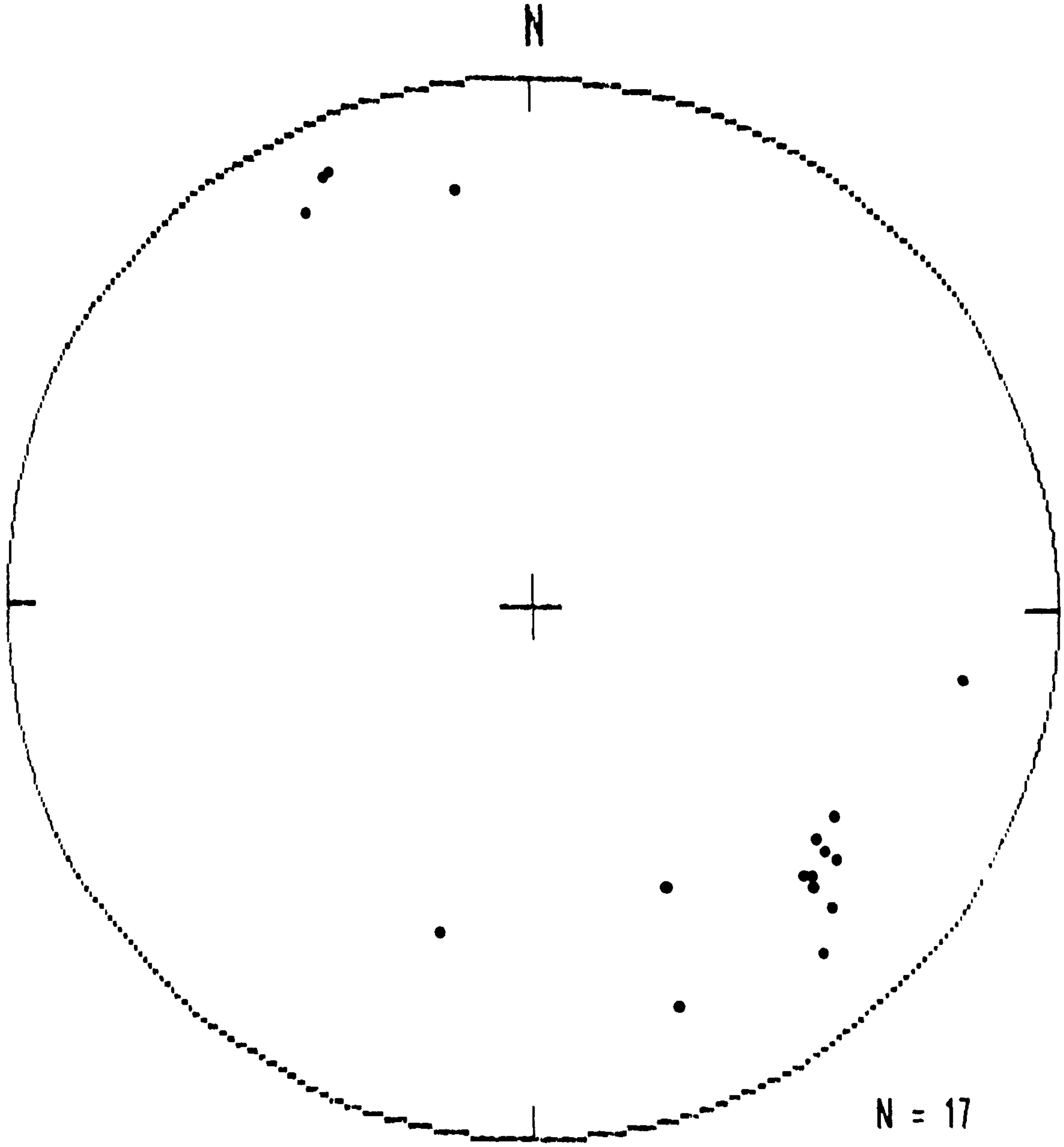


Fig.3.8 Stereonet projection of F2 fold axes for entire study area; plotted on Schmidt equal area net

TABLE 3.1 SUMMARY OF FOLD SETS, FOLIATIONS AND FAULTS

		SW-VERGING FOLDS (TYPE 1) - TIMING ?
	S-EARLY	BEDDING PARALLEL, SCHISTOSITY ASSOC. WITH BIOTITE & CALC-SILICATE PORPHYROBLASTS
	F2	NE-VERGING RECUMBENT, ISOCLINAL FOLDS (TYPE 2) ASSOCIATED WITH
	S2	AXIAL PLANAR SCHISTOSITY & CRENULATIONS SYNMETAMORPHIC
D2		
	F2	NE-VERGING UPRIGHT, OPEN TO TIGHT FOLDS (TYPE 3) ASSOCIATED WITH
	S2	PERVASIVE AXIAL PLANAR SLATY & FRACTURE CLEAVAGE & CRENULATIONS SYNMETAMORPHIC
		NE AND SW-DIPPING THRUSTS IN CORE AND ON FLANKS OF PCA (EXAMPLE GUSTY THR.)
?		HORIZONTAL, NE-VERGING (?), POST-METAMORPHIC BAKER FLAT FAULT
D3 OR LATER		SW AND NE-DIPPING CRENULATIONS STEEP, SOUTHWEST-DIPPING THRUSTS (EXAMPLE PEAK, LITTLE PEAK & CREVASSE THRS.)
	St	TRANSVERSE FOLIATIONS
D4		NORMAL FAULTS

of quartz pebbles. It is folded by small, recumbent southwest-verging folds (Plates 2.18).

3.4. Foliations in gneisses

Three foliations and one lineation are present in outcrops of the Hugh Allan Gneiss (lat. 52°21', long. 118°34'). Reliable structural measurements were difficult to obtain due to slumping and small outcrops surfaces. Gneissic banding and a schistosity found in biotite-rich layers within gneissic layers are commonly steeply northeast- to southwest-dipping. The most commonly observed foliation in the gneisses is either manifested as a fracture plane, or as a crenulation cleavage. The average strike is 255° and average dip is 65°NW. Small-scale, tight generally upright to reclined folds involving the gneissic banding are associated with axial planar crenulations that dip to the southwest (average dip of 66°SW) and southeast.

3.5 Transverse foliations

A northwest-dipping crenulation (St) striking about 255° with average dip of 40°NW was observed in most of the study area, and was observed as far east as 3 km east of the axis of the PCA. This trend is parallel to the most common foliation in the Hugh Allan Gneiss. This foliation crenulates various mesoscopic fabrics such as the S2 cleavage and therefore postdates the PCA. The relationships with respect to the late steep, southwest-dipping thrusts are unknown.

3.6 Interpretation of megascopic structures and mesoscopic fabrics

3.6A S-early foliation

The relationship of the S-early foliation to other foliations is uncertain, due to its local occurrence in Middle(?) Cambrian strata on the west flank of the PCA and because it could not be related to any folds. It may be equivalent to an early cleavage observed in upper Miette Group strata on the west flank of the PCA, where it is crenulated by crenulations associated with upright F2 folds (Fig.3.6). An early, bedding-parallel schistosity has been observed by Ferri (1984), Gal et al. (1989) and Lickorish and Simony (1991) on the west flank of the southern PCA. This foliation is present only in Middle Cambrian Chancellor Group strata and locally in the Mahto Formation and absent in the lower Gog Group and the Miette Group. It is crenulated by the pervasive upright cleavage associated with the main deformation phase related to formation of the PCA. It has been suggested by these workers that a décollement at or near the Gog-Chancellor contact was active during early deformation allowing upper and lower structural levels to deform independently.

In the Mica Dam area to the southwest, Simony et al. (1980) described a composite S1+2 foliation on the west flank of the Shuswap metamorphic complex. There S1, (which is also near bedding-parallel) is ascribed to the regional F1 event which produced southwest-verging recumbent folds such as the large scale Scrip Nappe. F2 folds which are tight, recumbent and northeast-verging fold the S1 schistosity and produce a combined S1+2 schistosity. S1+2 is folded by large scale, upright F3 folds like the Mica Creek Antiform. This raises the possibility that S-early of the study area could be related to southwest-verging folds observed in the study area and that it could be correlated with the southwest-verging F1 folding event observed west of the Rocky Mountain Trench.

Until recently there has been little evidence for southwest-verging deformation in the Rocky Mountains east of the Rocky Mountain Trench. Charland (1989) and Leonard (1985) recorded southwest-verging folds in the hanging wall of the Vallee and Hugh Allan (Purcell) thrusts. Southwest-verging folds in the footwall of the Hugh Allan (Purcell) Thrust were observed by Leonard (1985) and by the author. There is however no evidence at this point that permits linking these structures to the F1 event west of the Rocky Mountain Trench.

In the Bulldog area to the northwest, McDonough and Simony (1988b) observed a S1 schistosity that is spatially restricted to basement gneisses but may also be present in cover rocks. These authors suggest that S1 is related to shearing along the basement-cover contact. To relate the S-early schistosity from the study area to basement-cover shearing is unreasonable because it occurs at very high stratigraphic levels in the Middle(?) Cambrian sequence far above the crystalline basement.

Although further work is necessary to better correlate the S-early foliation it appears reasonable to suggest that it is either the equivalent of the S1 schistosity described by Ferri (1984), Gal et al. (1989) and Lickorish and Simony (1991) or a footwall structure related to the Hugh Allan (Purcell) thrust.

3.6B Northeast-verging structures

Two sets of northeast-verging folds (recumbent and upright) and associated foliations have been described in the Western Main Ranges (Table 3.2) and are correlated in this thesis with the D2 and D3 events documented in the Omineca Crystalline Belt. Regionally there is evidence that the recumbent, isoclinal fold set predates the upright fold set (McDonough and Simony, 1988a,b, Grasby, pers.comm., 1991). These fold sets are related to northeast-directed thrust movement and have been interpreted as 1) separate deformation

TABLE 3.2 REGIONAL STRUCTURAL AND METAMORPHIC COMPILATION

OMINECA CRYSTALLINE BELT	WESTERN MAIN RANGES					
	SELWYN RANGE CHARLAND (1989)*1	SELWYN RANGE MOUNTJOY & GRASBY*2	NORTHERN PARK RANGES THIS STUDY	SOUTHERN PARK RANGES CRAW (1977)	WOOD RIVER AREA SIMONY ET.AL. (1980)	SOLITUDE RANGE GAL ET.AL. (1989)
D1 SW-VERGING FOLDS (SCRIP NAPPE)	D1 SW-VERGING FOLDS		S-EARLY ?			
D2 NE-VERGING REC. FOLDS PEAK METAMORPHISM DURING & OUTLASTING D2	D2 NE-VERGING REC. FOLDS (BLACKMAN ANTICL.) PEAK METAMORPHISM DURING & OUTLASTING D2	D2 NE-VERGING REC. FOLDS & LOW-ANGLE THRUSTS (BLACKMAN ANTICL. & HUGH ALLAN THR.)	D2 NE-VERGING RECUMBENT & UPRIGHT FOLDS & AXIAL PLANAR FOLIATIONS THRUST FAULTS (GUSTY) PEAK METAMORPHISM	F1 ISOCLINAL FOLDS METAMORPHIC PEAK ATTAINED BETWEEN D1 AND D2	F2 NE-VERGING REC. ISOCLINAL FOLDS METAMORPHISM	F1 NE-VERGING REC. ISOCLINAL FOLDS
D3 NE-VERGING UPRIGHT FOLDS	D3 CHEVRON FOLDS	D3 NE-VERGING UPRIGHT FOLDS (PCA, FRA) PEAK METAMORPHISM		F2 UPRIGHT FOLDS MINOR METAMORPHIC RECRYSTALLIZATION, MAIN FORMATION OF PCA	F3 UPRIGHT FOLDS & FOLIATIONS	F2 UPRIGHT FOLDS & FOLIATIONS METAMORPHIC PEAK
		D4 POSTMETAMORPHIC THRUSTS (WEST PURCELL & SPLAY)	D3 POSTMETAMORPHIC CRENULATIONS & THRUSTS (I.E. CREVASSE)			
		TRANSVERSE FOLIATIONS	TRANSVERSE FOLIATIONS			
		NORMAL FAULTS	NORMAL FAULTS			

*1 Hanging wall of Vallee (Hugh Allan) thrust *2 Footwall of Hugh Allan Thrust events, or 2) as early and late stages of a single progressive deformation event (Forest, 1985), 3) as the result of a Sanderson-type deformation (Leonard, 1985), and 4) as early and late stages of development of the PCA (Craw, 1977, Simony et al., 1980, Gal et al., 1989).

The northeast-verging recumbent (type 2) and upright (type 3) folds are interpreted in this thesis as having formed during a progressive, largely synmetamorphic deformation event (D2) related to continued northeast-verging thrust movement and formation of the PCA. Fold styles and attitudes may be the function of ductility of deforming strata. Recumbent folds are expected to develop in ductile lithologies, and upright folds in more competent grit and quartzite lithologies. This holds true for most folds observed in the study area. Furthermore, another possible control on fold attitudes may be their position on the large scale PCA structure. Some overprinting of low-angle and upright fabrics is expected during a progressive deformation event especially during tightening and rotation of structures.

Movement on the low-angle Hugh Allan (Purcell) thrust and associated northeast-verging recumbent folding (ie. Blackman anticline) occurred prior to upright PCA-related folding (Mountjoy, 1988), suggesting that it took place early during D2. Whether some of the recumbent folding observed in the study area is related to the emplacement of this thrust is not known, but possible.

An alternative interpretation of the deformational sequence in the map area is to assign southwest-verging structures (type 1 folds) to D1 deformation, northeast-verging recumbent or low-angle structures (i.e. Hugh Allan thrust, Blackman anticline, Selwyn Range Decollement and Ptarmigan Creek Fault Zone) to D2 deformation and all upright structures (PCA and FRA) to syn-metamorphic D3 deformation (Grasby, pers.comm. 1991, Table 3.3).

