



## TECTONIC SIGNIFICANCE OF STRATIGRAPHIC AND STRUCTURAL CONTRASTS BETWEEN THE PURCELL ANTICLINORIUM AND THE KOOTENAY ARC, EAST OF DUNCAN LAKE (82K)

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**KEYWORDS:** Regional geology, stratigraphy, Windermere Supergroup, Horsethief Creek Group, Hamill Group, deformation, thrust faults.

### INTRODUCTION

The main goal of this study is to elucidate the nature and tectonic significance of the profound stratigraphic and structural changes that occur between the crest of the Purcell anticlinorium and the Kootenay Arc.

Reconnaissance (1:250 000) mapping by Reesor (1973) outlined conspicuous contrasts between the thick basal Paleozoic (Hamill-Badshot) succession that overlies the Windermere Supergroup in the western Purcell Range and the thin, condensed early Paleozoic succession with overlapping Upper Devonian strata that occurs in the eastern Purcell Range. Reesor also described the abrupt contrast between the tight upright fold structures in this area and the refolded, west-verging, recumbent isoclinal folds that occur immediately to the west in the Kootenay Arc. He also showed that several small granitic plutons in the area probably were emplaced while the folding was still underway.

The rocks exposed in this area (Figure 1-1-1) record both the Late Proterozoic - early Paleozoic birth and development of the Cordilleran miogeoclinal passive margin of North America (Bond and Kominz, 1984; Bond *et al.*, 1985), and the late Mesozoic - early Cenozoic deformation, regional metamorphism and granitic plutonism resulting from "collisions" between North America and a series of allochthonous terranes that have been accreted to it (Monger *et al.*, 1982).

Detailed geological mapping (1:50 000 and greater) was completed during July and August of 1991 and 1992 within an area of about 900 square kilometres in the western Purcell Mountains, between Duncan Lake and the headwaters of Toby and Jumbo creeks (Figure 1-1-2). This work will link the detailed mapping along the Kootenay Arc by Fyles (1964) to the detailed mapping by Root (1987) and Pope (1990) in the central and eastern Purcell anticlinorium.

The main objectives of this study are: (1) to establish the nature and tectonic significance of the stratigraphic relationships within the thick sequence of Windermere, Hamill and Badshot strata in the study area; (2) to investigate the stratigraphic and tectonic relationships between these strata and the condensed overlapping early Paleozoic succession that occurs on "the Windermere high" to the east, below the Mount Forster thrust fault in the central and eastern Purcell Mountains (Root, 1985; Reesor, 1973); (3) to establish the nature, evolution and regional tectonic significance of the change in structural style between the study area and the adjacent areas in the Kootenay Arc and in the central Purcell

Mountains; and (4) to investigate the relationship between the initial structural configuration of the rifted margin and the major structures that developed during Mesozoic terrane accretion and deformation of the margin.

### SUMMARY OF STRATIGRAPHIC RELATIONSHIPS

#### WINDERMERE SUPERGROUP

The Windermere Supergroup in the study area comprises the Toby Formation and the overlying Horsethief Creek Group. Although the Horsethief Creek Group was previously undivided in this area, mappable units can be recognized within it at a scale of 1:50 000 or greater. Two markedly contrasting sequences of units have been defined by detailed mapping of the Horsethief Creek Group in the study area. Variations between the thin sequence exposed to the south and east, and the thicker sequence exposed to the north and west are summarized in Figure 1-1-4.

The southern and eastern sequence is exposed in the Jumbo, Toby, Glacier, and Hamill Creek drainages. It lies apparently conformably on cobble or boulder conglomerate of the Toby Formation, which in turn rests unconformably on the Dutch Creek and Mount Nelson formations of the Middle Proterozoic Purcell Supergroup. The lower part of the Horsethief Creek Group is in general characterized by fine-grained rocks. A laterally continuous unit of marble and calcareous slate (Ht1) lies at the base, overlain by a unit characterized by graded beds of slate and metasiltstone (Ht2). The middle of the Horsethief Creek Group (Ht3) contains abundant discontinuous grit and pebble conglomerate beds (metre scale) and interbedded pelite. Both feldspar and mafic fragments or minerals are common in these rocks. The coarse facies fine upward to overlying pelitic rocks (Ht4). The sequence is overlain by a quartz grit unit, transitional to the overlying Hamill quartzite (Hmt). Total thickness of this sequence varies from a maximum of about 1500 metres in Jumbo Creek to less than 200 metres at Eagle Nest Lake.

