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MINERAL RESOURCES DIVISION
Geological Survey Branch

GEOLOGY OF THE PURCELL SUPERGROUP IN THE FERNIE WEST-HALF MAP AREA, SOUTHEASTERN BRITISH COLUMBIA

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SUMMARY

The Fernie west-half map area is underlain by Middle Proterozoic Purcell Supergroup, Late Proterozoic Windermere and Paleozoic miogeoclinal rocks. The Purcell Supergroup, the main focus of this study, has been affected by tectonic events in Middle and Late Proterozoic, Early Paleozoic and Mesozoic time.

The Purcell Supergroup comprises a thick accumulation of clastic and carbonate rocks that are interpreted to have been deposited in a large intracratonic basin. The northeastern margin of the basin is exposed in the northern part of the Fernie west-half sheet. It developed by growth faulting and is characterized by rapid and pronounced facies and thickness changes, in contrast with more subtle changes that occur elsewhere in the basin.

Moyie sills form an extensive suite of basaltic rocks that intruded the Aldridge and Fort Steele formations, the lower part of the Purcell Supergroup. Many of these sills were intruded at very shallow depths in unconsolidated, water-saturated sediments. Hence a Middle Proterozoic date of 1445 Ma from one of the sills defines the minimum age of deposition of lower and basal middle Aldridge, and of stratiform mineral deposits such as the Sullivan orebody.

Sullivan, a massive sulphide lead-zinc-silver deposit in Aldridge Formation turbidites, is the largest mineral deposit in the area. It has produced in excess of 125 million tonnes of ore from an original deposit of about 160 million tonnes. Other deposits in the Purcell Supergroup include lead-zinc replacement deposits in Upper Purcell carbonates and numerous lead-zinc-silver and copper veins.

This report describes in detail the stratigraphy, depositional environment and tectonic setting of the Purcell Supergroup (Chapter 2). Chapter 3 describes the Moyie sills and presents evidence that they record a magmatic event during deposition of the host Aldridge and Fort Steele formations. Granitic rocks are described in Chapter 4, and the structure and tectonic history of the area, in Chapter 5. Mineral deposits are classified and described in Chapter 6 and the controls of mineral deposition, including both the synsedimentary tectonic setting and later tectonic events, are outlined.

CHAPTER 1: INTRODUCTION

LOCATION, TOPOGRAPHY AND ACCESS

The Fernie west-half map area straddles the southern Rocky Mountain Trench, with the Purcell Mountains on the west and the Kootenay Ranges of the Rocky Mountains on the east (Figure 1). The Rocky Mountain Trench is a broad, northwesterly trending valley 1500 kilometres long. In its southern part it contains the southward-flowing Kootenay River and is floored by a thick accumulation of Quaternary and Recent sand and gravel deposits. It trends northwestward in the southern part of the Fernie map area, and begins to swing northward near latitude 49°45′N. The eastern edge of the trench follows the locus of a large west-dipping normal fault, referred to as the Rocky Mountain Trench fault.

The Purcell Mountains extend westward from the Rocky Mountain Trench to Kootenay Lake. The topography of the eastern side of the Purcell Mountains, within the Fernie west-half map area, is somewhat subdued, with only a few peaks above 2300 metres in elevation. The Kootenay Ranges east of the trench include the northern Hughes Range north of the Wild Horse River, the southern Hughes Range between the Wild Horse and Bull rivers and the Galton Range to the south. Relief in the Kootenay Ranges is great, with the Steeples in the southern Hughes Range rising abruptly from an elevation of approximately 800 metres near the floor of the trench to greater than 2800 metres.

Access throughout the area is excellent with Highway 3/93 following the Moyie River northeastward to Cranbrook and then south in the Rocky Mountain Trench to Jaffray and Fernie, and Highways 93 and 93a continuing north from Cranbrook in the trench or through Kimberley, respectively. Well-maintained gravel roads or logging roads are present in most valleys.

GEOLOGICAL WORK

Exploration, discovery and mining of lead-zinc-silver deposits, including the North Star and St. Eugene, date back to the 1890s. The largest deposit in the area, the Sullivan

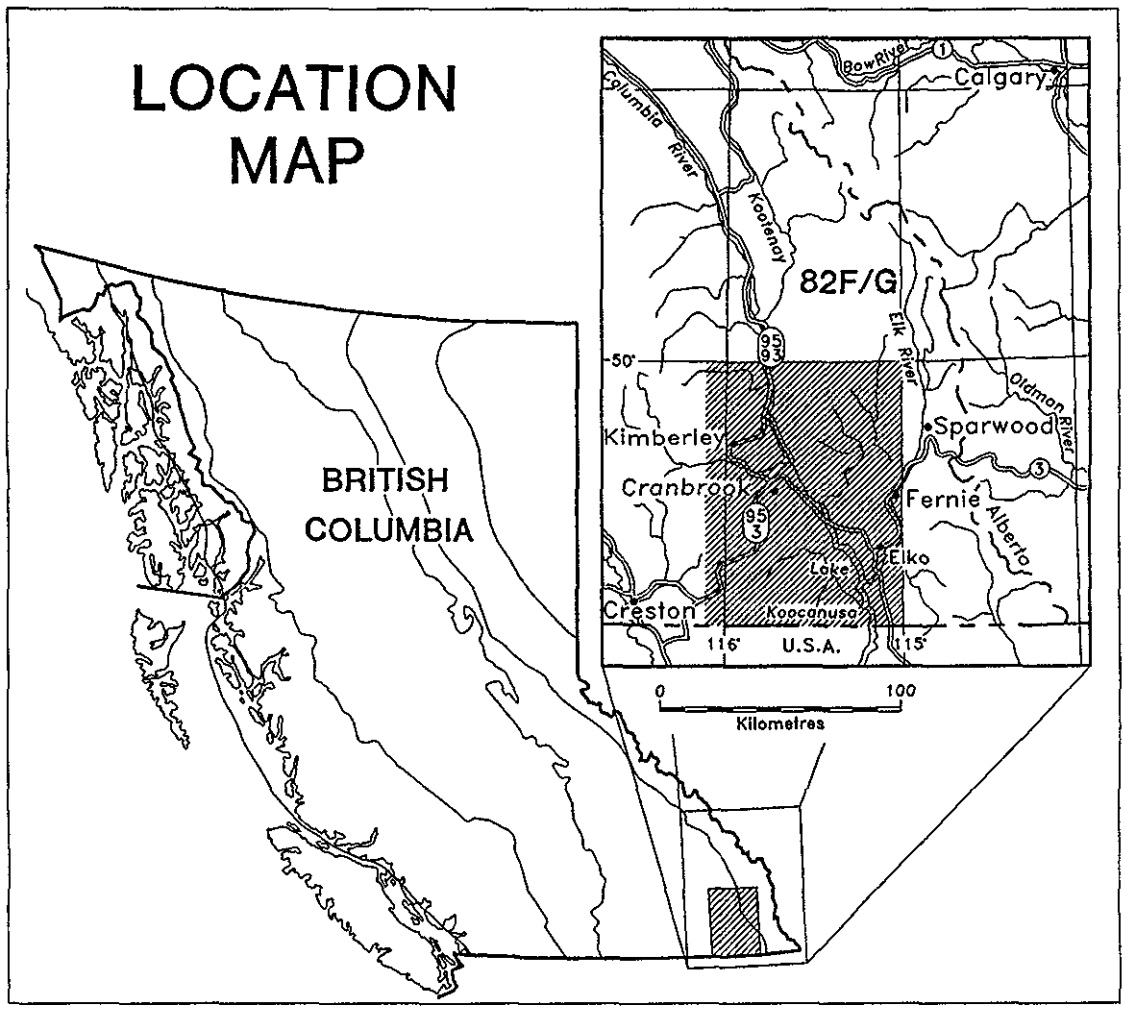

Figure 1. Location map outlining the Fernie west-half map area (Figure 2).

orebody, has produced intermittently since 1903 (Hamilton *et al.,* 1982), and contributed approximately one third of British Columbia's metallic mineral wealth in the period 1909 to 1986.

The first reconnaissance geological mapping in the area was by Bauerman (1884) followed by Daly (1912). Schofield (1915) and Rice (1937) mapped part of the Cranbrook sheet, and Leech published the complete geology of the Fernie west-half sheet in 1960. Theses by G. Benvenuto and M.E. McMechan of Queens University concentrated on the structure and stratigraphy of rocks east of the Rocky Mountain Trench (Benvenuto, 1978; McMechan, 1980).

Work by the author began in 1977, with mapping in the northern Hughes Range east of the trench (Höy, 1979). Subsequently, the Moyie Lake (Höy and Diakow, 1982), Cranbrook – Sullivan mine (Höy, 1984c) and Skookumchuck (Carter and Höy, 1987a) map areas were released at 1:50 000 scale. The geology of the Fernie west-half map area was compiled by Ginette Carter and released as a 1:100 000 open file map (Höy and Carter, 1988), (Figure 2, in pocket, map and cross sections).

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CHAPTER 2: THE PURCELL SUPERGROUP

INTRODUCTION

The Fernie west-half map area is divided by the Rocky Mountain Trench, a wide, generally north-northwesterly trending valley that separates the Purcell Mountains on the west from the Hughes, Lizard and Galton ranges, the most western of the Rocky Mountain Ranges, on the east (Figure 1). The Purcell Mountains and the western ranges of the Rocky Mountains are underlain by the Middle Proterozoic Purcell Supergroup, the Late Proterozoic Windermere Group and Paleozoic miogeoclinal rocks. North of the St. Mary fault and in the northern Hughes Range, Windermere Group rocks unconformably overlie Purcell rocks. Between the St. Mary and Moyie faults and north of the Dibble Creek fault, Purcell rocks are overlain by Cambrian rocks, whereas south of the Moyie fault they are overlain by Devonian carbonate rocks (Figure 3). As the main focus of this study is the Purcell Supergroup, it will be described in considerable detail whereas Windermere and Paleozoic sedimentary rocks are described only briefly.

Purcell Supergroup rocks and correlative Belt Supergroup rocks in the United States comprise a thick sequence of predominantly clastic and carbonate rocks of Middle Proterozoic age (Price, 1964; Harrison, 1972). The base of the Purcell Supergroup is not exposed in Canada. It is inferred to rest unconformably on basement gneiss that in the Alberta foothills and in Montana has been dated at 1700 to 1900 Ma (Burwash *et al.*, 1962; Obradovich and Peterman, 1968) and is unconformably overlain by the Late Proterozoic Windermere Group or by Cambrian clastic or carbonate rocks (Table 1).

TABLE 1
TABLE OF FORMATIONS

CORRELATION CHART

		NELSON E1/2	FERNIE W1/2	IDAHO, MONTANA	
PALEO-ZOIC		HAMILL	CRANBROOK		
LATE PROT.	WINDER-MERE	HORSETHIEF CREEK			
		TOBY			
MIDDLE PROTEROZOIC	PURCELL	MT. NELSON		GARNET RANGE	
			ROOSVILLE	McNAMARA	MISSOULA
			PHILLIPS	BONNER	
		DUTCH CREEK	GATEWAY	MT. SHIELDS	
			SHEPPARD	SHEPPARD	
		SIYEH	NICOL CREEK	PURCELL LAVA	WALLACE
			VAN CREEK	SNOWSLIP	
		KITCHENER	KITCHENER	HELENA EMPIRE	
		CRESTON	CRESTON	ST. REGIS REVETT BURKE	RAVALLI
		ALDRIDGE	ALDRIDGE	PRICHARD	
		MOYIE SILLS	FORT STEELE		

Geochronological studies (Hunt, 1962; Obradovich, 1973; Obradovich and Peterman, 1968; Zartman *et al.*, 1982) suggest Belt-Purcell sedimentation occurred between approximately 1500 Ma and 900 Ma. An age of approximately 1440 Ma for early (Aldridge) sedimentation is supported by a potassium-argon date of 1436 Ma for biotite adjacent to a sill at the Sullivan mine (LeCouteur, 1979) and a uranium-lead age of 1433 Ma for the Crossport C sill that intrudes rocks correlative with the Aldridge Formation in Idaho (Zartman *et al., op. cit.*). Potassium-argon dates of Moyie sills (Chapter 3) range from 523 to 1918 Ma. Young dates may reflect metamorphic resetting and the older dates, probably excess argon. A 1445 Ma uranium-lead date from zircon in a Moyie sill (Chapter 3) is believed to indicate the age of deposition of host lower middle Aldridge rocks in the Purcell Mountains.

Magnetostratigraphic data (Elston and Bressler, 1980; Elston, 1983) suggest, however, that the entire Belt-Purcell Supergroup was deposited between approximately 1500 Ma and 1200 Ma. On the basis of a review of geochronological data, McMechan and Price (1982a) support termination of Belt-Purcell sedimentation during the East Kootenay orogeny at 1300 to 1350 Ma.

Purcell Supergroup rocks in Fernie west-half are exposed in the Purcell Mountains and the Hughes, Lizard and Galton ranges east of the trench. Throughout the Purcell Mountains, formations are generally thick, contacts between them are gradational, and lateral facies or thickness changes are gradual. However, in the northern Hughes Range the lower part of the Purcell Supergroup is markedly different, with predominantly fluvial, alluvial fan and deltaic deposits at the base, overlain by a relatively thin and heterogeneous Aldridge succession. Facies and thickness changes within the Aldridge Formation are pronounced here indicating influence of syndepositional faults or growth faults. A thick succession of turbidites, interlayered with gabbroic sills, was deposited to the south and west. The transition between these contrasting facies marks the edge of the Purcell basin in early Purcell time. The tectonic disturbance recorded in these rocks continued intermittently near the basin edge during deposition of younger, generally shallow-water sediments.

FORT STEELE FORMATION

The Fort Steele Formation is exposed along the western slopes of the Hughes Range and in scattered outcrops on the floor of the Rocky Mountain Trench to the west (Figure 4). The total thickness of the exposed section is in excess of 2000 metres; the base is not exposed.

DESCRIPTION

The Fort Steele Formation comprises predominantly crossbedded and massive quartz arenite, quartz and feld-

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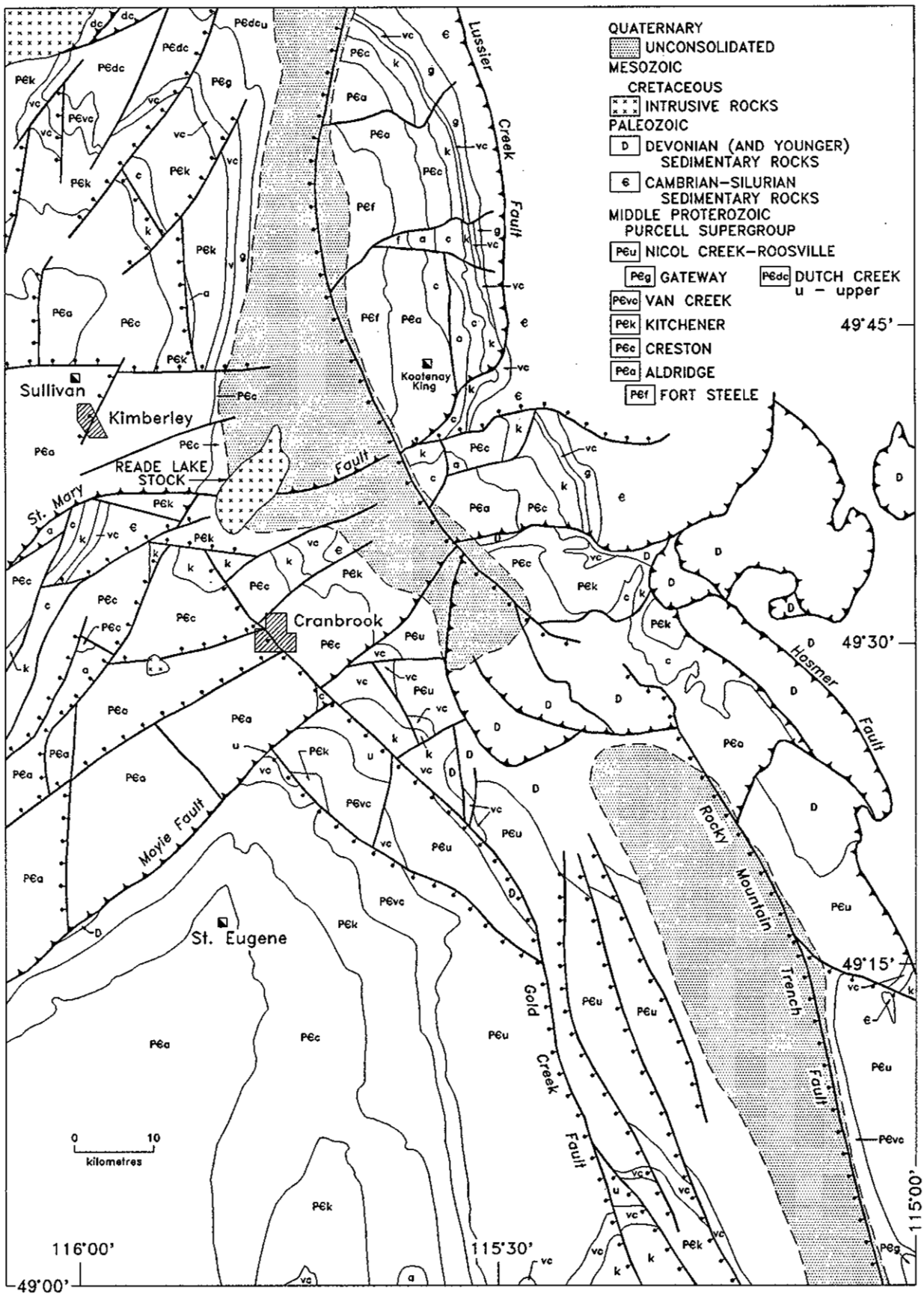


Figure 3. Simplified geological map of the Fernie west-half map area (82G W½).

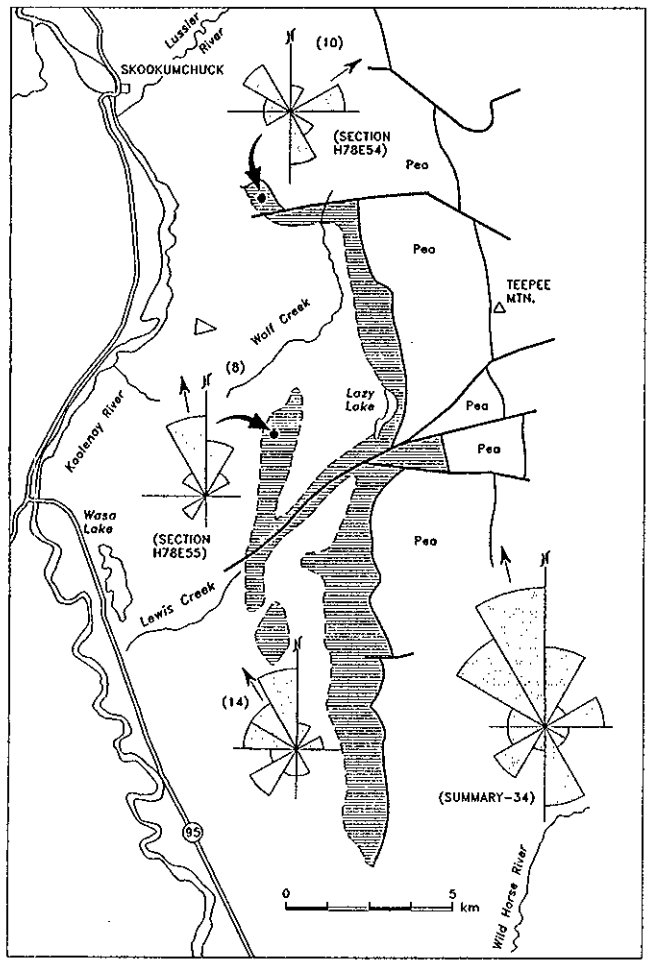


Figure 4. Distribution of the Fort Steele Formation, northern Hughes Range, showing paleocurrent data in three locations. The summary of all paleocurrent measurements is illustrated in the rose diagram on lower right of diagram.

spathic wacke and siltstone, interpreted to be primarily deposits of a braided fluvial system. The formation is characterized by thick sections of massive and crossbedded quartz arenite and a number of large fining-upward cycles, termed megacycles, that are several hundred metres thick. Fine-grained siltstone and argillite facies are not abundant, comprising less than 10 per cent of the total exposed succession. These are interpreted to be alluvial fan and fan-delta deposits.

The megacycles are made up of many smaller fining-upward cycles commonly 10 to 20 metres thick. An idealized cycle is illustrated on Figure 5. Thick-bedded medium to coarse-grained massive quartz arenites (orthoquartzite) form discontinuous beds up to a metre thick at the base of a cycle. Trough crossbedded arenites commonly overlie or are interbedded with the massive arenites (Plate 1). Up-section within the middle member of an ideal cycle, quartzites are more feldspathic and commonly more persistant laterally, and sedimentary structures are smaller. Trough and planar crossbedded quartz wackes and arenites (Plate 2), as well as crosslaminated, massive and faintly laminated quartz wacke beds are common. Thin fining-upward sequences a few metres thick are common in the middle part of a cycle and

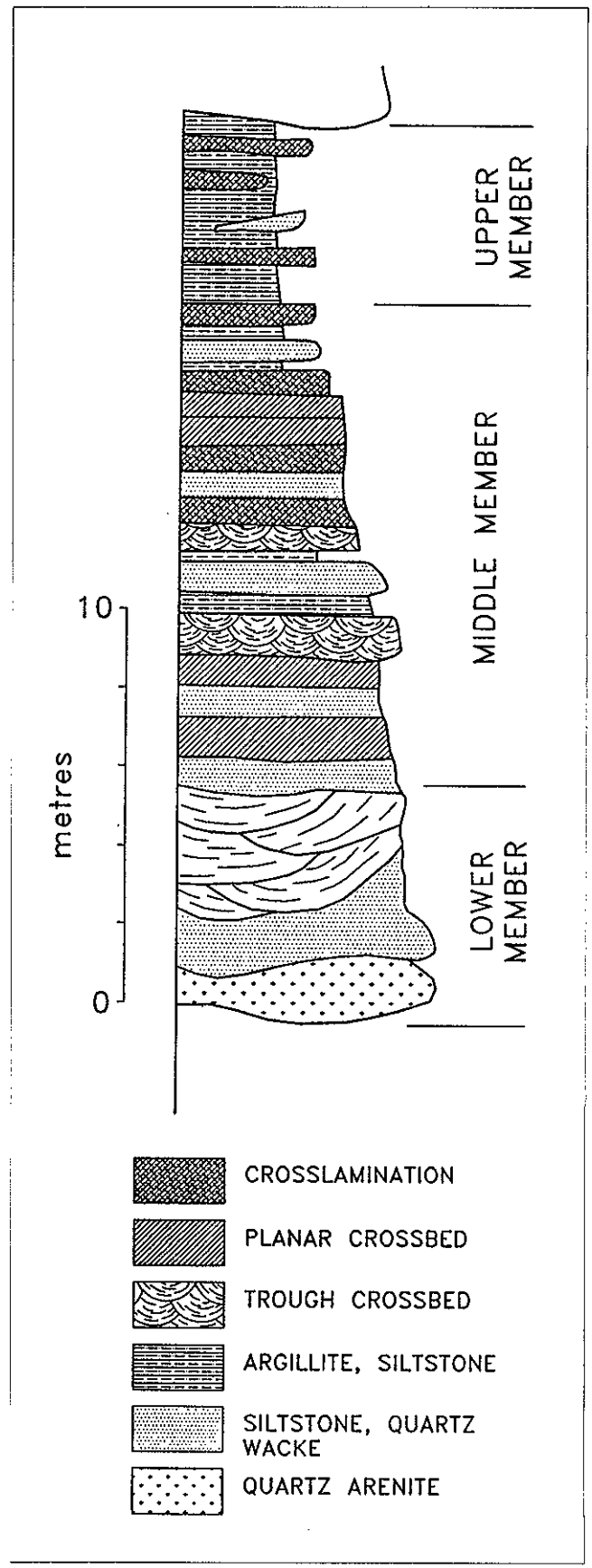


Figure 5. An ideal fining-upward cycle from the Premier Lake section (1), Fort Steele Formation.

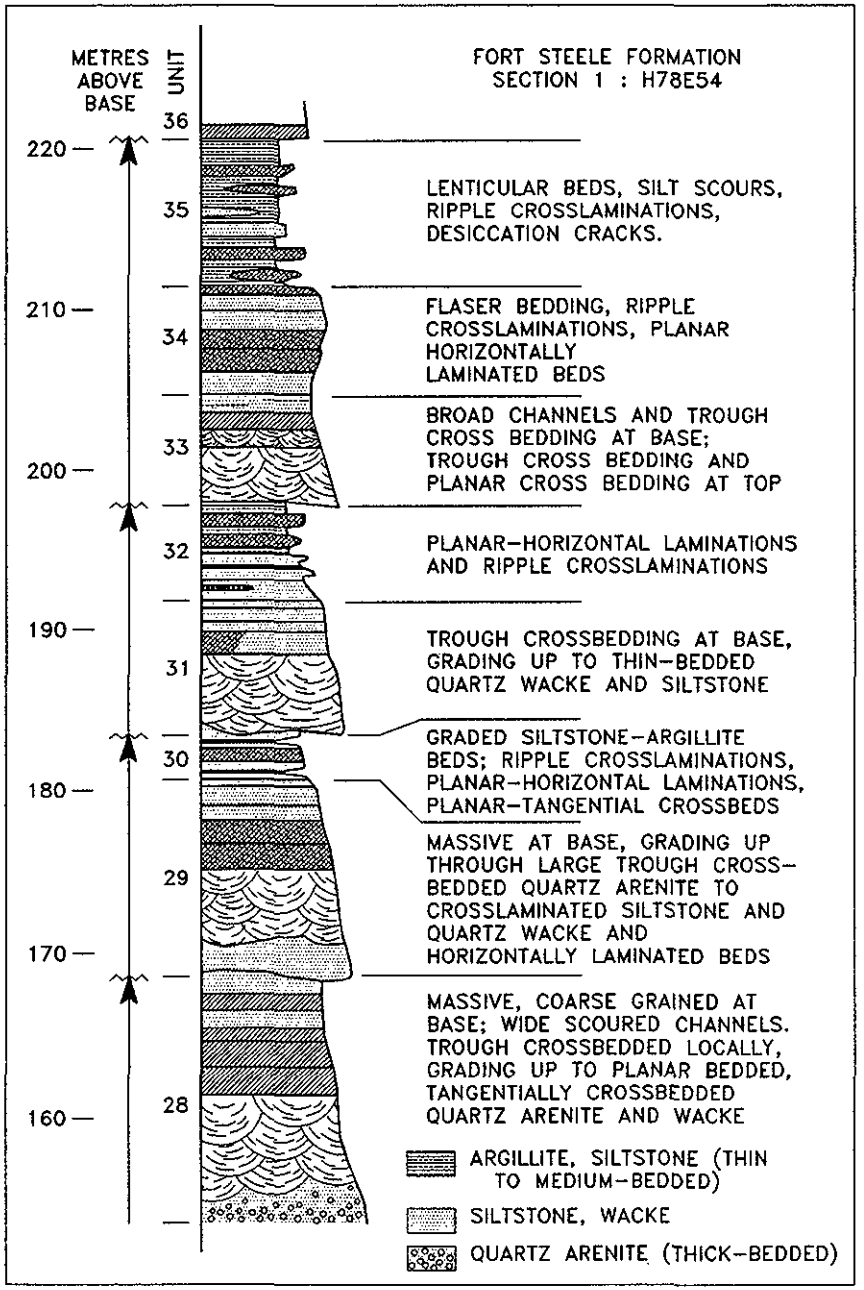


Figure 6. Detail of a Fort Steele measured section, showing a fining-upward megacycle; (Section 1, H78E54, Appendix 1).