TABLE 3.3 REGIONAL STRUCTURAL EVOLUTION

D1	- southwest-verging structures (ie. Scrip Nappe, HW Hugh Allan thrust)
early D2 (D2)	- NE-directed thrusting and folding, (ie. Hugh Allan thrust, Blackman anticline)
late D2 (D3)	- NE-directed thrusting and folding (recumbent and upright, ie. PCA, FRA ?) synmetamorphic (Late Jurassic to Early Cretaceous) to postmetamorphic
D3 or later (D4)	- Chatter Creek Thrust, possibly West Purcell Thrust and splays, and postmetamorphic thrusts in study area (Crevasse, Little Peak, Peak)
D4 (D5)	- Eocene normal faults

bold = author's interpretation
in parenthesis = alternative interpretation
(see section 3.6.b)

3.6C Late crenulations

Three different post-D2, postmetamorphic crenulations occur in the area. The transverse St foliation is the latest one. The southwest- and northeast-dipping crenulations may have formed during continued thrust movement and tightening of the overall structure, or during Chatter Creek-related transpression.

Enigmatic transverse foliations near the Rocky Mountain Trench have been noted by Murphy and Rees (1983), Carey and Simony (1984), closer to the study area by McDonough (1984) and McDonough and Simony (1988b) on either side of the Bearfoot Thrust, and by Forest (1985) and Leonard (1985) in the Ptarmigan Thrust sheet. They were described as late postmetamorphic crenulations by both Forest and Leonard, but as syn- to late metamorphic by McDonough and Simony (1988-b).

Several mechanisms have been proposed to explain these foliations. Carey and Simony (1984) suggested that they are related to dextral motion on strike-slip faults in the Rocky Mountain Trench. McDonough (1986, 1988b) objected to this interpretation by pointing out that these foliations do not exhibit the right kind of shear couples for dextral strike-slip motion. Movement of thrust faults over side ramps has been suggested as a mechansim to produce transverse foliations by Carey and Simony (1984) and Leonard (1985). As Forest (1985) pointed out, the regional character of the foliations, assuming that they are all related, can not be accounted for by a lateral ramp. To understand the origin and timing relationships of these transverse foliations a more detailed regional study on both sides of the Rocky Mountain Trench is required.

3.6D Postmetamorphic thrust faults

Late, postmetamorphic thrusts were observed in the western part of the study area; 1) Baker Flat Fault, and 2) three, steep thrust faults (Peak, Little Peak and Crevasse) which break the west flank of the PCA. They cut thrusts assigned to the synmetamorphic D2 event. Baker Flat Fault is truncated by the Crevasse Thrust. The southwest-dipping thrusts from the study area may be related to movement on the West Purcell Thrust and its postmetamorphic splay (Mountjoy, 1988, and personal comm.) since they appear to merge with this fault. Late stage movement on the Chatter Creek Fault has been documented by Dechesne and Mountjoy, 1988; Dechesne, 1990; Mountjoy and Grasby, 1990; Grasby and Mountjoy, 1991). No similar structures have been mapped in the study area.

3.7 Regional variations of the PCA

The PCA varies greatly in shape and structural style from its northern to its southern end. These changes appear to be largely a function of relative competency, layering configurations and thicknesses of the involved stratigraphic units .

The PCA north of Wood River is characterized by 1) open flanks and a slightly asymmetric form; 2) complex folding of middle Miette Group strata in the core of the structure; and 3) a faulted west flank of Miette Group through Middle Cambrian strata, cut by steep to vertical normal faults.

The form and structural style of the PCA change significantly south of Wood River. In the Solitude Range it is box-shaped with a flat top and steep to overturned faulted flanks (Mielliez, 1972). Further south in the Blackwater Range the PCA is characterized by steep limbs and southwesterly overturned bedding and early faults on the west flank (Ferri, 1984). Large-scale disharmonic folding and a detachment horizon occur between the tightly folded Gog Group in the core and the overlying Chancellor Group due to marked competency contrasts at this contact. The basal unit of the Chancellor Group is greatly thickened above this detachment. To accommodate the Miette Group at depth, Ferri (1984) balanced the section at depth by cutting the Miette-Gog Group contact with relatively small west-dipping thrust faults.

Balkwill (1972) suggested the possibility of a detachment between the Miette and the Gog groups. His cross-section through the PCA shows large folds in the Gog Group above this detachment. He balanced the section in the middle Miette Group, by 1) small imbricate thrusts in psammitic strata and, by 2) disharmonic folds in pelitic strata.

Price (1986) developed a tectonic wedge model to explain structures with zones of opposing vergence in the Canadian Cordillera. He applied this concept to the PCA. The tectonic wedge in this case consists of Proterozoic rocks riding on a southwest-dipping thrust above the Lower Paleozoic shale succession, and bound upwards by a zone of southwest-verging thrusts on the west flank of the PCA.

The open shape and absence of major overturning of the northern PCA can be explained by the presence of Miette Group strata of intermediate competence, capped by the competent Gog Group and overlying massive Middle(?) Cambrian carbonates. The southern PCA contains less competent predominantly shaly Cambro-Ordovician strata at the surface, and is characterized by an asymmetric, tight form and pronounced outward overturning of earlier folds and faults away from the fold axis. The relative proximity of the PCA to the Purcell thrust or other major thrusts near the Rocky Mountain Trench might be another factor controlling the shape and tightness of the anticlinorium.

3.8 Regional cross-sections and deep structure of the PCA

Surface structure observations from the study area constrain the upper part of the PCA, but do not provide enough information to limit the structure at depth. It is necessary, therefore, to extrapolate structures from the northeast where the deepest structural levels of the western Main Ranges are exposed in the FRA. Although no early, low-angle, thrusts are observed in the PCA they presumably occur at depth in order to thicken up the sequence down to the crystalline basement. Two regional cross-sections through the PCA (Fig. 3.8a,b) are drawn with structural information from cross-sections by Dechesne and Mountjoy (1991) (Fig. 3.9 a,b). Cross-section A (Fig.3.8a) is based on the interpretation that basement is not involved in the thrusting, whereas in cross-section B (Fig. 3.8b) crystalline basement is involved. In this interpretation basement slices are derived from further west and did not originally underlie the Rocky Mountains. Basement involvement requires smaller amounts of displacement due to an originally thicker rock package involved in the thrusting. The structure at depth beneath the Ptarmigan Fault Zone in both sections is highly interpretative. In cross-sections A and B (Fig. 3.8a,b) movement on the Chatter Creek thrust and a more easterly normal fault have been restored, and movement on minor faults has been ignored.

There is no significant difference in the structure at depth for both models. Both show the PCA as a broad, open slightly asymmetric fold above two gently folded decollements. It should be noted that there is a slight step on the west flank of the PCA. Both cross-sections can be modified to include about 500 m of possible lower Miette Group strata as reported immediately northeast of the study area (Mountjoy and Grasby, 1990). Seismic reflection data across the southern PCA near Canal Flats (Eaton and Cook, 1988) suggests that the basal decollement is located above basement and that basement rocks are not involved in thrusting beneath the PCA. This does not imply however that the deformation has to be thin-skinned beneath the northern PCA.

3.9 Origin of the PCA

Several questions about the PCA remain largely unanswered. Large-scale regional anticlines can be produced in a variety of ways. They can form above ramps in underlying

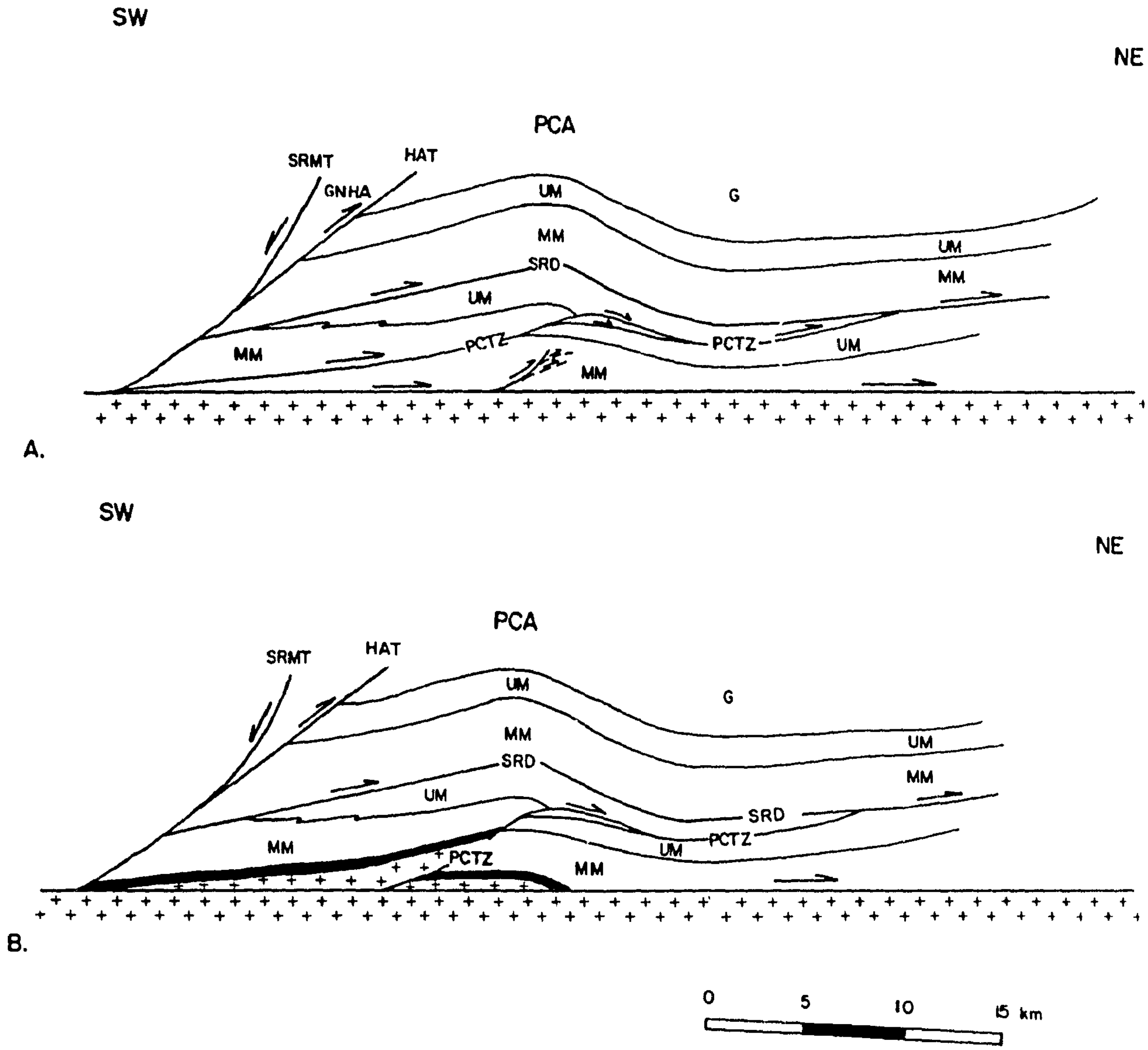


Fig.3.9 Inferred regional cross-sections through PCA, before Chatter Creek movement
a) model # 1 crystalline basement is not involved
b) model # 2 crystalline basement is involved
see Fig.1.2. for location of line of section

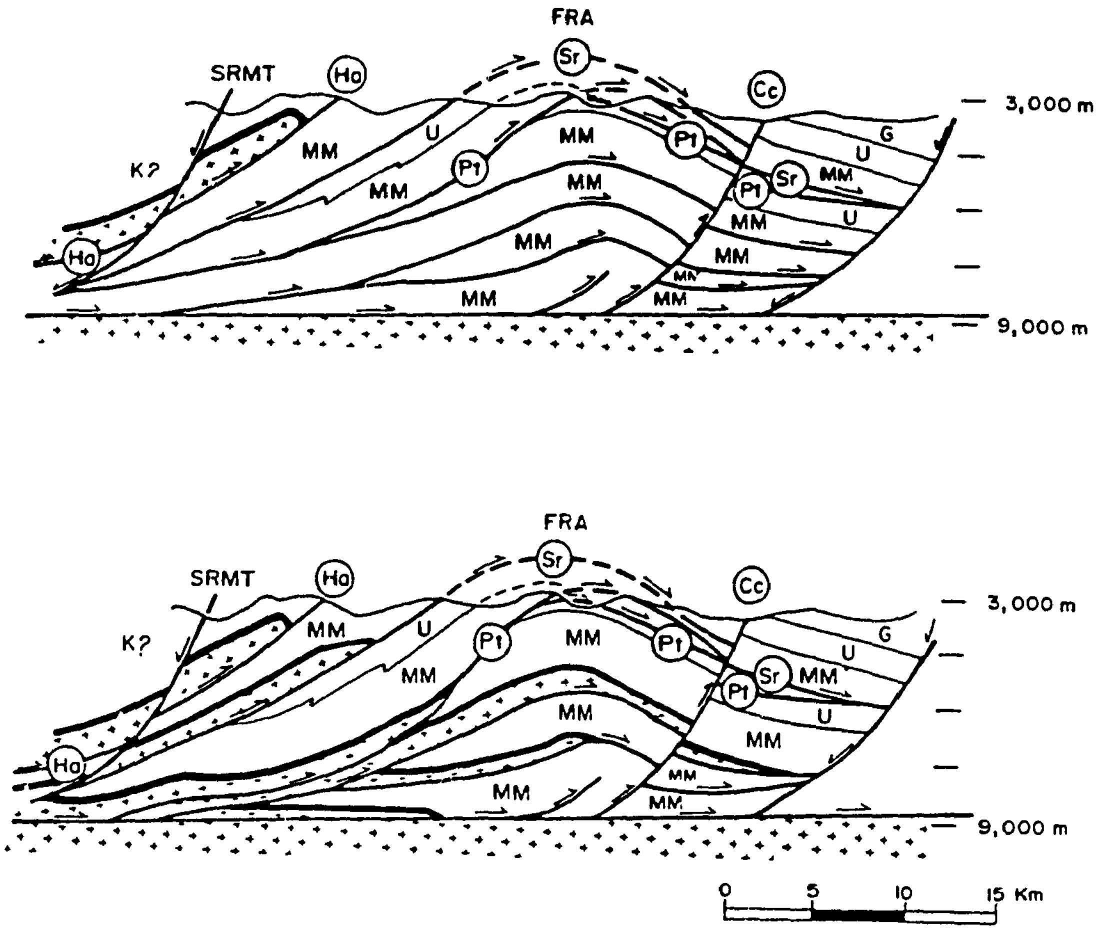


Fig.3.10 Regional cross-sections through FRA, from Dechesne and Mountjoy (1991)

faults or above duplex structures or simply as a response to compression. LITHOPROBE seismic reflection data suggest that several ramps occur along the basal decollement beneath the southern PCA (Eaton and Cook, 1988). This may also be the case for the northern PCA. The PCA may have formed during the movement of underlying faults (ie. PCFZ, SRD) or the basal decollement over a ramp. Crystalline basement may or not be involved in such a ramp.