The northern and western sequence is well exposed in Howser, Tea, and Rory creeks and on adjacent ridges. It consists of a lower sequence (Ht5) of rhythmically interbedded, thick (tens of metres) feldspathic grit or conglomerate and slate. These coarser clastic rocks are overlain by a sequence of dark marble and calcareous slate (Ht6) up to several hundred metres thick. The upper part of the Horsethief Creek Group (Ht7) contains abundant slate or pelitic schist, siliceous carbonates, minor grit, and a remarkable amount of graded quartz sandstone. Discontinuous greenstone lenses are common in Unit Ht7. Near the mouth of

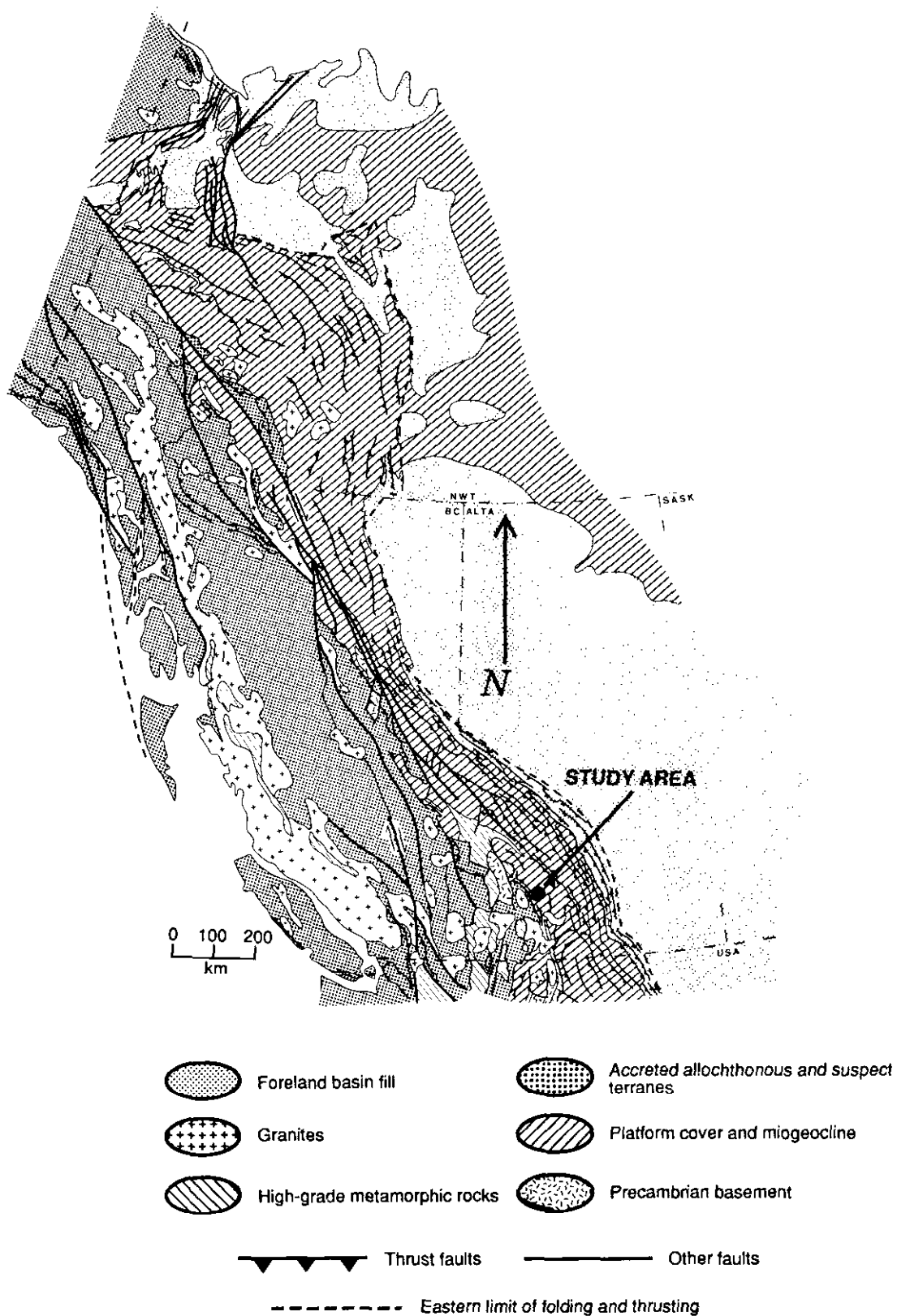


Figure 1-1-1. Tectonic map of the Canadian Cordillera showing location of the study area.  
Modified after Douglas (1968) and Price (1986).