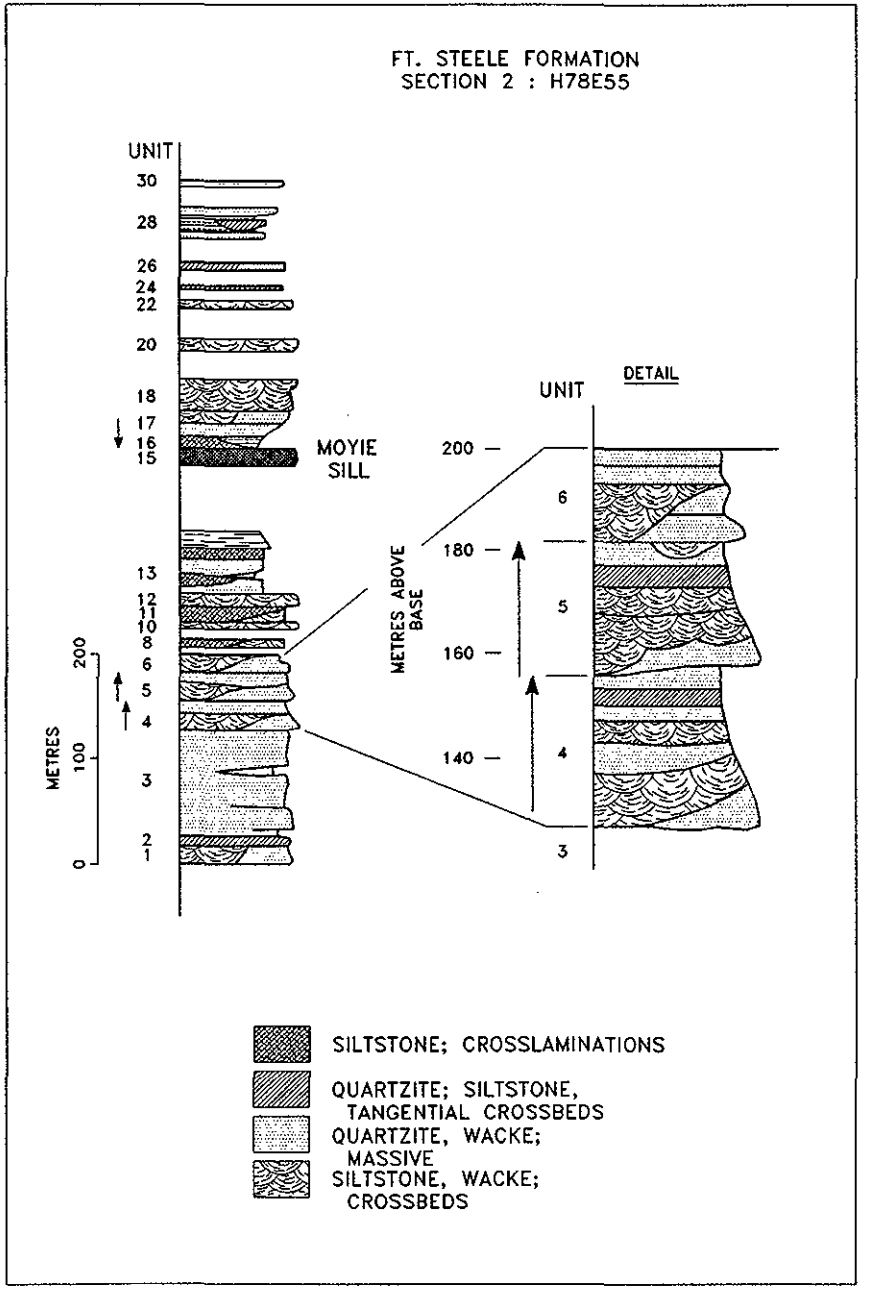


Figure 7. Detail of a Fort Steele measured section, Lazy Lake area; (Section 2, H78E55, Appendix 1).

Plate 1. Trough crossbedding in fluvial quartz arenites in the basal member of a large fining-upward cycle within the Fort Steele Formation; (Section 1, H78E54, Premier Lake area).

Plate 2. Planar crossbeds in thin-bedded quartz arenite layers in the middle part of a cycle in the Fort Steele Formation; (Section 2, H78E55, Lazy Lake area).

comprise trough crossbeds grading up through planar-tabular crossbeds into horizontally laminated sandstone. Thin interlayered siltstone lenses and rare mud-cracked beds may comprise a small proportion of the lower part of the middle member of a cycle (Figure 5) but become more prominent near the top.

The upper member of an ideal cycle comprises thin-bedded, commonly lenticular siltstone and wacke, interbedded with laminated, desiccated silty argillite (Plate 3). The siltstone lenses may be crosslaminated or horizontally laminated and scour underlying argillite.

The general fining-upward nature of a megacycle is due to a superposition of a number of the smaller cycles, with the lower members more prevalent near the base of a megacycle and upper members more prevalent near the top (*see, for example,* the Premier Lake section, Figure 6). The top of the Fort Steele Formation (*see* Section 3, Appendix 1) grades through several hundred metres of lenticular bedded siltstone-argillite, graded siltstone-argillite couplets, and thinly laminated argillite with desiccation cracks, into laminated argillite and siltstone with no desiccation cracks and only rare silt laminations. These latter rocks are included in the basal part of the Aldridge Formation.

Facies Trends and Paleocurrent Analyses

No systematic lateral facies trends were noted in the Fort Steele Formation. The most northerly section, the Premier Lake section (1; Appendix 1), is dominated by fining-upward cycles on various scales. These are less prominent in the Lazy Lake (Figure 7) and Mount Bill Nye sections (2 and 3) but this may be due in part to incomplete exposures or the large scale of measurements in these sections. The greater proportion of finer grained rocks in the Mount Bill Nye section merely reflects a higher stratigraphic position where proportionately less coarse clastics occur.

Limited paleocurrent data have a complex pattern (Figure 4) but generally indicate a northerly or northwesterly trend. The wide dispersion is not particularly unusual considering the variety and large size range of structures measured (the 'rank' of Miall, 1974). It is noteworthy, however, that the least dispersion occurs in the southern sections, presumably closer to a source terrain.

Interpretation

Crossbedded quartzites and interbedded siltstone and argillite, commonly desiccated, characteristic of much of the Fort Steele Formation, are typical sediments of a fluvial depositional environment. The abundance of medium to coarse-grained quartz arenite and wacke relative to fine-grained rocks suggests further that a braided system rather than a meandering system predominated (Walker and Cant, 1979).

Interpretations of the thick sections illustrated in Figure 6 are difficult and not very precise. However, the Premier Ridge section is similar in many respects to the Donjek River section of Williams and Rust (1969) and the smaller fining-upward cycles to the Battery Point model section described by Cant and Walker (1976) and comparison to these sections allows a more detailed interpretation. In general, the smaller fining-upward cycles represent the development of channels, subsequent filling and final abandonment. The coarse-grained, more massive facies and overlying thick trough crossbedded arenites at the base of the ideal cycle (Figure 5) are channel floor and in-channel deposits. Planar-tabular crossbeds, relatively common in braided fluvial systems (Miall, 1977) probably formed in migrating bars (*see, for example,* Miall, *op. cit.* and Cant and Walker, *op. cit.*). Thinner bedded sandstone layers with ripple crosslaminations and climbing ripples that typically occur higher in the cycle are lower energy deposits formed in shallower parts of the channel, perhaps during waning flood stages or during the latter stages of channel filling and subsequent abandonment. These are overlain, at the top of the cycle, by interbedded siltstone and argillite, deposited in abandoned channels or perhaps on floodplains as overbank deposits.

ALDRIDGE FORMATION

The Aldridge Formation (Schofield, 1915) is at the base of the Purcell Supergroup in the Purcell Mountains and the Lizard Range and overlies the Fort Steele Formation in the Hughes Range (Plate 4). Within the Purcell Mountains, it has been subdivided into three main divisions (Reesor, 1958): the lower Aldridge comprises rusty weathering siltstone, quartz wacke and argillite; the middle Aldridge, grey weathering quartz wacke and siltstone interbedded with silty argillite; and the upper Aldridge, rusty to dark grey weathering laminated argillite and silty argillite. In the northern Hughes Range, the middle and upper Aldridge are thinner but lithologically similar to the middle and upper divisions in the Purcell Mountains. The lower division (Unit A1), however, is distinctive; it is characterized by diverse lithologies, pronounced facies and thickness variations and a conspicuous carbonate unit near its base.

The Aldridge Formation is correlative with the Prichard Formation in Montana (Harrison, 1972), with the Haig Brook, Tombstone Mountain, Waterton and Altyn formations in the Lewis thrust sheet in southeastern British Columbia (Price, 1964; Fermor and Price, 1983) and perhaps, in part, with the Fort Steele Formation in the Hughes Range. Its total exposed thickness ranges from 2060 metres in the northern Hughes Range (Höy, 1982a) to greater than 4200 metres in the southern Purcell Mountains (Edmunds, 1977).

Unit A1 – Hughes Range

The lowest division of the Aldridge Formation in the northern Hughes Range is referred to as Unit A1. Based on matching laminated siltstone markers, the upper part of Unit A1 correlates with the middle part of the middle Aldridge in the Purcell Mountains (J. Hamilton, personal communication, 1989) but the exact correlation of the lower part is not known; the lower-middle Aldridge transition is not recognized in the Hughes Range. Unit A1 comprises dominantly

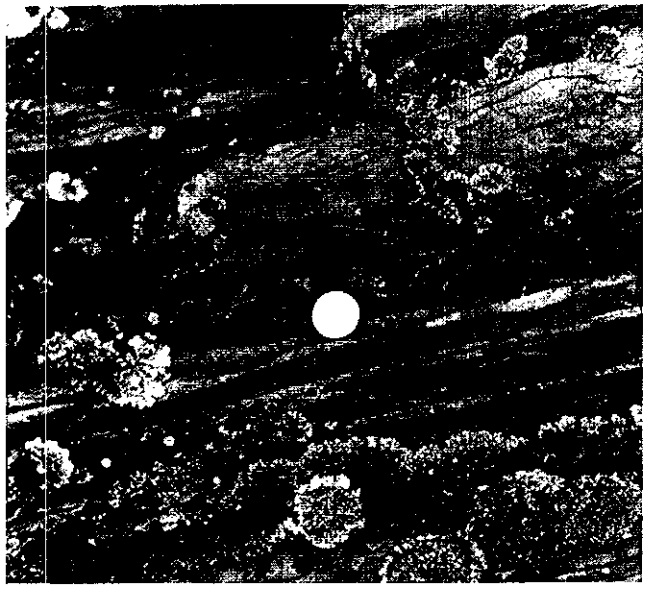


Plate 3. Lenticular-bedded siltstone in the upper part of a Fort Steele cycle. Note desiccation cracks in the argillite members indicative of alternating conditions of slack water depositing muds, subaerial exposure, then current activity; (Section 1, H78E54, Premier Lake area).

fine to medium-grained clastic rocks and a conspicuous carbonate unit. Leech (1960) included the carbonate unit and underlying strata in the Fort Steele Formation, but it is proposed here that these units be included in the Aldridge Formation which they more closely resemble.

The basal member of Unit A1 (A1a) varies in thickness from approximately 90 metres (Section 4, Appendix 1, Wasa Creek) to 114 metres (Section 3, Mount Bill Nye). It consists of medium to dark grey to black, finely laminated argillite and siltstone. Flaser and lenticular bedding occur occasionally and graded siltstone-argillite couplets up to 3 centimetres thick may define bedding. Its basal part is generally coarser grained and may include minor quartz wacke, siltstone and wacke with dolomitic cement.

A1b is a conspicuous unit, from 20 to more than 100 metres thick, characterized by abundant carbonate and referred to as the "carbonate marker unit" (Figure 8). It consists primarily of interlayered silty or argillaceous dolomite, dolomitic argillite or siltstone interbedded on a 2 to 3-metre scale. Dolomitic layers are brown weathering, commonly finely laminated and may contain isolated mound-shaped stromatolites or cryptal algal mat deposits. Lenticular beds, crossbeds, scours and ripple marks are common within siltstone or dolomitic siltstone. Grey limestone, interbedded with dolomite, is prominent near the top of Unit A1b just north of Wasa Creek; thinly interbedded chert and dolomite (Plate 5), and pods of brown-weathering dolomite in siltstone are occasionally present.

Unit A1b grades upward into A1c, a succession of interbedded argillite and siltstone. South of Lewis Creek, A1c can be subdivided into three subunits. These include a massive to faintly laminated black graphitic argillite, overlain by a lighter coloured grey, greenish grey or tan, finely laminated siltstone or silty argillite and, finally, a medium to

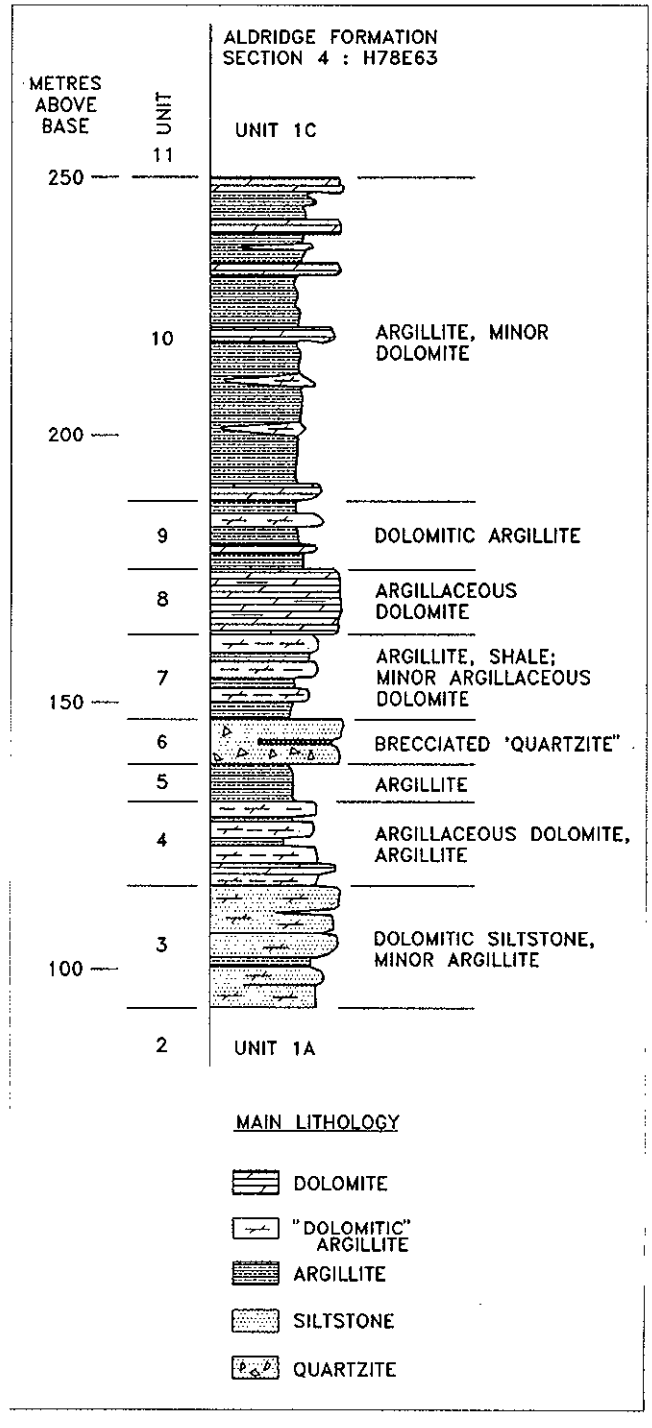


Figure 8. Detailed section through carbonate marker unit (A1b), Aldridge Formation, northern Hughes Range; (Section 4, H78E63, Appendix 1).

dark grey, rusty weathering, massive to faintly laminated argillite. Rusty weathering dolomite pods, minor calcareous argillite and rare, thin silty quartzite layers occur locally within the two upper subunits. Unit A1c thins to the north, from approximately 1160 metres (Section 3) at Mount Bill Nye to only 326 metres (Section 4) north of Wasa Creek (Figure 9). The threefold subdivision is also not as apparent to the north; here Unit A1c consists primarily of rusty

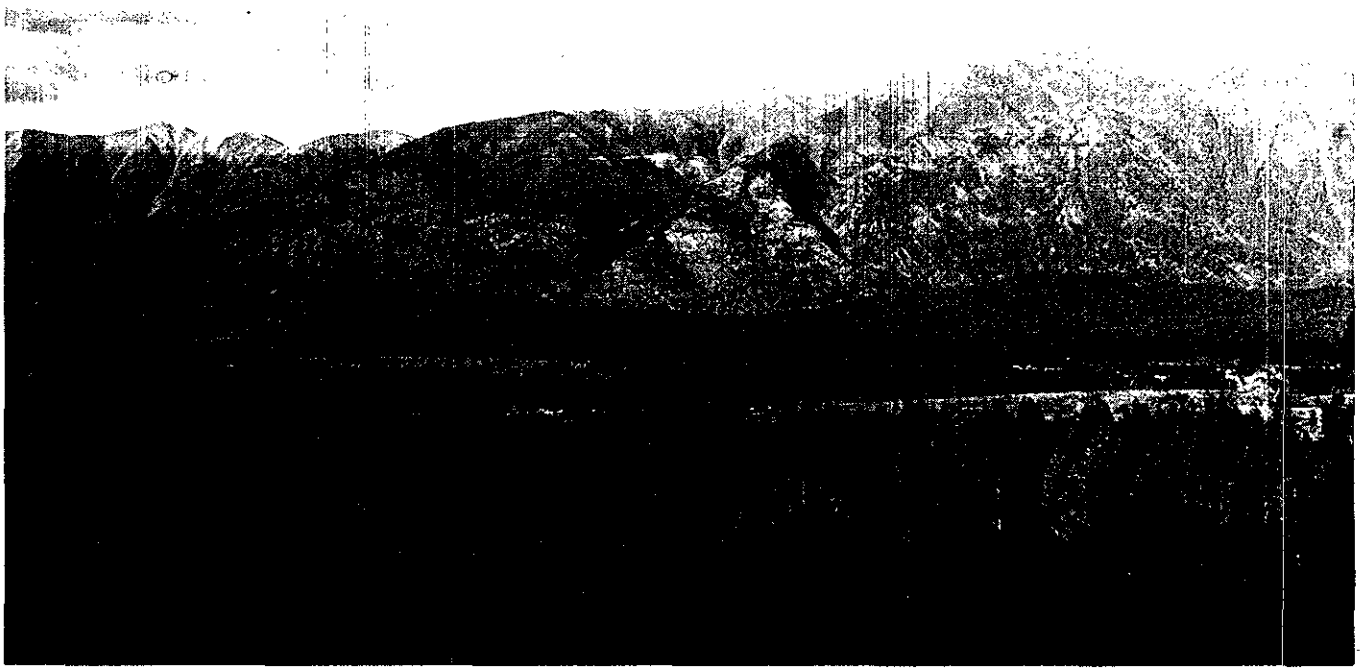


Plate 4. Northern Hughes Range, viewed to the east, with resistant exposures of the Fort Steele Formation on the lower slopes and the Aldridge Formation at higher elevations.

weathering, massive to thinly laminated dark grey argillite and only minor finely laminated siltstone.

Unit A1d is a distinctive unit south of Lewis Creek that hosts both the Kootenay King and Estella lead-zinc deposits. It consists largely of buff-weathering dolomitic siltstone interlayered with buff to grey, finely laminated argillite. Sedimentary structures, including lenticular bedding, flaser bedding, tangential crossbedding and graded siltstone-argillite couplets, commonly with flame or load casts at their base, are conspicuous (Plate 6). To the south, the unit becomes a coarser grained tan siltstone or wacke with only very minor argillite or dolomitic siltstone (Figure 9). To the north it changes to a dark, finely laminated argillite with only minor interbedded siltstone. Contacts with underlying argillite of Unit A1c and overlying, generally dolomite-free siltstone and argillite of Unit A1f are gradational across many tens of metres.

Unit A1f comprises siltstone and argillite with minor dolomitic siltstone and occasional wacke and quartz arenite beds. Graded bedding is common and ripple crosslaminations, lenticular bedding and mud-chip breccias occur in the middle and upper parts of the unit. The contact with the overlying middle Aldridge is placed at the base of the first prominent, thick-bedded quartz wacke turbidite sequence.

A number of thick, massive to faintly laminated quartz arenite or quartz wacke beds (referred to as 'quartzites' and mapped as Unit A1e) occur within A1d and less commonly within A1c. The most conspicuous of these, the Kootenay King quartzite (Section 6, Appendix 1) overlies A1c just north of the Wild Horse River. It consists of a sequence of interbedded wacke, arenite and argillite up to 250 metres thick. Coarse, angular rip-up clasts occur at the base and individual quartzite sequences within the Kootenay King quartzite may be graded with quartz arenite beds at the base and siltstone and argillite at the top. A similar "quartzite", also containing coarse angular siltstone clasts, occurs near Wasa Creek. These quartzite units thicken and become coarser grained to the south; the Kootenay King quartzite is not recognized north of Mount Bill Nye and the thick Wasa Creek "quartzite" appears to have pinched out before the ridge north of Wasa Creek.

DISTRIBUTION AND FACIES TRENDS

Unit A1 is characterised by rapid and pronounced thickness and facies changes. It thickens from approximately 2000 metres east of Wasa to 2500 metres near Lakit Mountain 14 kilometres farther south (Figure 9). This thickening occurs almost entirely within Unit A1c. Unit A1b is a dolomite of essentially constant thickness between Lakit Mountain and the Wasa area, as is the argillite at the top of Unit A1f. Facies changes generally involve fining of units northward; thick sections of quartz-rich siltstone in the

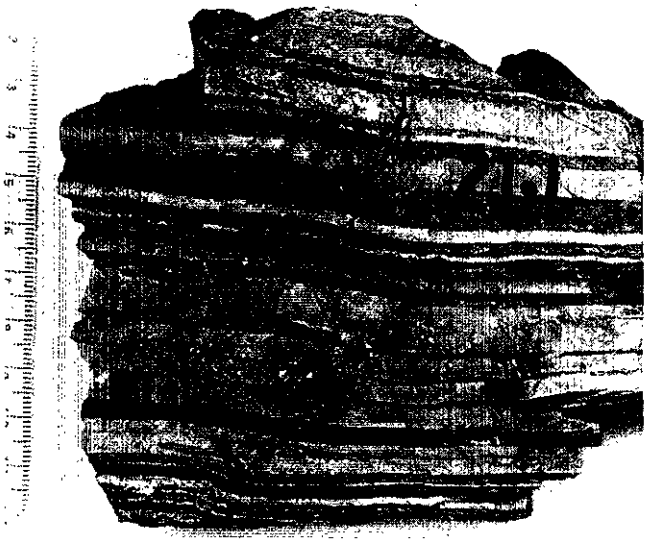


Plate 5. Interbedded chert and brown-weathering siliceous dolomite, Unit A1b, Aldridge Formation, northern Hughes Range.

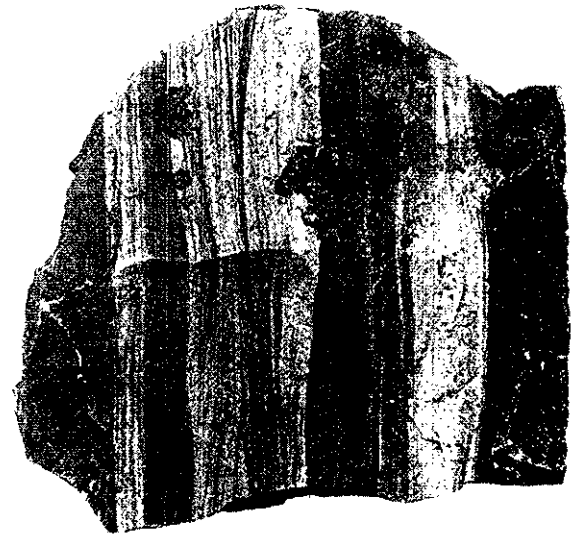


Plate 6. Flaser bedding in Unit A1d, Aldridge Formation, northern Hughes Range; sample width is approximately 10 cm.

south give way to finer grained and more dolomitic siltstone and finally grade into laminated black argillite. Thick, coarse-grained quartzites of Unit A1e that contain fine to coarse angular clasts near their base also become finer grained and thinner northward, and eventually appear to pinch out.

DEPOSITIONAL ENVIRONMENT

Unit A1 records a marine transgression from the fluvial and alluvial fan deposits of the underlying Fort Steele Formation to basinal AE turbidites of the overlying middle Aldridge. Although evidence for subareal exposure, such as salt casts or desiccation cracks, is not present in Unit A1, other structures, textures and facies suggest that at least the basal part of the succession was deposited in a platformal or shallow-water environment.

Black silty argillites of Unit A1a are subaqueous, perhaps lagoonal or mud-flat deposits. Siltstone layers may represent silt introduced to the muds during storms, either blown in as aeolian grains or washed in. These deposits are overlain by the extensive carbonate marker unit, A1b. Algal mats and occassional stromatolites in this unit indicate a shallow-water environment.

The most striking thickness and facies changes in Unit A1 are within A1c (Figure 9) and record initiation of tectonic disturbance. Dolomitic and argillaceous siltstones in northern exposures, possibly deposited in a lagoonal environment, give way to the south to more clastic slope facies. The dramatic southward thickening of coarser units, interlayered with finely laminated siltstone and argillite, suggests that deposition of the coarse-grained units was influenced markedly by periodic movement of growth faults located to the south. Coarse-grained quartzites in the Kootenay King area (Unit A1e) that locally contain large angular lithic fragments may be channel deposits that fed turbidite deposits to the south. A similar unit just north of the transverse Lewis Creek - Nicol Creek fault zone that thickens and becomes coarser grained to the south, suggests that this zone was also tectonically active in Aldridge time. In summary, Unit A1c comprises sandstones and siltstones that were shed southward into a deepening basin, probably in response to periodic movement of growth faults.