Horizontal and vertical changes in competency can also be invoked to explain the origin and variable geometry of the PCA. Ferri (1984) attributed positioning of the PCA in part to a change from the ductile, highly metamorphosed and polydeformed strata in the Omineca Crystalline Belt to less deformed and metamorphosed rocks of the Rocky Mountains. Price (pers.comm., 1990) suggested that the PCA is lithologically controlled by the presence of the Kicking Horse Rim to the east in addition to vertical changes in competency. East of the Kicking Horse Rim Middle Cambrian strata consist predominantly of massive, platformal carbonates, whereas west of it Middle Cambrian Chancellor Group strata consist of less competent carbonates and shales. As this rim crosses the PCA at an oblique angle, south of the Wood River it does not appear to affect the northern part of the PCA.

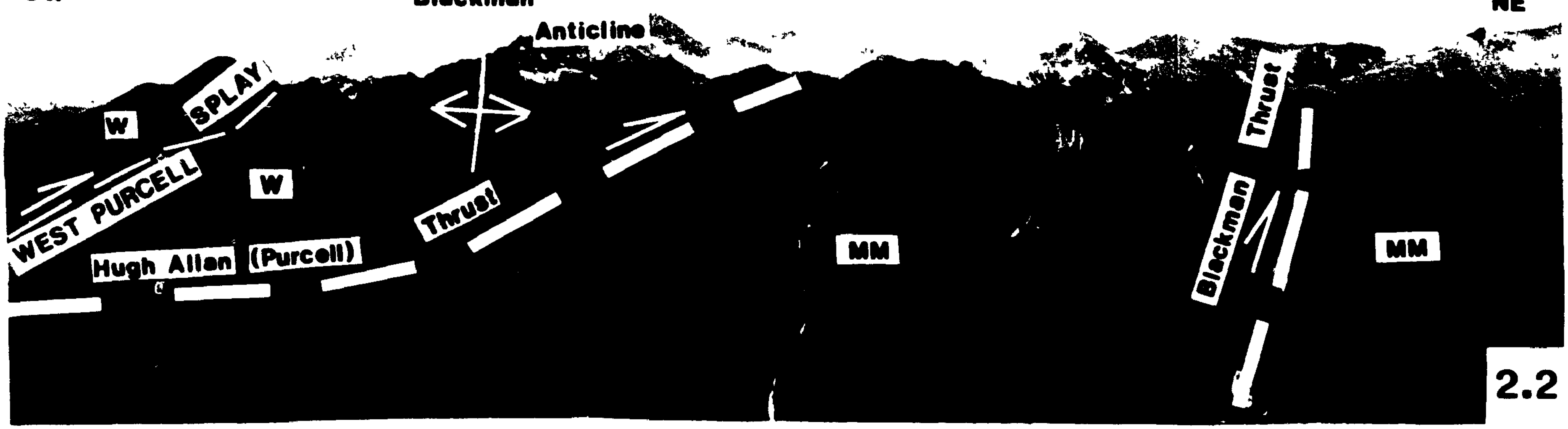
There is evidence that large-scale detachments occur beneath the PCA along most of its length. Extrapolating from the southern Selwyn Range into the study area suggest that the northern PCA is underlain by decollements (PCFZ, SRD) at the level of the Miette Group. Further south detachments have been interpreted at or near the Miette-Gog Group contact (Balkwill, 1972) and higher stratigraphically at or near the Gog-Middle Cambrian contact (Ferri, 1984, Eaton and Cook, 1988, Gal et al, 1989, Lickorish and Simony, 1991). In the latter two cases these detachments can be attributed to marked vertical changes in competency. This kind of structural configuration may have been a contributing factor in the positioning and formation of the PCA, by allowing lower and upper structural levels to deform independently.

Plates

2.1 View north of upper middle Miette Group exposed on east flank of PCA, north of Dawson Creek

2.2 Panoramic view north across Hugh Allan Creek, showing splay of West Purcell, Hugh Allan (Purcell) thrust and Blackman thrust (see Mountjoy, 1988) (from left to right), W = western stratigraphy

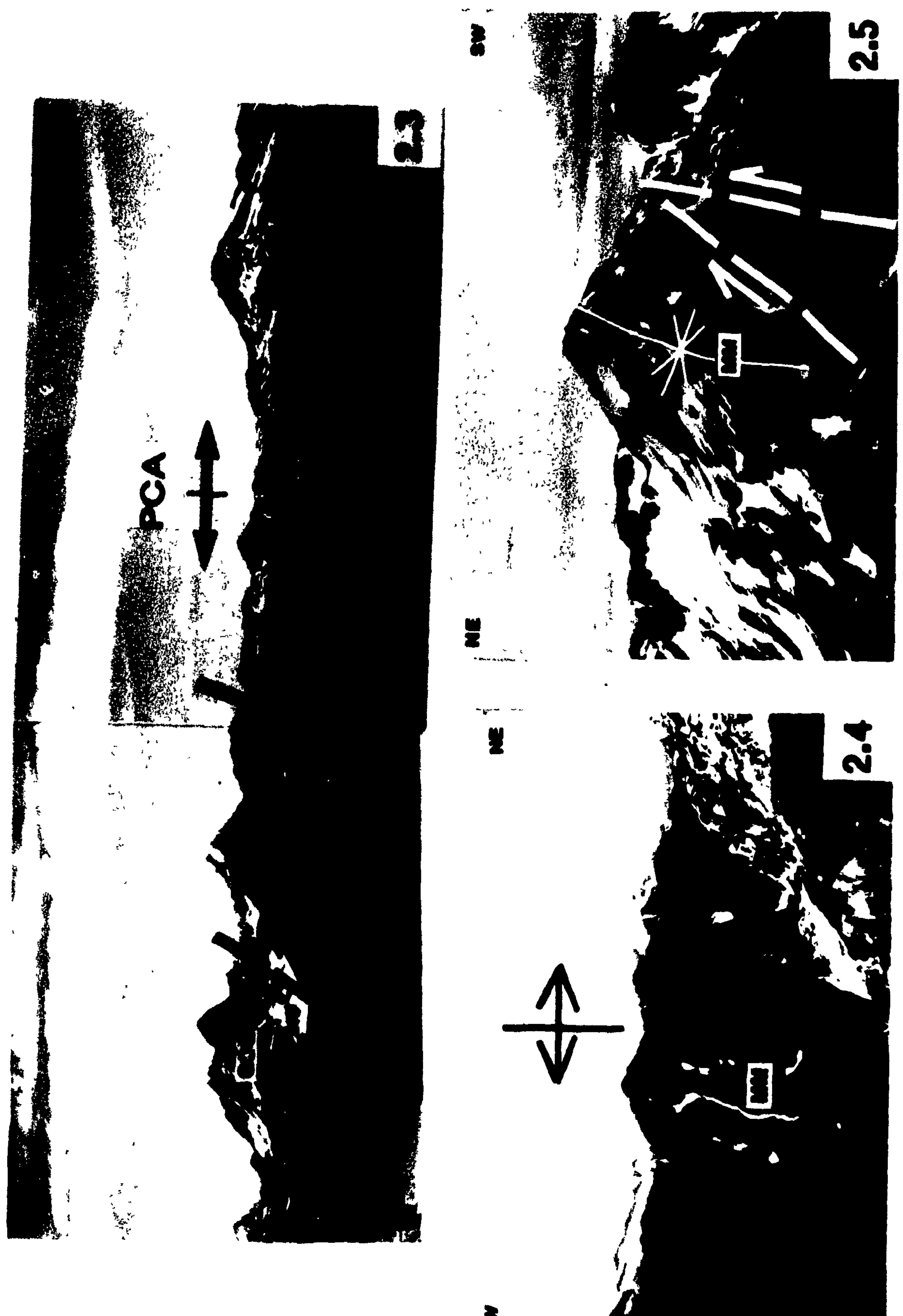

SW
NE
2.1


SW
Blackman
Anticline
NE
SPLAY
W
WEST PURCELL
W
Thrust
Hugh Allan
(Purcell)
MM
Thrust
Blackman
MM
2.2

2.3 Panoramic view northwest across Dawson Creek, showing both flanks and core of the PCA and normal fault between Gog and upper Miette

2.4 View north of upright F2 folds in core of PCA, north of Dawson Creek

2.5 View southwest of folds truncated by thrust faults in core of PCA, on ridge north of Dawson Creek

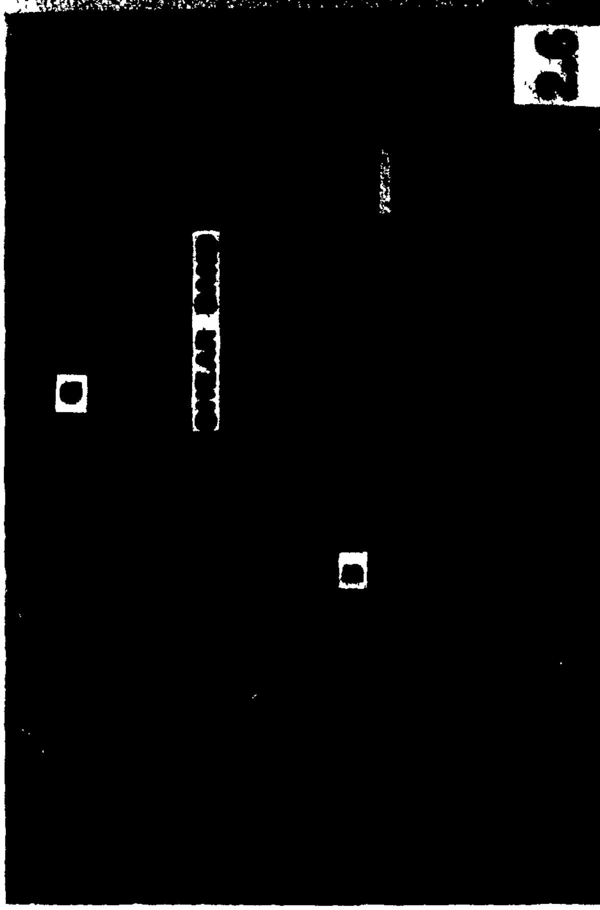

PCA
2.3
NE
SW
2.5
NE
SW
2.4

2.6 Shear band or possibly solution plane in upper Miette pelites, near Gog Group contact, headwaters of Baker Creek, B = biotite, G = garnet

2.7 View southeast of structures in Peak thrust sheet, immediately northeast of Baker Glacier, McN = McNaughton Fm.

2.8 View north of BS, north of Baker Creek, involving Gog Group strata, McN = McNaughton Fm., Mu = Mural Fm., Ma = Mahto Fm.

2.7



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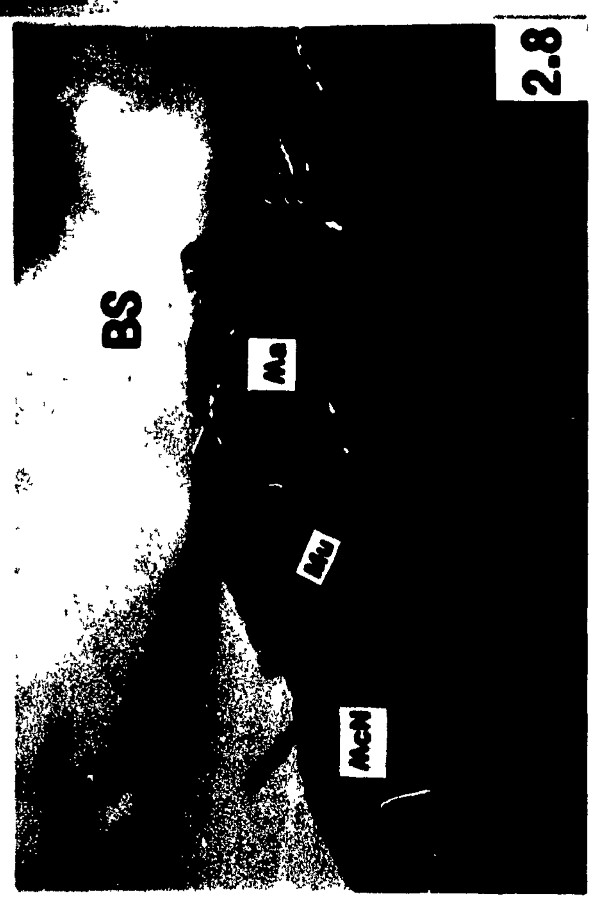
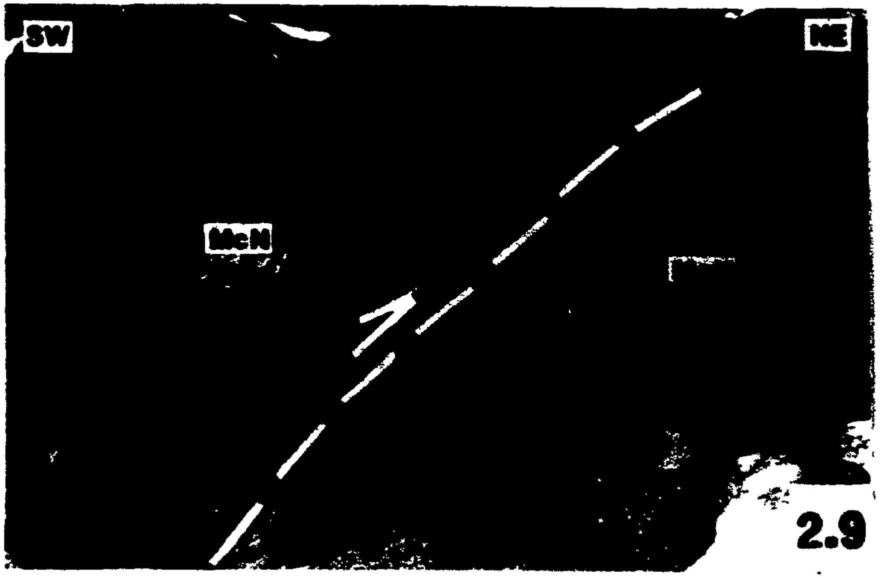


