PRELIMINARY GEOLOGY OF THE CRESTON MAP AREA, SOUTHEASTERN BRITISH COLUMBIA (82F/2)

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INTRODUCTION

This article summarizes preliminary results of the East Kootenay project after completion of one month of fieldwork in the Creston map area (82F/2) in 1994. The project will provide a new 1:50 000-scale geologic map (Open File 1995-15) and improved stratigraphic correlations. Mapping concentrated on extending work westward from the Yahk map area (Brown and Stinson, 1995, this volume), across the Creston valley and up to the Windermere Supergroup. The northwest third of the map sheet, underlain by Jurassic and Cretaceous plutons, was not studied

PREVIOUS WORK

The Creston map area lies along the International Boundary, in the southern part of the Nelson map area (82F). Initial geological investigations were undertaken by Daly (1912) as he surveyed the international border area in the early 1900s. Complete 1:250 000-scale coverage of the Nelson East Half map area was finished in 1938 (Rice, 1941). Recent 1:100 000-scale mapping of the region has been published by Reesor (1993; Figure 1). A new 1:250 000-scale coloured compilation map for the entire British Columbian Purcell anticlinorium is now available (Höy *et al.*, 1995).

Several theses have been completed in the vicinity of the Creston map area. Most notable is the detailed structural study by Glover (1978). His 1:25 000-scale map of the Summit Pass area overlaps the western part of the Creston map area and has been incorporated in this study (Figure 1). Stratigraphic divisions adopted by Glover (following those of Rice, 1941) are largely maintained here. A thesis by Barrett (1982) describes structures in the Bayonne batholith, along the northern edge of the Creston map area, that may be related to the Purcell Trench fault. Immediately north of the Creston map area, LeClair (1982, 1983) studied the area west of Kootenay Lake. Farther northeast, two theses examine in detail the upper Purcell and Windermere stratigraphy (Root, 1987; Pope, 1989). Significantly, these two works have substantially different interpretations of the upper

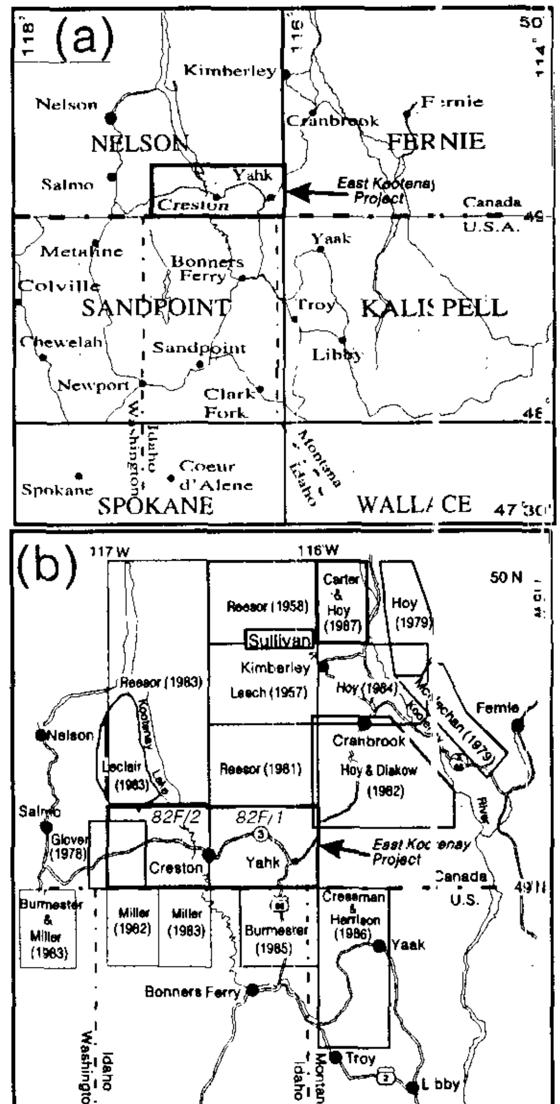

Figure 1. Location of the Creston and Yahk map areas (dark hatched rectangle) relative to areas of previously published geologic maps. (a) The 1:250 000, 1:126 720 or 1:100 000-scale map coverage includes: Fernie West-half (82G/west) -- Leech (1958, 1960), Höy and Carter (1988), Höy (1993); Nelson East-half (82F/east) -- Rice (1941) Reesor (1993); Sandpoint (82C) -- Miller (in preparation), Aadland and Bennett (1979); Kalispell (82B) -- Harrison *et al.* (1992); Spokane, Griggs (1973), Stoffel *et al.* (1991); Wallace -- Harrison *et al.* (1986). (b) The 1:50 000, 1:48 000 and 1:25 000-scale maps in the immediate vicinity of the Creston map area include: Burmester and Miller (1983), Glover (1978), Leclair (1983) and Miller (1982, 1983).

Purcell stratigraphy; Root proposes that the Mount Nelson Formation be included in the Windermere rather than Purcell Supergroup. A thorough geochronometric study of plutonic and metamorphic rocks in the Creston map area was completed by Archibald *et al.* (1983, 1984), including documentation of a Tertiary thermal event west of the Purcell Trench fault.

Mapping south of the International Boundary includes 1:250 000-scale maps by Aadland and Bennett (1979) and Stoffel *et al.* (1991; Figure 1a). More detailed mapping adjoining the Creston map area includes Miller (1982, 1983; Figure 1b) and a study of paragneiss along the west side of the Purcell Trench west of Bonners Ferry by Nevin (1966).

GEOLOGICAL SETTING

The map area straddles a structural and metamorphic transition from the Purcell anticlinorium to the Kootenay Arc and includes important structures such as the southern extension of the Hall Lake fault and the northern extension of the Purcell Trench fault (Figure 2). It provides a unique opportunity to map changes from low grade, broadly folded, unfoliated Purcell Supergroup strata of the anticlinorium into equivalent but higher metamorphic grade and polydeformed rocks. The Purcell Supergroup, a thick succession of siliciclastic and carbonate rocks of Middle Proterozoic age, is unconformably overlain to the west by the Upper Proterozoic Windermere Supergroup. Small Jurassic

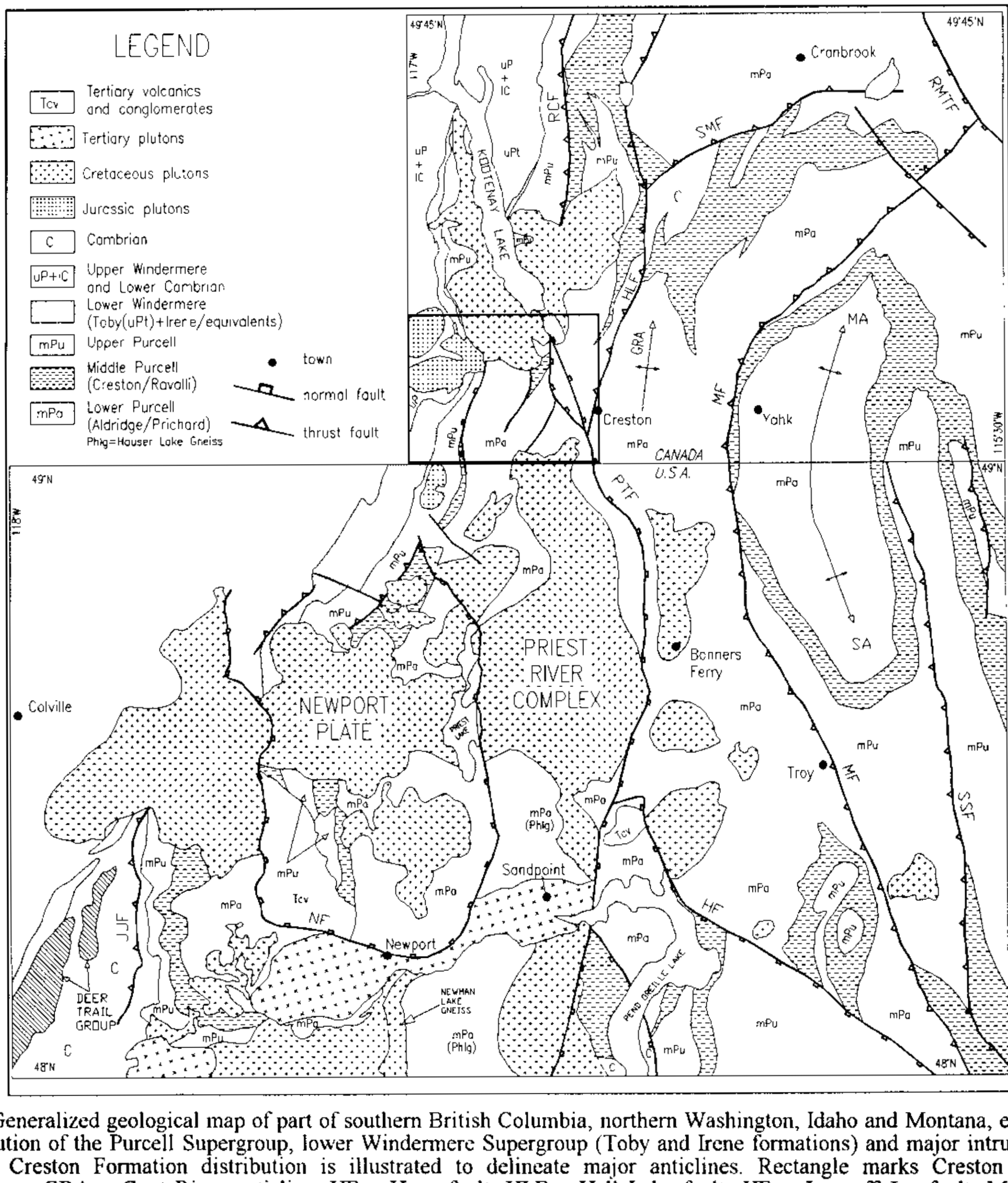

Figure 2. Generalized geological map of part of southern British Columbia, northern Washington, Idaho and Montana, emphasizing the distribution of the Purcell Supergroup, lower Windermere Supergroup (Toby and Irene formations) and major intrusive suites. Simplified Creston Formation distribution is illustrated to delineate major anticlines. Rectangle marks Creston map area. Abbreviations: GRA = Goat River anticline, HF = Hope fault, HLF = Hall Lake fault, JJF = Jumpoff Joe fault, MA = Moyie anticline, MF = Moyie fault, NF = Newport fault, PTF = Purcell Trench fault, RCF = Redding Creek fault, RMTF = Rocky Mountain Trench fault, SMF = St. Mary fault, SSF = Snowshoe fault. Modified after Höy *et al.*, 1995, Miller (1982, 1983), Stoffel *et al.* (1991) and Harrison *et al.* (1992).

plutons and extensive Cretaceous batholiths dominate regions north and south of the Creston map area. These plutons have been mapped by Daly (1912), Rice (1941), Reesor (1973, 1983, 1993) and Miller (1982, 1983), and studied by Archibald *et al.* (1983, 1984).

Most of the mapping focused on the Purcell Supergroup; with its tripartite subdivisions: lower (Aldridge and Creston formations), middle (Kitchener Formation), and upper (Dutch Creek and Mount Nelson formations; Figure 3). Stratigraphic distinctions and nomenclature problems arise in this part of the western Purcell Basin. For example, Kitchener and Siyeh formations are not distinguishable, unlike farther to the east, which led to the use of Kitchener-Siyeh Formation (Rice, 1941). In addition, important regional markers to the east (Nicol Creek Formation and Phillips Formation/Bonner Quartzite) are absent or rare. The Dutch Creek and Mount Nelson formations were originally defined by Walker (1926) in the Windermere area and have been extended south to the Creston map area. The Windermere Supergroup comprises up to 9 kilometres of polymictic conglomerate, volcanics, carbonate and siliciclastics. The lower units are generally

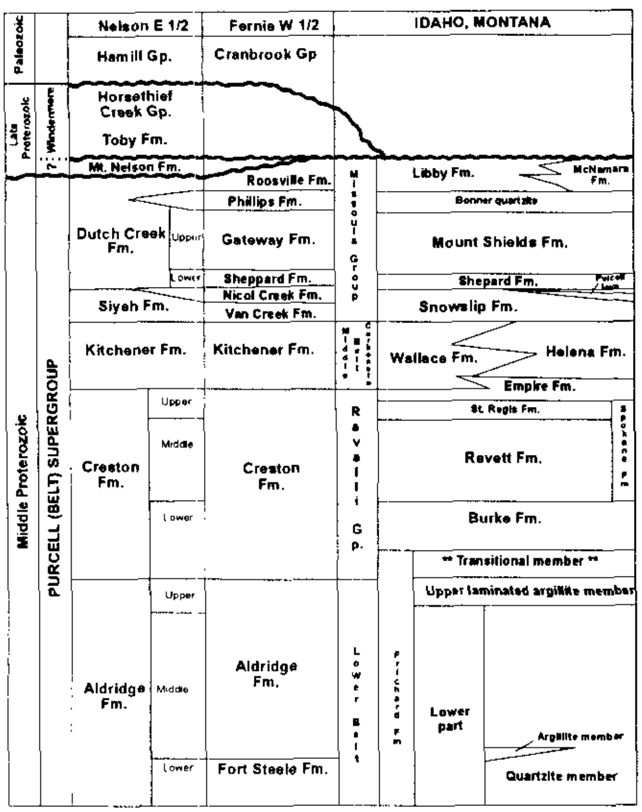

Figure 3. Table of formations for the Purcell Supergroup and their correlative units within the Belt Supergroup of Idaho and Montana. Nelson East Half from Rice (1941) and Reesor (1981, 1983); Fernie West Half from Leech (1958); Idaho and Montana from Harrison *et al.* (1992) and Harrison and Cressman (1993). The *transitional member* of the Prichard Formation (Cressman, 1989) correlates with lower Creston Formation.

interpreted to record a rifting event and are overlain by more extensive deep-water sediments believed to represent shelf progradation, although much debate continues about these reconstructions (Ross *et al.*, in preparation).