Turbidite deposition, first evident in Unit A1d, records continued transgression. These are distal turbidites generally consisting of laminated siltstone overlain by ripple-crosslaminated siltstone. Only rarely is the basal graded siltstone unit preserved. The bulk of Unit A1d, however, comprises finely laminated or massive interturbidite mudstone. Coarse channel sands (Unit A1e) first appearing in Unit A1c, also cut the thinly bedded distal turbidites and dolomitic mudstone of Unit A1d. Prominent facies changes in A1d, similar to those in the clastic members of A1c, indicate deposition was also modified by growth faults.

The depositional environment of the basal part of Unit A1f is similar to that of A1d, a slope or basin setting. Sedimentary structures formed by current activity are less common than in A1d, but indicate that a considerable part of the unit comprises distal turbidites. Argillaceous siltstone at the top of Unit A1f (Figure 9) records deposition in a basin during a period of relative tectonic stability.

Lower Aldridge

Exposures of lower Aldridge rocks are restricted to the Kimberley area between the St. Mary and Kimberley faults, west of Moyie Lake along the Moyie fault, and in the vicinity of Mount Mahon in the southwest corner of the map area (Figure 1). The total thickness of the lower Aldridge is not known as its base is not exposed.

The lower Aldridge comprises dominantly rusty weathering, thin to medium-bedded, fine-grained quartz wacke and siltstone (Plate 7). It is commonly intruded by a number of thick gabbroic sills referred to as the Moyie sills. Quartz wacke beds are commonly graded or crossbedded and, less

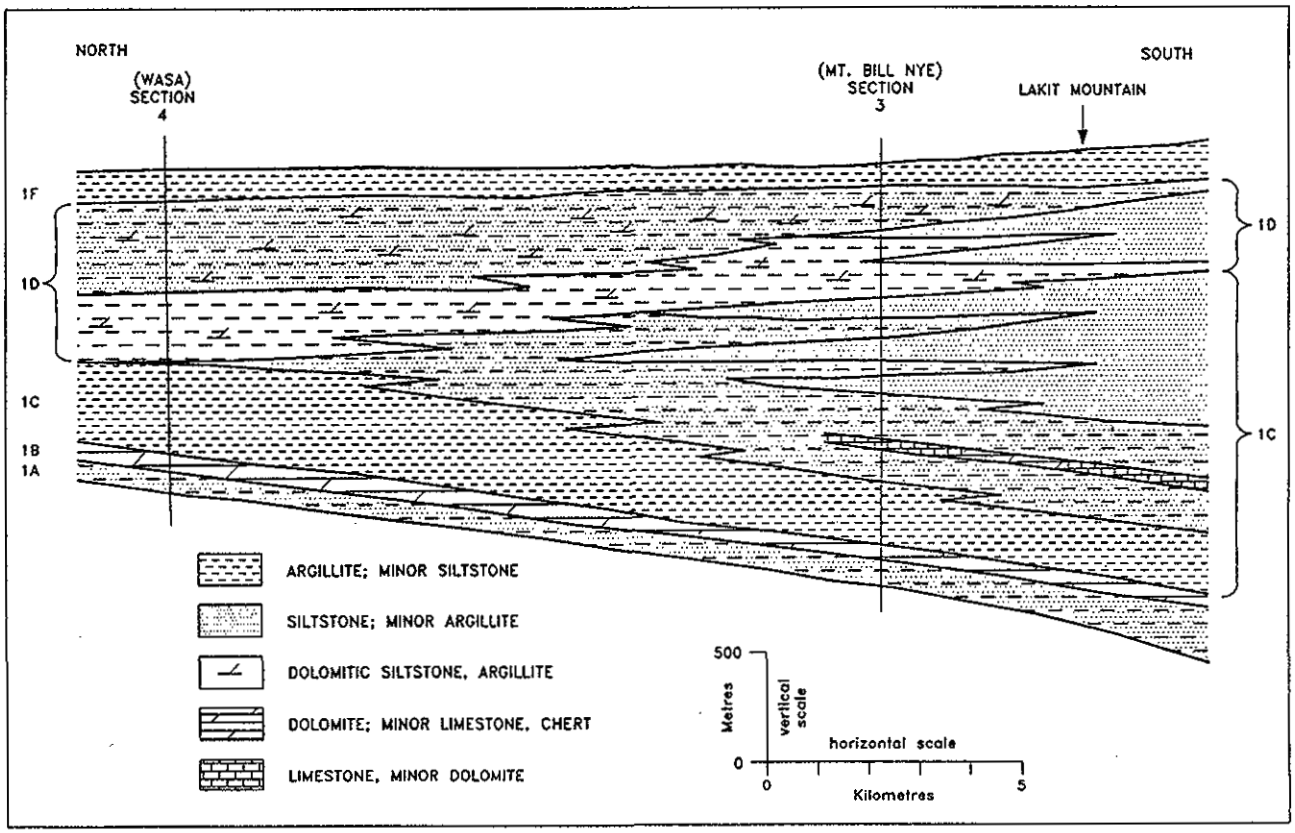


Figure 9. A schematic north-south stratigraphic section of Unit A1, Aldridge Formation, northern Hughes Range (Sections 3 and 4 are described in Appendix 1).

commonly, have well-defined basal scours, indicative of turbidite deposition. They may be interlayered with siltstone or argillite, or form fining-upward sequences several tens of metres thick that are capped by thinner bedded siltstone layers. In the Kimberley area, a conspicuous succession of medium to thick-bedded, grey-weathering quartz wacke and arenite, 250 metres thick, is lithologically similar to the basal part of the middle Aldridge. The top of this succession is approximately 300 metres below the base of the middle Aldridge. This succession may correlate with interbedded quartz wacke and siltstone in the basal part of the measured section at Rabbit Foot Creek (Figure 10).

The upper part of the lower Aldridge is generally finer grained and thinner bedded. Rusty weathering, thin-bedded siltstone and minor argillite predominate. Siltstone and argillite are massive to finely laminated, commonly graded, and contain finely disseminated or wispy, irregular pyrrhotite laminations. The well-bedded nature of the siltstone layers, grading and rare crosslaminations suggest "distal" turbidite deposition.

The lower-middle Aldridge contact is placed at the base of the first prominent blocky, grey-weathering quartz wacke beds. It is a gradational contact and rusty weathering quartz wacke beds are conspicuous in the top few tens of metres of the lower Aldridge (Plate 8; Figure 10) and thin to medium-bedded argillite and siltstone are interbedded throughout the lower part of the middle Aldridge (Plate 9). Locally, a continuous sheet of intraformational conglomerate occurs at

Plate 7. Thin to medium-bedded, commonly graded, siltstone and wacke turbidites of the lower Aldridge Formation; (Section 5, H83M60, Rabbit Foot Creek).

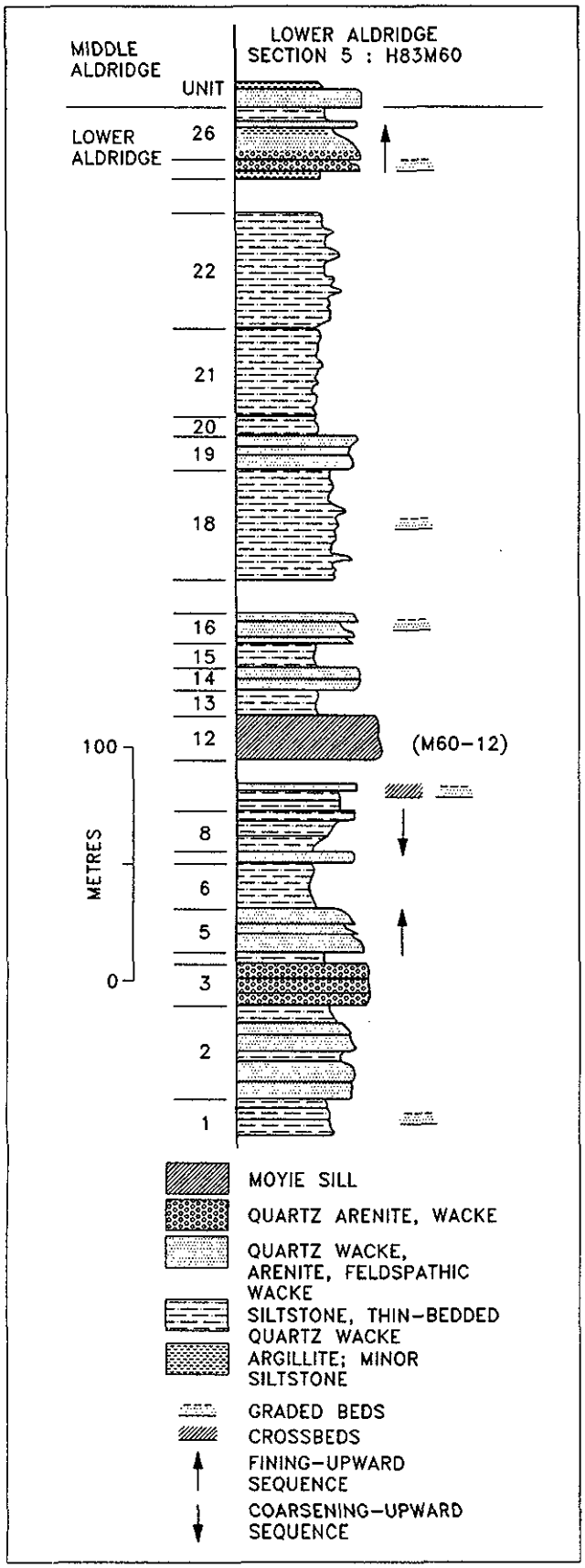


Figure 10. A lower Aldridge section, Rabbit Foot Creek area; (Section 5, H83M60, Appendix 1).

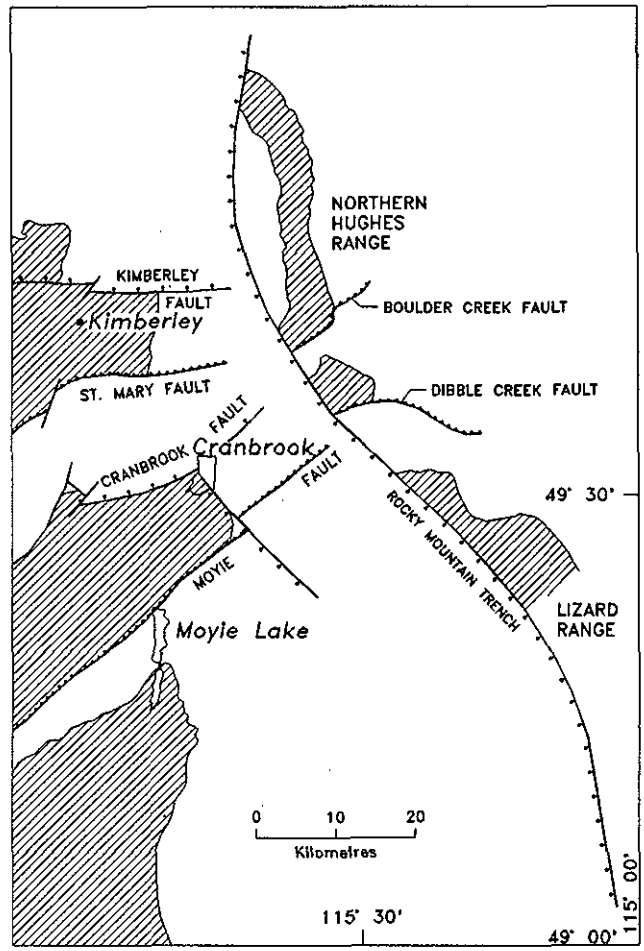


Figure 11. Distribution of the middle Aldridge Formation, Fernie west-half map-area.

the contact, as at the Sullivan mine (Hamilton *et al.*, 1983a, 1983b; Jardine, 1966) and at a small mineral occurrence in the Dewar Creek area (Gifford, 1971; Reesor, 1958). These conglomerates, and others within the lower and middle Aldridge, are described below.

Middle Aldridge

The middle Aldridge comprises more than 2000 metres of dominantly well-bedded, medium to locally coarse-grained quartz arenite, wacke and siltstone. It is exposed in the Hughes and Lizard ranges east of the trench, in the vicinity of the Sullivan mine, between the Cranbrook and Moyie faults southwest of Cranbrook, and in the core of the Moyie anticline south of Moyie (Figure 11).

A continuous section of the middle Aldridge is not exposed in the Purcell Mountains; the most complete section, between the Moyie and Cranbrook faults, is broken by a number of faults. In general, the basal part comprises interbedded quartz wacke and arenite with only minor sections of silty argillite. Exposures of the basal part are typically grey weathering; however, in recent man-made exposures, such as roadcuts along Highway 3a, these units are typically rusty weathering. Within the upper part of the middle Aldridge, quartz arenite and quartz wacke beds become thinner and less pure, and the proportion of inter-

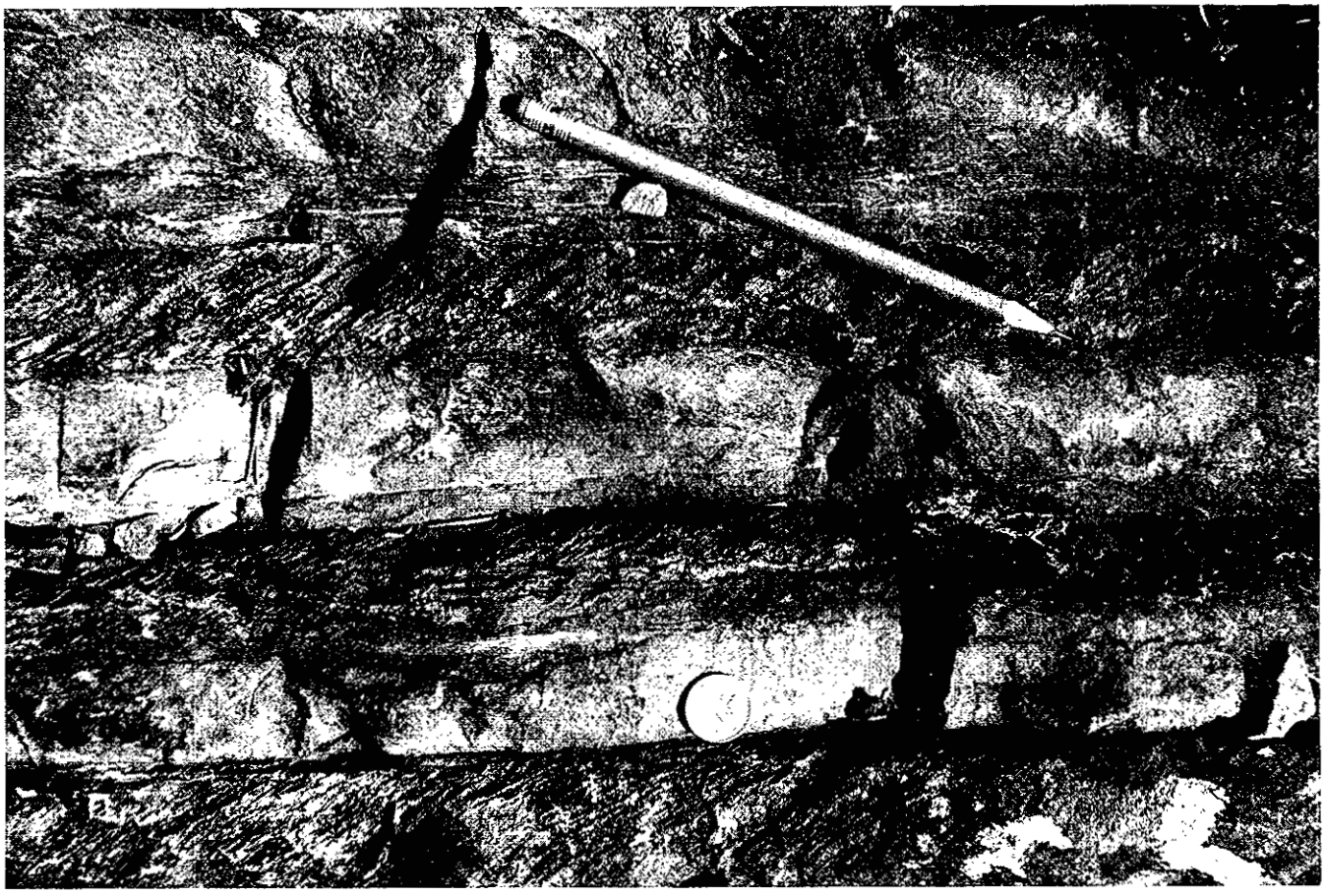


Plate 8. Graded turbidite beds of the lower Aldridge Formation. Note well-developed cleavage in argillaceous siltstone above the more competent, graded wacke; (Section 5, H83M60, Rabbit Foot Creek).

Plate 9. Rusty weathering turbidites at the lower-middle Aldridge contact, Rabbit Foot Creek area; (Section 5, H83M60).

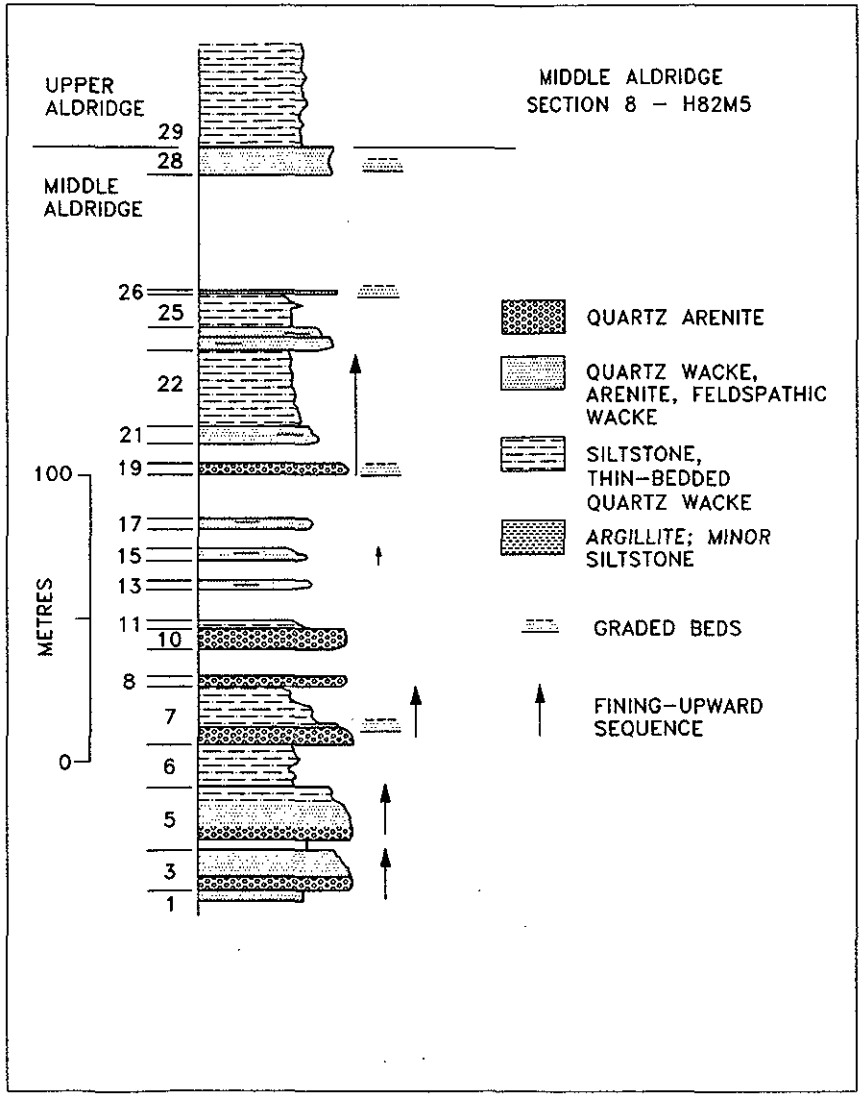


Figure 12. A section of the upper part of the middle Aldridge Formation, Midway mine area; note the fining-upward turbidite cycles; (Section 8; Appendix 1).

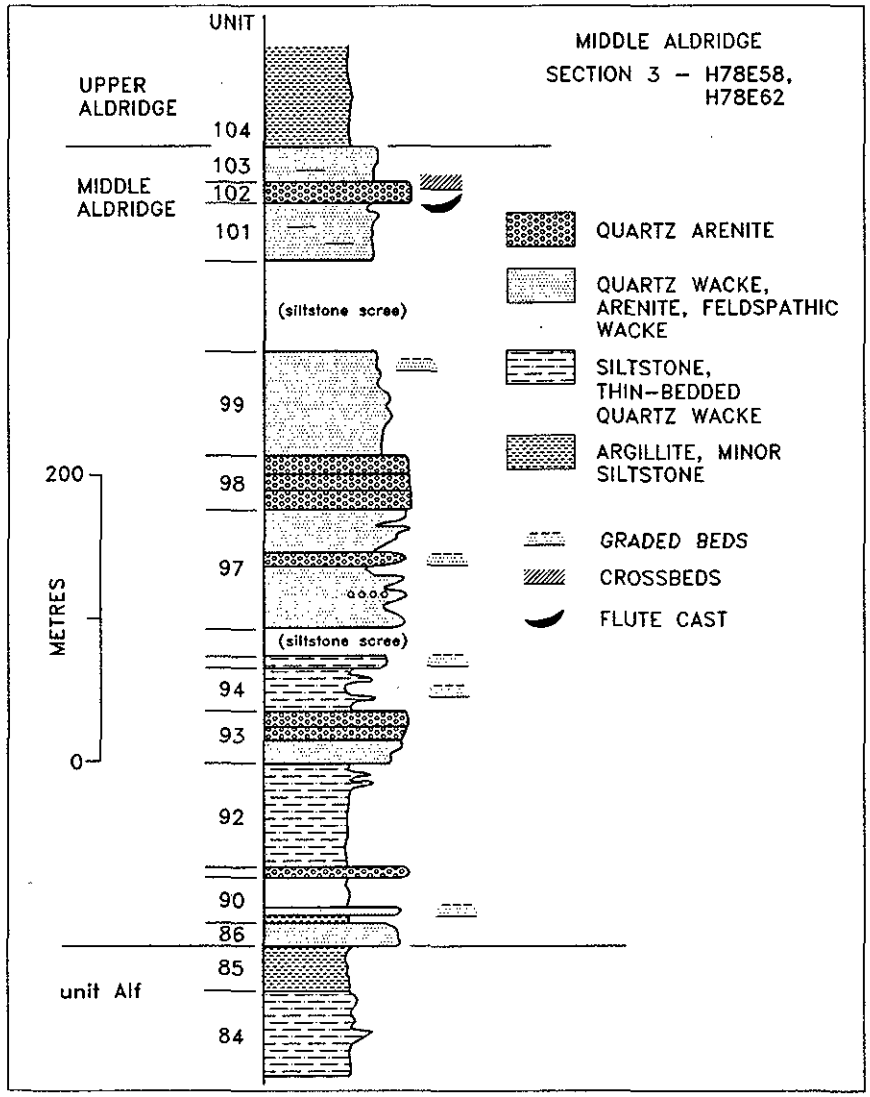


Figure 13. A complete middle Aldridge section, Mt. Bill Nye area, northern Hughes Range; (Section 3, Appendix 1).

Plate 10. Thick-bedded, overturned AE turbidites of the middle Aldridge Formation exposed on the Kootenay King access road, northern Hughes Range.

Plate 11. AE turbidites of the middle Aldridge Formation exposed at the Lumberton turnoff on Highway 3 south of Cranbrook; for detail, *see* Plate 12.

bedded siltstone and argillite increases. The upper part of the middle Aldridge comprises a number of distinct cycles of massive, grey quartz arenite beds that grade upward into

Plate 12. Detail of middle Aldridge turbidites, Lumberton exposure on Highway 3 south of Cranbrook; note thin graded beds at top, current ripple laminations beneath coin scale and load structures, including load-casted ripples (Reineck and Singh, 1975, p. 76), in lower layers.

an interlayered sequence of quartz wacke, siltstone and argillite, and are capped by siltstone and argillite (Figure 12). The contact with the upper Aldridge is placed above the last bed of massive grey quartz arenite (Höy and Diakow, 1981).

The middle Aldridge in the Mount Fisher area east of the Rocky Mountain Trench comprises interbedded "quartzite", siltite and argillite (McMechan, 1981). Although its base is not exposed, it is estimated to be of comparable thickness to the succession in the Moyie Lake area. In the Hughes Range just north of Mount Fisher, the middle Aldridge is lithologically similar, but considerably thinner. It ranges from approximately 700 metres near Lakit Mountain in the south, to 390 metres at Mount Bill Nye, and only 240 metres northeast of Wasa (Section 4, Appendix 1). Thick-bedded quartz arenite predominates in the middle part of the Mount Bill Nye section, with interbedded quartz arenites and thin-bedded siltstone in the lower part and dominantly quartz wacke and siltstone at the top (Figure 13).

Quartz arenite and wacke beds of the middle Aldridge have many structures typical of "classical" or "proximal" turbidite deposits (Bishop *et al.,* 1970; Edmunds, 1973;

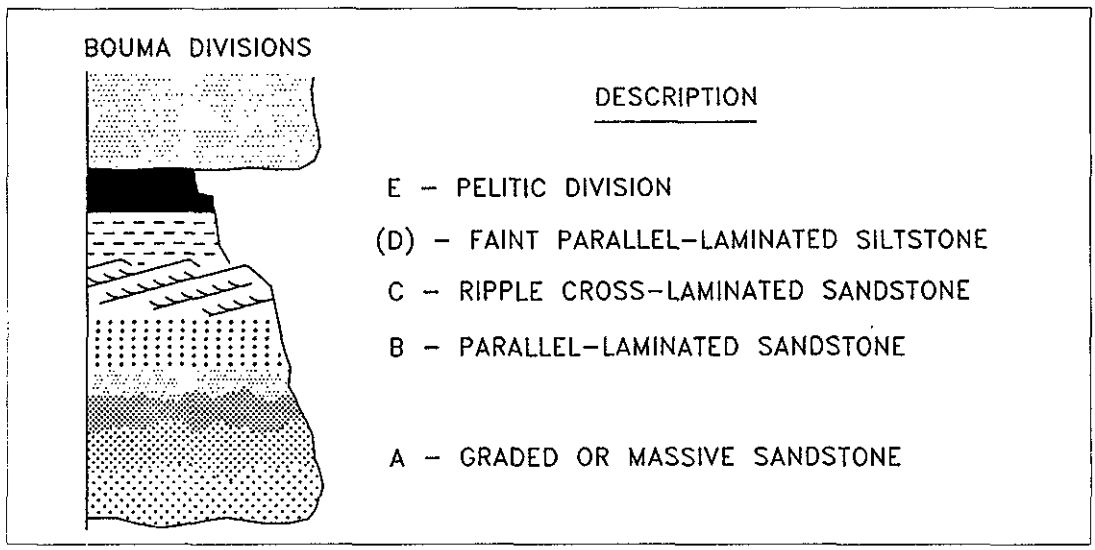


Figure 14. Classical Bouma facies (after Bouma, 1962; Walker, 1979).