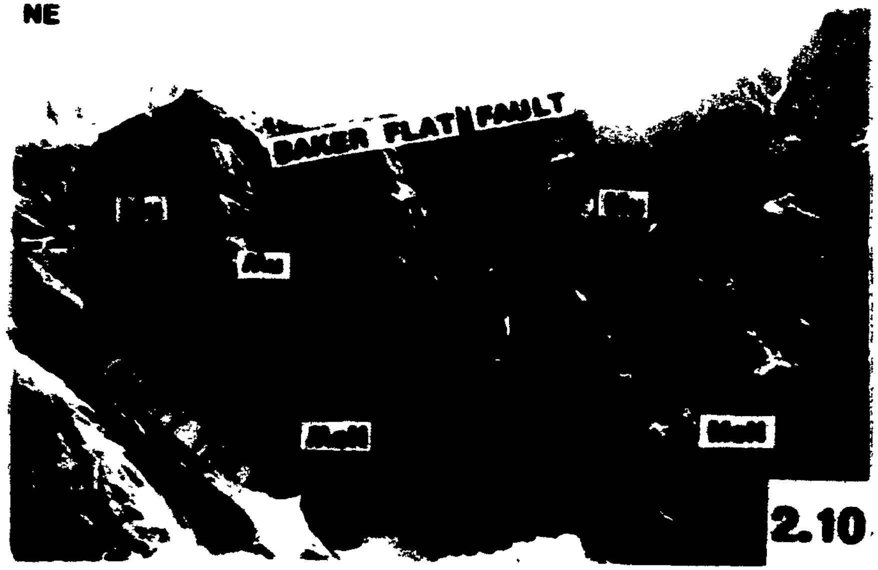
2.8

2.9 Small, southwest-dipping D2 thrust fault in footwall of Baker Flat Fault, possibly forming part of small duplex structure, south side of Baker Glacier

2.10 View southwest of northeast-dipping Baker Flat Fault of uncertain displacement that cuts two steep SW-dipping thrust faults (Gusty and Little Gusty thrusts), south side of Baker Glacier

2.11 View north of Baker Flat Fault and Crevasse Thrust, involving Gog Group strata, north side of Baker Glacier


SW
NE
McN
2.9

NE

BAKER FLAT FAULT
McN
McN
2.10

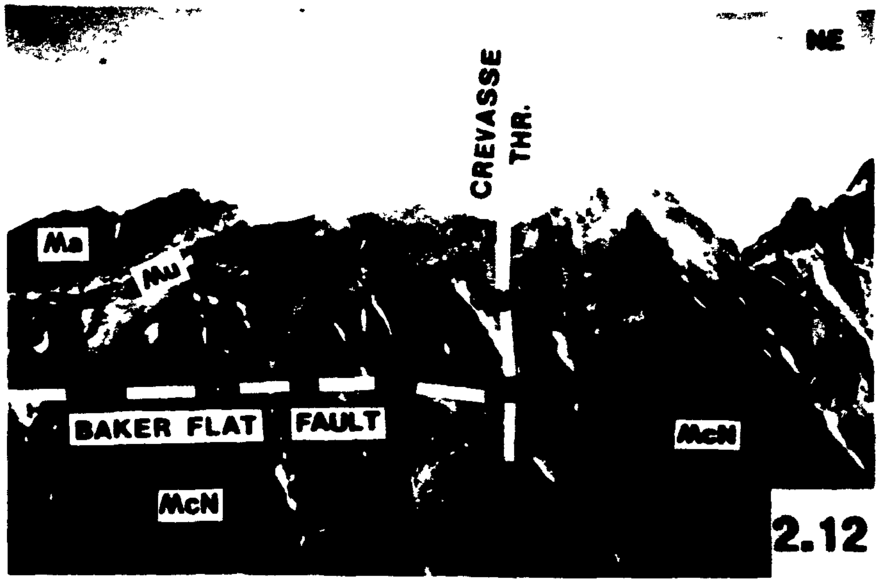

SW
Mu
BAKER FLAT
FAULT
Mu
Mu
CREVASSE
TMB.
Mu
2.11

2.12 View north across Baker Creek of Baker Flat Fault truncated by Crevasse Thrust

2.13 View southwest of northeast-verging recumbent F2 syncline, possibly a drag fold of Baker Flat Fault, south side of Baker Glacier; axial traces of F2 fold =heavy line, and possibly late upright fold = dashed line

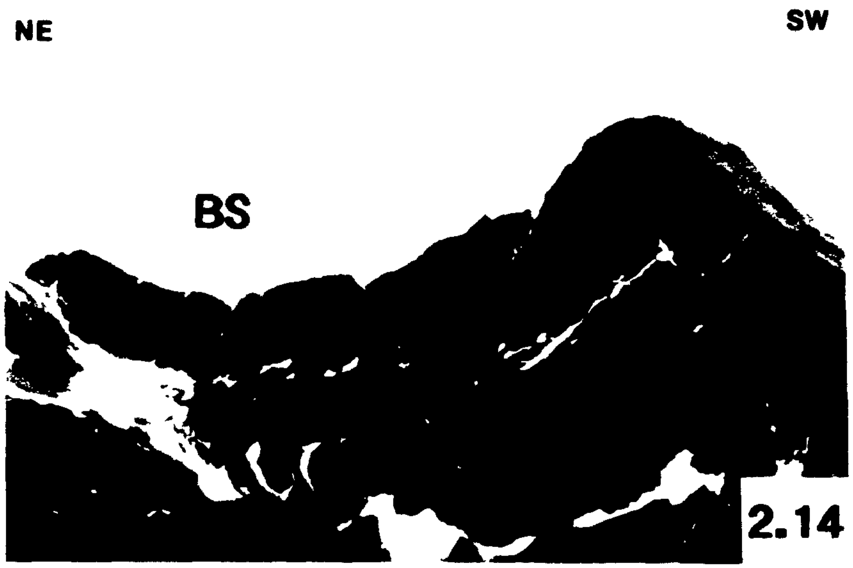
2.14 View south across Baker Creek of BS, involving Middle(?) Cambrian strata, broken by normal faults

2.15 F2 folds and S2 cleavage with late offset along cleavage, on west flank of PCA, north of Baker Creek headwaters



2.12

2.13



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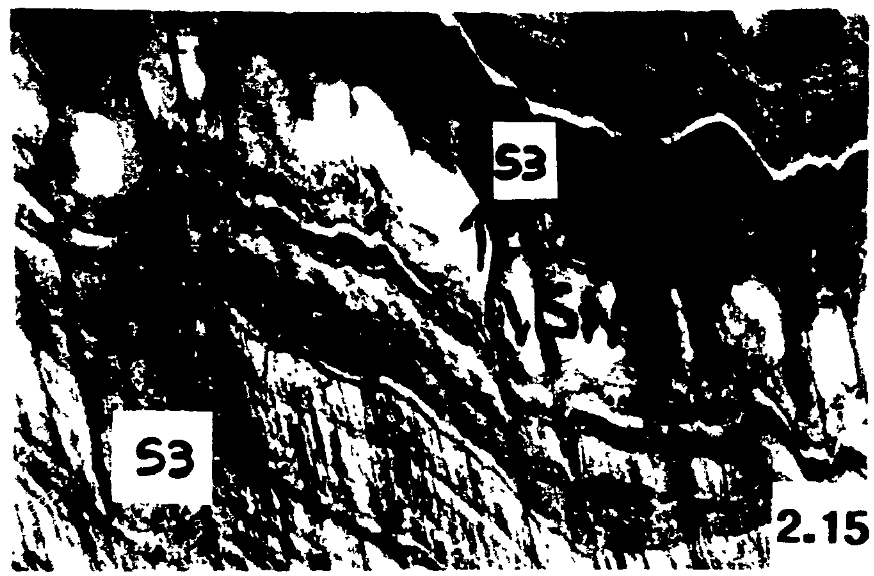


2.15

2.16 Steep pervasive S2 fracture cleavage and bedding (So) in upper middle Miette Group strata in core of PCA, on ridge north of Dawson Creek

2.17 View northwest of tectonic shear fabric in McNaughton Formation quartzites in Peak Thrust Sheet, north of Baker Glacier,

2.18 Same fabric as in 2.15., folded by small southwest-verging folds, north of Baker Creek

2.17

2.16

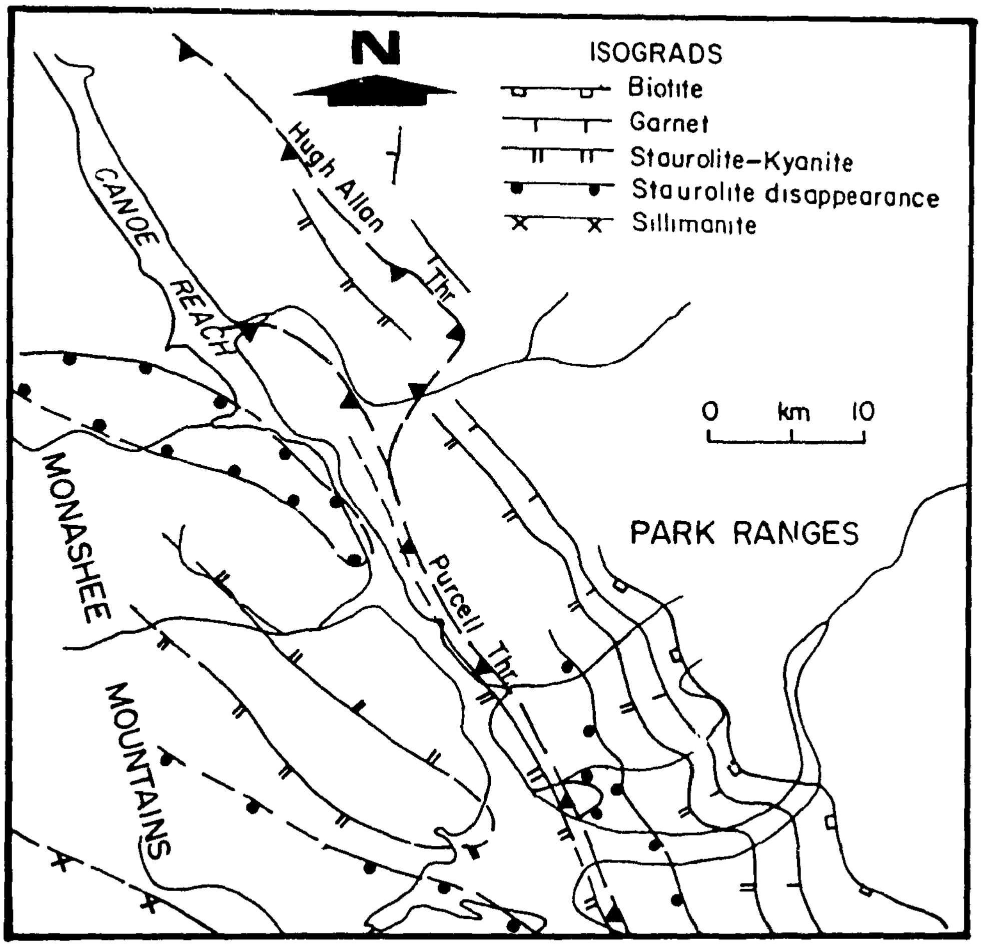
2.18

CHAPTER 4 - METAMORPHISM

4.1 Regional metamorphic setting

Metamorphic isograds in the Western Main Ranges are generally subparallel to the regional NW structural trend (Fig. 4.1). Metamorphism is Barrovian in nature, increasing southwestward from greenschist to amphibolite grade. Peak metamorphic conditions were reached at temperatures between 550°and 640°C and pressures between 5.3 and 6.3 kb (Leonard, 1985, Charland, 1989) in the western part of the Selwyn Range. Rocks west of the Rocky Mountain Trench were metamorphosed at higher temperatures and pressures than those east of the Trench. Craw (1977) estimated pressures in the southern Park Ranges to be lower than those on the west side of the Trench by 2 to 3 kb, explaining this pressure contrast by significant vertical postmetamorphic movement on the Purcell thrust. The garnet and staurolite isograds appear to be offset along Hugh Allan Creek (Fig.4.1) by the Hugh Allan thrust or by an as yet unrecognized structure. Charland (1989) suggested caution in correlating structures and metamorphic timing across the Vallee (Hugh Allan?) thrust because the deformational histories of hanging wall and footwall may be different.

Metamorphic grade in the northern Park Ranges increases from greenschist in the east to lower amphibolite facies in the west. The garnet-in and staurolite-in isograds trend NW through the study area (Figs. 1.2, 3.1, 4.1). The biotite isograd could not be mapped accurately due to the sporadic occurrence of biotite. Four metamorphic zones were recognized in pelitic rocks: 1) chlorite zone, 2) biotite zone, 3) garnet zone and 4) staurolite-kyanite zone. The most common observed mineral assemblages in these zones are: chlorite, albite, +/- chloritoid (chlorite zone); biotite, albite, +/- chloritoid, +/- chlorite (biotite zone); garnet, biotite, plagioclase



4.1 Regional metamorphic map, modified from Craw (1977), Leonard (1985) and and Mountjoy (1988) (oligoclase + albite), +/- chloritoid (garnet zone) and staurolite, kyanite, garnet, plagioclase (oligoclase + albite), biotite (staurolite-kyanite zone). These assemblages also contain quartz , muscovite and +/- oxides.

4.2 Petrography and microtextures

A moderately to strongly developed matrix foliation (Se) is present in pelitic thin sections. It consists of a schistosity defined by aligned muscovite, chlorite, biotite, ilmenite and elongated quartz grains. On the east flank and in the core of the PCA outcrop observations and oriented samples show that this foliation corresponds to the axial planar cleavage related to upright northeast-verging F2 folds. On the west flank of the PCA the predominant matrix foliation (Se) predates crenulations associated with upright F2 north-east-verging folds. It may correspond to S-early but this could not established with certainty. Timing relationships between deformation and metamorphic porphyroblast growth could only be determined for thin sections from the west flank of the PCA, Se in the following descriptions therefore is a pre-S2 foliation. Thin sections from the east flank and the core of the PCA provided little information about metamorphic timing due to the low grade of metamorphism and small size of porphyroblasts.

Many garnet and biotite, and less commonly staurolite, porphyroblasts show an internal foliation (Si) consisting of aligned quartz and ilmenite inclusions. Porphyroblasts are classified using the textural relationships between the porphyroblasts, their inclusion trails (Si) and the matrix foliation (Se).