The Priest River Complex, a north-trending Eocene core complex, comprises Precambrian basement gneiss, metamorphosed Purcell/Belt strata, and deformed and massive Cretaceous plutons (Figure 2; Rehrig *et al.*, 1987). It also includes the Spokane Dome mylonite zone (Rhodes and Hyndman, 1984; Rhodes, 1986), and Hauser Lake gneiss. The northern end of the Priest River Complex comprises Cretaceous granitic rocks and amphibolite grade metamorphic rocks derived from the Aldridge/Prichard Formation. These granitic rocks are the West Creston and Corn Creek gneisses, and Rykert pluton (Daly, 1912; Miller, 1982; Archibald *et al.*, 1983, 1984; Figure 4).

STRATIGRAPHY OF THE CRESTON MAP AREA

PURCELL SUPERGROUP

ALDRIDGE FORMATION

The Aldridge Formation underlies about half of the Creston map area and changes character between discrete fault-bounded blocks. East of the Okell fault (Figure 4), Aldridge Formation is unfoliated and low metamorphic grade, similar to most of the Yahk map area. However, metamorphic grade and penetrative fabrics increase to the west, hindering subdivision of the formation and locally making correlations speculative. The rusty weathering (disseminated pyrite and pyrrhotite) characteristic of the Aldridge formation is a useful feature used to distinguish it from the grey-weathering metamorphosed Creston Formation. The more phyllitic and sericitic Aldridge Formation adjacent to faults can resemble the Creston Formation, for example 4.6 kilometres north of Creston on Highway 3A. More detailed mapping is needed to define the relationships between low and high-grade areas. Marker laminates have been identified in a few localities where metamorphic grade is low to moderate (D. Anderson, personal communication, 1994). Primary sedimentary structures (graded bedding, crossbedding, flames and scouring) are evident locally in the lower grade blocks.

CRESTON FORMATION

The Creston Formation is undivided in the map area because of the superimposed deformation and metamorphism. Lower metamorphic grade exposures include waxy pale green and grey, thin-bedded to laminated argillite to siltstone couplets, phyllitic siltstone and quartz arenite, as exposed east of North Star Mountain (Figure 4). Local ripple marks indicate

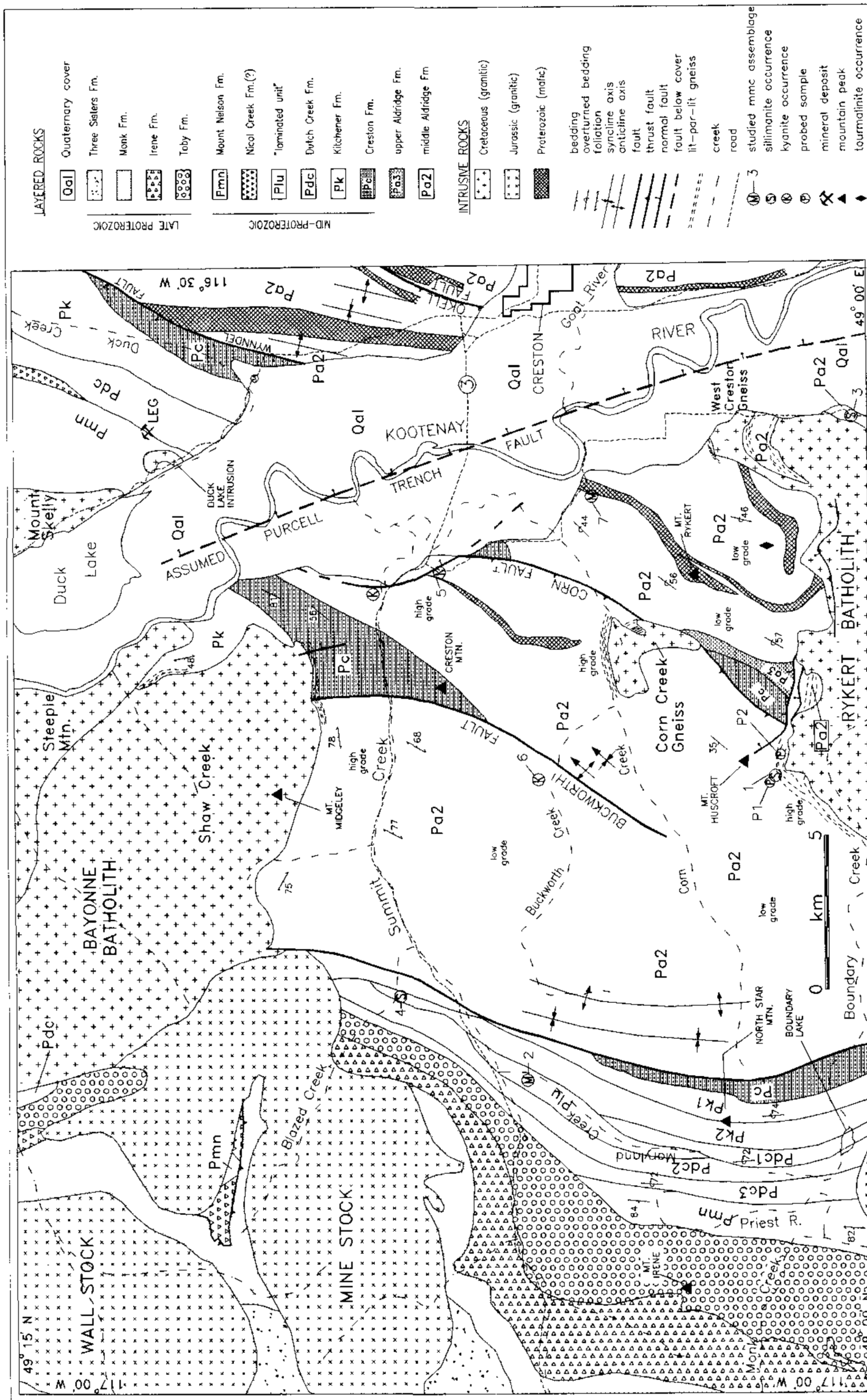

Figure 4. Simplified geology of the Creston map area (82F/02).

Photo 1. Thinly bedded quartz arenite with coarsely crenulated argillaceous interbeds, metamorphosed Creston Formation.

Photo 2. Cone-shaped stromatolite from the Kitchener Formation dolomite 900 metres east of North Star Mountain (DBR94-505).

deposition within fair-weather wave base. In this area the Creston Formation is overprinted by post-tectonic biotite porphyroblasts. The metamorphosed Creston Formation consists of non-rusty, light grey weathering, thin-bedded to laminated muscovite schist, biotite-muscovite-quartz schist and meta-arenite. Outcrops 2 kilometres west of the Summit Creek bridge along Highway 3 are typical. Bedding and more rarely crossbedding may be preserved, even where medium-grained schist with prominent phyllosilicate crenulation is developed (Photo 1).

The Creston Formation here in the northwestern part of the Purcell Basin is generally finer grained and thinner than the succession in the Yahk map area. The middle Creston Formation is known to produce strong aeromagnetic anomalies, for example, in the Moyie anticline (Brown and Stinson, 1995, this volume). A 1:250 000-scale aeromagnetic anomaly south of Wynndel suggests that the Creston Formation extends to the southwest under the Quaternary cover in the Kootenay valley. In the same area there is an odd pattern with two anomalies of unknown origin. Farther west, a faint and broad anomaly in the Maryland Creek area may also be correlated with Creston Formation and perhaps some mafic sills (discussed later).

KITCHENER FORMATION

Kitchener Formation consists of a basal carbonate unit and an upper argillite succession in the North Star Mountain area (Figure 4). The **lower carbonate unit** (Pk1) in the North Star Mountain area is a carbonate-rich succession about 1000 metres thick, dominated by dark brown to tan-weathering dolomitic phyllite, dolomite, dolomitic siltstone with minor limestone (marble), and lesser quartz arenite. Fine sericitic-rich layers are metamorphosed clayey layers. Pale greenish grey fissile dolomitic siltstone has a pitted weathered surface where pyrite cubes (up to 5%) have been dissolved. A pale green phyllitic siltstone and argillite facies within the carbonate thickens to the south. The medium to thick-bedded basal dolomite, east of North Star Mountain, contains rare domal and cone-shaped stromatolite mounds (Photo 2), up to 2 metres across, indicating shallow-water deposition. These stromatolites are reliable indicators of tops and indicate that the southeast-dipping section is overturned. The dolomite units produce deep red-brown soils that help delineate the dolomite horizons in areas of poor exposure. Fining-upward sequences, pinch and swell, and hummocky bedforms suggest deposition within storm wave base, slightly deeper than the Creston Formation.

A series of discontinuous **carbonate breccia horizons** occur in two areas, Wilds Creek and North Star Mountain. Those near Wilds Creek are part of a group of breccias that extend northward along the western edge of the Purcell anticlinorium (Brown and Klewchuk, 1995, this volume). On North Star Mountain, at least three irregular and discontinuous zones of breccia are exposed, however, their lateral extent is difficult to establish. The breccias in both localities have similar appearances, although, it is unclear whether they occupy the same stratigraphic position. The North Star Mountain breccia comprises angular dolomite fragments up to 25 centimetres long (average 2 to 5 cm), and rare subrounded white quartz and arenite fragments supported in a light brown to tan carbonate matrix. Grey argillite clasts occur sporadically. Surface exposures are roughly pitted due to differential weathering of the different carbonate and argillite fragments. The breccias are interpreted to be karst (solution collapse) features.

Above the carbonate succession (Pk1) is about 750 metres of dark grey **phyllitic argillite** (Pk2) that was not studied.

DUTCH CREEK FORMATION

The Dutch Creek Formation consists of a lower carbonate (Pdc1), overlain by an argillite succession (Pdc2) and locally a laminated unit (Plu), and capped by an upper carbonate (Pdc3).

The **lower carbonate** (Pdc1), dominated by dolomite, extends from the border northward 9 kilometres to Maryland Creek. It consists of thin to medium-bedded dolomite with green phyllitic layers. The central part is mainly massive, crumbly, grey argillaceous dolomite, with interbedded laminated dolomite. Locally, siliceous knots are common. Towards the top, it is mainly laminated argillaceous dolomite with pyrite porphyroblasts. This grades upward into light green-grey dolomitic argillite and grey to dark green argillite of the middle Dutch Creek unit (Plu). Near the top of the unit quartzite beds are interbedded with the dolomite.

A distinct unit, informally called the "laminated unit" (Plu) comprises well laminated siltstone that crops out in several locations. The alternating light grey and light green laminae give it a distinctive appearance. It is characterized by its soft, friable and even-bedded bedform. Uncracked, even clay to silt couplets are interbedded with thicker, continuous, flat-laminated sandstone layers. Siltstone layers are commonly attenuated and more deformed parts of the unit are chlorite-sericite phyllite. Planar crossbedding, climbing ripples and oscillation ripples were observed in some exposures (Photo 3). The outcrop 6 kilometres west of Blazed Creek along Highway 3, is marked by fine disseminated magnetite crystals. It appears to have an anomalously low metamorphic grade and is only locally crenulated. Towards the southern end of its interpreted extent it is mainly thin-bedded light grey to green siltstone, characterized by tabular bedsets with angular crosslaminations. This sediment type is not seen farther south, where the middle Dutch Creek Formation is entirely argillite.

An **argillite succession** (Pdc2), dominated by microlaminated sericitic phyllite with minor deeply weathered dolomitic beds less than 2 centimetres thick, separates dolomite horizons. It is a heterogeneous succession of black phyllitic argillite, pale green sericite schist and quartzitic schist. A small building stone quarry in quartzitic sericite schist operates intermittently north of Maryland Creek.

A succession of dolomite, argillite and quartzite (unit Pdc3) forms the uppermost unit of the Dutch Creek Formation in the Maryland Creek area. The first occurrence of a thick dolomite horizon (>1m) is taken to be the basal contact. Cream-coloured, pure, fissile dolomite and dolomitic siltstone are medium to thin bedded and include interbeds of microlaminated black graphitic argillite, similar to the underlying unit. Rare cryptoalgal laminations may be stromatolites. Laminated fine-grained orthoquartzite beds, up to 4 metres thick, are a small component of the section. Pure, light grey to white, fine-grained dolomite interbedded with thick (1 to 2 m) beds of limestone (marble) mark the top of the Dutch Creek Formation in the Maryland Creek area.