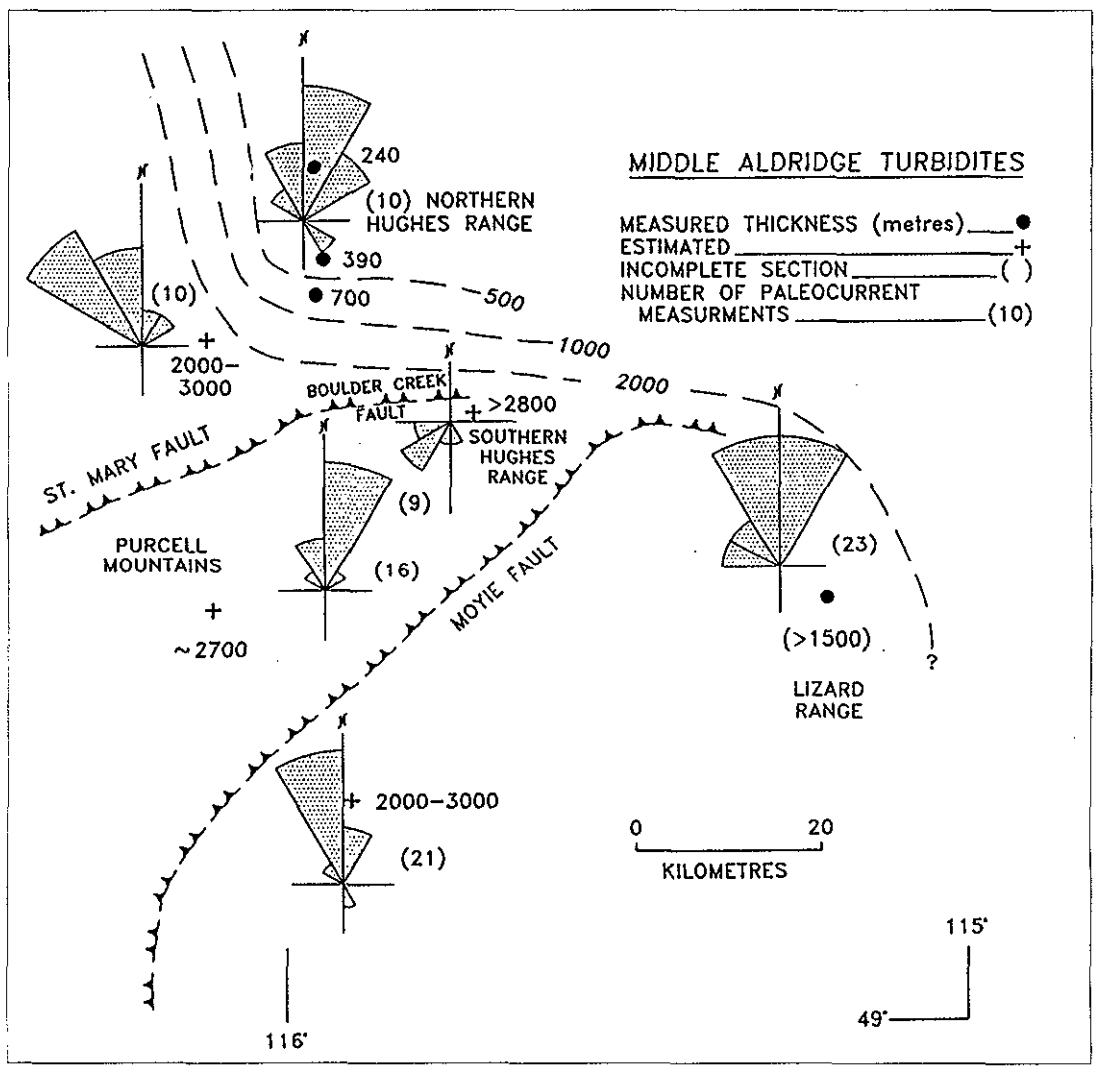


Figure 15. An isopach map of middle Aldridge turbidites, restored for movements on the St. Mary and Moyie faults. Rose diagrams are measured and restored paleocurrent directions from basal scours and crosslaminations.

Plate 13. Flute marks preserved on the lower surface of a turbidite bed, middle Aldridge Formation, Premier Lake area.

Plate 14. Convoluted bedding and flame structures at the base of a turbidite layer, middle Aldridge Formation; (Lumberton exposure south of Cranbrook).

Bouma, 1962; Walker, 1979). They are laterally extensive and commonly parallel sided (Plates 10 and 11). Individual beds range in thickness to more than a metre; thicker quartz arenite beds may be amalgamated, comprising a number of individual turbidite beds without either an intervening silt component or recognizable graded beds. In general, the beds are massive or poorly graded with coarse quartz grains (to 1-2 mm maximum) near the base and finer grained, less pure arenite or wacke tops. Arenaceous beds are generally grey weathering and medium to thick bedded and are commonly separated by thin layers of argillaceous siltstone. Wacke beds are rusty weathering and thin to medium bedded. They may have an internal stratification, with graded, laminated and crosslaminated divisions (Plate 12). Only rarely is the ideal Bouma facies (Figure 14) represented (Edmunds, *op. cit.).*

Sole markings at the base of the turbidite beds provide a local flow direction for turbidity currents (Figure 15). These markings include scours and tool marks and, near the base, flame structures (Plates 13 and 14). Local flow direction has also been determined from crosslaminations in the C division of the turbidite beds.

Siltstones in the middle Aldridge Formation are massive, finely laminated or, less commonly, graded. They are predominantly turbidite deposits, presumably deposited from slower currents than the quartz arenite facies. Argillite, the

"pelitic" division in a turbidite facies model, is in part deposited by turbidity currents but also represents interturbidite pelagic muds.

Quartz wackes and arenites are composed of quartz, plagioclase, biotite, sericite and minor potassic feldspar, muscovite and garnet (Edmunds, 1977). Argillites are composed primarily of biotite and sericite. With increasing metamorphic grade, and adjacent to some of the Moyie sills, coarse-grained biotite may be abundant. The biotite adjacent to sills is a contact metamorphic mineral that is commonly aligned parallel to axial planes of folds. As the deformation postdated intrusion of the sills, it is suggested that the biotite (or an earlier phyllosilicate) was rotated during deposition.

In summary, the middle Aldridge comprises thick-bedded, massive to graded quartz arenite and wacke beds, thin-bedded siltstone, and minor argillite. These beds were deposited from turbidity currents of variable strength. A number of finely laminated siltstone and argillite sequences that have been used as marker beds by geologists for Cominco Ltd. and others (Heubschman, 1973) are also present within the middle Aldridge. These, as well as intraformational and crosscutting "conglomerates", are described below.

LAMINATED SILTSTONE MARKERS

The marker units are sequences of laminated dark and light siltstone, up to several metres thick (Plate 15), in which each lamina can be matched in precise detail for distances up to several hundred kilometres (Heubschman, 1973). The pattern of laminae in each sequence is unique and hence recognition of a specific sequence of laminae allows accurate positioning of isolated outcrops or drill intersections within the thick middle Aldridge succession. At least fourteen of these marker sequences are recognized. Locally, the markers are interrupted by turbidity deposits, or partly or totally removed due to erosion by turbidity currents (H.C. Morris, personal communication, 1984).

Individual lamina commonly range from 1 to 20 millimetres thick (Edmunds, 1977). They comprise dominantly fine-grained quartz, feldspar, muscovite and biotite, with minor sulphides, tourmaline, epidote and apatite. The darker bands have similar mineralogy to the lighter bands but contain several per cent carbon, minor sphene and monazite (Heubschman, *op. cit.;* Leitch *et al.,* 1991). Based on their common occurrence as anhedral grains with a clast-like habit, Leitch *et al. (op. cit)* tentatively interpret that most of the grains, including quartz, plagioclase, apatite, monazite and possibly some of the coarse muscovite, are detrital. The unusually high content of sphene, monazite and carbon in the darker laminae are reflected in their geochemistry with high calcium, titanium, phosphorus, carbon and rare-earth element (REE) values (Leitch *et al., op. cit.).*

The origin of these remarkable siltstone units is enigmatic. Each one records an event that occurred simultaneously across a basin many hundred kilometres across, during a period of relative quiescence. Heubschman concluded that algal "blooms" formed near the surface of the Proterozoic sea, then settled during deposition of eolian silts and muds forming the distinctive laminations. This model does not require different sedimentological processes during light or dark laminae deposition, differences that would be difficult to envisage over such a large area. It is compatible with a compositional change that involves variable carbon content and with the ratios of light-dark bands remaining constant rather than the absolute thicknesses.

CONGLOMERATES

Locally within the upper part of the lower Aldridge, at the lower-middle Aldridge transition, and in the lower part of the middle Aldridge, there are conformable or crosscutting zones of intraformational conglomerate or of massive, unbedded siltstone or wacke. Intraformational conglomerate is particularly prominent in the footwall of the Sullivan orebody; it is described in Chapter 6.

Intraformational conglomerate layers are generally massive to poorly bedded (Plate 16); occassionally they are crudely graded with coarser clasts at the base (Hamilton *et al.,* 1982, 1983a,b). Clasts range in diameter from a few millimetres to 30 centimetres. They may be closely packed or widely dispersed throughout a silty matrix. Generally, clasts and matrix have compositions similar to that of the host Aldridge Formation and therefore recognition of individual clasts is often difficult.

Intraformational conglomerate layers in Unit A1 in the Hughes Range grade laterally from coarse, poorly sorted pebble conglomerate in the south to thin arenites in the north. Their spatial distribution, in the vicinity of transverse faults with inferred Purcell-age movements, suggests a genetic link with these growth faults.

Crosscutting zones of conglomerate or massive sandstone are less common. A zone of massive sandstone several tens of metres wide and containing abundant small lithic fragments is exposed in a roadcut on Highway 3A just south of Moyie. It is vertical, cutting across essentially flat-lying middle Aldridge turbidite beds. Its contact is irregular and a poorly developed vertical banding is apparent in the first few metres of the edge of the zone. The zone dies out upsection, and is overlain by flat-lying turbidite beds.

Other crosscutting zones occur beneath the Sullivan orebody, North Star Hill and at the St. Joe prospect. In contrast with the Moyie structures, these are associated with tourmaline alteration and sulphide mineralization. On North Star Hill, irregular crosscutting zones and concordant layers of conglomerate are conspicuous in the upper part of the lower Aldridge. Clasts of argillite, quartzite and tourmalinite up to 5 centimetres across occur in a dark grey quartzite or siltstone matrix. Both stratabound conglomerate and a large crosscutting conglomerate breccia occur in the footwall of the Sullivan deposit (Jardine, 1966; Hamilton *et al.,* 1982). At the St. Joe prospect, a crosscutting fragmental unit several metres thick is overlain by an intraformational conglomerate unit suggesting fragmentals were extruded onto the seafloor.

The variety of units loosely referred to as conglomerates suggests a number of diverse origins. Crosscutting zones beneath the Sullivan orebody and on North Star Hill, associated with hydrothermal tourmaline alteration, are inter-

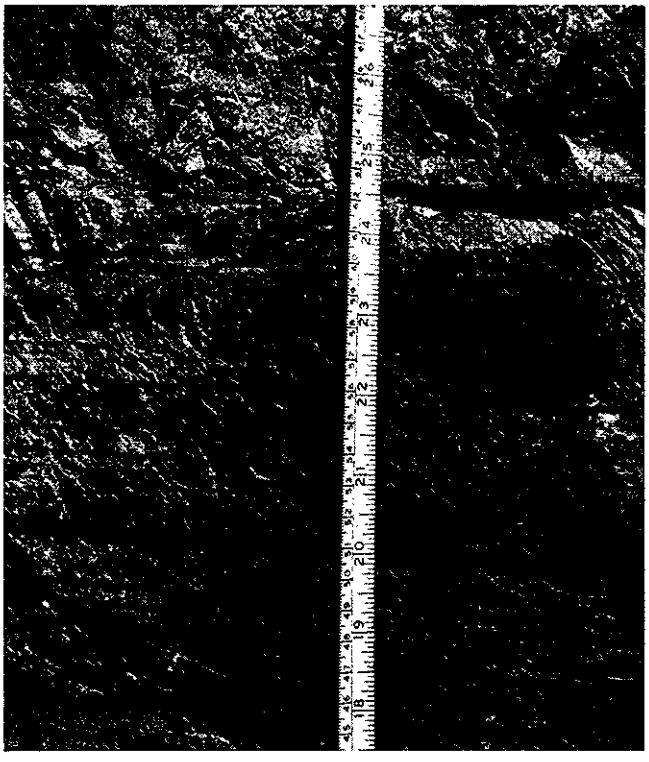


Plate 15. Laminated siltstone marker unit in the middle Aldridge Formation along Highway 3 at the north end of Moyie Lake.

preted to be part of brecciated footwall feeder zones to overlying mineralization. Massive, crosscutting zones of both limited vertical and lateral dimension, such as occur near Moyie, may be large-scale dewatering structures as proposed by F.R. Edmunds (personal communication, 1980). They may be related to expulsion of pore water as a result of intrusion of underlying gabbroic sills (Höy, 1989). Intraformational conglomerates, as occur in the Hughes Range, are interpreted to be channel deposits that feed turbidite fans. Channel erosion and deposition may have been triggered by movement on transverse growth faults located near the Boulder Creek and Lewis Creek fault zones.

Upper Aldridge

The upper Aldridge Formation comprises about 500 hundred metres of dominantly medium to dark grey siltstone, argillaceous siltstone and argillite. It is generally rusty weathering, thin bedded and thinly laminated. Thin graded siltite-argillite couplets and lenticular bedding with tan siltstone lenses in argillite are common bed-forms (Plate 17); syneresis cracks are commonly observed near the top of the upper Aldridge. Massive, or less commonly, crossbedded quartz arenite and quartz wacke beds occur near the top of the upper Aldridge in a section above the Midway mine (Section 8, Appendix 1). In the Hughes Range, 3 metres of buff to pink-weathering dolomitic siltstone is recognized at the top (Section 4); it has also been noted in the Lizard Range and near Moyie Lake (McMechan, 1981).

The contact of the upper Aldridge with the Creston Formation is relatively abrupt, and is placed where green-

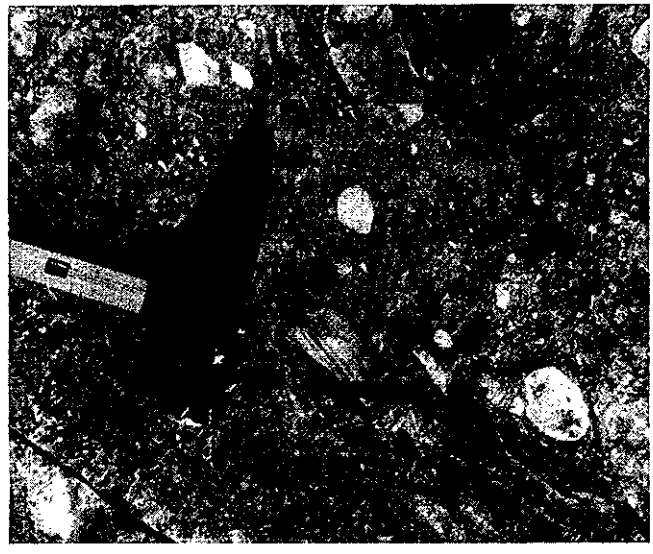


Plate 16. Massive intraformational conglomerate unit near the lower-middle Aldridge transition at the Vulcan-Hilo showing. Note that both clasts and matrix are derived from the immediately underlying lower Aldridge Formation.

tinged siltite layers first appear. Elsewhere, a massive, thick-bedded siltstone or wacke marks the base of the Creston Formation.

Facies Trends and Interpretation

Lower Aldridge siltstones and wackes are predominantly turbidite deposits (McMechan, 1981). They include crossbedded and laminated siltstone, divisions D and C in the Bouma facies model and, in the Kimberley area, a thick sequence of graded quartz arenite beds with only minor interbeds of argillaceous siltstone. These are predominantly A-E turbidites, deposited from higher velocity currents.

The transition from lower Aldridge to middle Aldridge in the Purcell Mountains and southern Hughes Range records a change from dominantly C-D-E turbidites to higher energy, or more "proximal" A-E turbidites. In the northern Hughes Range, however, rocks correlative with the lower part of the middle Aldridge, Unit A1, are dominantly platformal and slope facies with only minor thin-bedded turbidite and channel deposits. The Rocky Mountain Trench and Boulder Creek fault zones mark the approximate loci of these lateral facies and thickness changes. A systematic and pronounced southward variation of Unit A1 involves thickening from 2000 metres northeast of Wasa to approximately 2500 metres near Lakit Mountain accompanied by coarsening of clastic units. These changes are caused by Purcell-age growth faults located near the Boulder Creek fault.

The middle Aldridge is estimated to be at least 2000 to 3000 metres thick in the southern Hughes Range and Purcell Mountains (Figure 1). In the northern Hughes Range, north of the Boulder Creek fault, a thin succession of middle Aldridge turbidites is correlative with the upper part of the middle Aldridge of the Purcell Mountains. This turbidite succession thins northward, from 700 metres near Mount Bill Nye (Section 3) to only 240 metres northeast of Wasa (Section 4).

Plate 17. Interlayered siltstone and silty argillite at the top of the upper Aldridge Formation, Highway 3 at Moyie Lake. Siltstone layers are commonly graded and crossbedded, and syneresis cracks are common in more argillaceous units.

Paleocurrent measurements in middle Aldridge turbidites, including basal scours and crosslaminations, are summarized as rose diagrams in Figure 15. In general, current directions are northerly in the northern Hughes Range, Purcell Mountains and Lizard Range, but trend southwesterly in the southern Hughes Range.

Upper Aldridge siltstone and argillite overlie middle Aldridge turbidites throughout the entire Fernie west-half map area. The upper Aldridge records final infilling of the Purcell basin by pelagic and wind-blown material (McMechan, 1981). Lack of turbidite material suggests movements on growth faults, active in middle Aldridge time, had effectively ceased. The upper Aldridge has a variable thickness, from a maximum of 565 to 700 metres in the Galton and southern Hughes ranges (McMechan, *op. cit.*); to 400 to 500 metres in the Purcell Mountains (421 metres in Section 8; 240 metres in Section 10). In the northern Hughes Range, it varies from 325 metres near Mount Bill Nye (Section 3) to 173 metres northeast of Wasa (Section 4).

Summary and Discussion — Fort Steele and Aldridge Formations

Lower exposures of Purcell rocks in the northern Hughes Range, the Fort Steele Formation, are dominantly fluvial quartzites that were shed northward, perhaps in response to bowing up of the crust near the northern margin of an older southwest-trending tectonic zone. The zone coincides with the northern edge of a rift structure that was postulated by Kanasewich (1968). It is parallel to prominent northeast-trending magnetic lineations and a Bouguer gravity low that reflect Archean and Early Proterozoic basement structures (Hoffman, 1989; Ross *et al.*, 1991). Overlying cryptal algal mat deposits, siltstone and argillite record the initiation of a transgression with deposition of lagoonal and slope facies. South and west of the northern Hughes Range, thick-bedded turbidites were being deposited. Hence, the Boulder Creek fault zone and Rocky Mountain Trench are interpreted to mark the edge of a structural basin. Dramatic changes in lithology and thickness at the "platformal" edge, and within Unit A1 in the northern Hughes Range, suggest that the basin edge developed by growth faults.

An isopach map of middle Aldridge turbidites, restored for movement on the St. Mary and Moyie faults (Figure 15), indicates a marked deflection in the basin margin near the present position of the St. Mary and Boulder Creek faults. Northerly directed currents paralleled the margin of the basin; south of the Boulder Creek fault they were deflected southwestward, parallel to the northeast-trending reentrant. In late middle Aldridge time, turbidites spilled over the northeast-trending platform margin and were deposited in the northern Hughes Range. Paleocurrent directions in these turbidites trend northerly, suggesting that they were influenced only minimally by the northeast reentrant and marginal growth faults.

Differential down warping continued in late Aldridge time, centred near the reentrant in the basin margin. Lack of turbidites in the upper Aldridge, however, suggests movement on marginal growth faults had temporarily ceased. Lenticular-bedded siltstone and subordinate dolomitic siltstone at the top of the upper Aldridge mark the termination of basinal Purcell rocks. The overlying Creston Formation is the base of the Upper Purcell platformal succession.

CRESTON FORMATION

The Creston Formation (Daly, 1905; Schofield, 1915) comprises dominantly green, mauve and grey siltstone, argillite and quartzite with numerous structures indicative of shallow-water to subaerial deposition. It comformably overlies upper Aldridge argillite and siltstone and is overlain by carbonate rocks of the Kitchener Formation (Table 1). The Creston Formation correlates with the Burke, Revett and St. Regis formations of the Ravalli Group in the United States (Harrison, 1972; Winston, 1986b), the Appekunny and Grinnell formations in the southwestern Clark Range (Price, 1964) and the Appekunny, Grinnell and part of the upper Altyn Formation in the northern and eastern Clark Range (Fermor and Price, 1983).

The Creston Formation comprises three main subdivisions: a basal silty succession of thin-bedded grey to green siltstone and argillite, a middle quartzite succession of coarser grained mauve siltstone and quartz arenite, and an upper succession of intermixed green argillaceous siltstone and minor quartz arenite. A similar subdivision is apparent farther west in the Purcell Mountains (Reesor, 1983, 1984). McMechan (1980, 1981) divided the Creston Formation into five informal members. The basal two (C1 and C2) comprise dominantly grey and green siltite-argillite couplets, C3 and C4 include the middle, generally mauve-tinged units, and C5, the upper, dominantly green siltite unit.

Measured sections of the Creston Formation in the northern Hughes Range and Purcell Mountains are illustrated in Figure 16. The contact with the underlying upper Aldridge is usually gradational, placed where either green-tinged, lenticular bedding or syneresis cracks become noticeable.

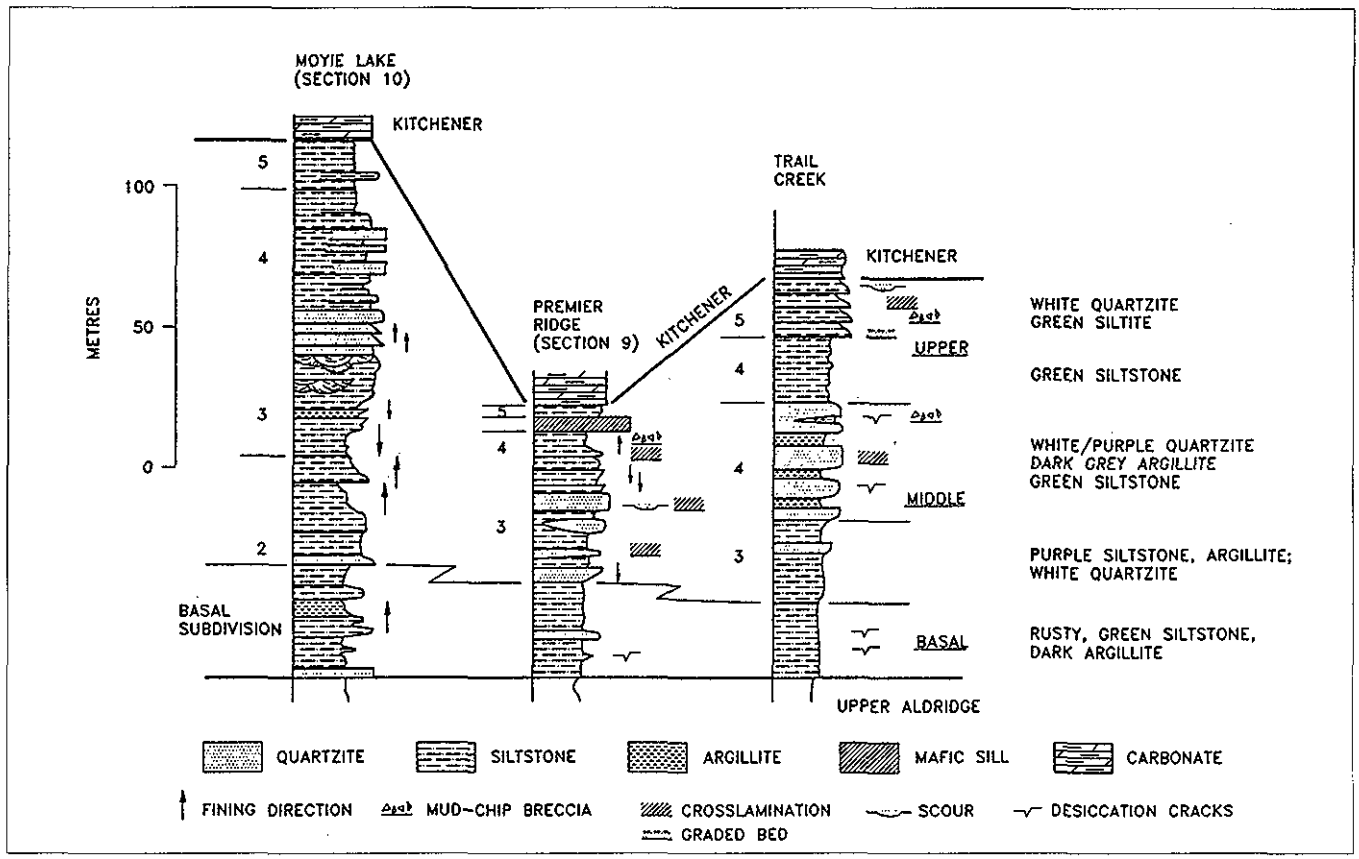


Figure 16. Sections of the Creston Formation, Moyie Lake, Premier Ridge and Trail Creek areas; the Premier Ridge (9) and Moyie Lake (10) sections are described in detail in Appendix 1.

Syneresis cracks are similar to mud cracks, but can form in a subaqueous environment (Reinick and Singh, 1975, p. 51). Commonly, a thick, generally massive, grey siltstone or impure quartzite marks the base of the Creston Formation (for example, Section 10, Appendix 1). In Montana, rocks similar to the basal Creston are commonly included in the upper part of the Prichard Formation (*see, for example,* Harrison *et al.,* 1986).