4.2A Garnet

Garnet porphyroblasts are euhedral to subhedral and vary in size between 0.2 mm and 1.5 cm. Most garnets are poikiloblastic and contain straight, curved or sigmoidal

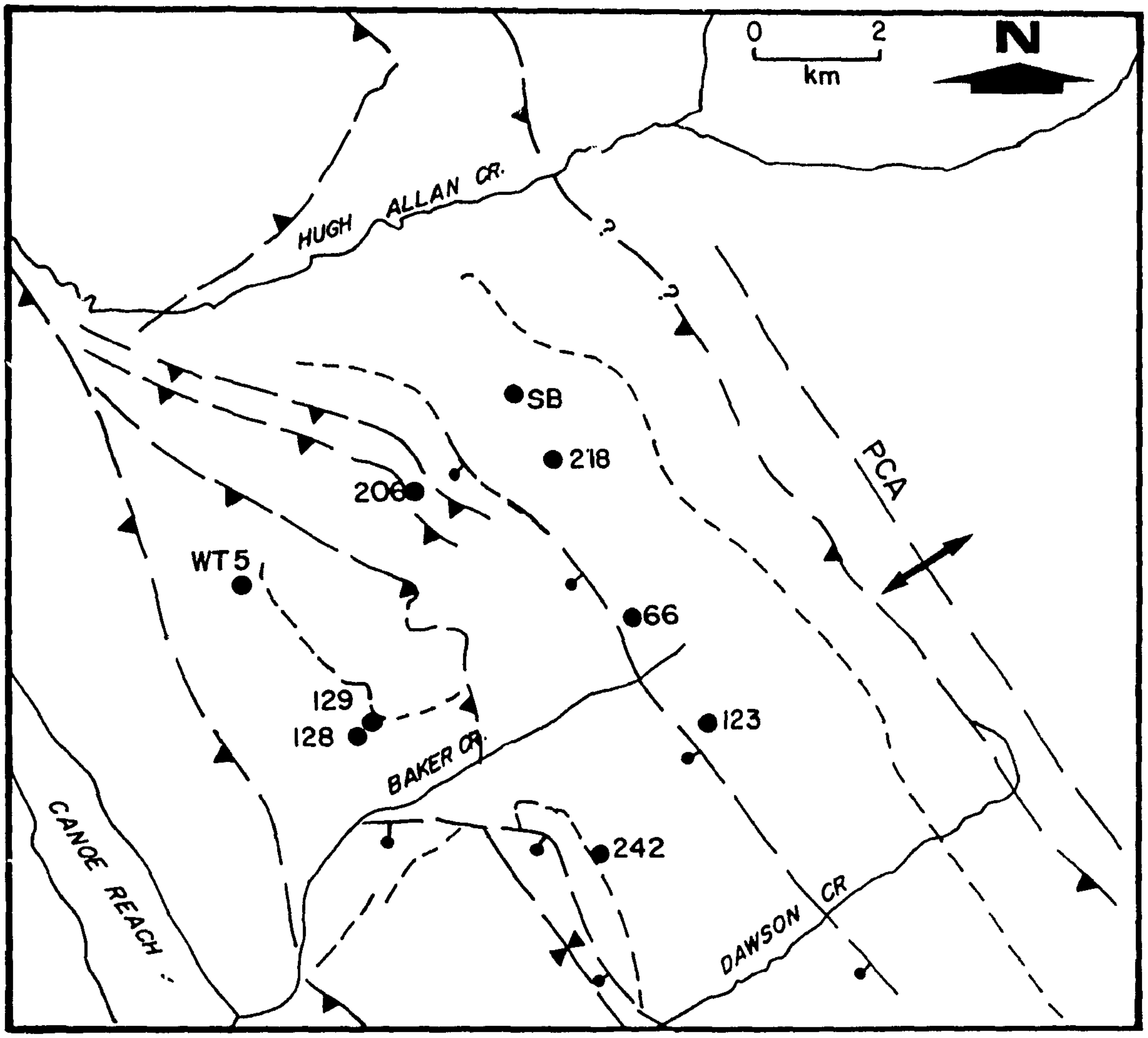


Fig.4.2 Location of samples shown on plates

inclusion trails. Inclusions are predominantly quartz or ilmenite. Inclusion-free garnets were also observed. Garnet porphyroblasts are replaced by chlorite along rims and fractures in some cases.

Four different types of garnet were observed in thin section (Table 4.1). Type I garnets contain straight to slightly curved inclusion trails that are oblique to Se, usually at angles close to 90°. They are enveloped by the schistosity and have quartz-filled pressure shadows (Plate 3.1). Type I porphyroblasts were observed in pelites of the upper Miette Group and the Mural Formation. Type II garnets (Plate 3.2) contain variably developed sigmoidal inclusion trails that are continous with the matrix foliation. This type of porphyroblast was found in upper Miette Group pelites on the west flank of the PCA. Type III garnets (Plates 3.3, 3.4) have straight or curved inclusion trails that are continous with and parallel to the matrix foliation, in some cases showing a slight Si-Se obliquity. Type III porphyroblasts were observed in upper Miette Group pelites on the west flank of the PCA and in Middle Cambrian pelites in BS. Type IV garnets (Plate 3.5) are characterized by Si-Se continuity and crenulated inclusion trails. Axial planes of microfolds of inclusion trails parallel those in the matrix.

4.2B Biotite

Biotite occurs in three different forms: as 1) porphyroblasts, 2) a matrix component aligned along with muscovite, chlorite and elongate quartz grains to form the dominant matrix foliation, and 3) secondary replacement of garnet. In some sections biotite porphyroblasts are partly replaced by secondary chlorite along rims and cleavage.

Type I porphyroblasts are lozenge-shaped and parallel or subparallel to the schistosity. They commonly show well developed pressure shadows (Plate 3.6). Some of these porphyroblasts have straight to slightly curved internal inclusion trails (Si) that are oblique to Se at angles close to 90°. Some of these porphyroblasts are crenulated (Plate 3.7). Type I porphyroblasts were observed in pelites of the upper Miette Group and the Mural Formation. Type II and III porphyroblasts are elongated parallel to the schistosity and show Si-Se continuity and were observed in Middle(?) Cambrian pelites in BS. Type II biotites contain sigmoidal inclusion trails (Plate 3.8). Type III biotites porphyroblasts show crenulated inclusion trails and crystal outlines (Plate 3.9). Type IV crystals have random orientation relative to the schistosity and lack well-defined inclusion trails.

4.2C Chloritoid

Chloritoid porphyroblasts occur sporadically throughout the biotite zone and in lower-grade rocks in pelites of the middle and upper Miette Group. In thin section they are tabular, euhedral, commonly twinned crystals with or without inclusions, varying in size between 0.1 cm and 0.4 cm.

Three types of chloritoid porphyroblasts were recognized in thin section. Type I porphyroblasts have an outer sheath of secondary chlorite, are enveloped by the schistosity and show quartz-filled pressure shadows (Plate 3.10). Most of these chloritoids are elongate parallel to the schistosity, whereas others occur at various angles to the schistosity. Type II chloritoids are parallel to the schistosity (Plate 3.11) and occur along undeformed parts of the schistosity between crenulations. Type III porphyroblasts are elongated parallel to crenulation hinges (Plate 3.12). Type IV chloritoid porphyroblasts show no apparent preferred orientation and occur at various angles to the schistosity.

4.2D Staurolite

Staurolite porphyroblasts are between 0.3 and 2 cm long and occur either as well-defined tabular crystals or with irregular, ragged outlines. Most porphyroblasts are poikiloblastic; inclusions are predominantly quartz, and occur with minor ilmenite and other oxides. Some crystals show a zonation with inclusion-rich cores and inclusion-free rims. Most staurolite porphyroblasts occur in quartz-rich garnet-biotite-muscovite schists of the upper Miette Group in BS.

Staurolite porphyroblasts exhibit four different types of texture. Type I porphyroblasts are characterized by Si- Se obliquity and are enveloped by the matrix foliation. Type II porphyroblasts show sigmoidal inclusion trails (Plate 3.13) in continuity with Se. Type III porphyroblasts are characterized by Si-Se continuity and have straight or curved inclusion trails (Plates 3.14,15). Type IV staurolite porphyroblasts are relatively small, tabular crystals randomly oriented in the matrix foliation and were observed in pelites of the McNaughton Formation.

4.2E Kyanite

Kyanite porphyroblasts are tabular, often twinned, 0.1 to 5 cm long crystals that are found in upper Miette Group pelites in BS. Many porphyroblasts are xenoblastic with very poorly defined, ragged outlines. Kyanite porphyroblasts are predominantly inclusion free but may contain small oxide and quartz inclusions. Well-defined inclusion trails are rare. Many kyanite crystals are kinked. Both kinked and unkinked porphyroblasts may be observed in the same thin section. Most pelite samples in which kyanite porphyroblasts were found show poorly defined or no matrix foliation. Due to this and the absence of good inclusion trails, reliable timing relationships between porhyroblasts and the schistosity could not be established in many cases.

4.2F Others

Plagioclase porphyroblasts were observed in upper Miette

TABLE 4.1. SUMMARY OF MICROTEXTURES

GARNET	TEXTURES
I	- Si-Se obliquity - enveloping foliation - pressure shadows
II	- sigmoidal Si
III	- Si is parallel to Se - straight or curved Si - may show slight Si-Se obliquity
IV	- Crenulated Si

BIOTITE	TEXTURES
I	- parallel to Se - enveloping foliation - pressure shadows - Si-Se obliquity - may be kinked by cren.
II	- elongated parallel to Se - Si-Se continuity - sigmoidal Si
III	- elongated parallel to Se - Si-Se continuity - crenulated Si and crystal
IV	- random orientation - no inclusion trails or absence of inclusions

CHLORITOID	TEXTURES
I	- chlorite sheath - enveloping fabrics - pressure shadows
II	- porphyroblasts parallel Se - occur between crenulation hinges
III	- porphyroblasts are parallel to crenulation hinges

IV	- random orientation

STAUROLITE	TEXTURES
I	- Si-Se obliquity - enveloping fabrics
II	- sigmoidal Si
III	- Si-Se continuity - straight or curved Si
IV	- random orientation

Si = internal foliation

Se = external or matrix foliation

pelites on the west flank of the PCA. They are between 0.2 and 0.6 cm long, oval-shaped and often have long axes aligned parallel to the S2 schistosity (Plate 3.16).

Amphibole porphyroblasts were observed in upper Miette Group calcareous pelites and in Middle(?) Cambrian strata and are of hornblende composition (Plate 3.16). They show linear inclusion trails that occur at small angles to the schistosity but appear to be continuous with it.

4.3 Interpreted timing of porphyroblast growth

The interpretation of timing relationships between deformation and metamorphism based on microtextures shown by porphyroblasts and matrix foliations may be difficult and ambiguous. Review of the literature shows that in many cases one particular texture may be interpreted in more than one way (Bell, 1985; Bell et al., 1986). Many of the textures observed in thin section have at least two interpretations (following either Spry, 1969, or Bell, 1985) and not enough evidence is available to choose between them.

4.3a Evidence for syn-S-early growth

Thin-section studies do not provide substantive evidence for porphyroblast growth during the formation of S-early. However in outcrops of Middle(?) Cambrian pelites, metamorphic porphyroblasts such as biotite and calc-silicate were observed parallel to the S-early schistosity, which may indicate growth prior to D2 or during early D2.

4.3.b Evidence for pre-Se growth

Type I garnet, biotite, chloritoid and staurolite porphyroblasts show relationships (see Table 4.1) to the main matrix foliation that can be interpreted as pretectonic (Spry, 1969; Yardley, 1989).

4.3c Evidence for syn-Se growth

Using criteria developed by Bell (1985) textures shown by Type I garnet, biotite and staurolite porphyroblasts could be interpreted as indicating growth during the development of a crenulation (in this case the pre-S2 matrix foliation), deforming an earlier foliation no longer recognizable in the matrix but preserved as Si within the porphyroblasts. This would make these porphyroblasts pretectonic with respect to D2.

Porphyroblasts that contain sigmoidal inclusion trails (i.e. type II garnets and staurolites, and type II biotites) suggest growth and rotation during the development of the schistosity according to Spry (1969) and others. Bell (1985) and others on the other hand argue that even though true rotational snowball garnet porphyroblasts exist, most sigmoidal inclusion trails can be explained by growth of the porphyroblast during the crenulation of an earlier foliation that was not preserved in the matrix. According to this interpretation sigmoidal Si trails represent microfolds of the earlier foliation. The two above interpretations both suggest pre-D2 growth.

Type II chloritoid porphyroblasts that occur along undeformed stretches of the schistosity (Plates 3.10a,b) can be interpreted in two different ways. They may have formed during the event that produced the matrix foliation. Alternatively, they could have grown during the formation of the S2 crenulation in areas of minimum shortening (i.e. areas between crenulation hinges), following Bell (1985). It was observed that some areas surrounding the porphyroblasts were not affected by the crenulations, suggesting that they were sheltered from the deformation by the crystal and that porphyroblasts grew prior to the crenulation or during early stages of development. Type III porphyroblasts observed in the same section as type II porphyroblasts are more difficult to explain with either of the above interpretations. It is unlikely that they grew at the same time the crenulation developed, because the crenulation hinges during deformation are areas of dissolution, unfavourable to porphyroblast growth.

4.3.d Evidence for post-Se, syn-S2 growth

Porphyroblasts that contain crenulated inclusion trails (type IV garnets, type III biotites) may be interpreted as syntectonic with the crenulation formation (Bell, 1985), or as posttectonic overgrowths of the crenulation (Spry, 1969, Yardley, 1989). Textures shown by type III and IV garnet and type III staurolite porphyroblasts (Table 4.1) can be interpreted as evidence for posttectonic, post-Se growth according to Spry (1969). Type III biotites, although showing similar textures to type IV garnets, could not have formed after the crenulation because the crystals are kinked by these crenulations.

4.3.e Summary and discussion

Microtextures observed in thin sections can be interpreted as evidence for metamorphic porphyroblast growth during the formation of the main matrix foliation (Se) observed on the west flank of the PCA (Spry, 1969 and Bell, 1985). They do however permit an alternative interpretation for the timing of metamorphism. It can be argued that porphyroblasts overgrew the main matrix foliation (Se) in various stages of being folded by syn-D2 crenulations. Subsequent strain produced tightening and deformation of fabrics and porphyroblasts. This interpretation is favoured in this thesis and suggests that the prominent matrix foliation (Se) is pre-metamorphic and that folds or crenulations of this fabric (F2 folds) are syn-metamorphic. The identity of Se needs yet to be established. It may have formed during early northeast-verging folding and correspond to S-early observed on the west flank of the PCA.