Howser Creek, the Horsethief Creek Group is overlain by upper Hamill quartzite. In all other localities, the top of the sequence is not exposed. The bottom of the Horsethief Creek Group is nowhere exposed in this area. However, the thickness of the exposed strata exceeds 2000 metres, and individual units are in general both thicker and more continuous than to the south and east (as observed by Reesor, 1973).

The divisions of the Horsethief Creek Group in the Howser Creek area closely resemble the lower clastic, middle marble and upper clastic divisions described from areas to the north by other workers (Read and Wheeler, 1976; Brown *et al.*, 1978; Pell and Simony, 1987). The southern and eastern sequence is more similar to that mapped by Reesor (1973) in the eastern Purcells, although it is thicker and contains less coarse clastic material than observed to the east. The top two units of the southern and eastern sequence (Ht3, Ht4) grade laterally into the upper part of the northern and western sequence (Ht7). Lateral relationships between the lower parts of the two sequences are unknown.

## HAMILL GROUP

### TRANSITIONAL UNIT

The Hamill Group (Walker and Bancroft, 1929) lies stratigraphically above the Horsethief Creek Group. Stratigraphic relationships within the Hamill Group are summarized in Figure 1-1-5. The contact between the Horsethief Creek and Hamill groups is marked by a distinctive transitional unit, which is included in the base of the Hamill Group. The transitional unit is characterized by quartz and feldspar grit and pebble conglomerate in a quartz sand matrix. This unit thins to the west and north, and is absent near Howser Creek. Laterally continuous dolostone and quartz grit beds are common in this unit to the east, whereas dolostone-clast conglomerate and rapid facies variations occur to the west. The lower contact is more abrupt to the east, whereas the upper contact with the lower Hamill Group is more abrupt to the west. The transitional unit and its relationships to Horsethief Creek and Hamill groups are in many ways similar to the Three Sisters Formation to the south (Little, 1960), and the Jasper Formation to the north (Lickorish, 1992).

### REMAINING HAMILL GROUP

The remainder of the Hamill Group, which overlies the transitional unit, is divisible within the study area into four map units, including the Mohican Formation (Fyles and Eastwood, 1962). The lowermost unit (Hm1) is a clean, crossbedded quartzite, with minor quartz grit and pebble conglomerate, and minor pelite. It lies conformably on the transitional unit. The middle Hamill Group (Hm2) contains pelitic schist, impure quartzite, minor carbonate and, most significantly, greenstone. This unit thins, and contains less abundant greenstone, to the east. In the Blockhead Mountain syncline, it contains little or no mafic material, and it pinches out. The upper part of the Hamill Group (Hm3) consists of clean, white quartzite at the base, and interbedded light and dark quartzite and pelite near the top. It is overlain by the Mohican Formation, a calcareous schist

which is transitional between the upper Unit Hm3 and the Badshot Formation. In the Blockhead Mountain syncline, the Mohican Formation contains a distinct, laterally continuous orthoquartzite marker unit.

The contacts between Units Hm1, Hm2, and Hm3 are abrupt, although where the less mature middle unit (Hm2) is absent, it is commonly difficult to distinguish between the lower (Hm1) and upper (Hm3) quartzite units. The contact between Unit Hm3 and the Mohican Formation is gradational. The total thickness of the Hamill Group varies from 900 to 1500 metres. The sequence described in this study area bears some marked similarities, as well as several differences, to those described by Höy (1974) to the south in the Kootenay Arc, and by Devlin (1989) to the north in the Dogtooth Range.

Within the Kootenay Arc (structural domain 1; Figure 1-1-3), Units Hm2 and Hm3 are exposed within the cores of recumbent anticlines, and no older rocks have been observed. An important relationship was documented in the adjacent western edge of the Purcell anticlinorium; upper Hamill Group (Hm3) directly overlies upper Horsethief Creek Group near the mouth of Howser Creek. This contact is apparently stratigraphic, and it is considered likely, therefore, that the lower part of the Hamill may be absent beneath the Kootenay Arc.

## BADSHOT FORMATION

The Badshot Formation (Walker and Bancroft, 1929) stratigraphically overlies the Mohican Formation of the Hamill Group. The Badshot Formation is characterized by cliff-forming, white to medium grey, commonly laminated marble or dolomitic marble. At the eastern edge of the area mapped by Fyles (1964), marble horizons tens of metres thick may be separated by grey, locally calcareous schist.