Description and Depositional Environment

The basal Creston comprises several hundred metres of interlayered argillite, argillaceous siltstone and minor quartz wacke. It is generally grey to dark grey and rusty weathering near the base, but as the siltite component increases upsection, it becomes green tinged. Thinly laminated argillite or siltite, graded siltite-argillite couplets (Plate 18), and lenticular-bedded siltstone are the most abundant bedforms; more massive medium-bedded quartz wacke is less common and brown-weathering silty dolomite layers are occasionally recognised (Unit 12, Section 8). Occasional scour-and-fill structures, rip-up clasts, ball-and-pillow structures, ripple marks, and crossbeds occur in the graded or massive siltstone-argillite interbeds. Syneresis cracks are common in the thin-bedded argillite and argillaceous siltite units (Plate 19). Many of these structures, particularly the syneresis cracks, local crossbeds and ripple marks, as well as the green coloration of siltstone layers, suggest a shallow marine or lacustrine environment. The absence of desiccation cracks, as noted by McMechan (1981), suggests deposition of the basal part of the Creston Formation in a subaqueous environment.

The thick, middle part of the Creston Formation comprises mauve or green argillite and siltstone with variable amounts of more massive quartz wacke or arenite. Siltstone-argillite couplets, up to several centimetres thick, dominate the basal part of the middle Creston. They differ from units

Plate 18. Graded siltstone layers with thin argillaceous siltstone tops in basal Creston Formation, southeast of Cranbrook.

Plate 19. Syneresis cracks preserved on a bedding plane, basal Creston Formation, Highway 3, Moyie Lake.

Plate 20. Thinly laminated, mauve-tinged siltstone in the middle part of the Creston Formation, Kiakho Lakes area; exposure width is approximately 2.5 m.

Plate 21. Ball-and-pillow structure in laminated purple and white siltstone in the middle part of the Creston Formation just northwest of Cranbrook. Rip-up clasts occur in the bed at the bottom of the photo.

Plate 22. Mud-chip breccias in fluvial quartzite of the middle Creston Formation, northern Hughes Range.

in the basal Creston as they are commonly purple in colour, thicker bedded and contain abundant mud cracks. Lenses of massive to graded, green, purple, or white quartzite that may contain large tangential crossbeds or wavy, irregular laminations are interbedded with the purple siltstone (Plates 20 and 21). The quartzites commonly scour the underlying siltstone and may contain numerous rip-up clasts (Plate 22). Coarsening-upward cycles, with massive to laminated purple and green siltstone at the base and interlayered purple siltstone and white quartzite with crossbeds, rip-up clasts, scour-and-fill structures and graded beds at the top are described in the Creston section at Premier Lake (Units 14, 15; Section 9).

A prominant, thick, white orthoquartzite unit occurs near the middle of the middle Creston. In the northern Hughes

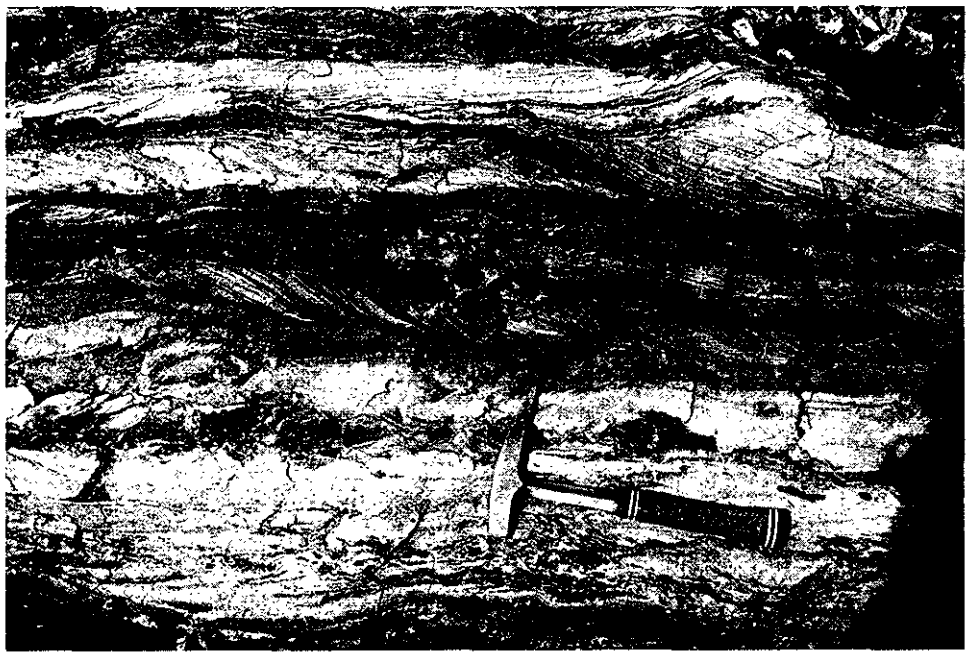


Plate 23. Crossbedded quartzite layers, mud-chip breccias and graded beds in the middle Creston Formation, northern Hughes Range.

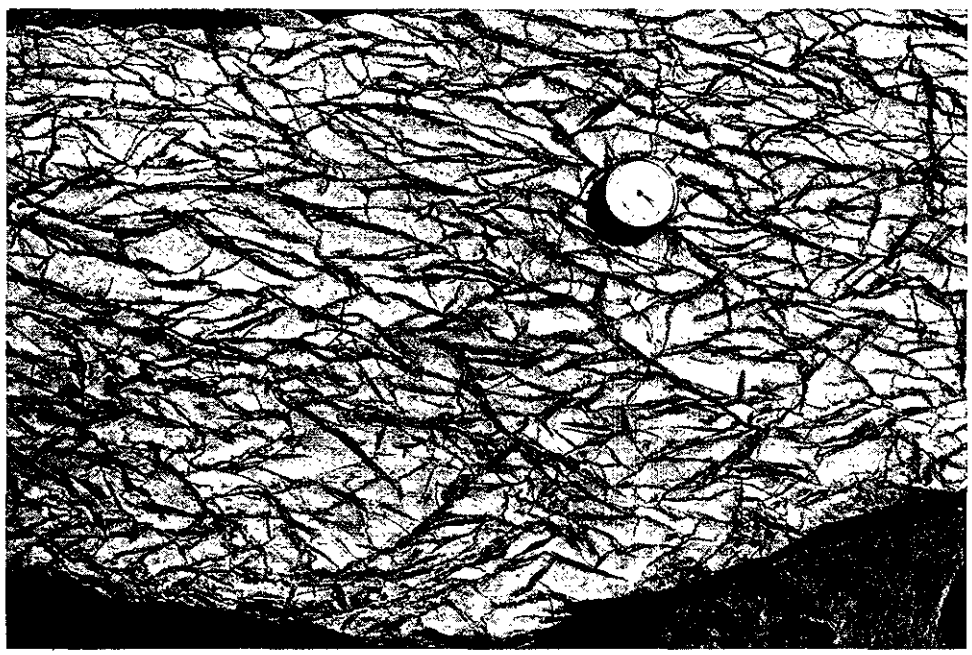


Plate 24. Mud cracks preserved on a bedding plane in green-tinged siltstone, Creston Formation, northern Hughes Range.

Plate 25. Asymetrical current ripples (with current direction from right to left), Creston Formation, Moyie Lake area.

Range east of the Rocky Mountain Trench, it is more than 100 metres thick (Units 23, 24; Section 9). It is medium to thick bedded and contains broad trough and tangential crossbeds and numerous rip-up clasts. The upper part of the quartzite unit comprises a number of coarsening-upward cycles, 3 to 10 metres thick, with purple and green siltstones at the base grading up through ripple crosslaminated siltstones and quartzites to massive thick-bedded quartzite at the top. Similar coarsening-upward cycles occur in the quartzite units at Moyie Lake (Unit 47, Section 10) and in siltstone-arenite units immediately below. Smaller fining-upward sequences are also common in the middle quartzite interval and overlying siltstone units. Based on lithologic similarity and stratigraphic position, this prominent massive quartzite may be the northern extension of the Revett Formation.

Interbedded mauve siltstone and argillaceous siltstone, white quartz arenite and minor green siltstone overlie the white quartzite units. Small fining-upward cycles are common, with massive to crossbedded quartzites at the base and thin-bedded, mud-cracked and rippled argillite or siltstone at the top (Plates 23, 24 and 25). Rip-up clasts, mud-chip breccias and some load casts occur throughout these units. Higher in the succession, laminated green siltstone and graded siltstone-argillite couplets become prominent. Surfaces may be mud-cracked or rippled, but these structures are less prominent than in underlying units. Small fining-upward cycles are common, with thicker bedded, white or green quartzite or more massive siltstone at the base grading up into thin-bedded siltite. These cycles are particularly prominent in the Trail Creek area east of the trench where white, crossbedded quartzite with numerous scours and rip-up clasts comprises more than 50 per cent of the top part of the Creston succession.

Numerous structures throughout the middle Creston, including mud cracks and mud-chip breccias, are indicative of periodic subaerial exposure. The prominent mauve or purple coloration of many units, oscillation ripple marks, and siltstone-argillite couplets suggest a shallow-water environment. The siltite-argillite couplets were formed by settling of silt and clay from clouds of suspended sediment that were repeatedly carried out onto shallow-water mudflats. The thick quartzite succession in the middle part of the Creston is dominantly fluvial sandstone deposited in extensive alluvial fans. The fining-upward cycles are similar to those described in the Revett and Bonner formations (Winston, 1978) and may record sediment deposition as flow velocities in broad channels decreased. Mauve, mud-cracked argillites at the tops of some of these cycles may be muds deposited in abandoned channels. Large-scale, coarsening-upward cycles are typical of river-dominated deltas (Miall, 1979) and formed as delta lobes prograded across mudflats.

The top of the Creston Formation generally comprises pale green laminated to massive argillaceous siltstone, commonly with a dolomitic cement. Structures indicative of subaerial exposure are less common, supportive of a basin-wide transgression in upper Creston time.

The contact of the Creston Formation with the overlying Kitchener Formation is gradational. East of the trench, it comprises a transitional zone of thin, regularly bedded siltstone-argillite that contains beds of dolomitic, buff-weathering argillite. The Kitchener contact is placed at the base of the first appearance of relatively pure, thick dolomite. West of the trench, the contact is commonly difficult to define. It is generally placed where brown-weathering, dolomite-cemented siltstone predominates over green siltstone (*see* Section 11).

Facies Trends and Interpretations

Figure 17, an isopach map of the Creston Formation, is based on measured and estimated thicknesses in the eastern Purcell Mountains and in the Western Ranges east of the Rocky Mountain Trench. Location of sections and isopachs have been restored for estimated right-lateral displacements of approximately 12 kilometres on both the St. Mary and Moyie faults (Benvenuto, 1978; this report).

The Creston Formation thickens westward from approximately 1300 to 1400 metres in eastern exposures in the Kootenay Ranges to greater than 2000 metres in the eastern Purcell Mountains. Farther west, the total thickness of the Creston Formation is less. Near Mark Pass west of

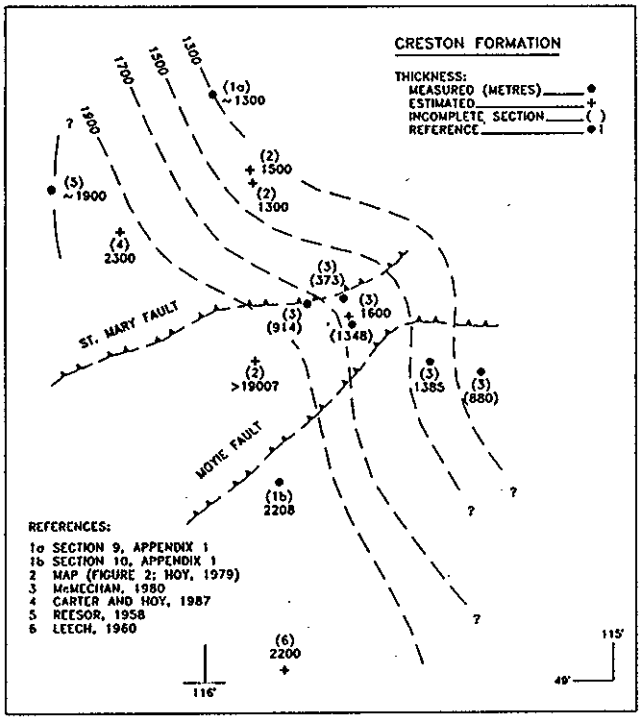


Figure 17. An isopach map of the Creston Formation, restored for approximately 12 kilometres of right-lateral movement on both the St. Mary and Moyie faults (see text for data source).

Skookumchuck, it is approximately 1900 metres thick (Reesor, 1958), near Findlay Creek, 1670 metres (Reesor, 1973) and south west of Kimberley, 1870 metres (Reesor, 1984). The rapid thinning at the approximate position of the trench corresponds approximately with the edge of the Purcell basin during deposition of Aldridge rocks. As well, the marked eastward deflection in the basin margin in the vicinity of the St. Mary and Boulder Creek faults, noted during deposition of Aldridge rocks, is still apparent.

Paleocurrent measurements in predominantly crossbedded quartz wackes and siltites of the middle Creston indicate a variable but generally northern, northeastern or northwestern current direction (Figure 18). These units are interpreted to be predominantly fluvial, deposited in braided channels or as sheet floods in alluvial fans (*see, for example,* Winston, 1986a). Their variable, but generally unimodal orientations contrast with bipolar orientations in the southern Hughes Range which are interpreted to be indicative of deposition in an intertidal environment (McMechan, 1980).

In summary, Creston rocks record progradation of mudflats and alluvial fans across the Purcell basin. Basal Creston rocks are predominantly argillites and siltites deposited on submerged mudflats. Sedimentary structures and facies trends in the middle Creston are indicative of fluvial and deltaic deposition as alluvial fans migrated across periodically exposed mudflats. A basin-wide transgression is evident in late Creston time, with deposition of dominantly pale green argillite and siltstone on extensive mudflats.

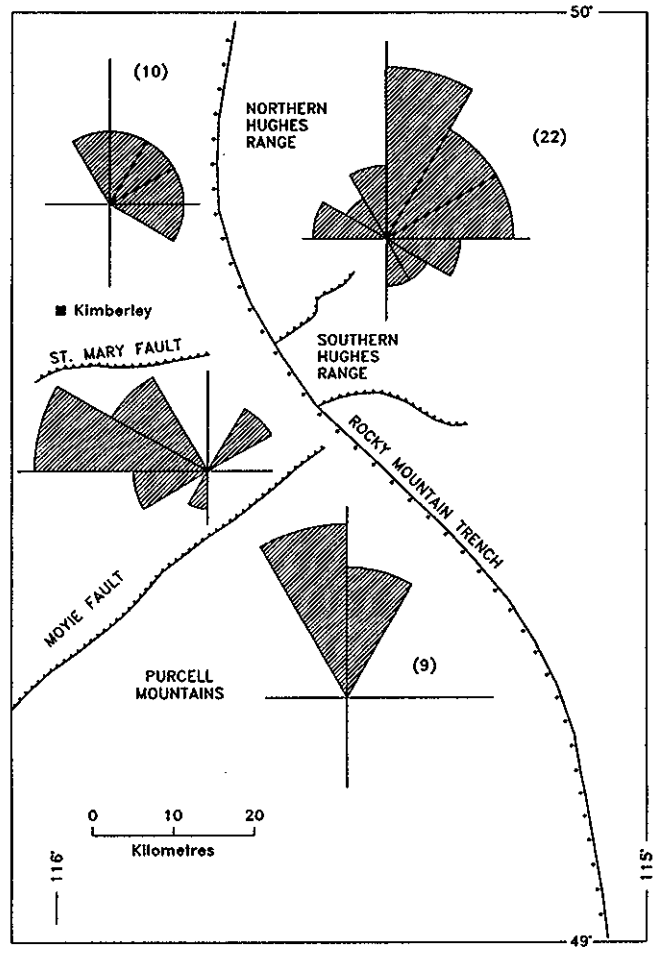


Figure 18. Rose diagrams of paleocurrent measurements in the middle part of the Creston Formation.

KITCHENER FORMATION

The Kitchener Formation is a dominantly carbonate unit between the Creston Formation and overlying siltites of the Van Creek Formation. It was defined by Daly (1905) and Schofield (1915). It correlates with the Empire and Helena formations in western Montana (Winston, 1986b) and with the middle part of the Siyeh Formation in the Galton and Clark ranges (Price, 1962; 1964; Fermor, 1980). The formation is divisable into two members, a lower green dolomitic siltstone and an upper dark grey, carbonaceous, silty dolomite and limestone.

Description – Northern Hughes Range

The Kitchener Formation in the northern Hughes Range varies in thickness from approximately 500 metres in the Trail Creek area to 800 to 900 metres east of Teepee Mountain, and approximately 1000 metres east of Premier Lake. It is readily divisible into lower and upper members, with the upper member further subdivisible into a lower, grey dolomitic unit and an upper interlayered dolomite, silty dolomite and siltstone unit.

A detailed section of the Kitchener Formation is described in Appendix 1 (Section 12) and illustrated in Figure 19. The lower member is approximately 150 metres

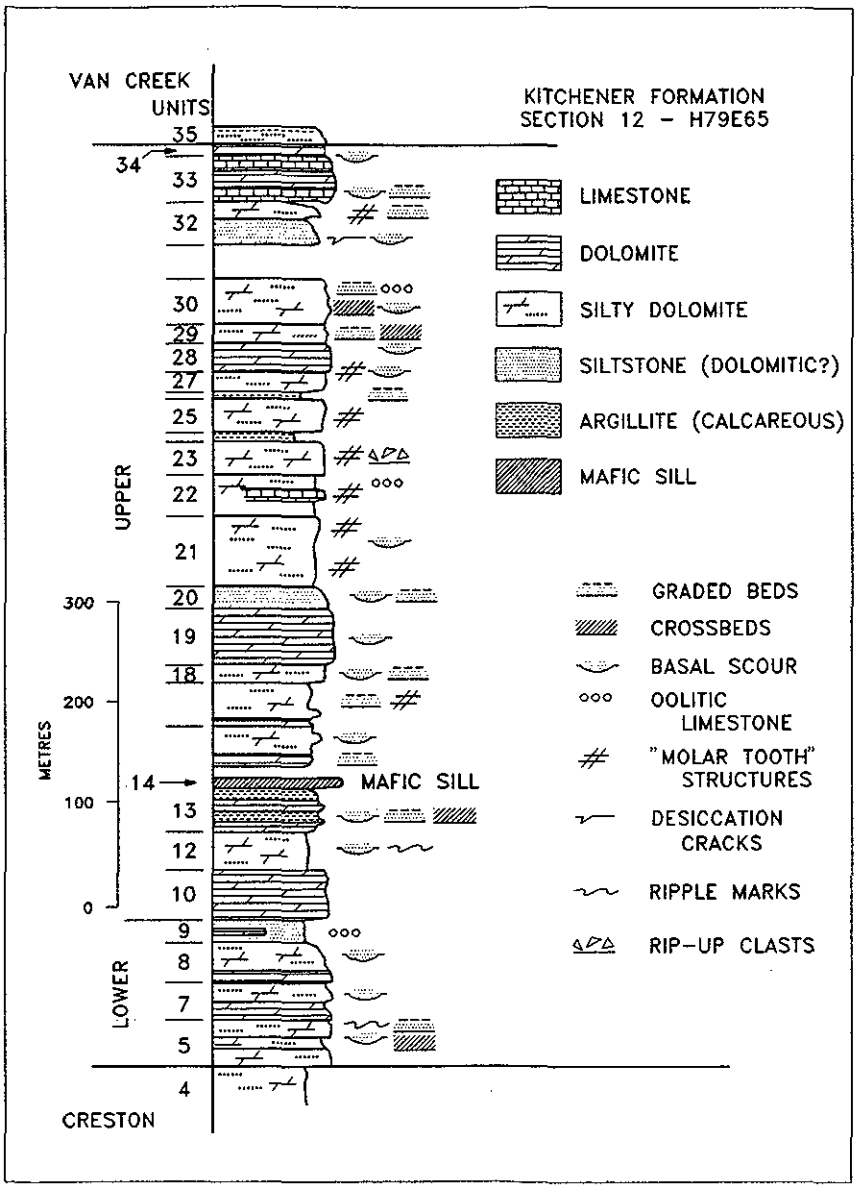


Figure 19. A measured section of the Kitchener Formation, Hughes Range; (Section 12, H79E65, Appendix 1).

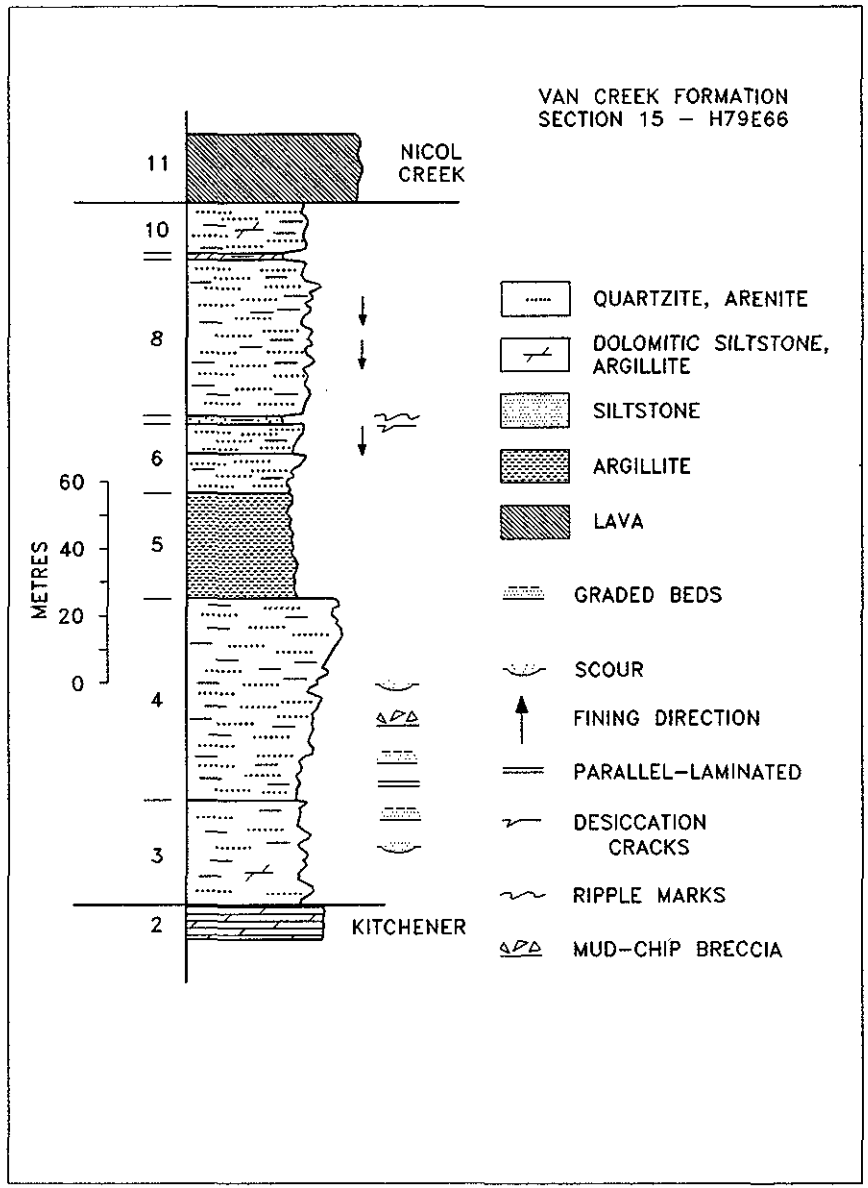


Figure 20. A measured section of the Van Creek Formation, Hughes Range; (Section 15, H79E66, Appendix 1).

Plate 26. Lenticular-bedded silty dolomite in the basal part of the Kitchener Formation, Moyie Lake area. Note dark calcite-filled crosscutting structures referred to as molar-tooth structures.

thick. The base of the lower member comprises interbedded buff-weathering, thinly laminated dolomite and buff to light green dolomitic siltstone that produces prominent brown-green striped outcrops. Crossbeds, scours and ripple marks, indicative of current activity, are abundant. Beds are commonly graded with siltstone overlain by dolomitic siltstone. Overlying units comprise a number of graded sequences with massive to argillaceous dolomite at the base and predominantly siltstone or dolomitic siltstone at the top. The top of the lower member includes interlayered pale green siltstone and dolomite, and a conspicuous section of thin-bedded oolitic limestone, green siltstone and massive dolomite. Structures indicative of current activity are common throughout the lower member.

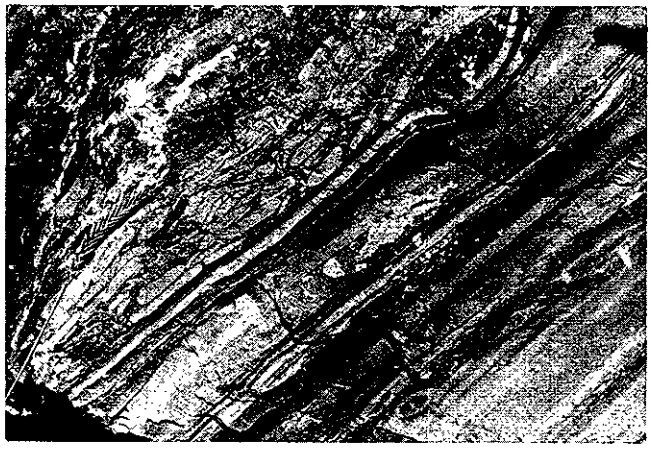


Plate 27. Thin-bedded silty dolomite, overlain by dolomitic mud-chip breccia, Kitchener Formation, Moyie Lake.

The base of the upper member (Units 10 to 17, Figure 19) comprises grey and black dolomite, argillaceous dolomite and argillite with occassional quartzite layers and minor limestone. Graded dolomite-argillite beds are common and, near the top of Unit 17, "molar-tooth" structures are first apparent. These are unusual and highly variable structures formed by small crenulated veinlets of calcite, approximately perpendicular to bedding, that weather in negative relief. They may be incorporated in clasts in mud-chip breccias and folded during compaction, suggesting that they are diagenetic in origin.

Silty dolomite and dolomitic siltstone with only minor argillite, dolomite and limestone overlies the argillaceous dolomites (Plate 26). Interbeds of oolitic limestone, scours, rip-up clasts and occassional fragmental limestone indicate local high-energy environments. Only a small portion of the succession comprises massive or laminated dolomite or argillite, indicative of more restricted, protected environments.

The uppermost units of the section are commonly green tinged, similar to the basal member. They include siltstone, limestone, dolomite and silty dolomite layers with crossbeds, scours, lenticular beds and graded siltstone -argillite couplets. Occassional desiccation cracks in argillite indicate periodic exposure. The Kitchener - Van Creek contact is placed above the highest dolomite layer.