The dolomite is overlain by black to rusty brown weathering crenulated graphitic argillite. A massive dolomite bed, 1 to 2 metres thick, occurs within the laminated black argillite. It is unclear whether this argillite marks the top of the Dutch Creek Formation or the base of the Mount Nelson argillite unit.

MOUNT NELSON FORMATION

The Mount Nelson Formation consists mainly of dark coloured phyllitic argillite with interbedded quartzite and lesser dolomite, west of the uppermost Dutch Creek carbonate (Figure 4). The rusty brown to grey argillite is phyllitic and locally crenulated, so primary features are not preserved. Strata are mainly graphitic (shiny dark grey to black) or chloritic (dark green) and locally contain numerous quartz pods and layers, some of which may be flattened clasts (Photo 4). The argillite is interbedded with several layers of medium to coarse-grained vitreous quartzite (quartz sandstone) that appear to be continuous over several kilometres. The medium to thick-bedded quartzite layers are 2 to 50 metres thick and are much more resistant than the argillite, hence they form prominent outcrops. They weather white, grey, brown and pink, and constitute

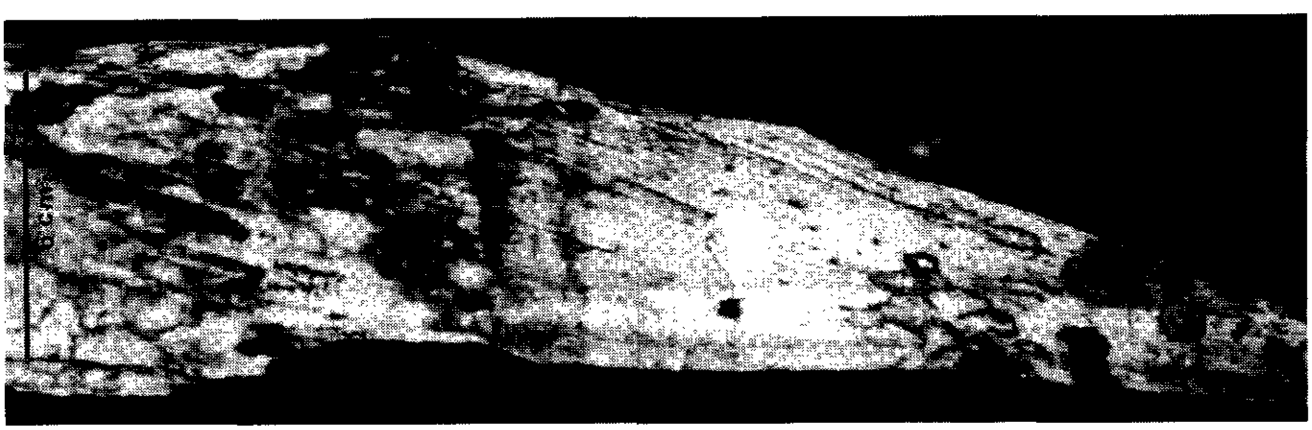

Photo 3. Planar crossbedding within the laminated unit.

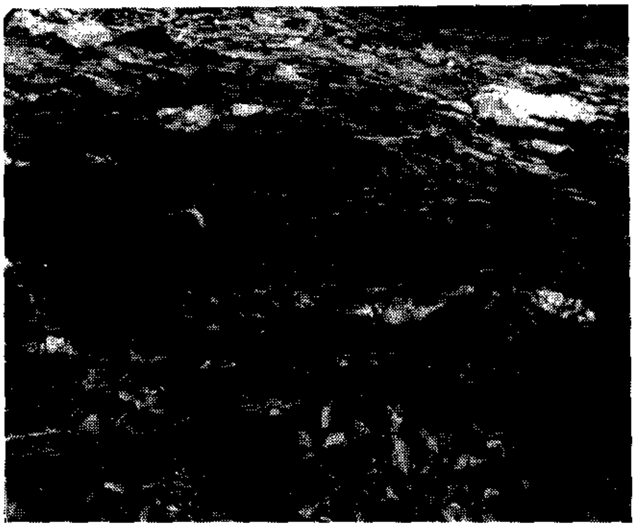

Photo 4. Deformed quartz fragments (possible clasts?) in argillite of the Mount Nelson Formation (PST94-296).

15% of the poorly exposed section. Rarely, a primary fabric consisting of tightly packed, rounded, blue quartz granules, is preserved. These are best preserved near the top of the Priest River canyon, 3 kilometres northwest of Boundary Lake. Less commonly, zones with numerous, large mudchips which are highly strained are present within the quartzite units. In the southernmost exposures just west of the Priest River canyon, quartzite is interbedded with buff dolomite.

Rare lenses of laminated, brown-weathering, silty dolomite up to several metres thick also occur within the Mount Nelson argillite. The continuity of the dolomites is difficult to determine compared to the quartzites, because they weather recessively. Several thicker dolomite units crop out in the southwest corner of the map area, truncated to the north by the unconformity at the base of the Toby Formation.

CORRELATION

Stratigraphic analysis completed around North Star Mountain strongly supports the correlation with the Deer Trail Group, which includes the Magnesite Belt of northeastern Washington (*see* Miller and Whipple, 1989) as first proposed by Glover (1978; Figure 5). The correlations would be: Kitchener argillite (Pk2) with the black and grey, clay and silt couplets of the Togo Formation; the lower Dutch Creek carbonate (Pdc1) with Edna Dolomites; argillite of the Dutch Creek Formation (Pdc2) with McHale Slate; Dutch Creek upper carbonate (Pdc3) with Stensgar Dolomite. Magnesite deposits are associated with the Stensgar Dolomite, and although the magnesite is remobilized, it is considered to be primary and associated with evaporitic facies (F.K. Miller, personal communication, 1994). In the northern part of the Purcell anticlinorium, the Mount Nelson Formation hosts the Brisco magnesite deposit (McCammon, 1965; Root, 1987).

The laminated unit resembles the Van Creek Formation of the eastern Purcell Supergroup as defined by McMechan *et al.* (1980) but, as mapped in the Creston area, it lies higher in the regional stratigraphy, above the Dutch Creek lower carbonate.

The Mount Nelson argillite and quartzite unit (Pmn), as mapped by Rice (1941) and Glover (1978), may correlate with the Buffalo Hump Formation, part of the Deer Trail Group of northeastern Washington. The correlation is based on the unusually coarse, quartz-rich sandstone and stratigraphic position within argillite and above a carbonate unit. Immediately south of the 49th Parallel, quartz-pebble sandstones within argillite west of the Continental Mountain pluton in northern Idaho have recently been included in the Buffalo Hump Formation (F.K. Miller, personal communication, 1994). Farther south, Buffalo Hump quartzite cuts down into the Stensgar Dolomite, implying an unconformity between the two units, perhaps analogous to the unconformity documented by Root (1987) at the base of the Mount Nelson. Late Proterozoic detrital zircon dates (circa 1.1 Ga) from the Buffalo Hump Formation, southeast of Colville (Figure 2), support a post-Purcell (Belt) Supergroup age of deposition (Ross *et al.* 1992). The quartzitic part of the Buffalo Hump Formation maybe the distal equivalent of the Phillips Formation (D. Winston, personal communication, 1994).

UPPER PROTEROZOIC WINDERMERE SUPERGROUP

PEBBLY ARGILLITE UNIT

A pebbly argillite unit, mapped this season, may represent a dropstone unit at the base of the Windermere Supergroup. This pyritic (1 to 5%), dark rusty brown weathering argillite lies above a Mount Nelson Formation carbonate horizon. The laminated argillite is distinguished from those in the Mount Nelson Formation by a marked increase in sulphide content, less penetrative fabric and presence of abundant pebbles. The isolated pebbles are supported in a black silty argillite matrix (Photo 5) and are interpreted to be ice-rafted dropstones. Pebbles of quartzite and dolomite predominate. Clast size and abundance increase up-section and the pebbly argillite apparently grades into polymictic conglomerate of the Toby Formation. The unit is exposed 4 kilometres southwest of the confluence of Summit and Maryland creeks, in more highly strained exposures on Highway 3, and along Placer Creek road at about the 1340-metre elevation. The unit appears to thin to the northeast. The argillite unit warrants careful study and better delineation.

The dropstone unit is tentatively correlated with basal Windermere Supergroup because of the inferred glacial environment at the time of deposition and its possible gradational contact with the Toby Formation.

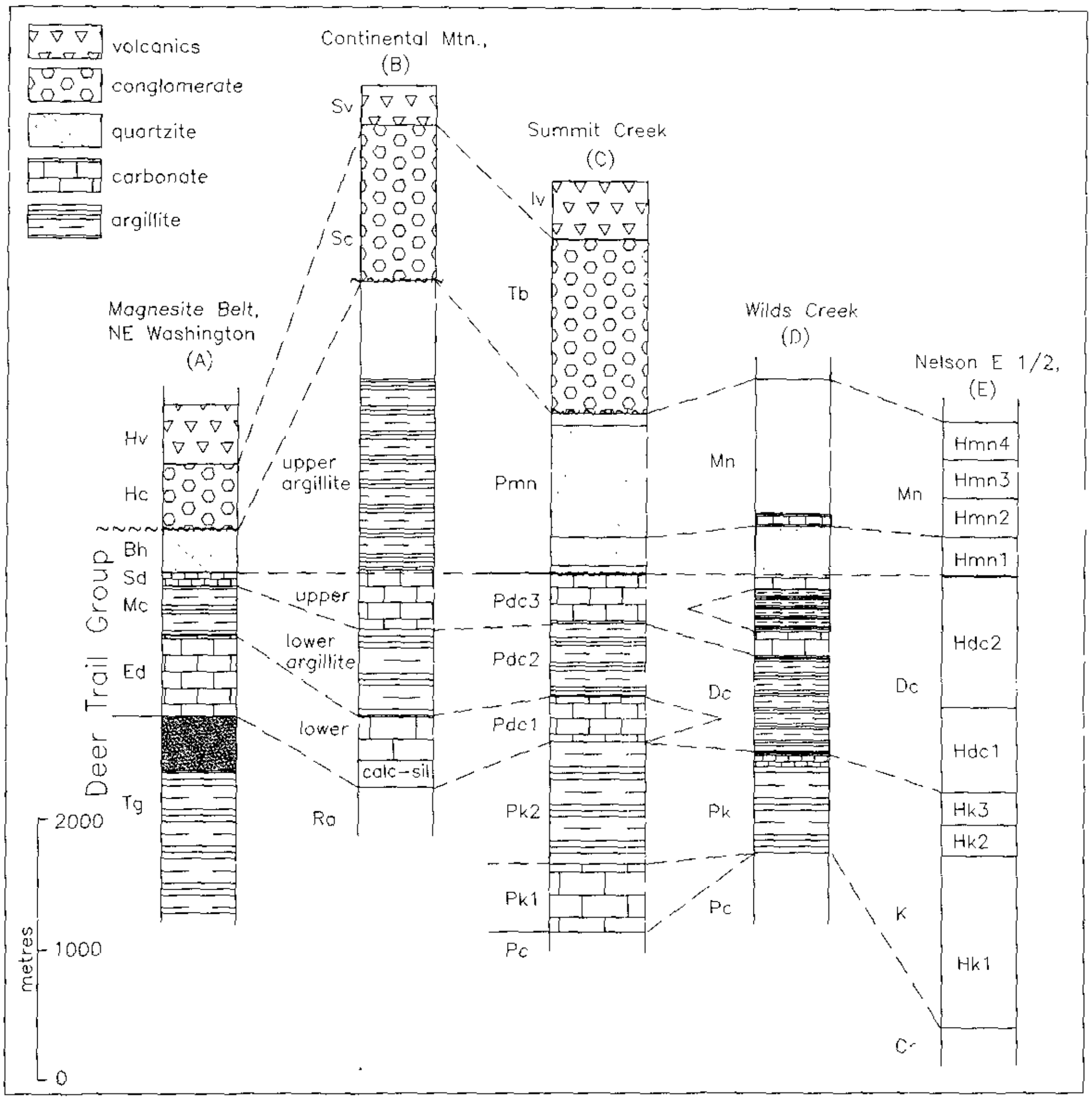

Figure 5. Comparison of schematic stratigraphic columns and potential correlations using the base of the Buffalo Hump Formation and possible correlatives as the datum. Columns A to C are correlated with reasonable confidence, however, comparisons of C to E remain speculative. Column references: (A) Miller and Whipple (1989), (B) Miller (1982; nomenclature has been revised since publication, therefore, it is not included here), (C) Glover (1978) and this report, (D) this report, (E) Reesor (1983). Abbreviations: Bh = Buffalo Hump Formation, Cr = Creston Formation, Dc = Dutch Creek Formation, Mn = Mount Nelson Formation, Ed = Edna Dolomite, Hc = Huckleberry conglomerate, Hv = Huckleberry volcanics, K = Kitchener Formation, Iv = Irene Formation, Mc = McHale Slate, Sc = Shedroof conglomerate, Sd = Stensgar Dolomite, Sc = Shedroof volcanics, Tb = Toby Formation, Tg = Togo Formation.