## PHYLLITE IN THE CORE OF THE BLOCKHEAD MOUNTAIN SYNCLINE

Silvery grey phyllite and interbedded an calcareous schist overlie the dolomitic marble of the Badshot Formation in the core of the Blockhead Mountain syncline. Root (1987) mapped this unit as lower Index Formation, of the Lardeau Group. The grey phyllite, however, differs in appearance from the lower Index Formation exposed to the west along Duncan Lake. The lower Index phyllite or schist is characteristically black, commonly graphitic, and contains abundant black or graphitic marbles above the contact with the Badshot Formation. Therefore, the schistose rocks in the core of the Blockhead Mountain syncline are included in the Badshot Formation.

## LARDEAU GROUP

The Index Formation of the Lardeau Group is well exposed in tight map-scale folds within the Kootenay Arc on the east side of Duncan and Kootenay lakes (Fyles, 1964). The Formation as mapped by Fyles (1964) includes: black, commonly graphitic phyllite or schist of the lower Index Formation, with interbedded black marble at the base; green phyllite or quartz-muscovite-chlorite schist, grey mar-

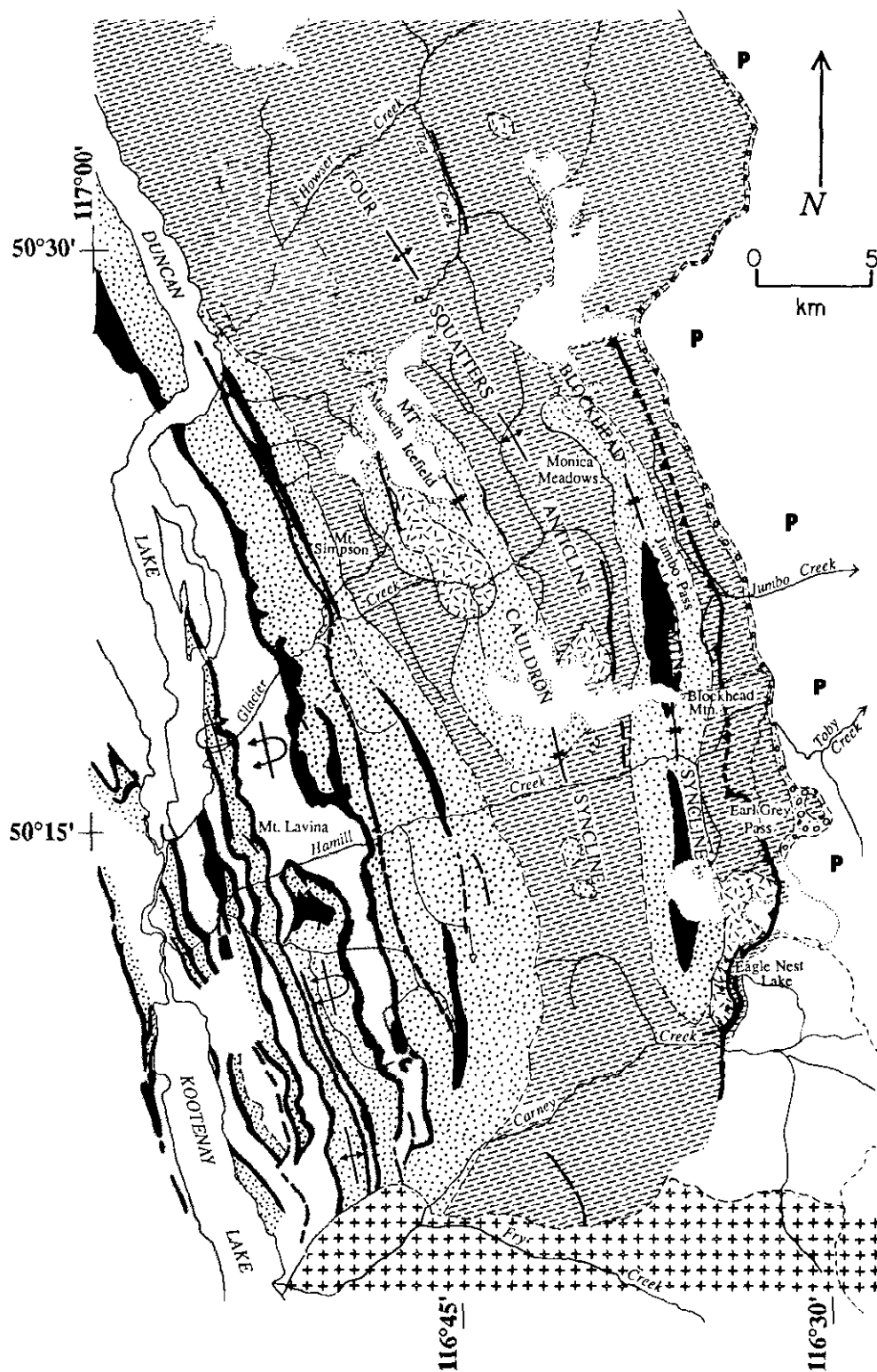
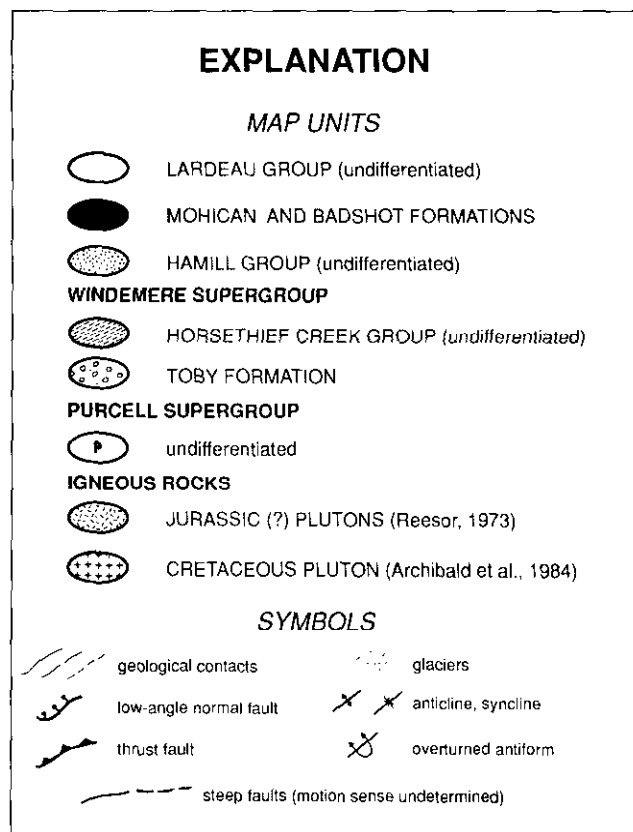