TABLE 4.2.
RELATIONSHIPS BETWEEN METAMORPHISM AND DEFORMATION

TIMING	OBSERVATIONS
Syn-S-early	-Calc-silicates, biotite lie in S-early
Pre-Se ? Early Se	-Garnet, biotite, chloritoid, staurolite type I (Spry,1969)
Syn-Se	-Garnet, biotite, chloritoid, staurolite type II porphyroblasts (Spry, 1969)
	-Garnet, staurolite type III, (Bell, 1985)
	-Garnet type IV, biotite type III, porphyroblasts (Bell, 1985, Bell)
	-Plagioclase parallels S2 foliations (outcrop observations)
	-Chloritoid types II and III ?
Post-Se	-Garnet, staurolite type III (Spry, 1969)
	-Garnet type IV, biotite type II (Spry, 1969)

TABLE 4.3 TIMING OF PORPHYROBLAST GROWTH

	syn-S-early	pre-Se	syn-Se	post-Se
garnet		xxxxxx	xxxxxx ------	xxxxxx
biotite	oooooo	xxxxxx	xxxxxx ------	xxxxxx
staurolite		xxxxxx	xxxxxx ------	xxxxxx
chloritoid		xxxxxx	------	
amphibole			------	xxxxxx
calc-silicate	oooooo			

xxxxxxx = following criteria of Spry (1969)
------- = following criteria of Bell (1985)
ooooooo = outcrop observations

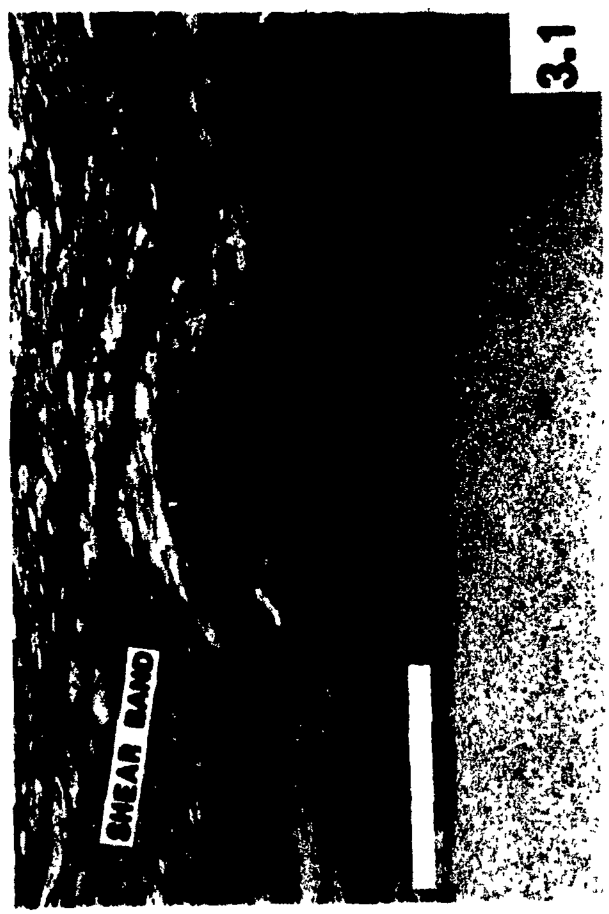
Plates

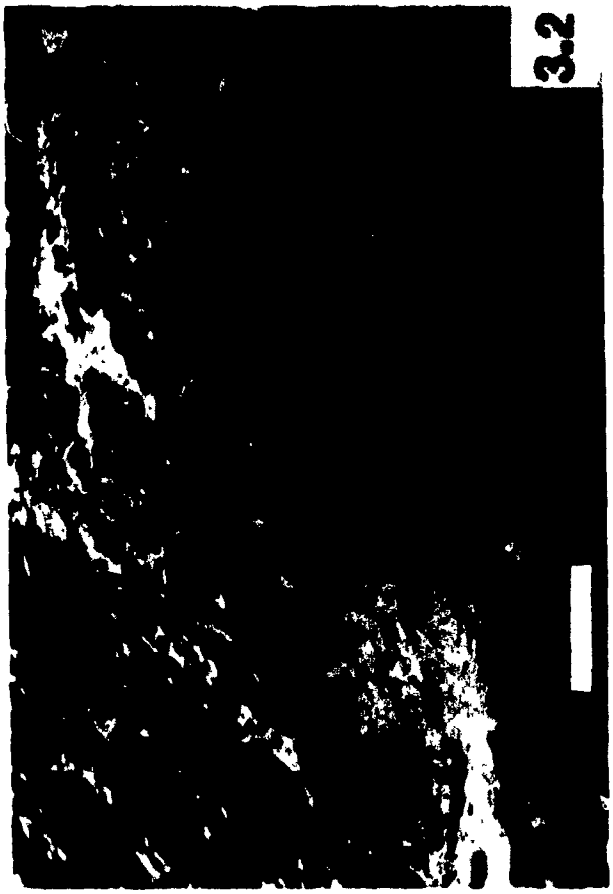
3.1 Type I garnet porphyroblast showing Si-Se obliquity, quartz filled pressure shadows and shear band (Sample #66, scale = 1mm), for location of samples see Fig.4.2

3.2 Type II garnet with sigmoidal Si (Sample #223, scale =1 mm)

3.3 Type III garnet porphyroblast showing Si-Se continuity and parallellism (Sample #211, scale = 1 mm)

3.4 Type III garnet with slight Si-Se obliquity (Sample #218, scale = 1 mm)


3.1
SHEAR BAND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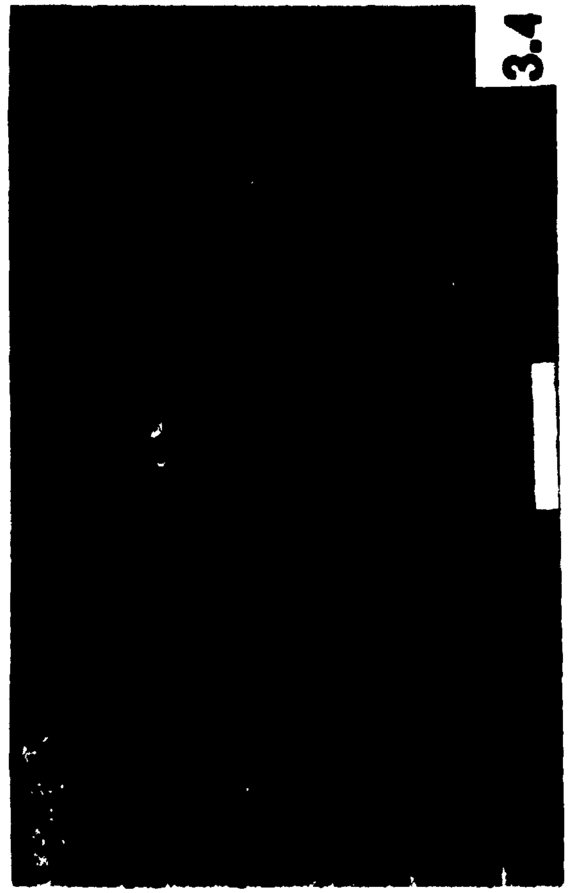
3.3


3.4

3.5 Type IV garnet porphyroblast with crenulated Si (Sample #206, scale = 1 mm)

3.6 Type I biotite porphyroblast showing Si-Se obliquity and quartz-filled pressure shadows (Sample #66, scale = 1 mm)

3.7 Crenulated type I biotite porphyroblast (Sample #128, scale = 1 mm)

3.8 Type II biotite porphyroblast with sigmoidal Si (Sample #242, scale = 1 mm)

3.5

3.6

3.7

3.8

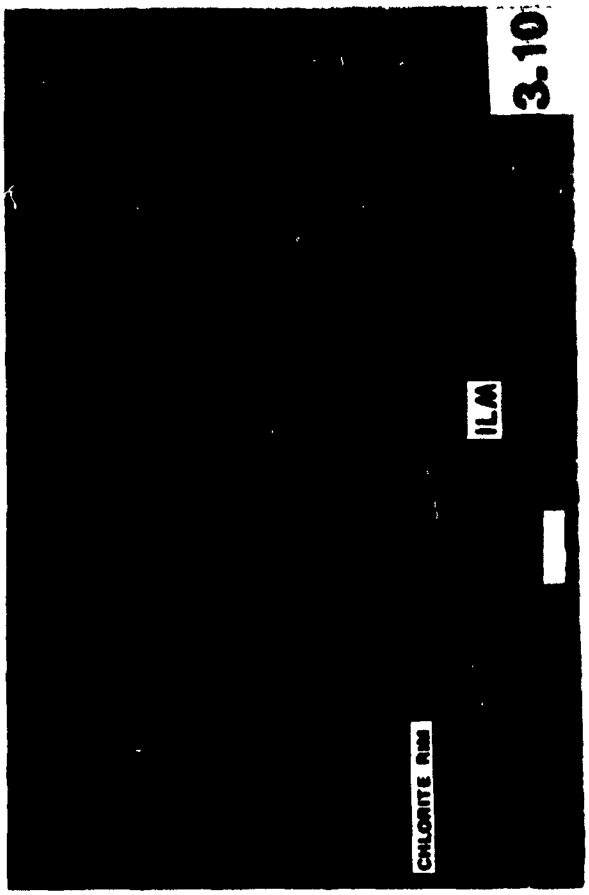
3.9 Type III biotite porphyroblast with crenulated Si (Sample #242, scale = 1 mm)

3.10 Type I chloritoid porphyroblasts with outer rim of chlorite and type III garnet porphyroblasts (Sample #123, scale = 1 mm)

3.11 Type II chloritoid parallel to schistosity (Sample #211, scale = 1 mm)

3.12 Type III chloritoid parallel to crenulation (Sample #211, scale = 1 mm)

3.9



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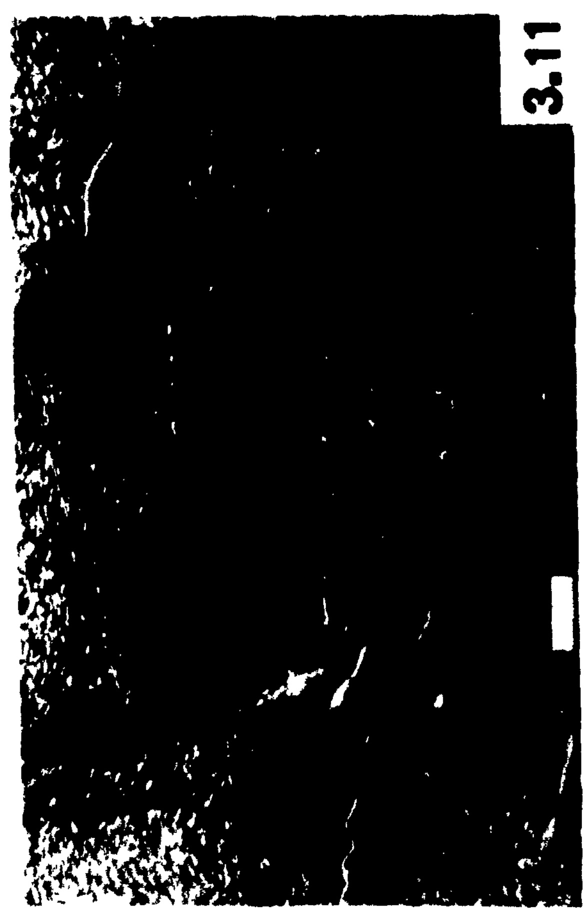

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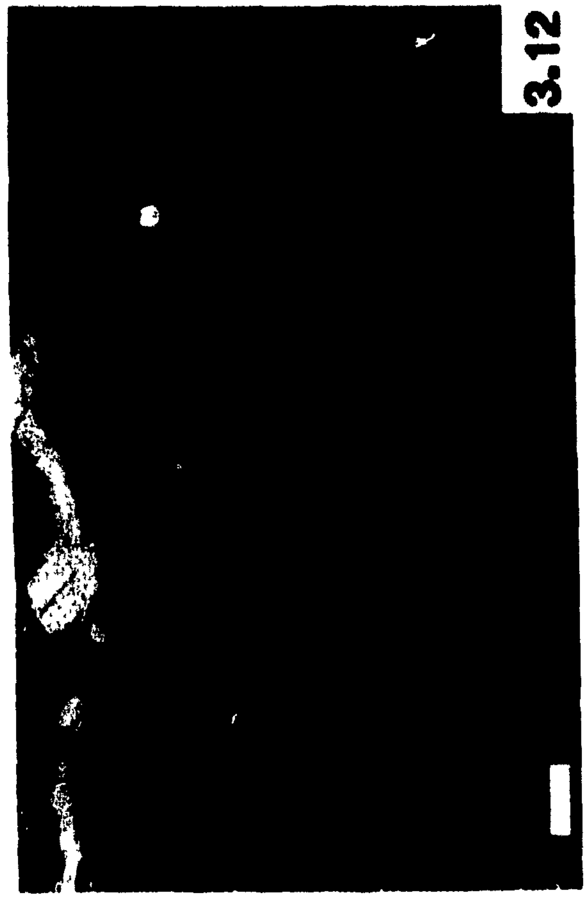

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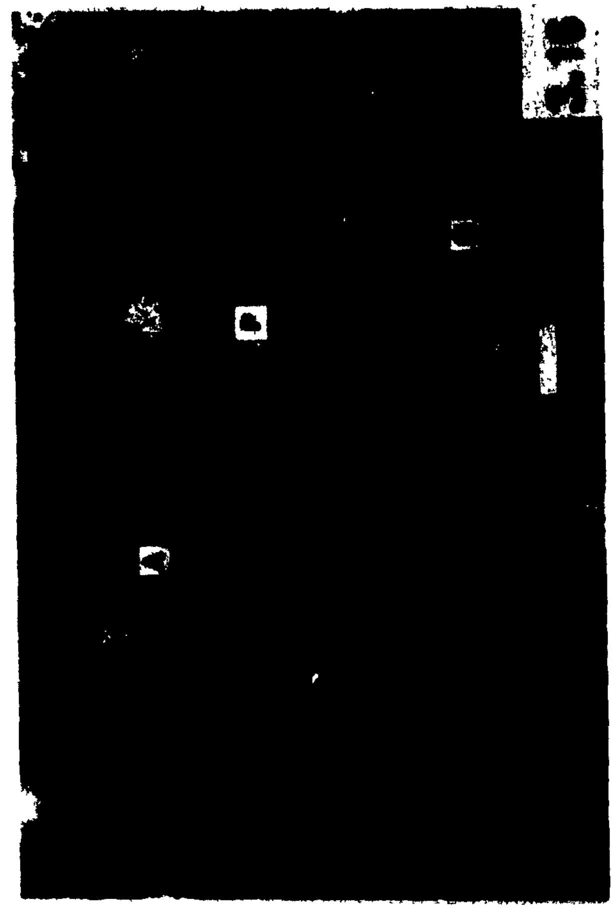

3.16

5.1. Conclusions

5.1A Stratigraphy

1. About 1200 m of middle Miette Group strata are exposed in the core and on the east flank of the PCA. They are divisible into a lower grit unit, the middle Old Fort Point Formation and an upper grit unit.