TOBY FORMATION

The Toby Formation comprises a syn-rift succession (Bennett, 1985) of diverse lithologies, including diamictites, polymictic conglomerate, pelite, carbonate, volcanic rocks, quartz sandstone and phyllite. It reaches a thickness of about 2050 metres along the U.S. border in the Creston map area (Glover, 1978, p. 27), although, it could be as much as 4 kilometres thick based on its map distribution. It thins rapidly to the north and south.

Toby Formation has been studied in detail along the length of the Cordillera by numerous workers and was briefly examined in this mapping project. Variably strained, polymictic conglomerate, pebble greywacke and sandstone dominate well exposed outcrops along Highway 3. Clasts are predominantly light grey to white quartzite and brown-weathering carbonate (mainly dolomite) with subordinate white quartz (vein material?) and phyllitic argillite. White quartzite clasts are up to about 1 metre long, but average between 10 and 20

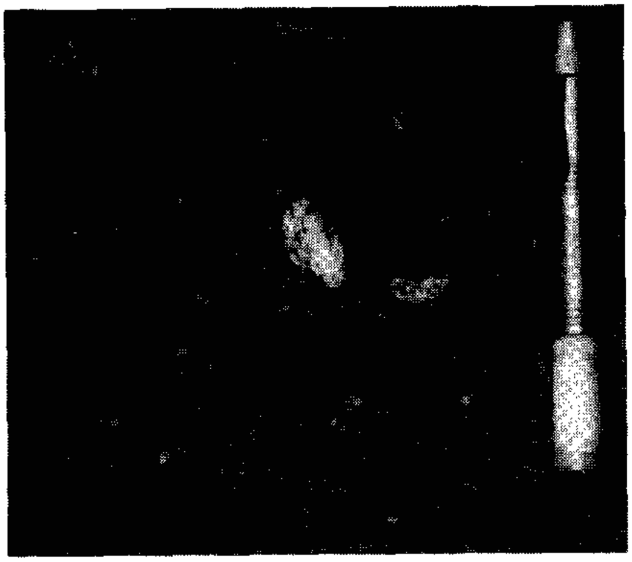

Photo 5. Quartzite pebble (possible dropstone?) in black argillite unit, interpreted to be basal Toby Formation (DBR94-236). Glacial striations are evident on the surface.

centimetres, though most are strongly flattened. Rare, large rounded clasts of granite and granitic gneiss (up to 60 by 60 cm) were observed towards the base of the Toby conglomerate, 10 kilometres south of Highway 3; granitic clasts were also noted west of the headwaters of the Priest River by Daly (1912). Most of the formation is well foliated and clasts are variably flattened (strain analysis was completed by Glover, 1978), but relict bedding is still evident from concentrations of clasts of similar sizes, and by colour differences related to changes in grain size of the matrix. Locally, the conglomerate has been reduced to a chlorite-sericite schist with faint ellipsoidal outlines of completely flattened clasts. These bands of intense deformation are probably shear zones.

Correlation

Daly (1912, p. 142) used the term "Irene Conglomerate Formation", and later Rice (1941) correlated it with the Toby Formation. To the south, the same unit is called the Shedroof conglomerate where it is up to 3250 metres thick in the Continental Mountain map area (Miller, 1982, p. 18). A thin sequence of Shedroof conglomerate and Leola volcanics also lies farther east, in the footwall of the northern extension of the Jumpoff Joe fault, 15 kilometres east of Sullivan Lake, Washington (Stoffel *et al.*, 1991). These conglomerates also correlate with the Huckleberry Formation (conglomerate member) of northeastern Washington.

Paleoenvironment

The depositional setting for the Toby conglomerate remains controversial. The glacial marine origin was proposed by Aalto (1971) and a nonglacial origin was suggested by Reesor (1973). Striated clasts have been reported between Invermere and Panorama which would support the glacial origin (G.M. Ross, personal communication, 1994). A combination of glacial and nonglacial deposition would accommodate the opposing views.

IRENE FORMATION

The Irene Formation comprises mafic volcanic rocks that gradationally overlie the Toby Formation along the western edge of the map area. The submarine tholeiitic flows (Bennett, 1985) locally display well developed pillows. The succession, at least 2000 metres thick, is schematically illustrated in Figure 6. Dark green massive flows and pillow basalt are common, with lesser mafic tuff and tuff breccia. Some of the pillows are unstrained and unaltered with chilled margins, chloritic selvages and minor intrapillow micrite (Photo 6). The closely packed pillows vary in size from 5 centimetres to 2 metres long and range in shape from circular to oblong. Chloritic fracture cleavage and epidote, iron carbonate, albite alteration patches are commonly developed. Subordinate lithic lapilli tuffs with pitted weathered surfaces, contain mafic fragments up to 20 centimetres long. Hyloclastite forms a minor component of the succession. Dolomite and dolomitic siltstone form two prominent units, each less than 20 metres thick, approximately 900 and 1800 metres above the base of the succession, immediately west of Mount Irene (Figure 6). Pale green tuff beds occur within the dolomites.

North of Highway 3, the bottom third of the Irene Formation consists of basaltic fragmental rocks, mainly breccia. Basaltic pebbles and cobbles are supported in a dark matrix with angular lithic fragments. The top two-thirds of the section consists mainly of pillow lava with some breccia and minor hyaloclastite. Several thin, aphanitic mafic sills and dikes were observed throughout the section. These are probably synvolcanic.

Age and Correlation

The Irene Formation correlates with the Leola Volcanics south of the border as described by Miller (1982) and the Huckleberry Formation (greenstone member) in northeast Washington, dated at about 762±44 Ma by the Sm-Nd isochron method (Devlin *et al.*, 1989).

Upper Conglomerate

The top of the Irene Formation is marked by a cobble to boulder conglomerate unit, 100 metres thick, exposed 3 kilometres west of Mount Irene (Photo 7). It can be traced northward from the border to Highway 3, where it crops out 28.3 kilometres west of the Summit Creek bridge, underneath the hydro transmission lines (Daly, 1912, p. 144; Glover, 1978). According to Daly (1912, p. 147) the dolomite clasts are locally oolitic and the largest angular clast measures 2.1 metres by 1.2 metres by 1 metre. Clasts are dominantly dolomite with lesser

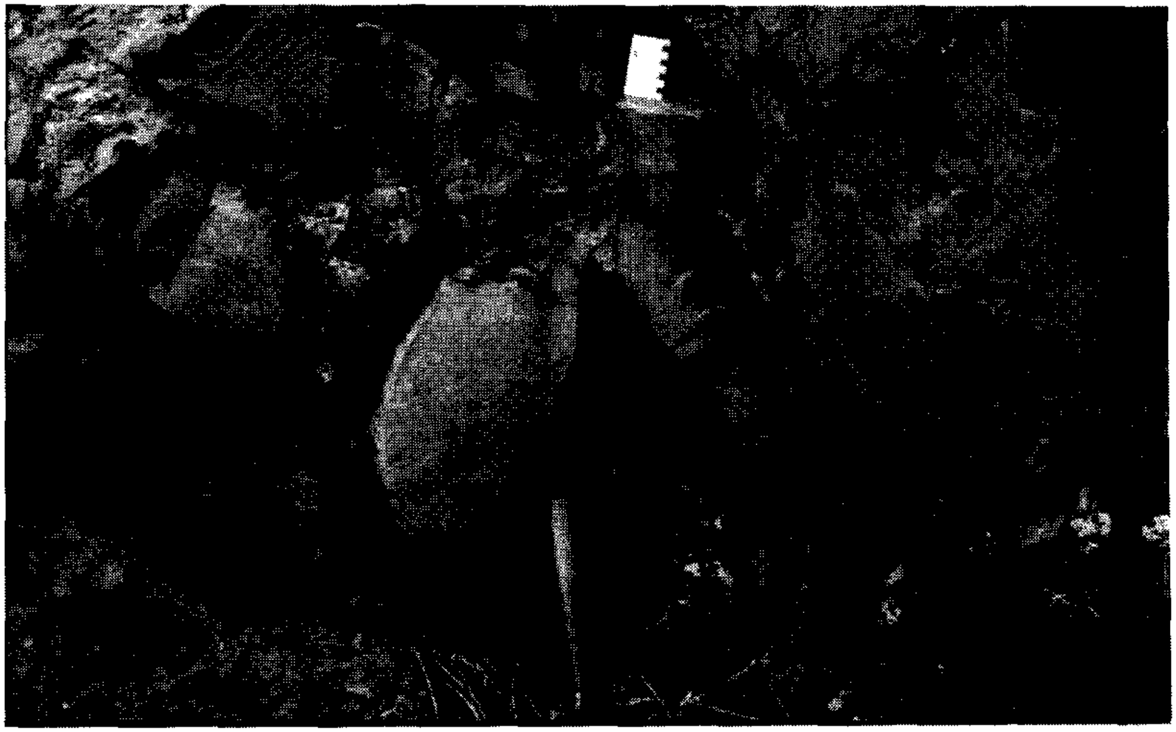

Photo 6. Well developed, unstrained pillow basalts of the Irene Formation (DBR94-564).

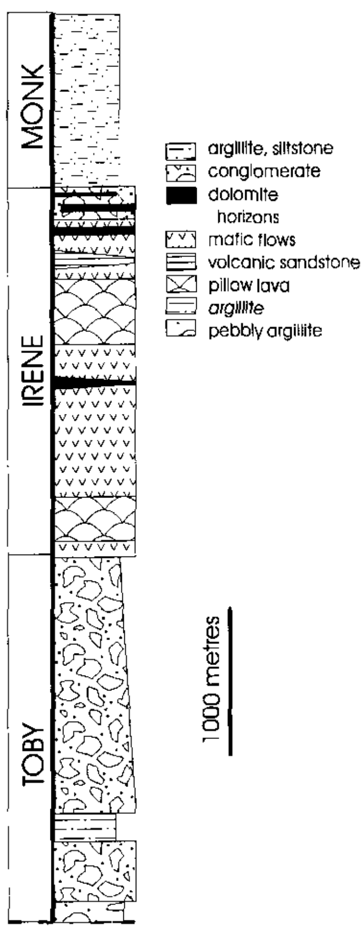

Figure 6. Composite schematic stratigraphic column of the Toby and Irene formations based on exposures along the unnamed ridge west of Mount Irene and near Highway 3.

rounded quartzite and rare brecciated dolomite, supported within a mauve to grey argillaceous matrix. No volcanic clasts were observed. Along Highway 3, the conglomerate unit comprises a 75-metre sequence of green pebbly wacke, pure dolomite, dolomite conglomerate, polymictic conglomerate cut by post-flattening granitic dikes, white limestone and capped with a quartz pebbly conglomerate. The conglomerate is overlain by the Monk Formation.

The provenance of the clasts is assumed to be cannibalistic erosion of the syn-Irene dolomite horizons, however, the apparent lack of any volcanic material, and a source for the quartzite, are problematic. Alternatively, the clasts may be derived from uplifted blocks of Mount Nelson and Dutch Creek strata. Additional study of clast compositions and size variations is required.

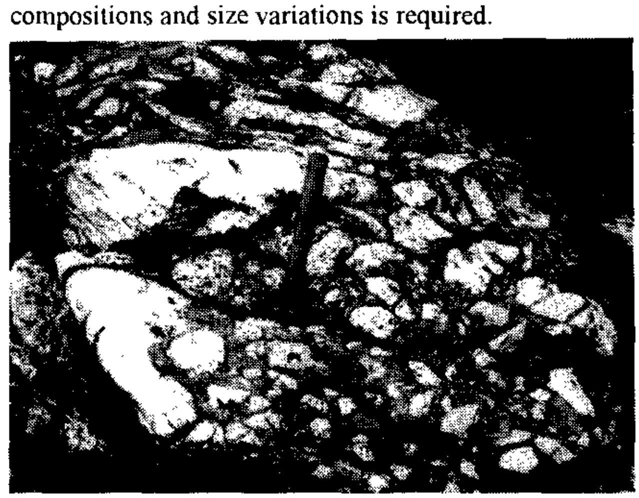

Photo 7. Matrix-supported dolomite conglomerate within the upper part of the Irene Formation (DBR94-561).

MONK FORMATION

The Monk Formation rests conformably on the Irene Formation and was examined briefly between Highway 3 and the southern contact of the Mine stock. Here it consists of fine-grained muscovite schist. Coarser muscovite-biotite schists with andalusite (and/or chloritoid?) porphyroblasts produce a spotted appearance. Towards the top of the observed section are thin-bedded quartz siltstone and sandstone couplets with rare granule-sized quartz grains. This may represent a gradual transition into the overlying grits of the Three Sisters Formation.

INTRUSIVE ROCKS

Proterozoic mafic sills and dikes are common in the middle Aldridge Formation and strata of the upper Purcell Supergroup. Younger plutonic rocks underlie the northwest half and part of the southern edge of the Creston map area. The middle Jurassic and Early Cretaceous plutons in the northwest corner were not examined during this project but have been studied by Archibald *et al.* (1983, 1984).