Figure 1-1-2. Simplified geological map of the study area and adjacent segment of the Kootenay Arc. Modified after Reesor (1973).



ble and minor greenstone of the upper Index Formation. The lower Index Formation, between the mouths of Glacier and Howser creeks, contains thin bands of ultramafic to mafic schist.

## SUMMARY OF STRUCTURAL RELATIONSHIPS

The study area is divisible into three domains with contrasting structural styles and tectonic histories (Figure 1-1-3). These are, from east to west: the western Purcell anticlinorium; a thin transitional belt; and the western Kootenay Arc.

### DOMAIN 1: PURCELL ANTICLINORIUM

The map pattern in Domain 1 is dominated by open to locally tight, upright folds, which deform an upward-facing stratigraphic sequence. The dominant regional schistosity or cleavage is axial planar to these folds. Locally developed shear zones are common and are parallel to the dominant foliation. Earlier east-verging recumbent folds are preserved in competent strata at outcrop scale, but do not affect the map pattern. A later crenulation or spaced cleavage commonly overprints the dominant foliation. The youngest observed structures are locally developed but widespread, east-striking left-lateral kink bands. Lower greenschist facies metamorphism accompanied the dominant phase of folding.

One significant fault was mapped within this domain, in the easternmost belt of Horsethief Creek Group. The fault is moderately west dipping and appears to cut the dominant

folds and axial planar cleavage. Stratigraphic relationships across the fault are striking and puzzling. Near Eagle Nest Lake, the fault juxtaposes the transitional unit at the base of the Hamill Group, in the hangingwall, against lowermost Horsethief Creek Group (Ht1) in the footwall. Approximately 1000 metres of Horsethief Creek Group strata are missing. Along strike to the north, in northernumbo Creek, the fault repeats part of the lower Horsethief Creek Group section. Both hangingwall and footwall units truncate against the fault toward the south. These relationships imply that the fault cuts a pre-existing structure.