2. The Old Fort Point Formation occurs about 700 m below the top of the middle Miette Group. It is characterized by a lower green-pelite-semipelite member, a middle carbonate member and an upper black pelite member.

3. The middle-upper Miette Group boundary south of Dawson Creek corresponds to a change from green pelites to black pelites. It is gradational in nature elsewhere in the study area and was placed arbitrarily at the uppermost 20 m thick grit unit.

4. The upper Miette Group is divisible into five distinct units (transitional, lower pelite, carbonate, upper pelite, and upper clastic units). The carbonate unit shows considerable thickness variations across the study area and into the southern Park Ranges. A boulder-conglomerate marker just above the middle-upper Miette Group contact may be correlative with a regionally mappable basal upper Miette Group marker. A newly recognized carbonate sequence at the top of the upper Miette Group on the west flank of the BS may be a Yellowhead-Cunningham equivalent.

5. Westward thinning of the McNaughton Formation from more than 800 m to about 300 m appears to be depositional in origin and may reflect approaching the northern continuation of the Dogtooth High.

6. Cliff-forming carbonates and pelites assigned to the Middle(?) Cambrian strata in the southwestern part of the study area are more similar to massive, platformal carbonates of the Main Ranges than to their shaly deeper-water Chancellor Group equivalents to the south. The Kicking Horse Rim which is

associated with this facies change lies west of the study area, and trends more northwesterly, cutting across the structural trend.

5.1B Structure

1. Southwest-verging folds of uncertain timing and origin were observed in the western part of the study area.

2. The S-early schistosity in the western part of the study area represents evidence for early deformation of unknown vergence and early porphyroblast growth. It may be a footwall structure to the Hugh Allan (Purcell) thrust or the equivalent of and early schistosity observed on the west flank of the southern PCA, that developed above a detachment at the Gog Group-Chancellor Group contact.

3. The principal deformation phase (D2) consists of northeast- verging thrusting and folding. Movement on the Hugh Allan (Purcell) thrust and associated northeast-verging folding (Blackman anticline) is thought to have occurred during early stages of D2, followed by the main, synmetamorphic D2 event consisting of the formation of the Porcupine Creek Anticlinorium and associated large-scale upright folds.

4. Late, post-metamorphic deformation in the study area, consisting of steep southwest-dipping thrusts and crenulations may be the result of overall tightening of the structure or be related to movement on the West Purcell Fault, its unnamed splay and other associated structures.

5. The PCA may be underlain by a series of low-angle detachments or décollements at different structural levels along most of its length. In the study area it is probably underlain by the southern extension of the Ptarmigan Creek Fault Zone and the Selwyn Range Décollement. In the southern PCA detachments are related to significant vertical competency contrasts at the Miette-Gog Group and Gog-Chancellor Group contacts. This type of structural configuration allowed lower

and upper structural levels to deform separately and probably contributed to the positioning and formation of the PCA. The PCA may have formed as the result of movement of underlying decollements over a ramp.

5.1C Metamorphism

1. Metamorphic porphyroblasts (chloritoid, biotite, garnet and staurolite) have overgrown the prominent pre-S2 matrix foliation on the west flank of the PCA and are associated with S2 crenulations related to PCA-related upright F2 folding. Biotite and calc-silicate porphyroblasts grew during the formation of the S-early schistosity suggesting that metamorphism initiated prior to or early during the D2 event.

5.2 Suggestions for future work

1. The nature and timing of early (S-early) deformation and southwest-verging structures in the western part of the study area remain unknown and require more detailed study.

2. It is necessary to learn more about late postmetamorphic thrusts and crenulations in the study area to determine whether they are related to late-stage tightening of the overall structure, movement on the West Purcell and associated faults or other regional tectonic events.

3. A more regional study of all late transverse (St) foliations is needed to better determine their origin and relative timing with respect to D2 structures.

4. Future work should attempt to map structures and lithological contacts across Hugh Allan Creek, in particular the Blackman thrust and the Old Fort Point Formation.

5. Seismic sections through the northern PCA could shed light on the nature of the deep structure and origin of the PCA.

6. Dating metamorphism in the Rocky Mountains is an important objective.

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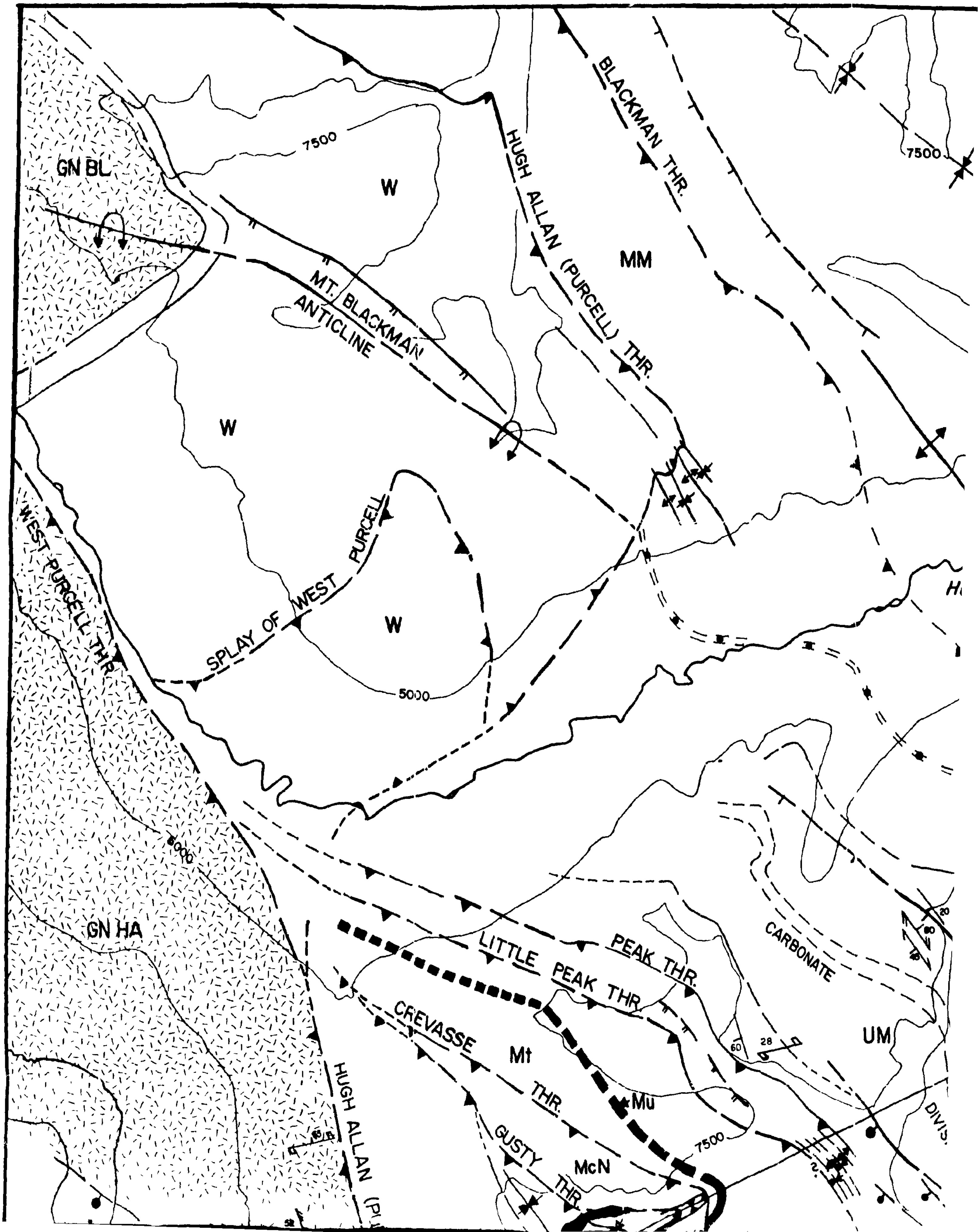

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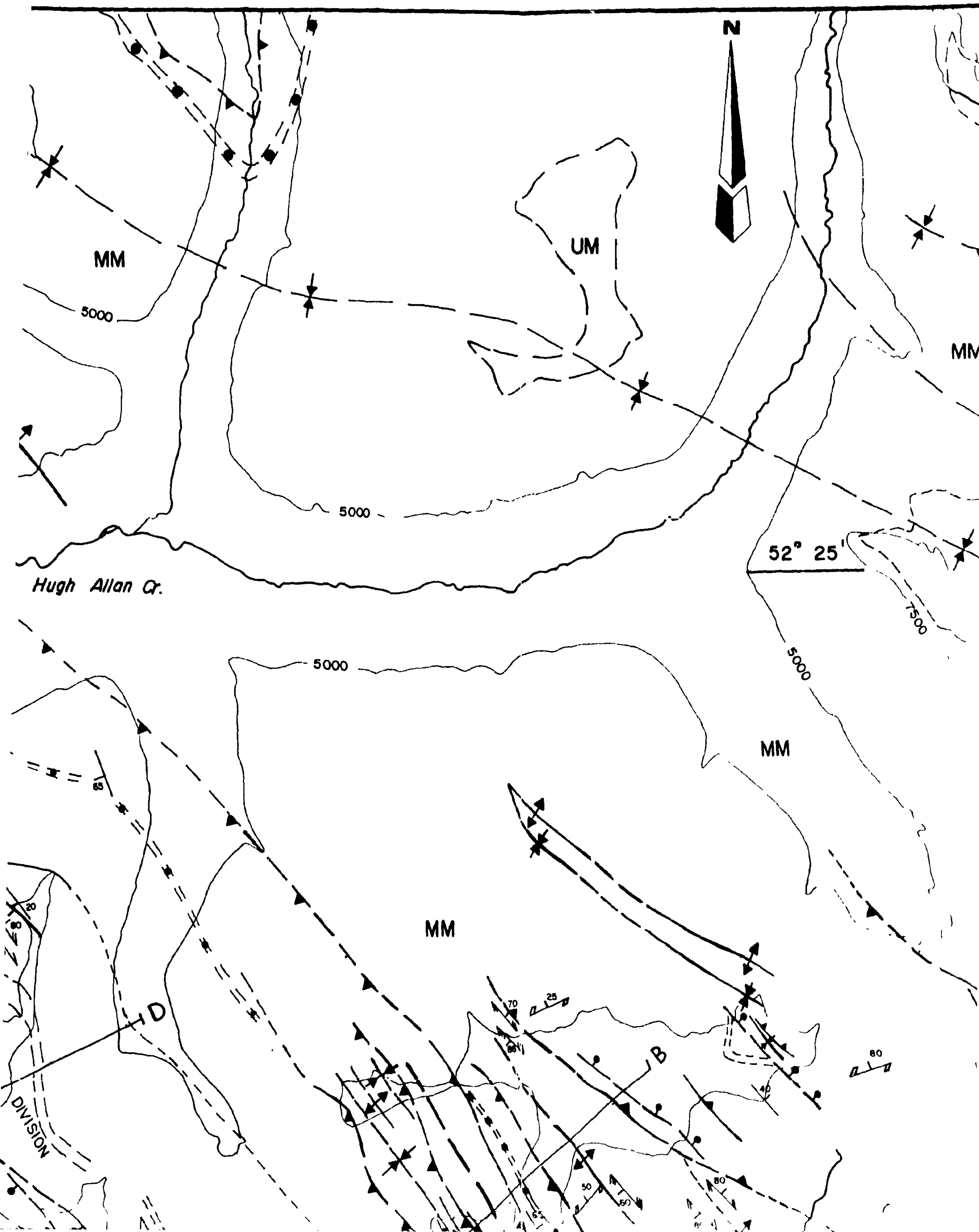
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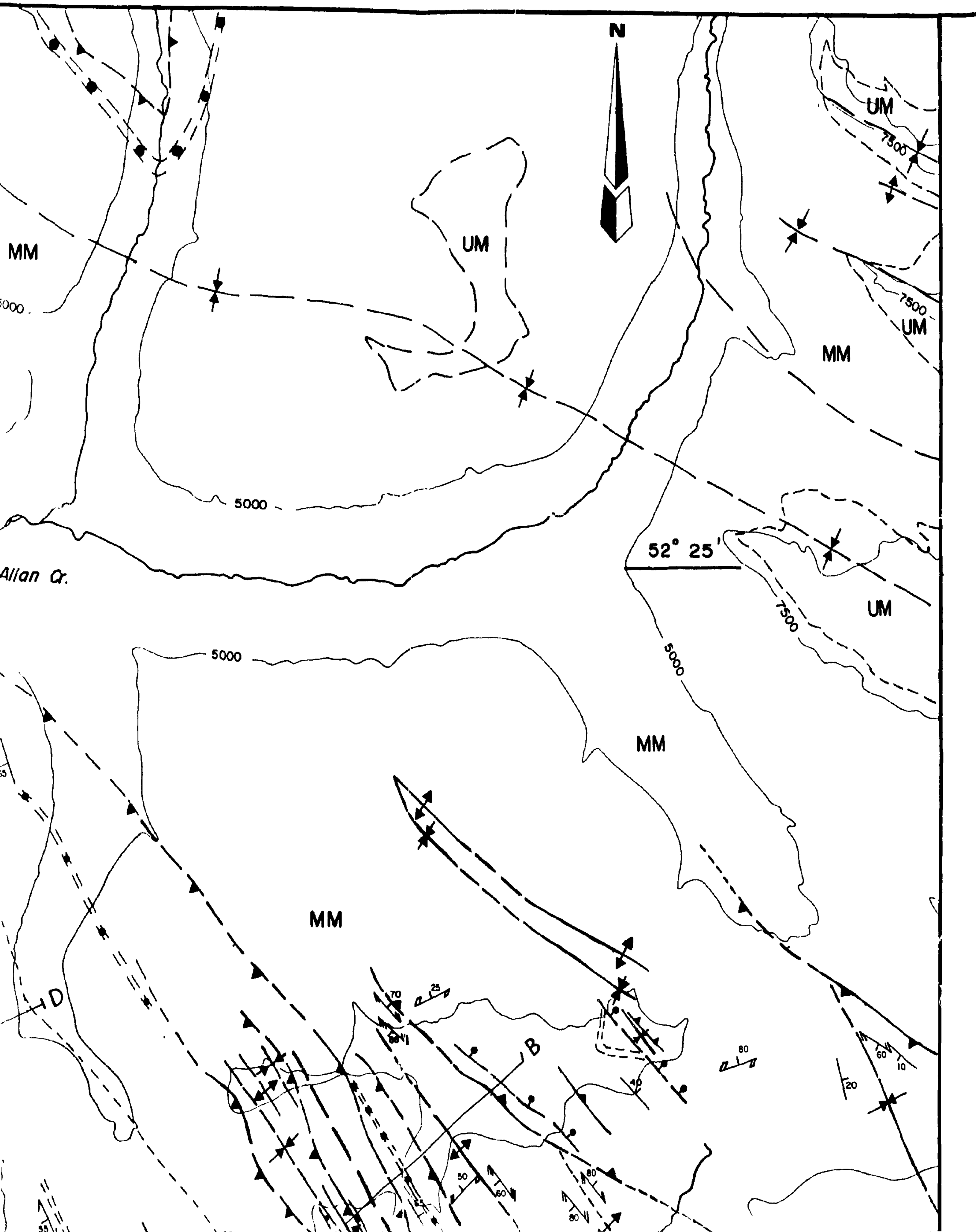
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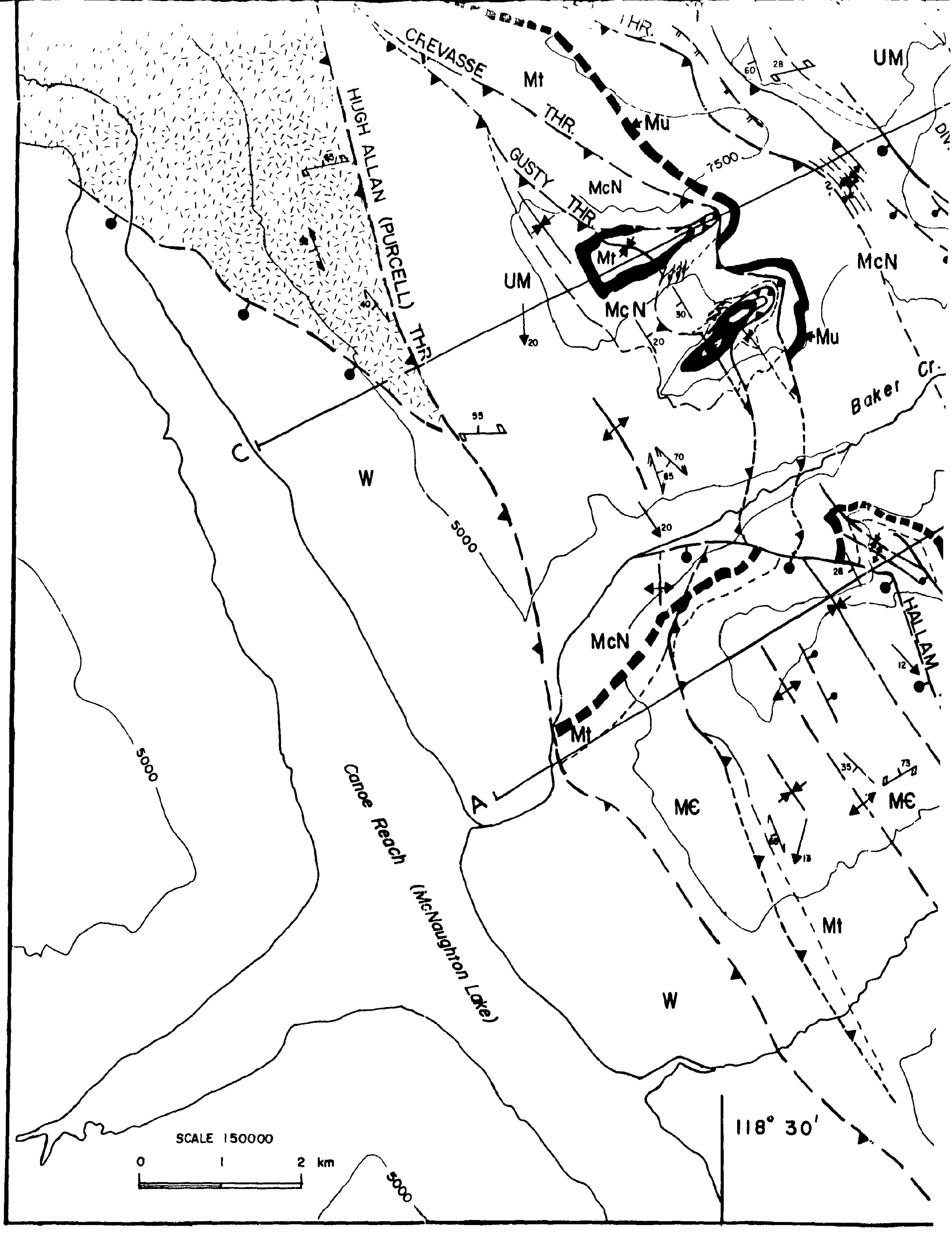
LEGEND