MOYIE SILLS – AMPHIBOLITE

A few of the dark green to black amphibolite layers discernible at 1:50 000 scale within the metamorphosed middle Aldridge Formation are depicted on Figure 4. The fine to medium-grained amphibole-rich rocks are interpreted to be metamorphosed Moyie sills as suggested by Daly (1912) and others. The amphibolites contain the mineral assemblage hornblende, plagioclase, quartz and staurolite. The amphibolite is commonly dotted with prominent pink garnet porphyroblasts. Due to ductile deformation west of the Creston valley, the sills are not as extensive or continuous as those to the east. East of the valley, thick sills near the town of Creston are cut by a network of quartz and quartz-carbonate veins that parallel and crosscut the chloritic foliation. These sills are continuous and display less ductile deformation.

MAFIC SILLS AND DIKES – NORTH STAR MOUNTAIN AREA

A series of mafic sills and dikes intrude upper Purcell Supergroup strata (Creston to Mount Nelson formations) near North Star Mountain, from the U.S. border northward to Highway 3. The narrow (15 cm to 5 m thick) black to dark green tabular bodies commonly parallel bedding and are therefore called sills, but locally they are discordant dikes. Some sills are magnetite rich and presumably produce the broad, moderate 1:250 000-scale aeromagnetic anomaly over the area. The sills comprise less than 5% of the section. Locally they contain rounded xenoliths of granitic gneiss.

As the mafic sills and dikes were emplaced into strata as young as Mount Nelson Formation, they may represent a magmatic event synchronous with Mount Nelson deposition or, more probably, they are feeders to the volcanic rocks of the Irene Formation.

MIDDLE JURASSIC – CONTINENTAL MOUNTAIN PLUTON

A biotite tonalite pluton is well exposed along the International Boundary cut southwest of Boundary Lake. The massive medium-grained tonalite forms the northern termination of the Continental Mountain pluton of Miller (1982). The tonalite contains ubiquitous epidote and trace hornblende (*ibid.*). Muscovite is common and may be a product of regional metamorphism that has affected the pluton (F.K. Miller, personal communication, 1994).

The age of emplacement of the pluton is interpreted to be at least 168 Ma, based on a titanite date and discordant zircon U-Pb data (J.L. Wooden, personal communication, 1994). The pluton yielded a biotite K-Ar date of 107 Ma (Miller and Engels 1975) and a trondhjemite phase on the east side of Continental Mountain produced biotite and muscovite K-Ar dates of 101 and 96 Ma (*ibid.*). These Cretaceous conventional K-Ar dates are interpreted to be cooling ages.

CRETACEOUS PLUTONS

Cretaceous intrusive rocks can be divided into large plutons (Bayonne batholith) and small sheet-like bodies (Corn Creek and West Creston gneisses). They are apparently coeval but contrast in mineralogy, tectonic fabric and size. The Bayonne batholith produces conspicuous donut-shaped aeromagnetic anomalies probably due to a mafic border phase.

BAYONNE BATHOLITH

The Bayonne batholith comprises at least three distinct plutons, Mount Skelly, Steeple Mountain and Shaw Creek (Daly, 1912, p. 289-296, Rice, 1941; Glover, 1978; Archibald *et al.*, 1983, 1984; Reesor, 1993). A two-mica granite called the Kootenay Landing granite by Barrett (1982) may correlate with part of the Steeple Mountain pluton. A small outlier south of the Mount Skelly pluton, here called the Duck Lake intrusion, was mapped immediately west of the lower reaches of Wilds Creek. This stock, 500 metres wide and 1500 metres long, comprises pale grey to white-weathering, massive, medium-grained hornblende biotite granite. Accessory minerals include trace amounts of honey-coloured titanite. Regional aeromagnetic data show that anomalously high values extend southward from the Bayonne batholith under the entire area, suggesting the Duck Lake intrusion is an offshoot of the Mount Skelly pluton.

The **Shaw Creek pluton** is light grey, massive biotite granite with potassium feldspar phenocrysts up to 2 centimetres long. A biotite-rich (>40% biotite) melanocratic phase of limited extent is locally foliated and contains biotite-rich granitic autoliths. Metasedimentary xenoliths are also exposed along Topaz Creek road. This phase is boudinaged then cut by muscovite-biotite-quartz-feldspar pegmatite.

Contacts of the Duck Lake intrusion are exposed on Highway 3A near Drywash Creek where fine-grained chlorite-biotite hornfels is well developed in meta-arenite and calcsilicate assemblages (epidote-chlorite-tremolite-diopside) of the Mount Nelson Formation. Dikes and sills extend into the host strata and there is no evidence of deformation along the intrusive contacts. This contrasts with the relationship of the Shaw Creek pluton to the west, across the Kootenay valley, where coarse mineral growth and penetrative deformation are evident.

The eastern contact of the Shaw Creek phase consists of rusty brown weathering, coarse-grained biotite-muscovite schist mixed with foliated granite (lit-par-lit gneiss) along the logging road 2.5 kilometres north of the Summit Creek bridge on Highway 3. Pods and lenses of quartz-feldspar-muscovite±biotite are interlayered with paragneiss (semipelite schist). The penetrative foliation dips moderately to the west, parallel to the intrusive contact. However, 200 metres northwest of the contact zone, the fabric is lost and the pluton comprises massive medium-grained, potassium feldspar megacrystic granite. The massive granite has been sampled for U-Pb dating and analyses are in progress. The southern contact of the Shaw Creek pluton is a heterogeneous zone of mixed granite sills and metasedimentary rocks (biotite schist), exposed along Topaz Creek road. In general, granite contacts parallel the phyllosilicate foliation.

PRIEST RIVER COMPLEX

The northern culmination of the Priest River Complex is represented by the Rykert batholith and two isolated gneissic bodies along the southern edge of the Creston map area (Figures 2 and 4).

RYKERT BATHOLITH

The Rykert batholith was named by Daly (1912, p. 284-287) and underlies about 27 square kilometres inside Canada, extending from the Creston valley 15 kilometres to the west. It has been referred to as Kaniksu batholith by Park and Cannon (1943), but it is recommended that this name be dropped because Kanisku Mountain actually lies farther west and is underlain by the Jurassic Continental Mountain pluton.

The light to dark grey weathering, biotite-rich granite is medium grained with coarse-grained layers rich in potassium feldspar megacrysts (some up to 7 cm long and well zoned). It is massive to variably foliated, commonly with dark grey mylonitic layers or gneissic layering. The two-mica granite is heterogeneous with a muscovite to biotite ratio of about 2:5 south of the border (Miller, 1983), although biotite and potassium feldspar contents vary greatly. Hornblende diorite xenoliths are rare. A homogeneous biotite granodiorite with no muscovite or garnet intrudes the two-mica phase of the Rykert batholith, 2.75 kilometres south of Mount Huscroft near Boundary Creek. The northwest edge of the pluton is a thick zone (>100 metres) of gneissic granite. The northeastern part of the batholith produces a strong, rectangular 1:250 000-scale aeromagnetic anomaly that extends to the northwest.

Age and Correlation

Correlative rocks south of the U.S. border include the Rykert granite and Shorty Peak pluton, that include porphyroblastic granitic gneiss (unit "gn"; Miller, 1983). The Newman Lake gneiss, biotite potassium feldspar megacrystic orthogneiss, dated at about 94 Ma (Armstrong *et al.*, 1987; Bickford *et al.*, 1985) may be equivalent to the Rykert batholith.

CORN CREEK GNEISS AND WEST CRESTON GNEISS

Two isolated granite gneiss bodies, the Corn Creek and West Creston, crop out west of the Creston valley and north of the Rykert batholith. The Corn Creek body was first recognized by Rice (1941), and later named the Corn Creek gneiss by Archibald *et al.* (1983). The West Creston gneiss is exposed 6 kilometres to the southwest, in the footwall of the Purcell Trench fault (Figure 4). Both gneisses are characterized by consistent gentle, north-dipping mylonitic foliations containing gently north-plunging stretching lineations. The granite orthogneisses comprise a series of sheet-like bodies (Photo 8) that may be part of a continuous north-dipping

Photo 8. Gneissic granite characteristic of the West Creston gneiss (DBR94-422). Pack for scale.

sheet extending north from Mount Rykert; the Corn Creek and West Creston gneisses and Rykert batholith may be linked at shallow depth below the surface.

Both bodies are pale grey weathering, two-mica granites with prominent gneissic layering. The leucocratic granite contains smoky quartz, garnet, muscovite and biotite. Narrow, lighter grey aplite and pegmatite dikes, layers and pods are abundant, cutting obliquely across the gneissic foliation. Biotite content of gneissic layers ranges from 0 to 25%. The Corn Creek gneiss covers less than 4 square kilometres and consists of at least three sheet-like bodies, exposed along the pipeline access road south of Corn Creek. Semi-concordant coarse-grained pegmatite (garnet, muscovite, potassium feldspar, plagioclase, quartz) layers and pods are isoclinally folded within the granite.

The West Creston gneiss underlies an area of less than 2 square kilometres along the western edge of the Creston valley (Photo 8). Its concordant contacts with the middle Aldridge Formation suggest. like the Corn Creek gneiss, is has a sill-like geometry, except for a band 300 metres wide that extends southward to the Rykert batholith. The northeastern contact zone with Aldridge Formation comprises about 15% pegmatite and abundant white quartz pods and layers. These rocks probably experienced partial melting.

Age and Correlation

Zircon and monazite U-Pb dating is in progress on samples from both gneisses, by Don Davis at the Royal Ontario Museum. A pluton in the Smith Creek area, south of Boundary Creek, correlative with part of the Corn Creek gneiss yielded a Cretaceous U-Pb date (J.L. Wooden, personal communication, 1994). Farther south, the Mount Spokane two-mica granite yielded dates between 72 and 92 Ma (Armstrong *et al.*, 1987) and 94 to 143 Ma (Bickford *et al.*, 1985) and may also correlate with Corn Creek gneiss. Conventional K-Ar techniques yield cooling or uplift dates ranging from 46.7 to 49.6 Ma (Archibald *et al.*, 1984). Similar concordant muscovite and biotite K-Ar dates between 50 and 55 Ma were obtained by Miller and Engels (1975). Correlative rocks south of the border are monzogranite of the Shorty Peak pluton and unit "gn" of Miller (1983).

Lit-par-lit gneiss unit

The border of the West Creston gneiss and Corn Creek gneiss is characterized by a zone of metasedimentary rocks (Aldridge Formation) intruded by a series of granitic sills (Figure 4). Amphibolite sills in the polydeformed areas are metamorphosed equivalents of the gabbro (Moyie) sills. The best exposures underlie the south-facing slope on the north side of Corn Creek. A series of at least five sills, comprising about 20% of the unit, forms prominent light grey weathering layers within the dark grey metasedimentary rocks. The two-mica, potassium feldspar megacrystic granite sills range from 0.5 to 20 metres thick, but average about 3 metres, and thin and thicken rapidly because they are boudinaged. The remainder of the section, meta-semipelites, is amphibolite grade and consists of plagioclase-muscovite-biotite-quartz schist (paragneiss locally). The same unit was mapped as "mixed rock" to the south by Miller (1983). This is the border zone of the Priest River Complex batholithic core. There is no fault at the contact between batholith and cover rocks in this area, in contrast to the southern Priest River Complex.

STRUCTURE

The following discussion of structural features in the Creston map area is divided into geographic areas that grossly correspond to structural domains. In the simplest terms there is an increase in metamorphic grade and intensity of deformation to the west, however, in detail things are more complicated. Penetrative phyllitic fabrics, local tight folding and overturned folds contrast with the broad, upright anticlinoria like the Goat River anticline and lack of fabrics in the Yahk map area (Brown and Stinson, 1995, this volume).

EAST OF PURCELL TRENCH FAULT

The southeast corner of the map area is largely covered by Quaternary deposits in the Creston valley, but isolated knolls expose the westernmost limb of the Goat River anticline and variably foliated middle Aldridge and Moyie sills southeast of the Okell fault (area 1 on Figure 7).

OKELL FAULT

The **Okell fault** is interpreted to be a major north-northwest-dipping, east-directed contractional fault that places middle Aldridge on Creston and upper Aldridge formations in the Yahk map area (*ibid.*). In addition, tight upright folds and pervasive cleavage are developed in wacke of the middle Aldridge Formation in its hangingwall (Photo 9). Folds with similar north-northwest-trending axes persist farther to the northwest. The Okell fault marks the boundary between less deformed, broad folds to the east, from phyllitic to sub-phyllitic tightly folded strata. The fault is presumed to be the southern extension of the Hall Lake/St. Mary fault system (see Reesor, 1981). To the south it is covered by thick Quaternary deposits in the Creston valley.

Farther north, a northeast-striking normal fault is required because of the truncation of a thick Moyie sill, and juxtaposition of middle Aldridge Formation against Creston Formation. This is named the **Wyndel fault**, although, it was not observed in outcrop. Northwest of the fault, the **Wilds Creek area** forms a homoclinal succession from Creston Formation to Mount Nelson Formation. Bedding and penetrative phyllitic chlorite-sericite foliations strike north-northwest and dip steeply

Photo 9. Tight folds with prominent fracture cleavage, 6 kilometres north of Creston along Lakeview road (DBR94-340). Outcrop is about 2 metres wide.