### DOMAIN 2: TRANSITIONAL

Domain 2 is a belt of subvertical rocks. The structural style is transitional between that of the Purcell anticlinorium to the east and the Kootenay Arc to the west. The stratigraphic sequence is upward facing and is deformed by upright isoclinal map-scale (km) folds and ductile high-strain zones. These structures deform earlier outcrop-scale isoclinal folds and an axial planar fabric, but no earlier map-scale structures have been observed in this domain. The

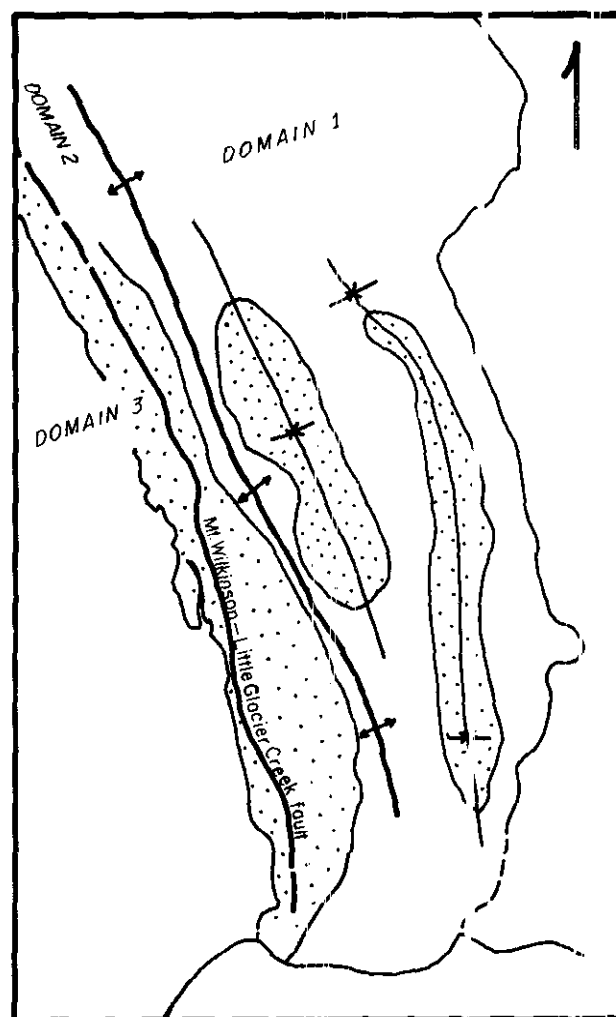


Figure 1-1-3. Sketch map showing locations of structural domains in the study area.