Description - Purcell Mountains, Southern Hughes Range

The Kitchener Formation in the Purcell Mountains is approximately 2200 metres thick in the Skookumchuck map area (Carter and Höy, 1987a), 2000 metres in the Kimberley area (Höy, 1983) and approximately 1600 to 1800 metres in the Moyie Lake area (McMechan, 1980; Höy and Diakow, 1982). West of the Skookumchuck sheet in the Cherry Creek area, it is about 1400 metres thick (Reesor, 1958; 1984) and farther southwest near Armour Peak, it is estimated to be 1900 metres thick (McMechan, *op. cit.)*.

As in the northern Hughes Range, the formation in the Purcell Mountains is divisible into a lower and an upper member. The lower member comprises dominantly pale green siltstone and dolomitic siltstone interbedded with rusty to buff-weathering silty or argillaceous dolomite layers typically 1 to 2 metres thick. The siltstone is commonly thinly laminated or consists of graded siltstone-argillite couplets. Mudcracks, lenticular beds, crossbeds, ripple marks and basal scours are common structures. Grey micritic limestone pods occur locally in some siltstone beds (for example, Unit 42, Section 11). "Dolomite" layers vary from a dark grey, argillaceous or silty dolomite to tan

Plate 28. Crosscutting molar-tooth structures in lenticular-bedded silty dolomite of the Kitchener Formation, Highway 3, Moyie Lake.

dolomitic siltstone. They are commonly lenticular bedded or contain discontinuous silt lenses.

The upper member of the Kitchener Formation comprises dominantly dark grey argillaceous or silty limestone and dolomite overlain by a succession of calcareous or dolomitic siltstones. Graded beds, with thin dolomite layers capped by either siltstone or dark grey argillite, are common throughout the upper member. Carbonate layers are commonly finely or irregularly laminated, massive, and locally crossbedded (Plate 27). Molar-tooth structures are locally abundant in silty dolomite layers (Plate 28). Calcareous, dolomitic or nondolomitic siltstone layers occur throughout the basal part of the upper member but predominate in the upper part. Siltstone layers are commonly graded with argillite cappings, locally crossbedded, and may have rippled surfaces. Syneresis cracks occur locally, particularly in the upper, more silty section, and mud cracks are uncommon. Thin oolitic layers occur near the base and top of the middle member and occasional layers of stromatolites are present throughout.

The Kitchener Formation records deposition in a carbonate shelf while the input of terrigenous clastic material was reduced (McMechan, 1980). Although local mudcracks indicate subaerial exposure, these structures are less abundant than in the northern Hughes Range, suggesting generally deeper water environments in the Purcell Mountains. However, ripple marks, crosslaminations, oolitic beds and the occasional stromatolite layers indicate local shallow-water shoal environments.

The contact of the Kitchener Formation with the overlying Van Creek Formation is transitional over many tens of metres. East of Moyie Lake, grey, thin-bedded argillaceous limestone grades upward into intercalated grey siltstone and green to brown silty limestone at the base of the Van Creek. Farther southeast (Section 14, Appendix 1), interbedded dark green, thinly laminated siltstone and pale green dolomitic siltstone occur at the top of the Kitchener. Interbeds of quartzite, mud-chip breccias and mauve and purple siltstones, similar to those in the Van Creek Formation, are common.

VAN CREEK FORMATION

The Van Creek Formation was defined by McMechan *et al.* (1980) as the succession of siltites and argillites between carbonates of the Kitchener Formation and volcanic rocks of the Nicol Creek Formation. It is equivalent to Unit 5a of Leech (1960), the "Siyeh Formation" as defined by Schofield (1915), but not the "Siyeh" as originally defined in Montana by Willis (1902) which includes rocks equivalent to the complete Kitchener - Van Creek succession. The Van Creek Formation correlates with the Snowslip Formation in Montana (Table 1).

The thickness of the formation varies from approximately 200 metres in the northern Hughes Range (Figure 20) and in the Steeples farther south (McMechan, 1980), to 550 metres in the Skookumchuck area (Carter and Höy, 1987a), 790 metres in the Bloom Creek area (Section 16, Appendix 1) and 926 metres near Cherry Creek (Section 21).

Description and Depositional Environment

The Van Creek Formation comprises dominantly pale to dark green siltstone and argillite, lesser mauve siltstone and occasional layers of quartzite or dolomitic siltstone. Mauve siltstone layers tend to increase upsection, although they are always subordinate to green layers (Plates 29 and 30). Dolomitic layers occur near the top of most sections (*see* Appendix 1) but are uncommon elsewhere in the formation. Units typically weather to a reddish orange or tan colour and small brown rust spots in many layers may be oxidized magnetite grains.

Siltstone layers are generally thin bedded, laminated and commonly graded with argillite tops. Mud cracks, mud-chip breccias, crosslaminations, scours and rippled surfaces are abundant locally but not as prevalent as in the green and mauve siltstones of the Creston Formation. Argillite and silty argillite are less abundant; they are thinly laminated, locally mud cracked or cut by syneresis cracks, and may form mud-chip breccias. Thick-bedded, crosslaminated quartzite occurs near the top of Section 16 (Unit 12), but is generally uncommon in the formation.

Plate 29. Interlayered green and purple (dark) siltstone in the Van Creek Formation on Moyie Mountain.

Coarsening-upward cycles are common. They typically comprise green, finely laminated argillite or silty argillite at the base, overlain by thin-bedded, locally mud cracked siltstone, and capped by thicker bedded, more massive or crossbedded quartzite (Unit 4, Section 15).

Most of the Van Creek Formation was deposited in a shallow-water environment. Periodic subaerial exposure is indicated by local occurrences of mud cracks and mud-chip breccias. The coarsening-upward cycles may be deltaic deposits, formed as river-dominated deltas extended outward across silty mudflats.

NICOL CREEK FORMATION

The Nicol Creek Formation (McMechan *et al.,* 1980) is a prominent sequence of amygdaloidal basaltic flows, tuffs and interbedded siltstone and sandstone in the southeastern Purcell Mountains, western Rocky Mountains and Clark Ranges. It has been informally referred to as the "Purcell lavas", and is equivalent to map unit 5b of Leech (1960) and volcanic rocks at the top of the "Siyeh" Formation in the Dewar Creek area (Reesor, 1958). The formation thickens southeastwards in the Purcell Mountains, from a few tens of metres of volcanic tuff near Buhl Creek (Reesor, 1958) to approximately 550 metres of predominantly basaltic flows at Mount Baker.

Plate 30. Laminated and crossbedded green and mauve siltstone of the Van Creek Formation, 3 kilometres north of the junction of Highways 3 and 95A.

The contact of the Nicol Creek Formation with the underlying Van Creek Formation is abrupt, placed at the base of the first lava flow or tuff horizon. Its upper contact with the Gateway Formation is also sharp. However, southeast of Cranbrook an unconformity at the base of the Gateway Formation cuts into the Nicol Creek Formation and has locally removed it entirely, such that the Gateway rests unconformably on the Van Creek Formation.

The age of the Nicol Creek Formation is not known. Biotite in hornfelsed strata beneath the lavas has been dated at 1075 Ma (Hunt, 1962). This date may not be reliable as potassium-argon dating of intrusive Moyie sills and of Mesozoic intrusions in the Purcell Mountains has variable results due to overprinting of later thermal events and to excess argon in hornblende (Höy and Van der Hayden, 1988; Chapter 4). Magnetostratigraphic studies (Elston and Bressler, 1980; Elston, 1983) suggest that the entire Belt-Purcell sequence was deposited prior to 1200 to 1300 Ma and that the lavas of the Nicol Creek Formation were extruded between 1350 and 1400 Ma. Following the successful extraction of zircons from the Moyie sills (Chapter 3) an attempt was made to extract zircons in lava samples. However, a bulk sample (10 kg) that was processed did not yield any zircons.

DESCRIPTION

Measured sections of the Nicol Creek Formation indicate that it commonly comprises a basal succession of massive, amygdaloidal or porphyritic flows, overlain by a volcaniclastic siltstone and sandstone member, and capped by an upper succession of flows (Figure 21). Where the forma-

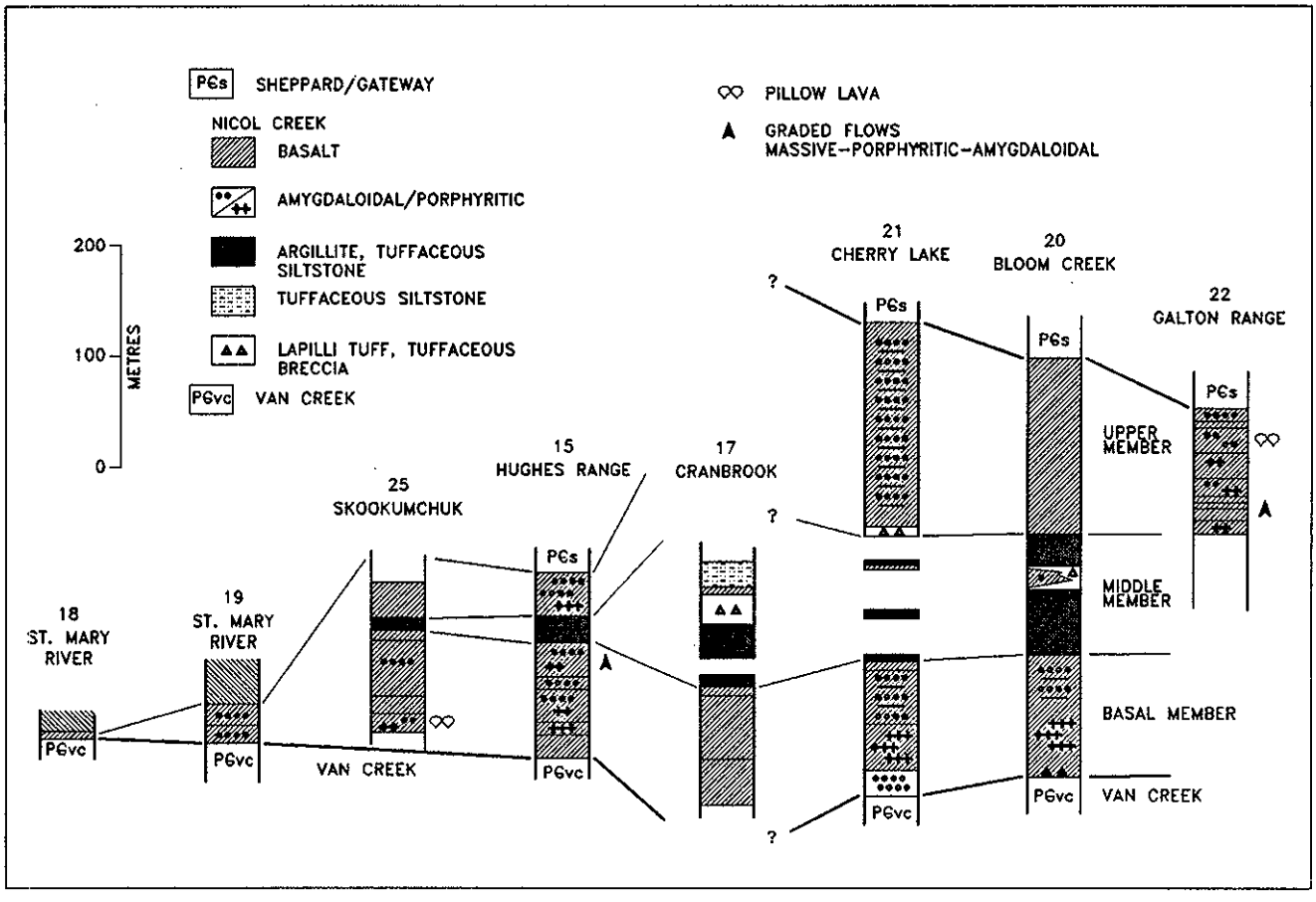


Figure 21. Measured sections of the Nicol Creek Formation.

tion is thin (Sections 19 and 23), the middle clastic unit is generally missing. The type section (McMechan *et al.*, 1980) is anomalously thick (608 metres) and includes a number of siltstone, sandstone or argillite intervals.

The basal member of the Nicol Creek Formation includes up to 100 metres of flows and minor pillow lavas, flow breccias and lapilli tuff. Tuffs are a very minor component of the formation. A few metres of green, thin-bedded, graded beds occur at the base of Sections 20 and 21. A few tuff beds up to 1 metre thick are also interbedded with flows. Although usually obscured by lichen growth on outcrops, the beds provide excellent bedding attitudes wherever found.

Lava flows in the lower member typically grade upward from a massive phase through a porphyritic phase and into an amygdaloidal or, less commonly, vesicular phase. Elsewhere, a succession of flows grades upward through many tens of metres from more massive flows at the base to porphyritic flows and amygdaloidal flows at the top (*see* Units 11 to 13, 15, Section 15; Unit 2, Section 19). Amygdules are generally quartz and/or chlorite filled; specularite or calcite were noted locally. Pipe amygdules and vesicules are common at the base of many flows and pseudo-bedding and stratigraphic facing may be derived from basalts displaying grading of amygdules (Plates 31 and 32). Porphyritic flows are characterized by phenocrysts of altered plagioclase that range in size up to several centimetres (Plate 33).

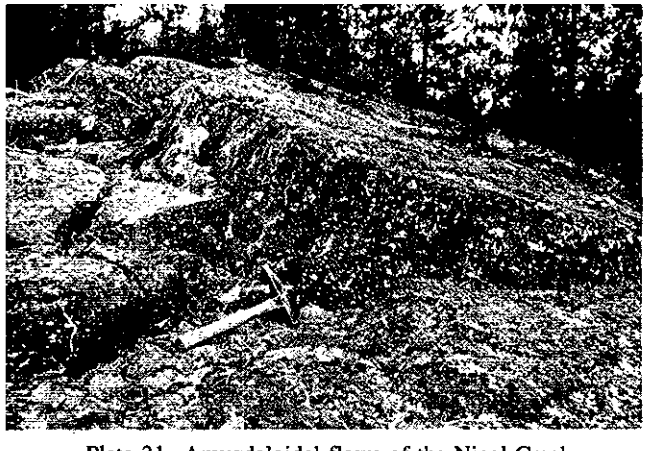


Plate 31. Amygdaloidal flows of the Nicol Creek Formation, east slopes of Joseph Mountain.

Volcanic breccias are rare in the Nicol Creek Formation. Some consist of angular purple and green fragments within a homogeneous flesh-coloured, mixed hyaloclastite(?) - silty(?) matrix; these breccias form irregular pods and beds within amygdaloidal basalt flows. They may be quench breccias, which formed as basalt interacted with either water or water-saturated sediments. Similar breccias occur higher in the Nicol Creek Formation on a ridge southwest of Gold Creek and Mount Baker, and in exposures in Teepee

Plate 32. Grading of amygdules in flow of the Nicol Creek Formation, east slopes of Joseph Mountain (photo by L. Diakow).

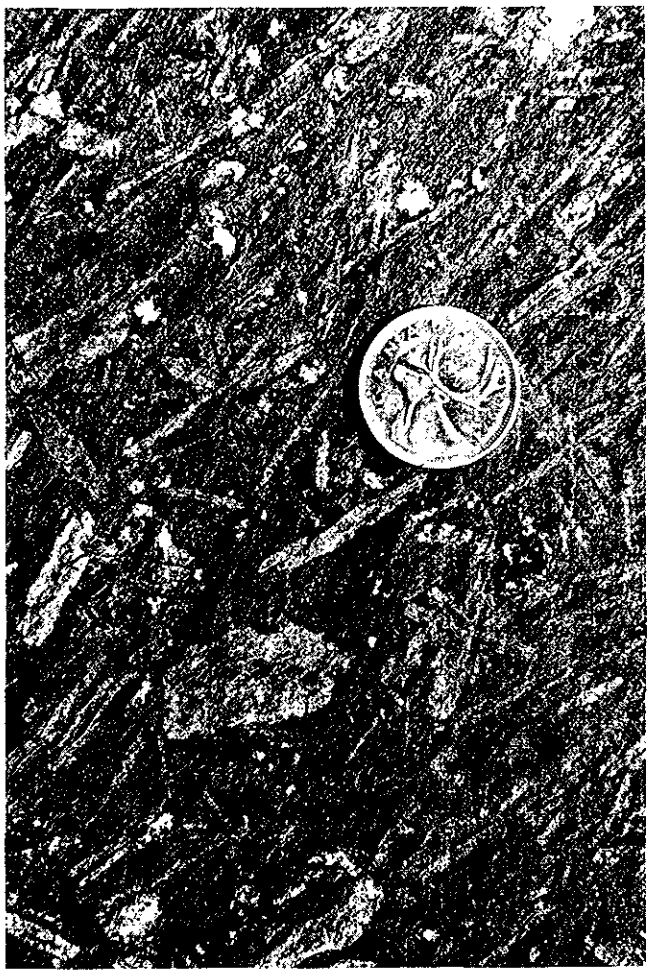


Plate 33. Porphyritic lava flow, Nicol Creek Formation, Bloom Creek area (photo by L. Diakow).

Plate 34. Explosive breccia, with angular clasts of basalt in siliceous matrix, east slopes of Joseph Mountain.

Creek. These form crosscutting structures as well as discontinuous layers and consist of highly angular fragments of amygdaloidal basalt, siltstone and chert in a cherty or fine-grained, siliceous clastic matrix (Plate 34). They are interpreted to have formed by explosive release of steam trapped beneath a lava flow as it flowed over submerged siltites. Less commonly, volcanic breccias comprise angular fragments of basalt in a lithologically similar matrix. Rarely, lapilli tuff was recognized (Plate 35). They are flow breccias formed by autobrecciation of a subaerial lava flow.

Pillow lavas are uncommon in the basal member. They occur near the base of a partially exposed section along Skookumchuck Creek (Section 25) and in a layer 2 metres thick in a section in the Galton Range (Unit 9, Section 22). Here pillows are massive, closely packed and in a hyaloclastite matrix. They overlie a flow with chert-filled amygdules and a thin (2 cm) pale green chlorite-altered top.

Volcaniclastic sandstone, siltstone and minor argillite comprise the middle member of the Nicol Creek Formation. The member is typically a few tens of metres thick, but varies from nonexistent in thin exposures to approximately 80 metres in the Bloom Creek section (Units 3 and 5, Section 20). The sandstones and siltstones are fine to coarse grained, green or, locally, maroon in colour, and commonly

Plate 35. Monolithic graded tuff, Joseph Mountain (photo by L. Diakow).

contain numerous sedimentary structures indicative of shallow, turbulent water and periodic subaerial exposure. These structures include crossbeds, rip-up clasts and scour marks. Tops of beds may have rippled surfaces, and graded beds, capped by argillite, are locally mud-cracked. Finely laminated, generally pale to dark green silty argillite and less commonly dolomitic argillite also occur in the middle member of the Nicol Creek Formation, but are less abundant than sandstone or siltsone. Lenticular beds, silt scours, mud-chip breccias and mud cracks are common structures in these layers.

The upper member comprises dominantly massive to amygdaloidal flows with occassional intercalated layers of tuff, epiclastic sandstone and siltstone, and volcanic breccia. Porphyritic flows are rare, in contrast with their common occurrence near the base of the lower member. In the type section, green siltstones and sandstones form a large proportion of the upper part of the Nicol Creek Formation and the subdivision into these informal members is not as apparent.

The top of the formation is commonly marked by a thin sequence of green epiclastic sandstone and siltstone. It usually overlies purple amygdaloidal basalt or may form a thin sedimentary layer between two flows.

Distribution

An isopach map of lava flows, volcanic breccias and pyroclastic rocks indicates that the thickest accumulation of volcanic rocks is centred in a northerly trending belt in the Hughes Range and Mount Baker area (Figure 22). The thickness of these volcanic rocks increases eastward from a few metres southeast of Kimberley (Sections 18, 19) and in the most western exposure east of Moyie Lake, to more than

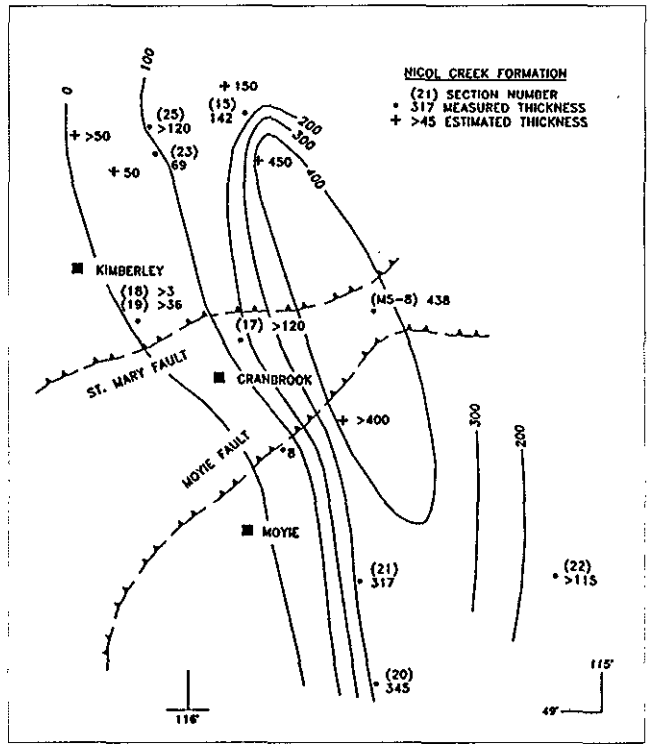


Figure 22. An isolith map of lavas of the Nicol Creek Formation, restored for movements on the St. Mary and Moyie faults (data from Höy, 1985 and McMechan, 1981).

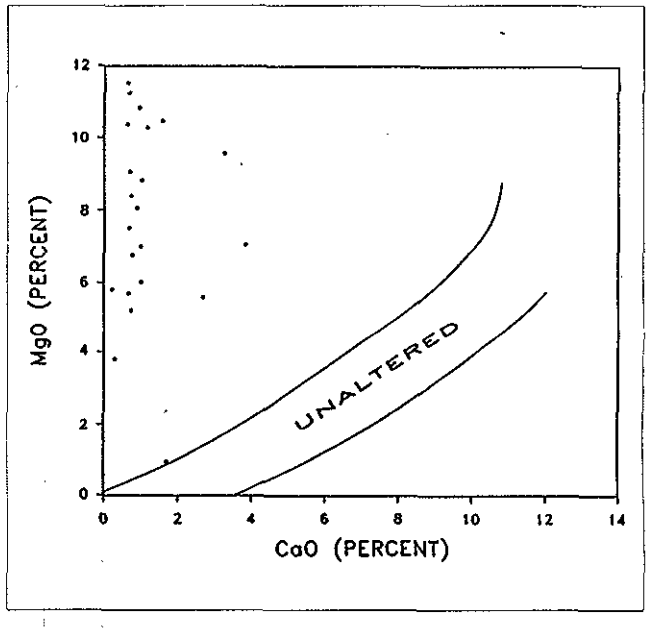


Figure 23. MgO/CaO plot of lavas of the Nicol Creek Formation designed to screen altered mafic volcanic rocks (plot after de Rosen-Spence, 1985).

TABLE 2
MAJOR AND MINOR ELEMENT ANALYSES OF SAMPLES OF THE NICOL CREEK LAVAS

Lab No.	Field No.	SiO_2	Al_2O_3	Fe_2O_3	MgO	CaO	Na_2O	K_2O	MnO	TiO_2	P_2O_5	BaO	CO_2	H_2O^+	H_2O^-
24954	80M54-10	48.84	15.20	12.07	11.09	0.63	0.202	3.300	0.054	2.145	0.32	0.08	0.07	6.41	0.40
24955	80M54-14	64.76	12.71	7.85	5.77	0.26	0.060	3.203	0.014	0.965	0.30	0.04	0.07	3.55	0.23
24956	TM M-5	48.87	15.62	14.80	5.54	2.70	3.266	2.380	0.215	2.065	0.39	0.18	0.86	4.63	0.27
24957	TM M-9	45.39	13.35	21.89	5.19	0.73	0.058	5.774	0.025	2.678	0.57	0.07	0.43	3.75	0.29
24958	TM M-10	40.52	15.28	23.29	6.00	1.03	0.242	4.658	0.021	2.816	0.53	0.04	0.07	4.58	0.43
24959	LD M-10	39.42	13.73	25.84	5.66	0.67	0.395	6.294	0.047	2.633	0.25	0.06	0.08	3.83	0.31
24960	LD M-14	47.99	13.53	17.65	8.37	0.70	1.208	1.901	0.017	2.717	0.48	0.04	0.07	5.24	0.32
24961	LD M-27	51.23	12.36	16.67	6.72	0.75	0.460	2.979	0.042	2.969	0.66	0.06	0.28	4.48	0.37
24962	LD M-37	42.77	18.33	14.34	11.40	0.59	0.072	4.751	0.038	1.436	0.15	0.05	0.33	7.23	0.29
24963	LD M-60	53.04	14.21	11.03	10.25	0.60	0.002	1.551	0.040	1.984	0.48	0.01	0.07	6.41	0.16
26379	LD82-1S	42.08	16.35	11.37	15.02	0.72	0.848	1.187	0.070	3.415	0.56	—	0.20	7.30	0.31
26380	LD82-2S	44.24	17.49	9.49	13.33	0.79	0.030	2.400	0.041	3.551	0.71	—	0.29	7.82	0.24
26381	LD82-3S	41.17	16.49	13.61	12.60	1.04	1.345	1.025	0.046	4.111	0.71	—	0.20	7.26	0.28
26382	LD82-4S	43.44	15.99	13.59	10.73	0.98	0.957	3.331	0.031	3.747	0.39	—	0.41	6.47	0.19
26383	LD82-5S	48.62	14.28	14.10	7.98	0.89	2.027	2.258	0.036	3.434	0.52	—	0.26	5.11	0.12
26384	LD82-1B	39.38	16.22	17.13	10.33	1.54	2.091	0.442	0.104	4.401	0.53	—	0.60	6.90	0.29
26385	LD82-2B	40.86	17.30	14.97	12.13	2.11	0.325	1.476	0.046	4.276	0.48	—	1.21	7.92	0.22
26386	LD82-3B	42.43	13.71	15.00	9.51	3.25	0.692	1.698	0.139	3.406	0.61	—	3.75	5.47	0.18
26388	KL11-12	38.39	18.01	20.92	3.78	0.29	0.051	7.448	0.016	4.665	0.08	—	0.34	3.77	0.24
26389	K28-15	45.39	15.72	13.60	7.01	3.84	3.461	2.067	0.204	2.402	0.32	—	1.48	4.33	0.28
26390	LD82-8110	43.92	15.70	12.95	10.23	1.17	0.824	2.287	0.107	4.112	0.76	—	0.47	6.46	0.24
26391	LD82-5825	42.29	14.36	14.70	12.13	0.75	0.077	1.866	0.035	3.544	0.80	—	0.20	7.18	0.25
22583	E36-6	44.16	14.86	19.82	8.75	1.00	1.659	4.440	0.045	2.800	0.55	0.04	—	—	—
22584	E36-23	47.39	16.80	12.68	9.03	0.66	0.289	5.827	0.063	2.492	0.05	0.05	—	—	—
22585	E64-11	47.82	18.69	10.83	6.93	0.97	4.741	2.399	0.097	2.232	0.46	0.08	—	—	—
22586	E66-4	51.70	15.37	11.99	7.51	0.65	3.384	2.350	0.069	2.281	0.53	0.05	—	—	—
22587	E68-7	43.38	15.21	18.14	0.97	1.74	3.281	3.318	0.660	0.064	0.01	0.11	—	—	—

— not analyzed

400 metres at Mount Baker, 438 metres in the type section in the Hughes Range and an estimated 450 metres farther north in the Hughes Range. The original eastern limit of the volcanic pile is not known as only younger rocks are exposed farther east in the Rocky Mountains. However, a thinning to the east and southeast is inferred as only 115 metres of lava flows were measured in the Galton Range (Section 22). Although the base of the Nicol Creek is not exposed here, it is assumed that most of the formation is represented.