Photo 10. Photomicrograph of the metamorphic assemblage kyanite (ky), staurolite (st), sillimanite (sl), muscovite (mu) and biotite (bi) developed in semipelitic schist of the middle Aldridge Formation, indicating bathozone 4 (PST94-6). Photo is 2.0 millimetres wide.

to the east and locally to the west. The southeast dips and apparent northwest facing direction suggest the stratigraphic succession is overturned. Much of the structural style is controlled by competency contrasts of the different lithologies; tight chevron folds are abundant in the sericitic phyllite unit (see photos in Brown and Klewchuk, 1995, this volume). Folded, white bull quartz veins and pods are abundant in drill core, some form centimetre-scale fish-hook shapes. The mineralized carbonate is phyllitic but the enclosed carbonate breccia displays no tectonic fabric, perhaps due to local flow of the carbonate unit along its contact with other units.

PURCELL TRENCH FAULT

A brittle, high-level fault zone, consisting of lensoidal blocks of middle Aldridge Formation, surrounded by sheared, slickensided surfaces, is exposed 1.75 kilometres south of the Summit Creek bridge along Highway 3. Outcrops to the east are low-grade meta-wacke with fine phyllosilicate minerals defining a weak foliation. To the west, rocks are polydeformed with the assemblage kyanite, sillimanite, staurolite, muscovite, biotite, magnesium-rich chlorite, which indicates metamorphism in bathozone 4 (Figure 8; Tables 1 and 2; Photo 10; sample PST94-6). This is interpreted to be a major fault zone that juxtaposes high and low-grade Aldridge Formation and probably represents a splay of the Purcell Trench fault (Figure 4).

Minor northwest-striking, moderate northeast-dipping normal faults cut the Shaw Creek granite along the Topaz Creek road at about 1300 metres elevation. The granite is fractured across a zone 2 metres wide and is clay altered and limonitic weathering. These faults may also be part of the Purcell Trench system, a major geomorphic feature that extends from Coeur d'Alene, Idaho about 650 kilometres northward to the Rocky Mountain Trench (LeClair, 1982). Much of the lineament corresponds to the trace of a major fault (Rice, 1941; Miller, 1982; LeClair, 1982). Mylonite zones and brittle faults in the Steeple Mountain pluton are also probably part of the Purcell Trench fault system (Barrett, 1982).

WEST OF PURCELL TRENCH FAULT

The region west of the Purcell Trench fault is divided into five areas: the Mount Rykert overturned block, Summit Creek, headwaters of Corn Creek, North Star Mountain, and northern Priest River complex (Figure 7).

MOUNT RYKERT OVERTURNED BLOCK

A huge (kilometre scale), overturned limb of low metamorphic grade Aldridge and Creston formations underlies Mount Rykert west of Creston. This panel is traceable to the Purcell Trench fault on the east and is bounded by another fault on the west. The southern margin is probably a faulted contact with the Rykert pluton. The structure is defined by bedding-cleavage relationships, and inverted stratigraphy based on graded bedding, and Creston and upper Aldridge below middle Aldridge Formation. Additional evidence comes from middle Aldridge Formation marker laminates that are in reverse order in this block (D. Anderson, personal communication, 1995). Isoclinal folds and transposed bedding of argillite in the upper Aldridge Formation may be related to the fold structure. The inverted limb may be part of a family of west-directed structures as discussed by Fillipone and Yin (1994) in the Cabinet Mountains, for example the Snowshoe thrust system. The trace of the bounding fault to the west is poorly defined and it is not possible to say whether the Corn Creek gneiss plugs the fault or rides on it (Figure 4).

SUMMIT CREEK AREA

Polydeformed, amphibolite-grade middle Aldridge strata underlie a wide area along the lower reaches of Summit Creek and near the confluence of Corn and Buckworth creeks. Here, biotite-muscovite schist containing rare kyanite and staurolite has abundant deformed pegmatite pods and layers, and rare amphibolite (metamorphosed Moyie sills). Mesoscopic isoclinal folds with angular to rounded closures have axial planar (S_1) foliation that is refolded by at least one younger deformation, suggesting significant structural thickening in the area. The complex folding and interference patterns require additional mapping to resolve, and this would be difficult because of the lack of marker units other than rare Moyie sills. Multiphase pegmatite emplacement is suggested by different geometries and relationships to hostrocks. Most are concordant to bedding and foliation, some are infolded and boudinaged with the metasedimentary rocks, and some are massive.

The Blazed Creek fault was shown as a steeply dipping, north-striking fault cutting across the Summit Creek area with Creston Formation on the west and Aldridge Formation on the east by Rice (1941). The fault was interpreted by Glover (1978, p. 8) to be the probable southern extension of the St. Mary fault and was considered to be regionally significant, especially after being included on the tectonic assemblage map of the Cordillera (Wheeler and McFeely, 1991). However, our mapping has found no structural or stratigraphical evidence for the fault. Strata previously considered Creston Formation (Rice, 1941) are now thought to be metamorphosed Aldridge Formation. This conclusion is consistent with K-Ar dating which shows no sharp discontinuity in cooling ages across this area (*cf.* Archibald *et al.*, 1984).

The Buckworth fault is indicated by the juxtaposition of Creston Formation against Aldridge Formation north of Highway 3, as originally mapped by Rice (1941). However, Rice interpreted the fault to bend to the southeast at Creston Mountain. We believe that it trends to the southwest, based on the abrupt termination of a regional aeromagnetic anomaly northwest of Mount Rykert.

Intense ductile deformation, including boudinage of metasedimentary rocks, is prominent adjacent to the Shaw Creek pluton, north of Highway 3 (Photo 11).

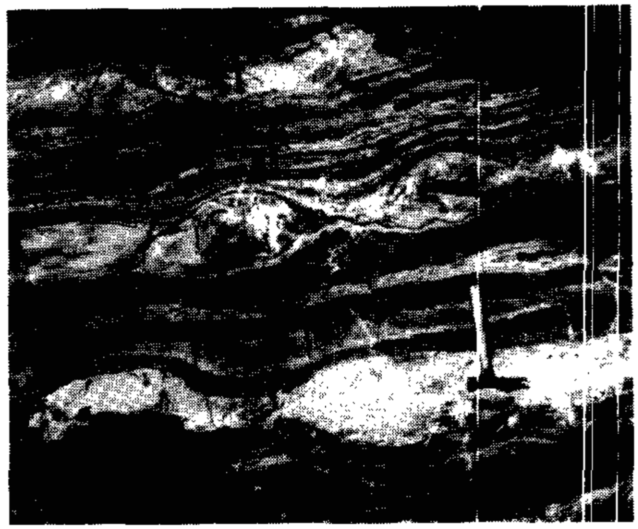

Photo 11. Boudinaged metasedimentary rock layers in high-grade rocks along the southern margin of the Shaw Creek pluton, 2 kilometres south of Mount Midgeley (DBR94-365).

HEADWATERS OF CORN CREEK

An inferred north-trending fault lies immediately west of a series of parallel, north-trending, upright antiform-synform pairs (about 100 m wavelengths) that are developed in the Aldridge Formation at the headwaters of Corn Creek. If the fault is east dipping, then the folds may be in the hangingwall of the west-directed structure. The fault places Aldridge Formation on the overturned upper Purcell stratigraphy in the Maryland Creek/North Star Mountain area

NORTH STAR MOUNTAIN AREA

The North Star Mountain area comprises a homoclinal succession of overturned, steeply east-dipping, upper Purcell and Windermere rocks. The area is characterized by strongly cleaved to phyllitic argillite units with flattened clasts in the Toby Formation conglomerate (Glover, 1978). Fold closures were rarely observed, but centimetre-scale isoclines were noted in sericitic phyllite of the Kitchener argillite unit (Pk2).

NORTHERN PRIEST RIVER COMPLEX

Prominent mylonitic foliations and stretching lineations (L-S tectonites) characterize the northern flanks of the Corn Creek and West Creston gneisses, and Rykert pluton. The foliation planes comprise muscovite and biotite with quartz ribbons that define consistent north-plunging stretching lineations. Sheath folds are exposed in an outcrop along the pipeline near Corn Creek (Photo 12). Axial planes are parallel to the mylonitic foliation and fold axes are collinear to the stretching lineations. The folds occur in a layer of gneiss about 1 metre thick with coarse, potassium feldspar megacrystic granite above and below.

Mylonitic fabrics are also present in the metasedimentary rocks adjacent to the Rykert batholith, but are more difficult to recognize due to their finer grain size and more homogeneous texture when compared to granitic intrusions. This strain is part of the northern termination of the Priest River Complex, an Eocene extensional complex that is well developed to the south.

BRECCIA-MICROBRECCIA ZONES

A series of at least four oriented and aligned, isolated exposures of green to brown-weathering brecciated granite are interpreted to be cataclasite. They trend east and cut the northern margin of the Rykert batholith for a strike length of at least 5 kilometres (Figure 4). The waxy green, altered granite consists of fine to aphanitic chlorite-sericite-clay minerals with anastamosing fractures and as pervasive replacement of the host. The rough-weathering brecciated granite is fractured but remains coherent. Some of the zones have brittle fractures and limonitic staining. The cataclasite is a soft and friable recessive unit only exposed along road cuts. The widest zone is estimated to be about 100 metres across.

The chlorite breccia zones are interpreted to be down-to-the-north, brittle fault zones superimposed on the earlier ductile mylonitic fabrics. These zones are similar to chlorite microbreccia zones documented by Harms and Price (1992) and Rehrig *et al.* (1987), and could be part of the same extension episode.

METAMORPHISM

The distribution of metamorphic rocks and the metamorphic history are complex west of the Purcell Trench. The following preliminary observations are offered to stimulate further studies in the area.

CONTRAST OF METAMORPHIC GRADE ACROSS PURCELL TRENCH FAULT

In general, there is a pronounced increase in metamorphic grade across the Purcell Trench fault at several latitudes in the map area. Along the U.S. border, phyllitic metawacke of the Aldridge Formation is greenschist grade at the Rykerts border crossing, however, 4.5 kilometres to the west, middle Aldridge Formation is in the amphibolite facies (sillimanite, muscovite, biotite) near Boundary Creek. Fifteen kilometres to the north, the same contrast is noted along Highway 3 between the roadcut at Creston and the first outcrop west of the Creston valley. Here, a strand of the Purcell Trench fault juxtaposes sillimanite-kyanite-staurolite-muscovite-bearing semi-pelitic rocks (bathozone 4) against phyllitic semipelites to the east. A comparison of contact metamorphic effects across the northern edge of the map area reveals a similar contrast in metamorphic grade. The Skelly pluton and Duck Lake intrusion have narrow thermal aureoles with fine-grained biotite hornfels on the east side of the Purcell Trench, whereas the Shaw Creek pluton west of the trench has transformed the country rock into coarse-grained biotite schist with lit-par-lit injections extending at least 750 metres from the intrusive contacts.

The psammitic composition of the Aldridge Formation restricts the development of aluminosilicate minerals to relatively few localities. However, a preliminary study completed during the 1994 field season has been able to bracket the conditions of metamorphism and to delineate several regions of contrasting metamorphic grade which correlate with structural

Photo 12. Sheath fold in Corn Creek gneiss, view to south (DBR94-547).

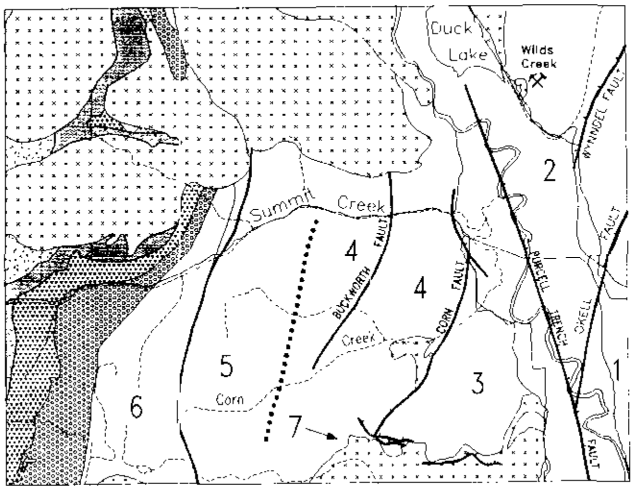

Figure 7. Structural blocks that comprise the Creston map area. These are based on preliminary and broad trends and by no means should they be considered as a rigorous structural analysis. 1 = west limb of the Goat River anticline; 2 = Wilds Creek block; 3 = Mount Rykert overturned block; 4 = Summit Creek; 5 = headwaters of Corn Creek; 6 = North Star Mountain; 7 = northern Priest River complex.

"blocks" already discussed (Figure 7). The area around Mount Rykert and along the western side of the study area is characterized by fine-grained phyllites and schists with small porphyroblasts of muscovite-chlorite (?) and biotite. The protoliths for these metasediments are recognizable as the Aldridge and Creston formations. These rocks appear to have been metamorphosed within the greenschist facies. Along the northern margin of the Rykert batholith, a north-dipping normal fault juxtaposes these low-grade metasedimentary rocks against the batholith.

The highest grade metamorphic rocks occur near granitic bodies such as the Rykert batholith, Corn Creek gneiss, and Bayonne batholith (Figure 4). A high-grade metamorphic domain also extends from the Corn Creek gneiss east to the Purcell Trench where the high-grade rocks have been faulted against low-grade rocks. Thus the changes in metamorphic grade appear to correlate well with the major compressional and extensional faults.