## Windermere Supergroup Stratigraphy

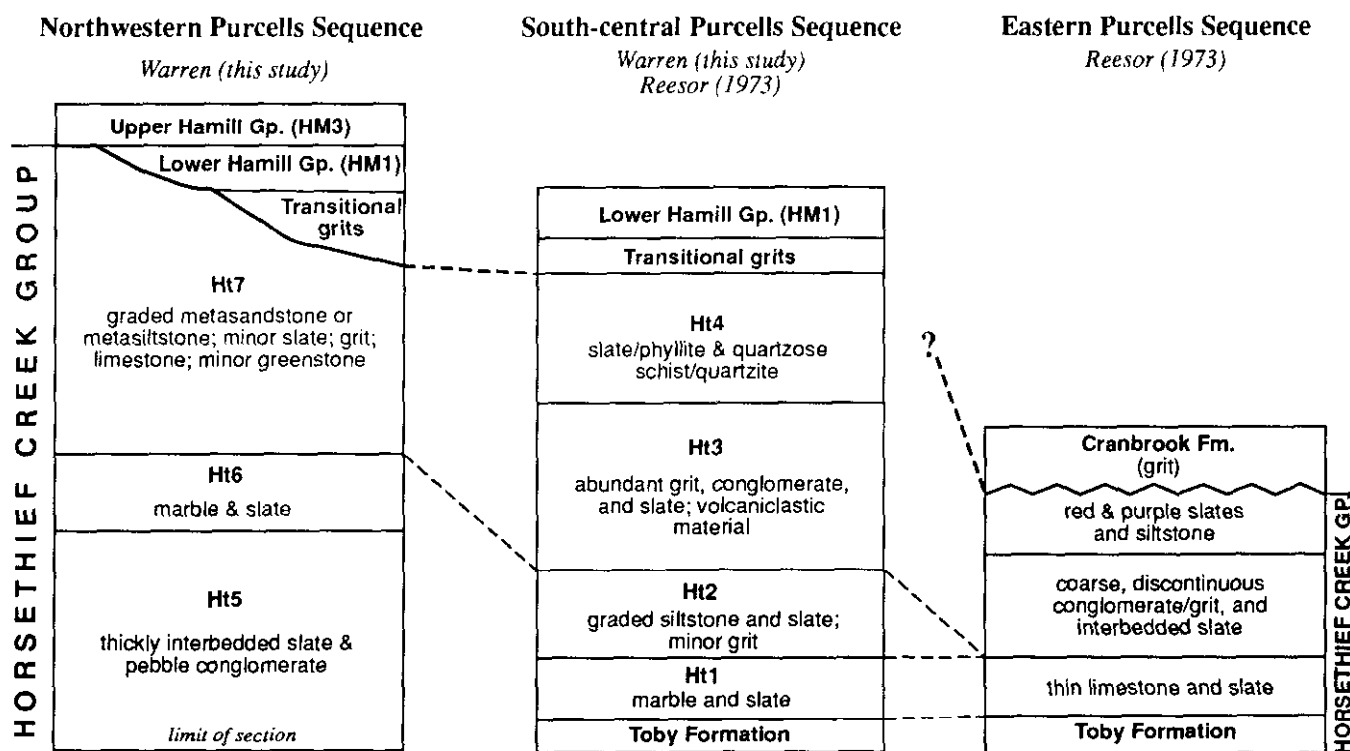


Figure 1-1-4. Stratigraphic relationships between sequences of Windermere Supergroup across the Purcell anticlinorium.

vergence of the early structures is unknown. The dominant deformation was accompanied by upper greenschist to amphibolite facies metamorphism.

### DOMAIN 3: WESTERN KOOTENAY ARC

Domain 3, which was mapped in detail by Fyles (1964), is characterized by the more intense and complex deformation that is typical of the Kootenay Arc. Large-amplitude (10 km scale) west-verging recumbent folds were deformed by two phases of upright, tight to isoclinal folds, under conditions of amphibolite facies metamorphism. Much of the stratigraphic sequence is overturned, and along the eastern boundary of the domain, the sequence is everywhere overturned.

The boundary between Domains 1 and 2 is defined by the axial trace of an anticline cored by Horsethief Creek Group. Strata east of this boundary are gently to moderately dipping, whereas strata to the west are subvertical. Although no significant fault was mapped along this boundary, it represents an abrupt contrast in metamorphic grade and structural style.

### NATURE OF DOMAIN BOUNDARIES

The boundary between Domains 2 and 3 is defined by a subvertical, locally mylonitic fault, which separates the Purcell anticlinorium from the Kootenay Arc. The fault is significant because it juxtaposes an upward-facing stratigraphic sequence to the east, against an overturned sequence to the west. Similar relationships have been

described along strike to the south by Höy (1974), along the West Bernard fault, and by Leclair (1988) along the Seeman Creek fault. The sense of motion along this fault has been a long-standing enigma, due primarily to the fact that the same map unit of the Hamill Group was observed on both sides of the fault. However, east of Duncan Lake, rocks of the middle and upper Hamill Group to the west, are juxtaposed against upper Hamill Group, and, where the fault intersects Duncan Lake, Index Formation. These relationships imply a west-side-up sense of motion, although this interpretation requires caution, as the fault cuts previously folded strata.

In all three structural domains, the second-phase structures are dominant. A poorly understood subhorizontal stretching lineation parallels the axes of second-phase folds in all three domains. It is important to note that the small early folds preserved in the eastern domain are east verging, whereas the large-amplitude early folds in the Kootenay Arc are west verging. The younger phase of upright folding in the Kootenay Arc is coplanar with the second-phase deformation, and similar in structural style. It probably represents a continuation of the dominant deformation. In Domain 1, the younger structures appear to have formed under slightly more brittle conditions than the dominant second-phase structures.

Granodiorite plutons were intruded late in the main phase of deformation in Domains 1 and 2 (Reesor, 1973; Warren and Price, 1992). Abundant granitic dikes or sills were intruded during the main phase of deformation in the southern part of Domain 3 (Fyles, 1964; Warren and Price, 1992).