Although vent facies as described by McGimsey (1985) in Glacier National Park in Montana were not recognized, it is probable that the lavas erupted from a northerly trending fissure beneath the thickest part of the volcanic pile (Figure 22) coinciding, in part, with the postulated eastern edge of the Purcell basin and with its intersection with northeast-trending basement structures.

Geochemistry

Analyses of lavas of the Nicol Creek Formation are given in Table 2. These analyses plot in the high-iron, tholeiitic field of Jensen's cation plot (Jensen, 1976) and in the alkaline field in an alkali-silica diagram. However, pervasive propylitic alteration and high MgO/CaO ratios (Figure 23) indicate that the major oxides are remobilized, thereby precluding definite classification of the lavas using these elements.

Many studies have demonstrated relative immobility of some trace and minor elements during regional metamorphism and many of these elements are diagnostic in classifying volcanic rocks and in determining their tectonic environment; some of these elements include niobium, yttrium, zirconium, titanium, phosphorus and chromium.

Niobium-yttrium ratios are an indication of alkalinity whereas titanium values are an index of basicity. Plots of Nb/Y versus SiO_2 or Zr/TiO_2 (Figures 24 and 25) suggest that Nicol Creek lavas are generally subalkaline to alkaline basalts. However, on a TiO_2 versus Zr/P_2O_5 binary plot, Nicol Creek lavas plot dominantly in the alkaline field (Figure 26). The alkaline nature of correlative Purcell lavas in Glacier National Park, Montana, has been shown by McGimsey (1985).

On a Ti-Y-Zr diagram, designed to determine the tectonic setting of basaltic rocks, samples of the Nicol Creek Formation plot in the "within-plate" or as "continental" basalts (Figure 27). In an oceanic environment, "within-plate" settings include volcanic islands or seamounts, rifts in mature volcanic arcs, or back-arc basins, as opposed to spreading ridges. In a continental setting, alkaline basalts occur most commonly in rift zones, generally resulting from cratonic uplift (Bailey, 1974). Supportive evidence for "rifting" during deposition of Nicol Creek lavas includes the preferential distribution of lavas coincident with the inferred Purcell basin margin in Aldridge time. The rifting involved reactivation of crustal faults near the margin of the basin. Associated block faulting and uplift is evident in immediate post-Nicol Creek time in the Skookumchuck area and by an unconformity at the base of the overlying Sheppard and Gateway formations farther south. This unconformity is commonly marked by a boulder conglome-

TABLE 2 — *Continued*
MINOR AND TRACE ELEMENT ANALYSES OF SAMPLES OF THE NICOL CREEK LAVAS

Zr	Y	Nb	Rb	Ta	CO	Ni	Cr	Sr	Th	U
277	43	22	35	<4	16	18	43	6	2	<2 ppm
190	30	10	71	<4	3	33	51	4	4	<2 ppm
260	39	23	29	<4	17	25	43	98	10	<2 ppm
291	38	26	104	<4	13	26	39	12	8	<2 ppm
298	47	27	87	<4	14	33	43	15	6	<2 ppm
279	37	23	59	<4	14	25	37	14	5	<2 ppm
290	41	28	23	<4	18	28	36	13	4	<2 ppm
307	40	28	49	<4	18	22	51	11	6	<2 ppm
234	36	17	35	<4	14	68	58	12	1	1
261	42	23	24	<4	14	17	41	0	3	<2 ppm
200	33	22	29	<4	17	71	43	7	4	<2 ppm
225	40	21	60	<4	13	30	27	2	4	<2 ppm
276	38	29	30	<4	15	52	97	11	1	<2 ppm
237	34	26	43	<4	20	35	34	36	4	<2 ppm
284	39	22	22	<4	17	25	31	22	4	<2 ppm
294	45	30	18	<4	19	44	63	20	4	<2 ppm
281	43	34	46	<4	18	44	37	29	6	3
286	45	29	44	<4	16	28	40	26	9	<2 ppm
424	60	39	175	<4	6	22	58	2	3	<2 ppm
182	27	14	42	<4	18	50	18	232	2	<2 ppm
282	49	33	56	<4	16	46	58	24	4	<2 ppm
308	46	30	34	<4	18	30	33	13	5	4
292	44	27	75	<4	18	29	39	42	4	<2 ppm
203	30	24	95	<4	13	28	30	16	9	<2 ppm
159	28	17	54	<4	14	30	28	83	7	<2 ppm
249	33	24	29	<4	16	38	38	34	10	<2 ppm
281	37	29	43	<4	16	51	88	27	4	<2 ppm

rate and locally cuts through and removes several hundred metres of the Nicol Creek Formation.

SHEPPARD FORMATION (LOWER DUTCH CREEK FORMATION)

The Sheppard Formation (Willis, 1902) includes up to several hundred metres of stromatolitic dolomite, quartz arenite, siltstone and argillite lying above the Nicol Creek Formation. It has been mapped as the lower part of the Gateway Formation by Schofield (1915), Leech (1958a,b, 1960), Höy and Diakow (1982) and Carter and Höy (1987b), but is described as a separate formation in this paper as suggested by Price (1964) and adopted by McMechan (1981).

The Sheppard Formation varies in thickness from less than 100 metres in exposures east of Moyie Lake, to 125 metres southeast of Mount Fisher (McMechan, *op. cit.)*, and 300 metres north of Diorite Creek in the northern Hughes Range. In the Skookumchuck area, it increases dramatically in thickness, from approximately 500 metres near Echoes Lake to 1500 metres in the Larchwood Lake area, 10 kilometres farther north (Carter and Höy, 1987a). This increase in thickness is accompanied by prominent facies changes in the Sheppard Formation and in the overlying Gateway and Phillips formations.

DESCRIPTION

The Sheppard Formation is characterized by an assemblage of green siltite, sandy dolomite, quartz wacke, distinctive stromatolitic dolomite and oolitic dolomite layers. Southeast of Cranbrook the base of the Gateway is locally marked by a fluviatile conglomerate that has removed up to several hundred metres of the underlying Nicol Creek Formation.

In the northern Hughes Range, north of Diorite Creek, the Sheppard Formation includes pale green to buff siltstone, overlain by interlayered buff dolomite, lenticular-bedded siltstone and minor purple argillite (Plate 36). Interlayered stromatolitic dolomite, dolomitic or quartz sandstone, and minor oolitic limestone and argillite overlie the more silty basal part of the formation (Plates 37 and 38). The basal part of the formation in the Galton Range is dominated by a carbonate-rich succession, including a number of prominent stromatolitic layers (Figure 28).

Northwest of Skookumchuck, the formation is marked by pronounced changes in thickness and lithology. At Echoes Lake (Figure 29), it is approximately 500 metres thick (Carter and Höy, 1987a) and lithologically similar to sections in the Hughes and Galton ranges. The basal part comprises mainly green, laminated siltstone, crossbedded and rippled sandstone and quartzite, with dolomitic siltstone layers throughout. Stromatolitic dolomite interbedded with quartzite, purple siltstone, massive dolomite and oolitic dolomite forms a distinctive package more than 100 metres thick near the top of the formation (Plates 39 and 40).

At Larchwood Lake, 10 kilometres farther north, the Sheppard Formation is estimated to be 1500 metres thick (Figure 29). This dramatic increase in thickness is largely

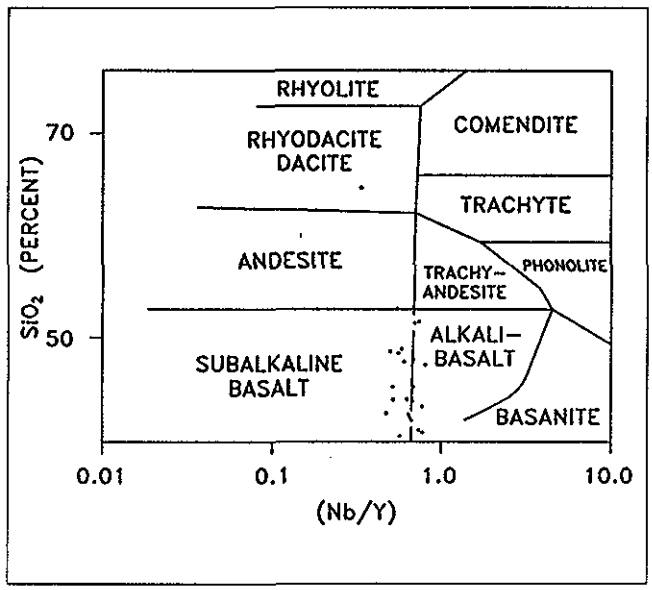


Figure 24. A Nb/Y versus SiO_2 plot of lavas of the Nicol Creek Formation indicating alkaline to subalkaline basaltic compositions (plot after Winchester and Floyd, 1977).

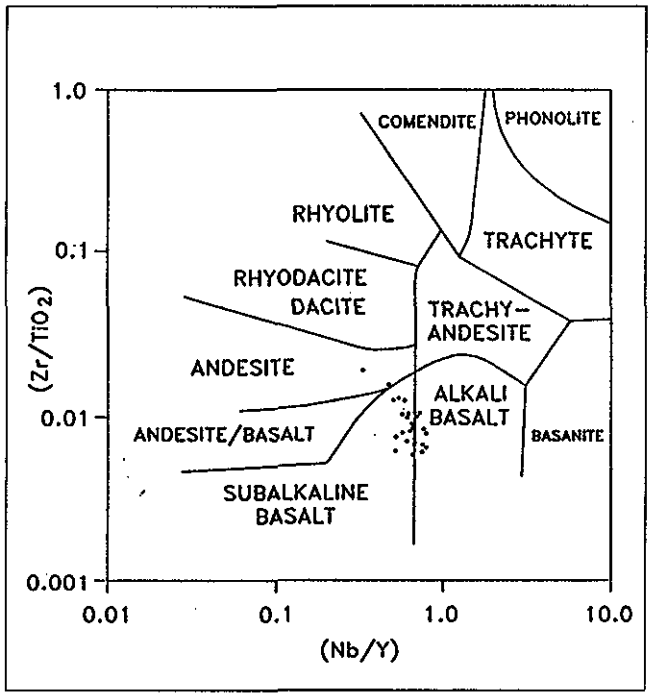


Figure 25. A Nb/Y versus Zr/TiO_2 plot of lavas of the Nicol Creek Formation indicating alkaline to subalkaline basaltic compositions (plot after Winchester and Floyd, 1977).

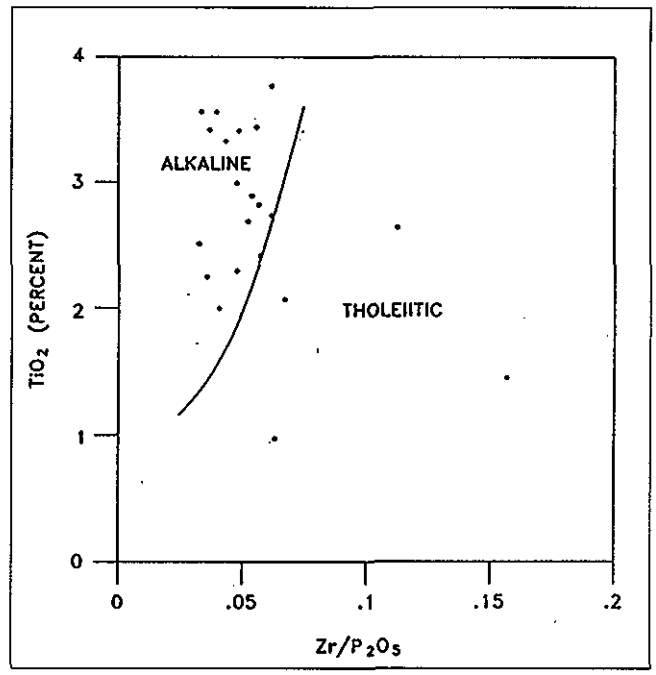


Figure 26. A TiO_2 versus Zr/P_2O_5 plot of lavas of the Nicol Creek Formation showing their dominantly alkaline nature (plot after Floyd and Winchester, 1975).

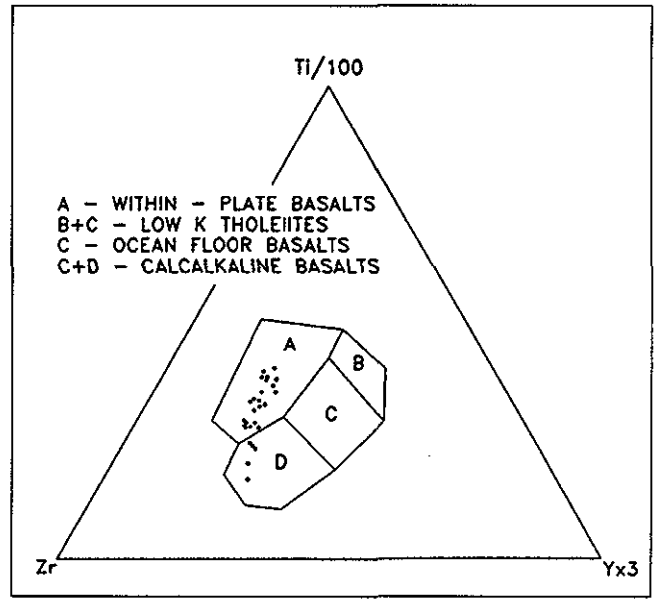


Figure 27. A Ti-Zr-Y ternary diagram of lavas of the Nicol Creek Formation indicating a "within-plate" tectonic setting (plot after Pearce and Cann, 1973).

accommodated by a thick succession of dominantly green siltstone, commonly in the form of graded siltstone-argillite couplets, that lies between the Nicol Creek lavas and the stromatolite-bearing sequence at the top of the Sheppard Formation. Farther west near Bradford Creek, the formation is still recognizable but is referred to as the lower Dutch Creek Formation. It comprises green siltstone and argillite with minor dolomitic siltstone and, near the top, stromatolitic dolomite. This stromatolitic sequence can be traced north of Bradford Creek and marks the contact between the lower and upper Dutch Creek. It comprises cycles of rounded and gritty quartz wackestone, overlain by oolitic, stromatolitic or massive dolomite. These cycles may contain a few thin, purple argillite beds with mud cracks and locally, rip-up clasts (Plate 41). They are overlain by and interbedded with

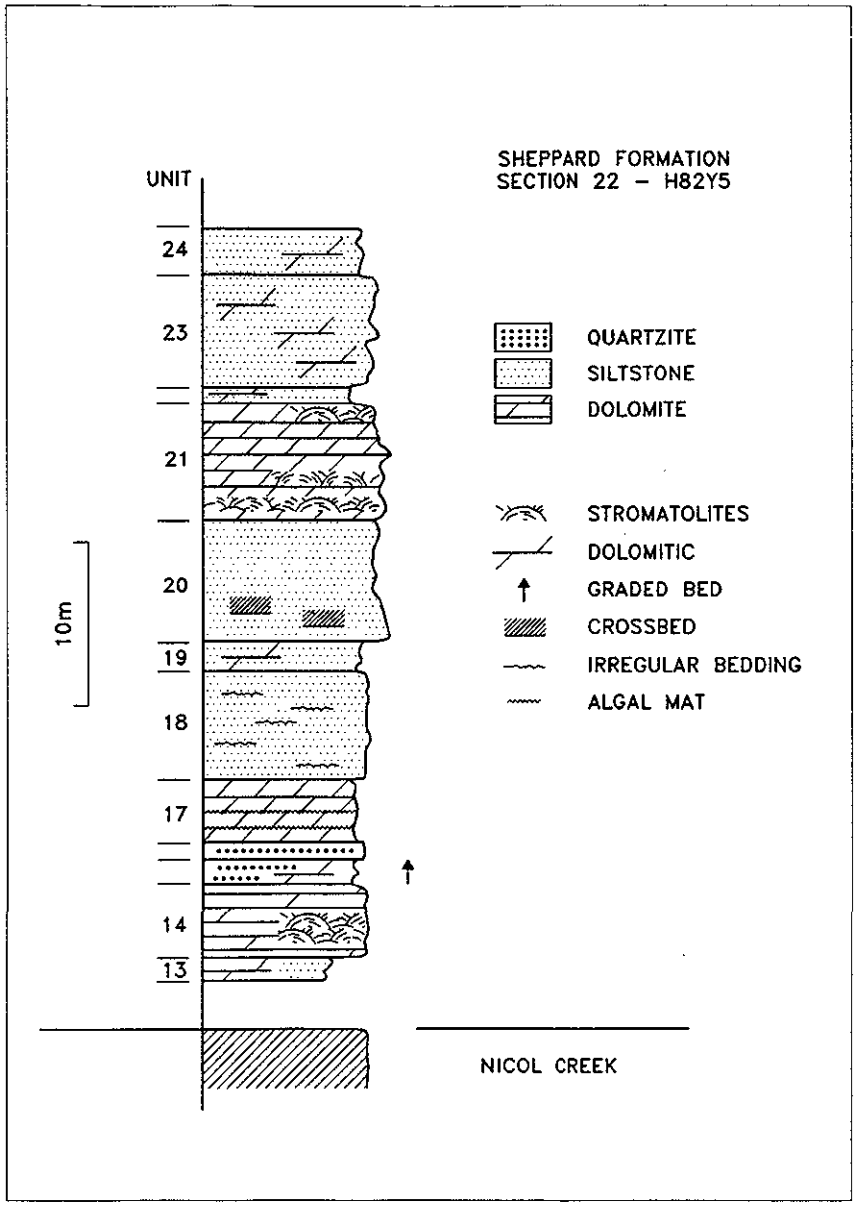


Figure 28. A measured section of the Sheppard Formation, Galton Range; (Section 22, H82Y5, Appendix 1).

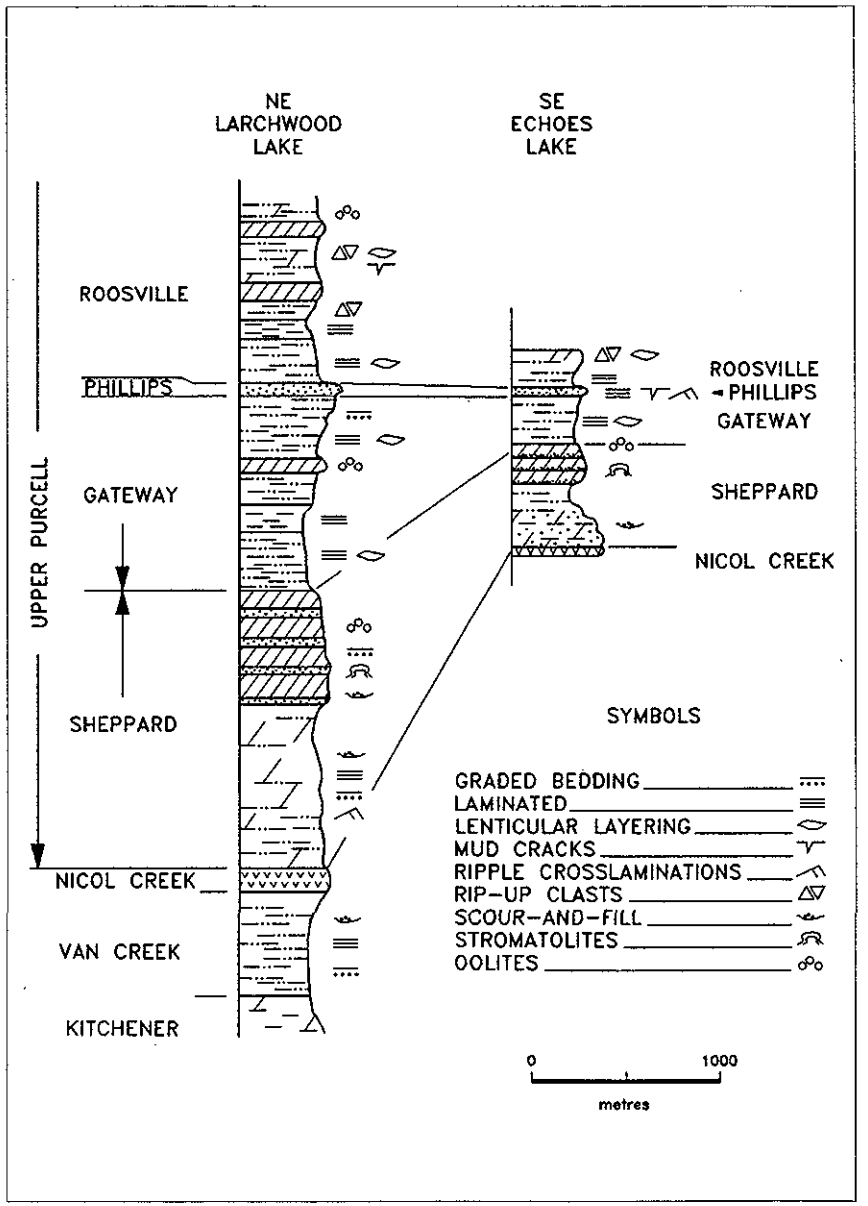


Figure 29. North-south correlation of Sheppard and Gateway formations, Skookumchuck area, showing the dramatic increase in thickness of units to the north. The Echoes Lake section is measured (Section 23, D82S1, S2); the Larchwood section is estimated (Carter and Höy, 1987a).

Plate 36. Thin, graded, green and mauve siltstone and argillite beds of the Sheppard Formation, northern Hughes Range, exposure width about 20 cm.

light green siltstone-argillite couplets, usually lenticular, laminated and graded.

The base of the Sheppard Formation southeast of Cranbrook comprises either a dolomitic sequence or a prominent fluviatile conglomerate. The conglomerate reaches a maximum thickness of approximately 9 metres; locally it has cut through and removed up to several hundred metres of the Nicol Creek Formation, including upper flows and underlying siltstone. The conglomerate is well indurated with matrix-supported, generally rounded clasts that range in diameter from less than a centimetre to 22 centimetres (Plates 42 and 43). Purple amygdaloidal basalt clasts comprise more than 80 per cent of the clast population with purple and tan siltstone, minor granite and porphyritic rhyolite(?) comprising the remaining 20 per cent. The provenance of these latter clasts is not known as no similar Purcell or pre-Purcell lithologies are recognized. It is assumed, based on their rounded habit and exotic provenance, that they have been transported considerable distance, indicating that the conglomerate marks an unconformity of regional extent.

The conglomerate may rest unconformably on Nicol Creek lavas or siltstone, but is commonly underlain by several tens of metres of purple and green siltstone and minor quartzite. The contact with these underlying siltstones appears gradational through a few metres of dominantly purple, graded sandstone beds with crossbedding and rippled surfaces. Underlying siltstone is thin to medium bedded, commonly laminated, with crossbeds, ripple marks and desiccation cracks. It is locally intruded by one or more thin mafic sills.

Elsewhere within the Moyie Lake map area (Höy and Diakow, 1982), the Sheppard Formation is a more typical

Plate 37. Stromatolitic dolomite of the Sheppard Formation, overlain by dolomitic algal mats and underlain by quartz sandstone, northern Hughes Range.

Plate 38. Stromatolitic dolomite of the Sheppard Formation, northern Hughes Range (photo by D. Johnson).

stromatolitic and oolitic dolomite, quartzite, siltstone and argillite succession up to 75 metres thick. It does not appear to be truncated by the conglomerate and clasts of dolomite are not recognized within the conglomerate.

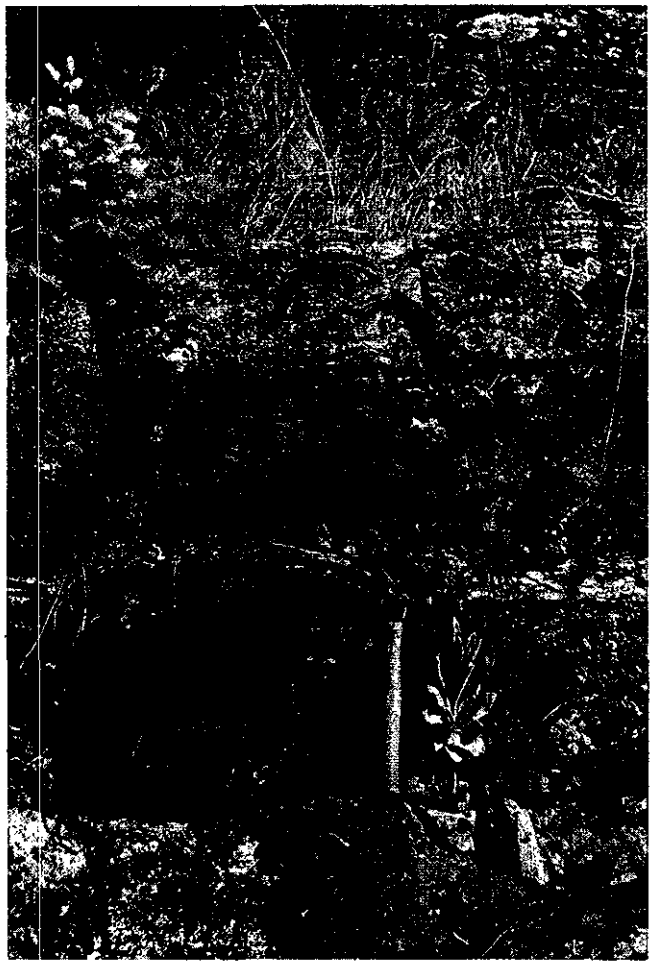


Plate 39. A section at the top of the Sheppard Formation, Skookumchuck area, with massive quartzite at the base, overlain by massive dolomite, crossbedded dolomite and stromatolitic dolomite; *see* detail in Plate 40 (photo by L. Diakow).