The predominant lithology within the highly metamorphosed metasedimentary rocks is fine-grained (0.25 - 0.75 mm) schists composed of muscovite, biotite, quartz, oligoclase with or without sillimanite and garnet. Garnet forms small (1 mm) idioblastic porphyroblasts. Staurolite forms large poikiloblasts which are intergrown with kyanite. Fine-grained sillimanite, muscovite and biotite define the dominant foliation which wraps around the porphyroblasts. In places, large kyanite porphyroblasts, up to several centimetres long, are embayed against biotite and quartz, but elsewhere, small, well formed crystals of kyanite lie within the foliation and are in contact with sillimanite. Rosettes of magnesium-rich chlorite occur as well. These relationships reveal that the growth of staurolite was within the stability field of kyanite. The textural relationships between kyanite and sillimanite suggest the early growth of kyanite and subsequent growth of both kyanite and sillimanite during creation of the primary foliation. This mineral assemblage is diagnostic of bathozone 4 (Carmichael, 1978).

Somewhat higher grade metamorphic rocks are exposed 2 kilometres northwest of Highway 3 up the Blazed Creek road, near the Mine stock (Figure 4). One pyritic specimen contains coarse-grained sillimanite and microcline, muscovite, biotite, plagioclase (An_{67})- quartz, titanite and tourmaline (Table 1; DBR94-77). The

TABLE 1
METAMORPHIC MINERAL ASSEMBLAGES AND ESTIMATED BATHOZONES
(AFTER CARMICHAEL, 1978)

Map Number	Sample Number	Lithology	Assemblage	Bathozone
1	DBR-94-181	Schist	mu, bi, qt, pl	>2
2	DBR-94-83	Schist	mu, qt, pl?, rt, tr, bi	>2
3	PST-94-11	Schist	mu, bi, pl, qt,sl	2-5
4	DBR-94-77-2	Meta-tourmalinite	sl, ti, tr, pl, ks, mu, bi	2-5
5	PST-94-6	Schist	bi, mu, ky, sl, st, qt, rt, il, ch	4
6	PST-94-62A	Schist	ky, sl, st, pl, qt, bi, ch, rt, il	4
7	DBR-94-169	Amphibolite	bi, hb, pl, qt, gt, ch, ep, il	na

Locations of specimens are shown on Figure 4. Abbreviations: bi = biotite, ch chlorite, ep = epidote, hb = hornblende, il = ilmenite, ks = potassium feldspar, mu = muscovite, na = not available, pl = plagioclase, qt = quartz, rt = rutile, sl = sillimanite, st = staurolite, ti = titanite, tr = tourmaline.

enrichment in boron, reflected by the high concentration of tourmaline, suggests metamorphism of a tourmalinite. The apparent coexistence of sillimanite, microcline and muscovite suggests higher temperatures during metamorphism than during regional metamorphism to the south. Glover (1978) reports relict andalusite with kyanite and sillimanite to the west near the Mine stock, which is compatible with metamorphism within bathozone 3 to 4.

THERMOBAROMETRY

In order to further constrain the conditions of metamorphism across this region, microprobe analyses of co-existing metamorphic minerals from three specimens were completed. All minerals were analyzed with an ARL-SEMQ electron microprobe at Queen's University, using an energy-dispersive spectrometer operating at an accelerating voltage of 15 kilovolts. Each mineral was analyzed for a count-time of 200 seconds. Structural formulae were computed using APL software developed by D.M. Carmichael at Queen's University. Metamorphic temperatures and pressures were calculated using TWEQ software (Berman, 1991), the thermodynamic database of Berman (1990, 1988), and the activity models included with the program. Further details of the analytical procedure can be obtained from the authors upon request.

RESULTS

Selected results of the microprobe analyses are listed in Table 2. Two specimens were collected near Mount Huscroft (Figure 4), and co-existing sillimanite-biotite-muscovite-garnet-oligoclase in one sample and co-existing muscovite-biotite-oligoclase-garnet in the other were analyzed. Because of the low anorthite content of plagioclase, the pressures obtained are interpreted as maximum values. Specimen DBR94-185 yields 5-kilobar pressure and 575°C utilizing the composition of garnet cores. Garnet rim compositions yield slightly lower estimates near 3.9 kilobars and 535°C. Specimen DBR94-183 yields similar pressures and temperatures of metamorphism after adjustment of the partial pressure of water to 0.3.

Quantitative microprobe analyses were attempted on a garnet-bearing amphibolite collected 5 kilometres south of Highway 3 (site M7 on Figure 4). This specimen yielded unrealistic pressures of 9 kilobars and 6 kilobars utilizing garnet core and rim compositions, respectively (Table 2, DBR94-169). The garnet in this specimen appears to have developed preferentially along several quartz-filled fractures and may not be in chemical equilibrium with the plagioclase in the matrix of the amphibolite. An attempt to constrain the conditions of metamorphism east of the Purcell Trench was unsuccessful. The two specimens analysed yielded unrealistic estimates of pressure and temperature.

DISCUSSION

The specimens collected for the microprobe analyses near Mount Huscroft yield metamorphic pressures and temperatures which are compatible with estimates from other specimens using the bathozone scheme; together they suggest metamorphism within bathozone 4 (Figure 8; Carmichael, 1978). Thus both methods indicate peak metamorphism within bathozone 4 across much of the region west of Creston. Archibald *et al.* (1983) reported slightly higher conditions of metamorphism farther to the west-northwest in the Summit Creek area and adjacent to the Mine stock. However, the metamorphism they describe occurred prior to the mid-Cretaceous as reflected by K-Ar cooling dates. The rocks discussed here did not pass through the blocking temperature of argon in mica until between 55 and 47 Ma (Archibald *et al.*, 1984). The similarity in metamorphic grade, however, suggests that metamorphism across this region occurred at approximately the same time (mid-Jurassic) and the difference in mica cooling ages reflects differential uplift and cooling.

LOW GRADE AREA – MOUNT RYKERT OVERTURNED BLOCK

Some areas west of the Creston valley were metamorphosed at relatively low grades (greenschist). For example, black silty mudstone interbedded with siltstone and arenite display well preserved crossbedding,

TABLE 2
MICROPROBE RESULTS FROM SELECTED SPECIMENS FROM THE CRESTON MAP AREA

Map Number	Specimen	Rock type	Assemblage	Kilobars	Degrees (°C)	Comments
P1	DBR94-183	semi-pelite	gt, bi, mu, pl, qt	3.25	525	$aH_2O = 0.3$; gt rim
P2	DBR94-185	semi-pelite	gt, sl, bi, mu, pl, qt	5.00 3.85	575 535	gt core gt rim

Specimen locations are shown on Figure 4. Detailed microprobe data are available from the authors upon request. Abbreviations: bi=biotite, gt=garnet, mu=muscovite, pl= plagioclase, qt=quartz, sl=sillimanite.

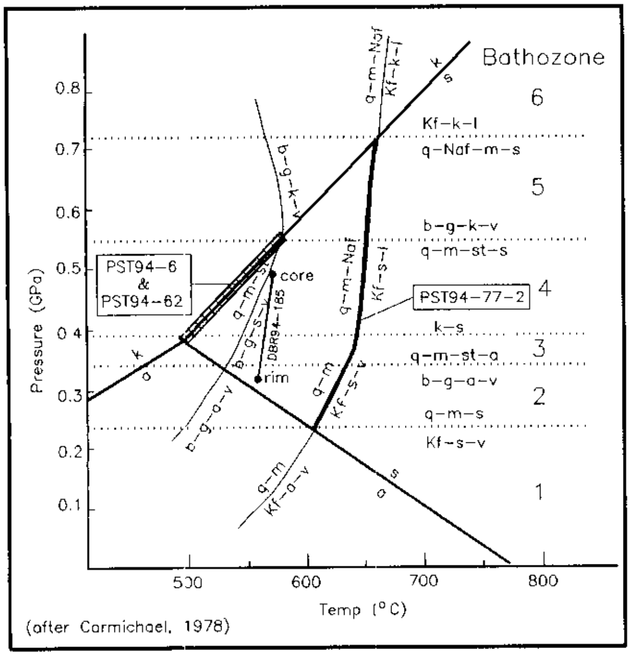

Figure 8. Pressure-temperature grid diagram for selected parts of the Creston map area.

graded beds and wavy bedding in much of the Mount Rykert area. The area is part of an overturned limb of a large, regional-scale fold, where penetrative fabrics and metamorphism are minor.

MINERAL OCCURRENCES AND EXPLORATION POTENTIAL

The Wilds Creek (Leg) stratabound zinc-barite deposit is the most important mineral occurrence in the Creston map area and is described by Brown and Klewchuk (1995, this volume). The Sullivan Two/Dodge property, a Sullivan-type sedex target west of Creston, covers sporadic and small galena-sphalerite-bearing quartz veins, and mudstone layers and mudchip breccia locally replaced by black tourmaline. These features generated exploration attention between 1984 and 1992 (Leask, 1992a, b). An eight-hole 900-metre drilling program was completed in 1990, and an additional 590 metres drilled in 1992 (Eldridge and Leask, 1991; Leask, 1992b). Farther north, the newly discovered meta-tourmalinite occurrence near Blazed Creek is currently mapped within the Kitchener Formation (site M7; Figure 4) and probably merits closer examination.

The regional stream sediment survey completed in 1977 detected several multi-element anomalies in an area underlain by basalt of the Irene Formation in the western part of the map area. An additional 35 stream sediment samples were collected during this mapping program and the results will be included in Open File 1995-15. Nine lithogeochemical grab samples of mineralized and altered lithologies have been submitted for geochemical analyses and the results will be tabulated in Open File 1995-15.

CONCLUSIONS

The area west of Creston is underlain by middle and upper Aldridge Formation and Creston Formation in domains of contrasting metamorphic grade. The Deer Trail Group and the stratigraphic succession around North Star Mountain are strongly correlative. The Dutch Creek dolomite (Pdc3) correlation with the Stensgar Dolomite implies some magnesite potential in the map area, as the Stensgar hosts numerous magnesite deposits in northeastern Washington. Elsewhere, however, correlations are hindered by variable metamorphism and deformation. The Wilds Creek area remains poorly correlated due largely to lack of exposure. In this northeast corner of the Creston map area, the stratabound zinc-lead-barite occurrence (Wilds Creek or Leg deposit) has regional significance. Potentially similar prospects along the western edge of the Purcell anticlinorium, some of which are under active exploration, include Mount Bohan (Hall property), LaFrance Creek (Wall and Dave claims) and past-producer Mineral King mine.

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REFERENCES

Aadland, R.F. and Bennett, E.H. (1979): Geologic Map of the Sandpoint Quadrangle, Idaho and Washington; *Idaho Bureau of Mines and Geology*.

Aalto, K.R. (1971): Glacial Marine Sedimentation and Stratigraphy of the Toby Conglomerate (Upper Proterozoic), Southern British Columbia, Northwestern Idaho and Northeastern Washington; *Canadian Journal of Earth Sciences*, Volume 8, pages 753-787.

Archibald, D.A., Glover, J.K., Price, R.A., Carmichael, D.M. and Farrar, E. (1983) Geochronology and Tectonic

Implications of Magmatism and Metamorphism, Southern Kootenay Arc and Neighbouring Regions, Southeastern British Columbia, Part I: Jurassic to Mid-Cretaceous; *Canadian Journal of Earth Sciences*, Volume 20, pages 1891-1913.

Archibald, D.A., Krogh, T.E., Armstrong, R.L. and Farrar, E. (1984): Geochronology and Tectonic Implications of Magmatism and Metamorphism, Southern Kootenay Arc and Neighbouring Regions, Southeastern British Columbia, Part II: Mid-Cretaceous to Eocene; *Canadian Journal of Earth Sciences*, Volume 21, pages 567-583.

Armstrong, R.L., Parrish, R.R., van der Heyden, P., Reynolds, S.J. and Rehrig, W.A. (1987): Rb-Sr and U-Pb Geochronolometry of the Priest River Metamorphic Complex - Precambrian X Basement and its Mesozoic-Cenozoic Plutonic-Metamorphic Overprint, Northeastern Washington and Northern Idaho; *in* Selected Papers on the Geology of Washington, Schuster, J.E., Editor, *Washington Division of Geology and Earth Resources*, Bulletin 77, pages 15-40.

Barrett, P.B. (1982): Petrology and Structure, Bayonne Batholith, Southern British Columbia; unpublished M.Sc thesis, *University of Montana*, 87 pages.

Bennett, S.M.H. (1985): Tectonics, Sedimentation, and Mineralization on the East Flank of the Purcell Anticlinorium, Southeastern British Columbia; unpublished Ph.D. thesis, Goldsmiths' College, *University of London*, 461 pages.

Berman, R.G. (1988): Internally-consistent Thermodynamic Data for Stoichiometric Minerals in the System Na_2O-K_2O-CaO-MgO-FeO-Fe_2O_3-Al_2O_3-SiO_2-TiO_2-H_2O-CO_2; *Journal of Petrology*, Volume 29, pages 445-522.