## Paleozoic Stratigraphy

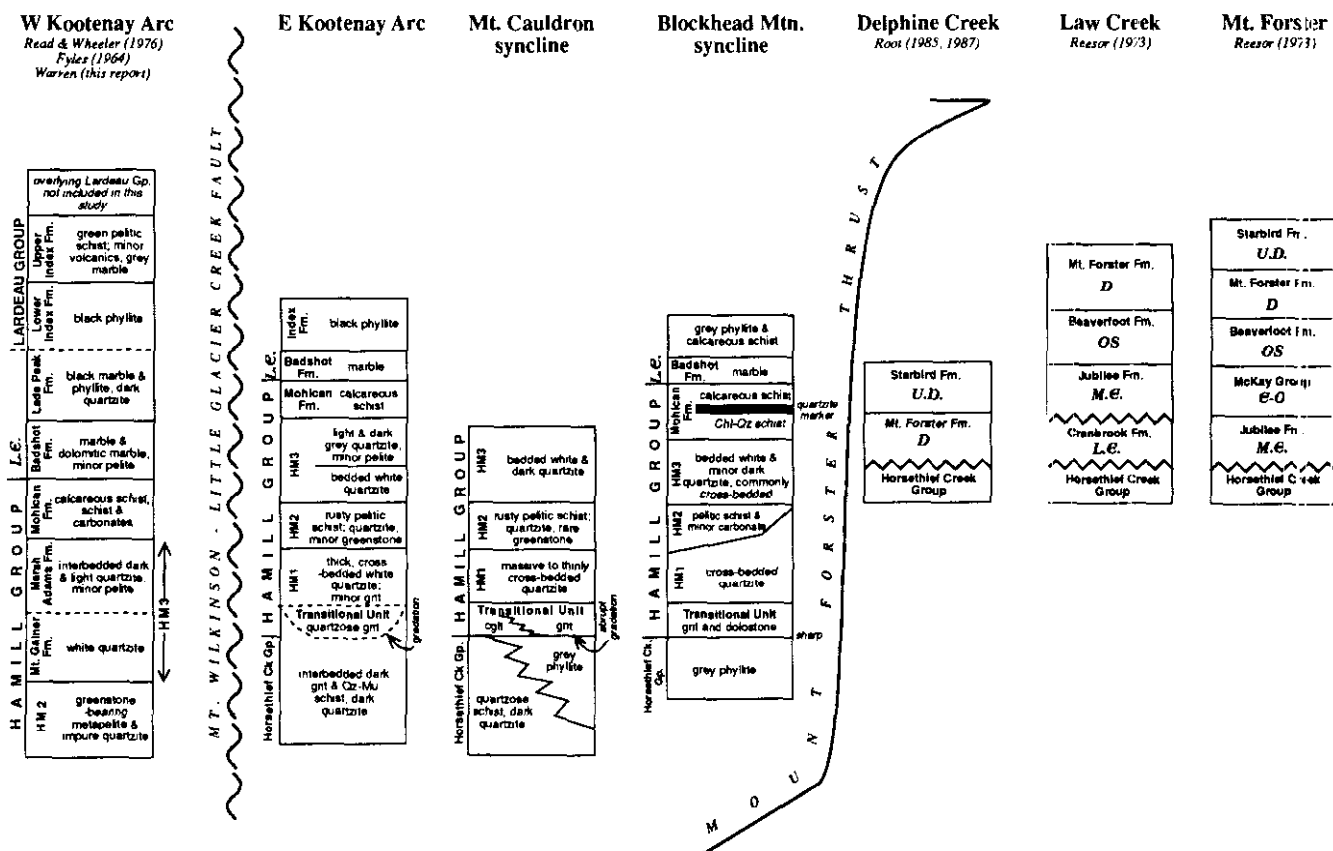


Figure 1-1-5. Stratigraphic relationships between lower Paleozoic rocks across the Purcell anticlinorium

A similar sill immediately south of the study area, on the west shore of Kootenay Lake, has yielded U-Pb zircon ages of  $173 \pm 5$  Ma (Smith *et al.*, 1992).

## SUMMARY

Stratigraphic relationships within and between Upper Proterozoic and Lower Cambrian rocks show that sedimentation during this interval was punctuated by several tectonic events, related to extension and/or rifting of the North American continental margin, and to emergence of "the Windermere high" (Reesor, 1973) as a high-standing continental crustal block. Regional sedimentation is disrupted at the base of the Windermere Supergroup, within the Horsethief Creek Group, beneath the Hamill Group, and again in the middle Hamill Group. Immature grit and greenstone within the Lardeau Group also imply tectonic events of an unknown nature. The duration of active tectonism was clearly longer than can be accounted for by recent models of continental rifting (*e.g.*, Bond and Kominz, 1984; Bond *et al.*, 1985). It is hoped that trace element and rare-earth element geochemical analyses of mafic igneous rocks in the Horsethief, Hamill and Lardeau groups will contribute to an understanding of the tectonic settings recorded by these rocks.

The boundary between the Purcell anticlinorium and the Kootenay Arc is a steep regional-scale fault, which separates rocks with early west-verging deformation, on the

west side, from rocks with early east-verging deformation, on the east side. Relationships within this study area strongly suggest that the west side moved up relative to the east side. Two other significant faults affect the western Purcell anticlinorium: a thrust fault in the Horsethief Creek Group near the Purcell divide, and the Mount Forster fault, which carries rocks of the study area in its hanging wall. Relationships between hanging wall and foot wall stratigraphy across all three faults suggest that they are influenced by structures related to the development of the "Windermere high" during Late Proterozoic/early Paleozoic extension.

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