STRATIGRAPHIC UNITS

M€?			MIDDLE (?) CAMBRIAN
Mt	Mahto Fm.	GOG GROUP	LOWER CAMBRIAN
Mu	Mural Fm		
McN	McNaughton Fm		
UM	upper Miette Gp.	MIETTE GROUP	HADRYNIAN
MM	middle Miette Gp.		
	Old Fort Point Fm.		
W	Western Stratigraphy		
	Basal Quartzite		
	Basement Gneiss		PRECAMBRIAN
GN BL	Blackman		
GN HA	Hugh Allan		

SYMBOLS

- Bedding
- S-early
- S 2
- S late
- S t
- F2 fold axes



CREVASSE THR.
HUGH ALLAN (PURCELL) THR.
GUSTY THR.
HALLAM
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Baker Cr.
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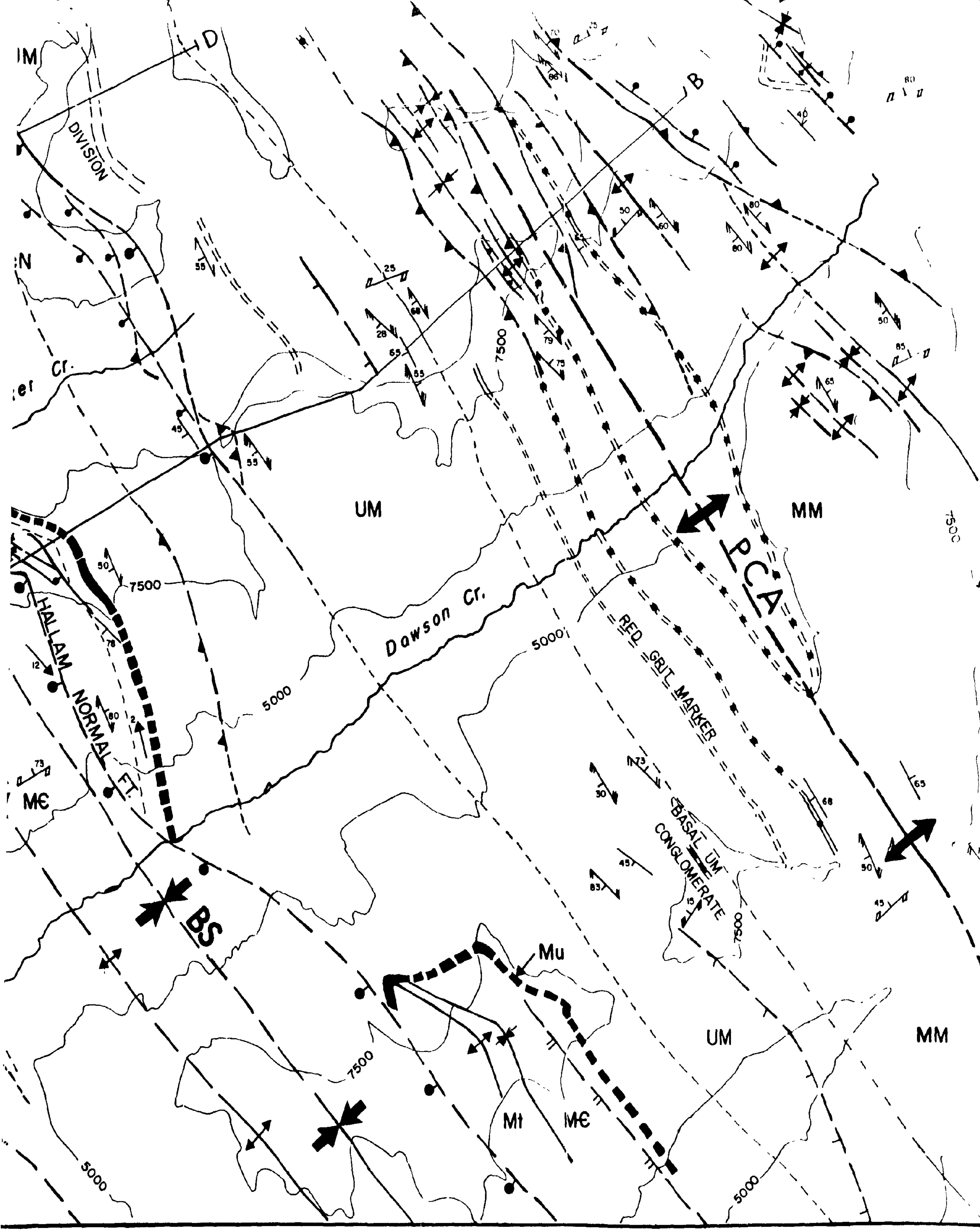

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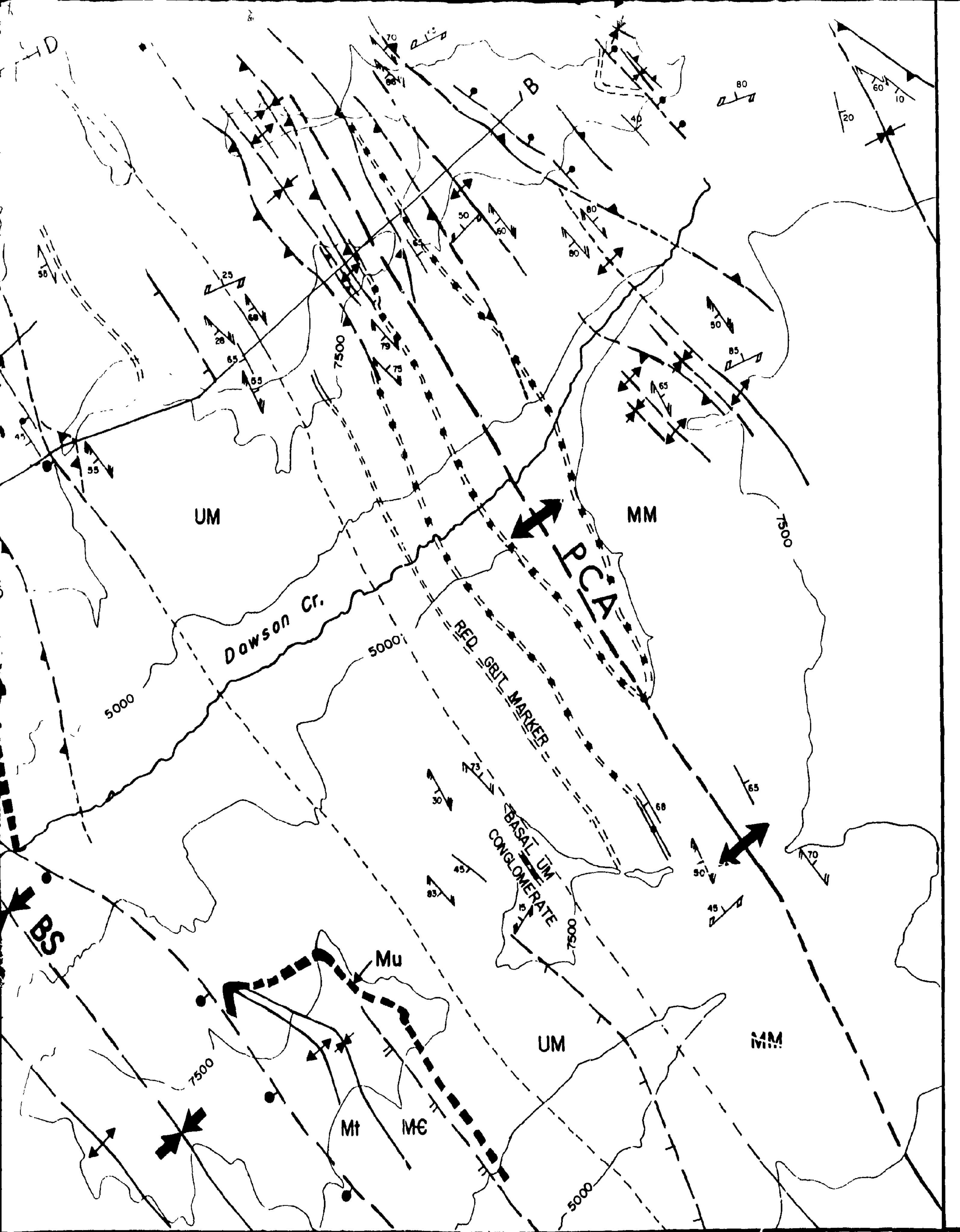

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7500
5000

S-early

S 2

S late

S t

F2 fold axes

Geological contact (observed, approximate or inte preted)

Thrust fault (" " ")

Normal fault (" " ")

Anticline (" " " overturned)

Syncline (" " ")

Garnet isograd (" " ")

Staurolite kyanite isograd " ")

Contours in feet

FIG. 5.1 GEOLOGICAL MAP 1:50,000 SCALE