Berman, R.G. (1990): Mixing Properties of Ca-Mg-Fe-Mn Garnets; *The American Mineralogist*, Volume 75, pages 328-344.

Berman, R.G. (1991): Thermobarometry Using Multiequilibium Calculations: A New Technique with Petrologic Applications; *Canadian Mineralogist*, Volume 29, pages 833-855.

Bickford, M.E., Rhodes, B.P. and Hyndman, D.W. (1985): Age of Mylonitization in the Southern Priest River Complex, Northern Idaho and Northeastern Washington; *Geological Society of America*, Abstracts with Programs, Volume 17, pages 341-342.

Brown, D.A., and Klewchuk, P. (1995): The Wilds Creek (Leg) Zinc-Lead-Barite Deposit, Southeastern British Columbia: Preliminary Ideas (82F/2); *in* Geological Fieldwork 1994, Grant, B. and Newell, J.M., Editors, *B.C. Ministry of Energy, Mines, and Petroleum Resources*, Paper 1995-1, this volume.

Brown, D.A. and Stinson, P. (1995): Geological Mapping of the Yahk Map Area, Southeastern British Columbia: An Update (82F/1); *in* Geological Fieldwork 1994, Grant, B. and Newell, J.M., Editors, *B.C. Ministry of Energy, Mines, and Petroleum Resources*, Paper 1995-1, this volume.

Burmester, R.F. (1985): Preliminary Geological Map of the Eastport Area, Idaho and Montana; *U.S. Geological Survey*, Open-file Report 85-0517, scale 1:48 000.

Burmester, R.F. and Miller, F.K. (1983): Preliminary Geological Map of the Abercrombie Mountain Area, Pend Oreille County, Washington; *U.S. Geological Survey*, Open-file Report 83-600, scale 1:48 000.

Carmichael, D.M. (1978): Metamorphic Bathozones and Bathograds: A Measure of the Depth of Post-metamorphic Uplift and Erosion on the Regional Scale; *American Journal of Science*, Volume 278., pages 769-797.

Carter, G. and Höy, T. (1987): Geology of the Skookumchuck Map area (W1/2), Southeastern British Columbia; *B.C. Ministry of Energy, Mines and Petroleum Resources*, Open File 1987-8.

Cressman, E.R. (1989): Reconnaissance Stratigraphy of the Prichard Formation (Middle Proterozoic) and the Early Development of the Belt Basin, Washington, Idaho and Montana; *U.S. Geological Survey*, Professional Paper 1490.

Cressman, E.R. and Harrison, J.E. (1986): Geologic Map of the Yaak River Area, Lincoln County, Northwestern Montana; *U.S. Geological Survey*, Miscellaneous Field Studies Map MF-1881, scale 1:48 000.

Daly, R.A. (1912): Geology of North American Cordillera at the Forty-ninth Parallel; *Geological Survey of Canada*, Memoir 38, Part 1.

Devlin, W.J., Bruekner, H.K. and Bond, G.C. (1989): New Isotopic Data and a Preliminary Age for Volcanics near the Base of the Windermere Supergroup, Northeastern Washington, U.S.A.; *Canadian Journal of Earth Sciences*, Volume 25, pages 1906-1911.

Eldridge, T.L. and Leask, G.P (1991): Report on the Sullivan Two Property; *B.C. Ministry of Energy, Mines and Petroleum Resources*, Assessment Report 21589.

Fillipone, J. A. and Yin, A. (1994): Age and Regional Tectonic Implications of Late Cretaceous Thrusting and Eocene Extension, Cabinet Mountains, Northwest Montana and Northern Idaho; *Geological Society of America*, Bulletin, Volume 106, pages 1017-1032.

Glover, J.K. (1978): Geology of the Summit Creek Area, Southern Kootenay Arc, British Columbia; unpublished Ph.D. thesis, *Queen's University*, 144 pages.

Griggs, A.B. (1973): Geological Map of the Spokane Quadrangle, Washington, Idaho, and Montana; *U.S. Geological Survey*, Map I-768, scale 1: 250 000.

Harms, T.A. and Price, R.A. (1992): The Newport Fault: Eocene Listric Normal Faulting, Mylonitization, and Crustal Extension in Northeast Washington and Northern Idaho; *Geological Society of America*, Bulletin, Volume 104, pages 745-761.

Harrison, J.E. and Cressman, E.R. (1993): Geology of the Libby Thrust Belt of Northwestern Montana and its Implications to Regional Tectonics; *U.S. Geological Survey*, Professional Paper 1524.

Harrison, J.E., Cressman, E.R. and Whipple, J.W. (1992): Geologic and Structure Maps of the Kalispell 1° x 2° Quadrangle, Montana, and Alberta and British Columbia; *U.S. Geological Survey*, Miscellaneous Investigations Series, Map I-2267.

Harrison, J.E., Griggs, A.B. and Wells, J.D. (1986): Geologic and Structure Maps of the Wallace 1° x 2° Quadrangle, Montana and Idaho; *U.S. Geological Survey*, Miscellaneous Investigations Series, Map I-1509-A.

Höy, T. (1979): Geology of the Estella - Kootenay King Area, Hughes Ranges, Southeastern British Columbia; *B.C. Ministry of Energy, Mines and Petroleum Resources*, Preliminary Map 36.

Höy, T. (1984): Structural Setting, Mineral Deposits and Associated Alteration and Magmatism, Sullivan Camp, Southeastern British Columbia; *in* Geological Fieldwork 1983, *B.C. Ministry of Energy, Mines and Petroleum Resources*, Paper 1984-1, pages 24-35.

Höy, T. (1993): Geology of the Purcell Supergroup in the Fernie West-half Map Area, Southeastern British Columbia; *B.C. Ministry of Energy, Mines and Petroleum Resources*, Bulletin 84.

Höy, T. and Carter, G.(1988): Geology of the Fernie West-half Map Sheet (and part of Nelson East-half); *B.C. Ministry of Energy, Mines and Petroleum Resources*, Open File 1988-14.

Höy, T. and Diakow L. (1982): Geology of the Moyie Lake Area; *B.C. Ministry of Energy, Mines and Petroleum Resources*, Preliminary Map 49.

Höy, T., Price, R.A., Grant, B., Legun, A. and Brown, D.A. (1995): Purcell Supergroup, Southeastern British Columbia, Geological Compilation Map (NTS 82G, 82F/E, 82J/SW, 82K/SE); *B.C. Ministry of Energy, Mines and Petroleum Resources*, Geoscience Map 1995-1.

Leask, G.P (1992a): Report on the Sullivan Two Property; *B.C. Ministry of Energy, Mines and Petroleum Resources*, Assessment Report 22344.

Leask, G.P (1992b): Report on the Sullivan Two/Dodge Property; *B.C. Ministry of Energy, Mines and Petroleum Resources*, Assessment Report 22523.

Leclair, A.D. (1982): Preliminary Results on the Stratigraphic, Structural and Metamorphism of Central Kootenay Arc Rocks, Southeastern British Columbia; *in* Current Research, Part A, *Geological Survey of Canada*, Paper 82-1A, pages 45-49.

Leclair, A.D. (1983): Stratigraphic and Structural Implications of Central Kootenay Arc Rocks, Southeastern British Columbia; *in* Current Research, Part A, *Geological Survey of Canada*, Paper 83-1A, pages 235-240.

Leech, G.B. (1957): St. Mary Lake, Kootenay District, British Columbia (82F/9); *Geological Survey of Canada*, Map 15-1957.

Leech, G.B. (1958): Fernie Map Area, West Half, British Columbia, 82G W1/2; *Geological Survey of Canada*, Paper 58-10.

Leech, G.B. (1960): Geology Fernie (West Half), Kootenay District, British Columbia; *Geological Survey of Canada*, Map 11-1960.

McCammon, J.W (1965): The Brisco Magnesite Area, British Columbia; *in* Minister of Mines Annual Report 1964, *B.C. Ministry of Energy, Mines and Petroleum Resources*, pages 194-199.

McMechan, M.E. (1979): Geology of the Mount Fisher - Sand Creek Area; *B.C. Ministry of Energy, Mines and Petroleum Resources*, Preliminary Map 34.

McMechan, M.E., Hoy, T. and Price, R.A. (1980): Van Creek and Nicol Creek Formations (new); A Revision of the Stratigraphic Nomenclature of the Middle Proterozoic Purcell Supergroup, Southeastern British Columbia; *Bulletin of Canadian Petroleum Geology*, Volume 28, pages 542-558.

Miller, F.K. (1982): Preliminary Geologic Map of the Continental Mountain Area, Idaho; *U.S. Geological Survey*, Open-File Report 82-1062.

Miller, F.K. (1983): Preliminary Geologic Map of the Smith Peak Area, Bonner and Boundary Counties, Idaho; *U.S. Geological Survey*, Open-File Report 83-602.

Miller, F.K. (in preparation): Geologic Map of Sandpoint 2° Quadrangle; *U. S. Geological Survey*.

Miller, F.K. and Engels, J.C. (1975): Distribution and Trends of Discordant Ages of the Plutonic Rocks of Northeastern Washington; *Geological Society of America*, Bulletin, Volume 86, pages 517-528.

Miller, F.K. and Whipple, J.W. (1989): The Deer Trail Group: Is it Part of the Belt Supergroup?; *in* Geologic Guidebook for Washington and Adjacent Areas, Joseph, N.L. *et al.*, Editors, *Washington Division of Geology and Earth Resources*, Information Circular 86.

Nevin, A.E. (1966): Geology of the Paragneiss on the East Flank of the Kaniksu Batholith, Boundary County, Idaho; unpublished Ph.D thesis, *University of Idaho*, 60 pages.

Park, C.F. Jr. and Cannon, R.S. Jr. (1943): Geology and Ore Deposits of the Metaline Quadrangle, Washington; *U.S. Geological Survey*, Professional Paper 202, 81 pages.

Pope, A.J. (1989): The Tectonics and Mineralisation of the Toby - Horsethief Creek Area, Purcell Mountains, Southeast British Columbia, Canada; unpublished Ph.D. thesis, *Royal Holloway and Bedford New College, University of London*, 350 pages.

Reesor, J.E. (1958): Geology of the Lardeau Map-area, East-half, British Columbia; *Geological Survey of Canada*, Memoir 369.

Reesor, J.E. (1973): Dewar Creek Map-area with special emphasis on the White Creek Batholith, British Columbia; *Geological Survey of Canada*, Memoir 292.

Reesor, J.E. (1981): Grassy Mountain, Kootenay Land District, British Columbia (82F/8); *Geological Survey of Canada*, Open File 820.

Reesor, J.E. (1983): Geology of the Nelson Map-area, East Half; *Geological Survey of Canada*, Open File 929.

Reesor, J.E. (1993): Geology, Nelson (East Half; 82F/1,2,7-10,15,11); *Geological Survey of Canada*, Open File 2721.

Rehrig, W.A., Reynolds, S.J. and Armstrong, R.L. (1987): A Tectonic and Geochronologic Overview of the Priest River Crystalline Complex, Northeastern Washington and Northern Idaho; *in* Selected Papers on the Geology of Washington, Schuster, J.E., Editor, *Washington Division of Geology and Earth Resources*, Bulletin 77, pages 1-14.

Rice, H.M.A. (1941): Nelson Map Area, East Half; *Geological Survey of Canada*, Memoir 228.

Rhodes, B.P. (1986): Metamorphism of the Spokane Dome Mylonitic Zone, Priest River Complex Constraints on the Tectonic Evolution of Northeastern Washington and Northern Idaho; *Journal of Geology*, Volume 94, pages 539-556.

Rhodes, B.P. and Hyndman, D.W. (1984): Kinematics of Mylonites in the Priest River "Metamorphic Core Complex", Northern Idaho and Northeastern Washington, *Canadian Journal of Earth Sciences*; Volume 21, pages 1161-1170.

Root, K.G. (1987): Geology of the Delphine Creek Area, Southeastern British Columbia: Implications for the Proterozoic and Paleozoic Development of the Cordilleran Divergent Margin; unpublished Ph.D. thesis, *University of Calgary*, 446 pages.

Ross, G.M., Bloch, J.D. and Krouse, H.R. (in preparation): Neoproterozoic Strata of the Southern Canadian Cordillera and Isotopic Evolution of Seawater Sulfate.

Ross, G.M., Parrish, R.R. and Winston, D. (1992): Provenance and U-Pb Geochronology of the Mesoproterozoic Belt Supergroup (Northwest United States): Implications for Age of Deposition and pre-Panthalassia Plate Reconstructions; *Earth and Planetary Science Letters*, Volume 113, pages 57-76.

Stoffel, K.L., Joseph, N.L., Zurenko Waggoner, S., Gulick, C.W., Korosec, M.A. and Bunning B.B. (1991): Geologic Map of Washington -- Northeast Quadrant; *Washington Division of Geology and Earth Resources*, Geological Map GM-39.

Walker, J.F. (1926): Geology and Mineral Occurrences of Windermere Map-area, British Columbia; *Geological Survey of Canada*, Memoir 148, 69 pages.

Wheeler, J.O. and McFeely, P. (1991): Tectonic Assemblage Map of the Canadian Cordillera and adjacent parts of the United States; *Geological Survey of Canada*, Map 1721A.

NOTES