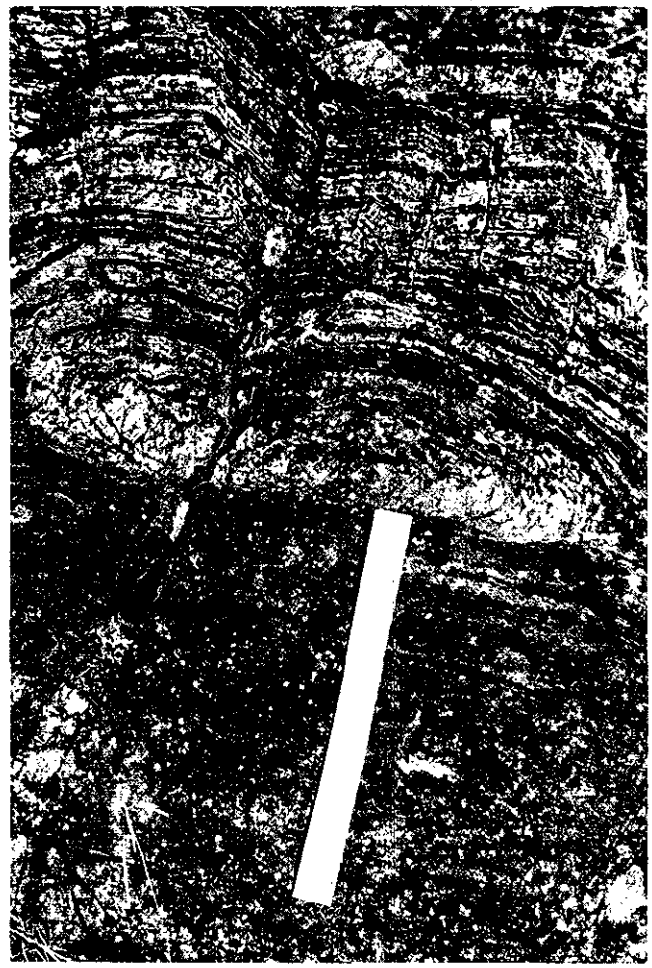


Plate 40. Stomatolitic dolomite overlying massive dolomite, Sheppard Formation, Skookumchuck area (photo by L. Diakow).

Ripple marks, mud cracks, mud-chip breccias and rare salt-crystal casts occur in the clastic beds. The sequence typically weathers to a buff-orange-brown colour, due to the high dolomite content.

Depositional Environment

Numerous sedimentary structures, including dessication cracks, mud-chip breccias and ripple marks, indicate alternating periods of submergence and subaerial exposure. Oolites indicate shallow turbulent water and stromatolites, also shallow water with profuse algal growth. The abundance of carbonate facies, particularly in the upper part of the Sheppard Formation, indicates a decrease in the supply of terrigenous clastic material. These conditions suggest deposition in a marine shelf environment or in a shallow lacustrine environment.

GATEWAY FORMATION (UPPER DUTCH CREEK FORMATION)

The Gateway Formation is defined by Daly (1912) to include siltite, argillite, arenite and dolomite between the Sheppard Formation and red and maroon siltstone and argillite of the overlying Phillips Formation. It correlates with the lower part of the upper Dutch Creek Formation northwest of Skookumchuck and in the Lardeau area (Reesor, 1973) and with the Mount Shields Formation in northern Montana (Winston, 1986b).

The Gateway Formation varies in thickness from approximately 500 metres near Cliff Lake (McMechan, 1981), Diorite Creek (Höy, 1979) and Echoes Lake, to 900 metres near Larchwood Lake (Carter and Höy, 1987a) and an estimated 1300 metres southeast of Moyie (McMechan, *op. cit;* Höy and Diakow, 1982).

Description

The Gateway Formation comprises dominantly pale green siltstone and minor dolomitic or argillaceous siltstone. In exposures east of the Rocky Mountain Trench it is readily divisible into a lower, predominantly siltstone succession and an upper more dolomitic succession. The lower siltstone succession north of Diorite Creek is 330 to 340

Plate 41. Rip-up clasts in mauve siltstone and argillite beds of the Sheppard Formation, north of Skookumchuck. Note imbrication of clasts indicating flow from right to left (photo by L. Diakow).

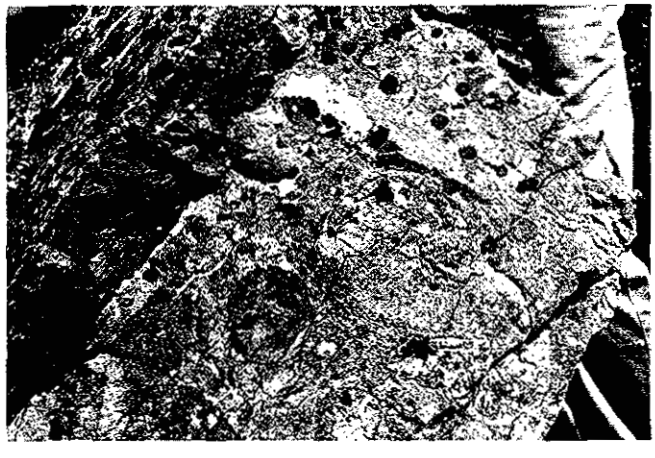


Plate 42. Conglomerate with large rounded exotic clasts that locally marks the base of the Sheppard Formation, Chipka Creek area, southeast of Cranbrook (photo by L. Diakow).

metres thick and comprises thin to medium-bedded, light green, grey or buff siltstone and minor purple argillaceous siltstone. The siltstones are commonly thin bedded and

Plate 43. Basal Sheppard Formation conglomerate, Chipka Creek area (photo by L. Diakow).

graded, with ripple marks, mud cracks, mud-chip breccias and occasional salt casts throughout. The lower siltstone is overlain by a succession of massive buff dolomite, light green siltstone, and minor thick-bedded grey limestone. This predominantly dolomitic succession is overlain by interlayered red and green siltstone and minor argillite in the transition zone beneath the Phillips Formation.

In the Skookumchuck area and southeast of Moyie Lake, the Gateway Formation is also predominantly a pale green siltstone succession with some intervals of mauve or purple silty argillite (Plate 44). Some dolomite and dolomitic siltstone, oolitic dolomite and cryptal algal dolomite also occur in the upper Gateway. A thin unit of dark grey and black, finely laminated siltstone and argillite is present just below the Phillips Formation.

Depositional Environment

Salt casts and symmetrical ripples throughout the Gateway Formation suggest deposition in shallow water; desiccation cracks, mud-chip breccias and oxidized facies indicate periods of subaerial exposure (Price, 1964; McMechan, *op. cit).*

Plate 44. Thin-bedded green and mauve siltstone with prominent ripple marks, Gateway Formation, Skookumchuck area (photo by L. Diakow).

The instability of the Purcell basin, recorded in dramatic facies and thickness changes in the underlying Sheppard Formation, continued locally during deposition of the Gateway Formation. The formation thickens rapidly to the north in the Skookumchuck area (Figure 29) primarily as the result of an increase in the pale green siltstone component. The absence of the overlying Phillips Formation, sparse outcrop and the similarity between lithologies in the upper Gateway and lower Roosville formations make it difficult to determine the thickness and extent of the Gateway Formation to the north and west.

PHILLIPS FORMATION

The Phillips Formation (Daly, 1912) is one of the most conspicuous regional marker units in the Purcell Supergroup. It is a distinctive red to purple quartzite and siltstone sequence that averages between 150 and 200 metres in thickness. It pinches out near Larchwood Lake in the Skookumchuck area, supplanted by green siltstone and quartzite of the Dutch Creek Formation.

Plate 45. Thinly laminated mauve siltstone of the Phillips Formation, Skookumchuck area (photo by L. Diakow).

Description and Depositional Environment

The Phillips Formation is characterized by thin-bedded, red, maroon and purple quartzite, siltstone and argillite (Plates 45 and 46). It has gradational contacts with both the underlying Gateway Formation and overlying Roosville Formation, with interbeds of green siltstone near the base and top. Ripple marks, crosslaminations, desiccation cracks and mud-chip breccias are common sedimentary structures, and micaceous siltstone and argillite beds are diagnostic. The disappearance of the Phillips Formation in the Skookumchuck area is rather abrupt. In the last recognized exposures at Larchwood Lake, however, the maroon colouring is not as conspicuous as in exposures farther south and is restricted to specific beds.

The pinch-out of the Phillips Formation is related to continued differential subsidence of the Purcell basin. The numerous sedimentary structures throughout the formation and the oxidized facies indicate shallow water and subaerial exposure.

ROOSVILLE FORMATION

The Roosville Formation (Daly, 1912) correlates with the upper Dutch Creek Formation in the Lardeau area (Reesor, 1973) and the McNamara Formation in northern Idaho and Montana (Winston, 1986b). Its thickness varies considerably, due to beveling by unconformably overlying Late Proterozoic, Middle Cambrian or Devonian rocks. Its greatest thickness is in the Gold Creek area where it is estimated to be approximately 1500 metres thick (Höy and Diakow,

Plate 46. Flaser bedding in mauve siltstone of the Phillips Formation, Skookumchuck area (photo by L. Diakow).

1982). Here, the sub-Devonian unconformity cuts down-section to the north through the Phillips Formation and into the Gateway Formation.

The Roosville Formation comprises argillite, siltstone, quartzite and dolomite. Dark grey argillite and silty argillite interbedded with green siltstone predominate in the lower part of the formation in the Gold Creek area. Higher in the succession, pale green argillaceous siltstone predominates, interbedded with mauve siltstone, some thin intraformational conglomerate layers and minor dolomitic siltstone and red argillite layers. Stromatolitic and oolitic dolomite are prominent locally. Syneresis cracks occur in the argillite beds, and mud cracks, rip-up clasts, mud-chip breccias and graded and lenticular beds are common throughout the succession.

Subtle facies changes in the Roosville Formation occur between Echoes and Larchwood lakes in the Skookumchuck area. Layers with rip-up clasts are abundant at Echoes Lake, less common and with more rounded clasts at Larchwood Lake, and rare north of Larchwood Lake.

DUTCH CREEK FORMATION

The Dutch Creek Formation is defined (Walker, 1926) as a group of rocks between the Purcell lavas (Nicol Creek Formation) and the Mount Nelson Formation. The lavas are not exposed in the Lardeau (Reesor, 1973) and Nelson east-half map areas (Rice, 1941; Reesor, 1983) and hence it is difficult to determine the exact thickness and extent of the Dutch Creek Formation there. It is estimated to be between 1200 and 1500 metres thick in the Windermere area (Reesor, 1973) and a 1300-metre section has been measured east of Kootenay Lake at Rose Pass (Rice, 1941).

In the Fernie west-half map area, the Dutch Creek Formation is only exposed northwest of Skookumchuck. The lower part of the formation is described in the section on the Sheppard Formation. The upper part includes the Gateway Formation, the Roosville Formation and overlying rocks beneath the Mount Nelson Formation. The maximum thickness of the Dutch Creek Formation in the Bradford Creek area is estimated to be 4800 metres, including approximately 3300 metres of upper Dutch Creek.

The upper Dutch Creek is discontinuously exposed north of Skookumchuck. A carbonate marker bed approximately 200 metres thick occurs within the formation some 3000 metres above the Nicol Creek lavas (Carter and Höy, 1987b). It is a massive, cream to tan-weathering, thick to medium-bedded dolomite and limestone unit. Crypto-algal features are present locally. The top and the base of the unit consist mainly of argillaceous silty dolomite. It is included within the Dutch Creek rather than the Mount Nelson Formation as the basal quartzite typical of the Mount Nelson is not exposed below it. Furthermore, green siltstone, black argillite and thin oolitic dolomite interbeds higher in the section probably correlate with similar facies in the Roosville Formation at Larchwood Lake.

MOUNT NELSON FORMATION

The Mount Nelson Formation comprises a thick sequence of quartzite, dolomitic argillite and siltstone that conformably overlies the Dutch Creek Formation. It was restricted by Bennett (1985, 1986) to include only the lower part of the formation as defined by Walker (1926) and by Rice (1941), Reesor (1973) and others. The upper part, informally named the Frances Creek Formation, (Bennett, *op. cit.*) is separated from the Mount Nelson Formation (new) by a disconformity.

The lower Mount Nelson Formation is divisible into three members in the Mount Forster map area (Bennett, 1985; 1986): a basal white orthoquartzite 100 to 200 metres thick, 100 to 300 metres of buff and grey dolomites and an upper unit, to 370 metres thick, of purple and red shale with buff dolomite interbeds. The overlying Frances Creek Formation comprises thick-bedded orthoquartzite, grey dolomite and interbedded sandstone and shale.

The total thickness of the Mount Nelson Formation (new) in the Mount Forster area varies from 500 metres to 1950 metres, due partly to erosion prior to deposition of the Frances Creek Formation or Windermere Supergroup and partly to syndepositional tectonics (Bennett, 1985; 1986). The Frances Creek Formation varies in thickness from 750 metres to 1020 metres. At Rose Pass east of Kootenay Lake, the entire Mount Nelson Formation is approximately 750 metres thick (Rice, 1941).

In Fernie west-half map area, the Mount Nelson Formation is only exposed at Lookout Mountain along the northern edge of the map area. It has a gradational contact with the underlying Dutch Creek Formation; phyllitic black argillite-siltstone rocks become increasingly more quartzitic and the interbeds of quartz wacke become cleaner upsection. The basal quartzite of the Mount Nelson is a clean, well-rounded and well-sorted, medium-bedded orthoquartzite containing a few thin beds of sandy dolomite. The basal quartzite is overlain by a mixture of white, green and

purple quartz arenite and dolomitic sandstone, locally gritty, as well as some purplish dolomite and argillite. Locally, the diagenetic character of these maroon beds is clearly demonstrated as the colouring crosscuts bedding planes and leaves spotty remnants of light green argillite. A buff-weathering sequence of dolomite overlies these quartz wacke, siltstone and argillaceous dolomite beds. This package is overlain by more green siltstone and minor purple siltstone and argillite. The total exposed thickness of the Mount Nelson Formation is approximately 400 metres.

SUMMARY AND DISCUSSION

The Middle Proterozoic Purcell Supergroup is a thick accumulation of dominantly clastic and carbonate rocks in the Purcell anticlinorium and Foreland Belt of southeastern British Columbia. The basal part of the supergroup comprises fluvial quartzites of the Fort Steele Formation, turbidite deposits of the Aldridge Formation and numerous gabbroic sills referred to as the Moyie sills. Overlying Purcell Supergroup rocks comprise dominantly shallow-water and subaerial deposits.

Tectonic models for the initiation and evolution of the Belt-Purcell basin involve Middle Proterozoic continental rifting or incipient rifting (Sears and Price, 1978; Price, 1981; Thompson *et al.,* 1987). Evidence for rifting includes the shape of the basin, cutting across generally northeast-trending basement structures, and the thick accumulation of flysch turbidites, interlayered with gabbroic sills, at the base of the Purcell succession. Price (1964, 1981) suggested that Belt-Purcell sediments were deposited on the western margin of the craton and Harrison (1972), that these sediments were deposited in an embayment of a marine miogeocline. Alternatively, Belt-Purcell sediments may be lacustrine, deposited in an intracratonic block-faulted basin in a large Proterozoic continent (Winston *et al.,* 1984).

The northeastern edge of the Belt-Purcell basin is exposed in the Fernie west-half map area. Purcell rocks along the margin are characterized by rapid and pronounced facies and thickness changes, in contrast to the subtle changes that occur generally throughout the basin (McMechan, 1981; Höy, 1982a). In the northern Hughes Range, fluvial quartzites and shallow-water siltstones of the Fort Steele Formation at the base of the exposed Purcell succession are overlain by a thin sequence of deeper water siltstone and quartzite of the Aldridge Formation. These give way to a thick succession of basinal turbidites to the south that are similar to turbidites in the Purcell Mountains west of the Rocky Mountain Trench (McMechan, 1981; Höy and Diakow, 1982). This indicates that in lower Purcell time, rocks within the northern Hughes Range were near the edge of a deep structural basin that lay to the south and west.

Prominent facies and thickness changes, coarse clastic facies and northward-directed paleocurrents suggest that the basin margin developed by growth faulting. This ancient faulted margin is approximately coincident with the north-trending Rocky Mountain Trench, but swings eastward following the locus of the Boulder Creek fault, the eastern extension of the St. Mary fault.

The prominent eastward deflection in the basin margin, near the present position of the St. Mary and Boulder Creek faults, coincides approximately with southwest-trending Precambrian structures that are recognized in basement rocks from geophysical data and are postulated to extend beneath the cover rocks into southeastern British Columbia. It is suggested that bowing up of the crust near the eastern deflection of the incipient Purcell basin margin, recorded in northward shedding of fluvial Fort Steele sediments, preceded continental rifting. Early stages in the development of the basin are marked by thick accumulations of Aldridge turbidites and voluminous intrusion of basaltic sills. North to northwesterly and locally westerly directed paleocurrents generally paralleled the margin of the basin. Overlying lower Purcell platformal rocks prograded westward over the basin margin and turbidite flysch package, but differential downwarping continued periodically along the edge of the basin, producing a small embayment during Creston time.

The basin margin remained tectonically active during late Purcell time. Faults were reactivated, probably to deep crustal levels, with resultant outpourings of subaerial to very shallow-water alkaline lavas of the Nicol Creek Formation. These lavas are preferentially distributed along the inferred northeastern margin of the Belt-Purcell basin.

Extensional tectonics are evident immediately following the effusive basaltic volcanism, producing a block-faulted basin. East of Moyie Lake, the base of the Sheppard Formation is marked by either a fluviatile conglomerate that locally has removed up to several hundred metres of the underlying Nicol Creek Formation or by a distinctive stromatolitic carbonate succession. It is probable that erosion and deposition of coarse conglomeratic fractions occurred on local fault-bounded tectonic highs whereas turbulent shallow-water carbonate facies were deposited in adjacent small basins.

Facies and thickness changes in upper Purcell rocks north and west of Skookumchuck also indicate that block faulting modified or controlled deposition in the Purcell basin. The most prominent growth faults occurred near Larchwood Lake; these cut and offset the Nicol Creek lavas and the Sheppard Formation but do not appear to continue through the Gateway Formation into the overlying Phillips and Roosville formations. A thinned upper Purcell stratigraphic succession at Lookout Mountain farther north indicates a tectonic "high," perhaps due to an uplifted block.

In contrast with a structural low in the Cranbrook area during lower Purcell time, a tectonic high is evident in late Purcell time. Upper Purcell rocks increase in thickness northwest of Skookumchuck and in the southeastern Purcell Mountains and the Galton Range; in the Hughes Range and the Purcell Mountains between Cranbrook and Skookumchuck, the upper Purcell succession is thinner. The high is approximately coincident with the thickest accumulation of Nicol Creek lavas and with the eastern deflection of the Belt-Purcell basin margin.

In summary, the northeastern edge of the Belt-Purcell basin was tectonically active throughout much of Purcell time. Deep crustal structures influenced a pattern of growth faults along the basin margin and perhaps in the floor of the basin, which in turn modified the depositional pattern of Purcell Supergroup rocks.

CHAPTER 3: MOYIE SILLS

INTRODUCTION

Moyie sills are restricted to the lower Aldridge, the lower part of middle Aldridge, and to correlative rocks in the northern Hughes Range east of the Rocky Mountain Trench. Diorite sills that occur higher in the stratigraphic succession are chemically and mineralogically distinct from the Moyie sills and appear to represent a later magmatic event, perhaps related to the Nicol Creek lavas. Moyie intrusions generally form laterally extensive sills. Their aggregate thickness in the Purcell Mountains exceeds 2000 metres (Reesor, 1958; Bishop, 1974a,b; Hamilton *et al.*, 1983a). Commonly, they comprise up to 30 per cent of lower and lower-middle Aldridge successions; in the Lamb Creek area west of Moyie Lake, an aggregate thickness of approximately 1300 metres of sills is interlayered with 2800 metres of lower and middle Aldridge sedimentary rock. Their abundance decreases up-section in the middle Aldridge, as the abundance of thick-bedded A-E turbidites decreases. The petrology and geochemistry of similar sills in northern Idaho has been described by Bishop (1974a,b).

FIELD RELATIONSHIPS

Moyie intrusions are generally a few tens to several hundred metres thick and commonly persist laterally for tens of kilometres. They generally form sills, although locally they may form dikes or thick lensoid intrusive complexes. A sill complex beneath the eastern part of the Sullivan orebody cuts sharply up-section at the western edge of the deposit, then cuts down-section farther to the west before forming a sill again at approximately the original stratigraphic level (Hamilton *et al.*, 1982). Moyie intrusions in the Lone Pine Hill area 7 kilometres southeast of Sullivan form thick, lensoidal intrusive complexes that thin rapidly toward their edges and locally cut sharply across stratigraphy (Höy, 1984b).

PETROGRAPHY

Moyie sills comprise dominantly gabbro and diorite. Marginal phases are commonly fine grained whereas the central parts of thicker Moyie intrusions are coarse grained and equigranular, and may include quartz diorite. The quartz diorite contains 10 to 20 per cent quartz and significant biotite in addition to hornblende. Biotite granophyre, ranging in composition from biotite granodiorite to biotite quartz diorite, also occurs near the centre of many of the thicker sills (Bishop, 1974a,b).

The sills comprise dominantly hornblende and plagioclase phenocrysts, typically up to 5 millimetres in diameter, in a finer grained groundmass of plagioclase, quartz, hornblende, chlorite and epidote. Hornblende phenocrysts, commonly partially altered to chlorite and epidote, are generally subhedral to anhedral with irregular ragged terminations. Plagioclase, identified as labradorite by Bishop (*op. cit.*), is generally clouded by a fine mixture of epidote and albite (?), particularly in the more calcic cores of zoned crystals. Accessory minerals include leucoxene, commonly intergrown with magnetite, as well as tourmaline, apatite, calcite and zircon. More mafic alkaline sills in the Mount Mahon area contain abundant sphene (~5 per cent), a distinctive brown amphibole, and rare scapolite.

SILL MODEL

A number of Moyie sills have unusual contacts, internal structures and other associated features that indicate that they intruded unconsolidated wet sediments. These include gradational contacts between sills and sediments, structures attributed to soft-sediment deformation, obliteration of sedimentary structures immediately adjacent to sills, and large-scale dewatering structures. Many of these features are similar to those described by Kokelaar (1982) and Krynauw *et al.* (1988) and attributed to fluidization of wet sediments at the margins of sills.

Although many Moyie sills have fine-grained chilled margins and sharp contacts with hornfelsed country rocks, others have coarse-grained basal margins and gradational contacts. The gradational sill-sediment contacts are characterized by a thin zone, up to a few centimetres thick, of coarse (2 to 3 mm), randomly oriented hornblende crystals in a fine-grained groundmass of quartz, biotite, chlorite, clinozoisite and sericite (Figure 30). The contact zone grades upward into a fine-grained quartz diorite phase that contains more abundant hornblende but less quartz. Downward, the large hornblende crystals gradually decrease in abundance into the contact sedimentary rocks, quartz content increases, and chlorite and clinozoisite become abundant. These textures grade into a hornfelsed marginal phase that contains fine-grained biotite, partly altered to chlorite close to the intrusion but unaltered further away. In summary, the contacts of these sills are gradational from hornfelsed country rock through an intervening zone characterized by coarse hornblende crystals in a mixed sediment-intrusive phase into a chilled marginal phase. The mixed sediment-sill phase is similar to the "granosediment" adjacent to the Grunehogna sill in Antarctica, interpreted to have intruded wet, unconsolidated sediment (Krynauw *et al.*, 1988).

Structures at the base of some sills resemble load casts and, less commonly, flame structures similar to those at the base of turbidites. The example illustrated in Figure 30 shows well-developed flame structures and small clastic dikes intruding the diorite. Contorted layering is restricted to the immediate footwall of the sill, suggestive of soft-sediment deformation caused by sill injection. The basal contact of this sill is locally gradational, as described above.

Other features above and below the sills, and in the sills themselves, are interpreted to be caused by expulsion of pore water as the sill intruded water-saturated sediments. These include the preferential distribution of hydrothermal quartz-calcite veins with epidote, talc and variable amounts

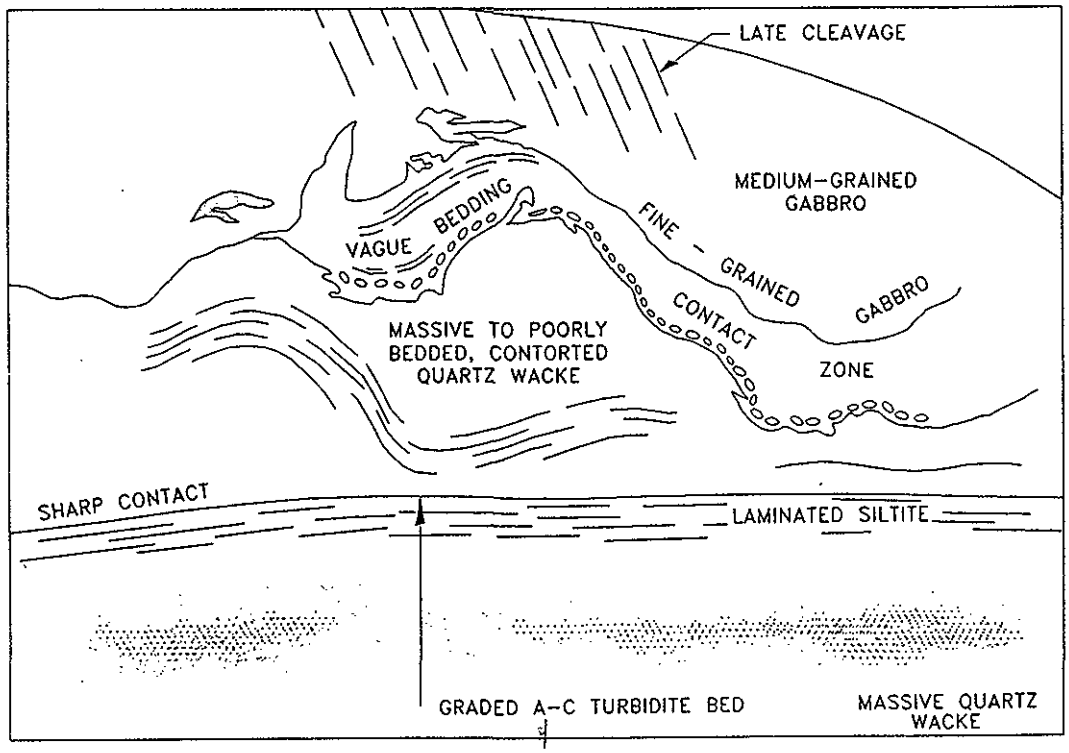


Figure 30. Details of a contact between a Moyie sill and middle Aldridge turbidites, Lamb Creek area; note features which indicate that the sill was injected prior to lithification of the quartz wacke, such as flame and load-cast structures at the base of the sill, and a mixed sediment-sill contact zone; (coin size=2.3 cm).

of pyrite and chalcopyrite near the base of, or cutting across the sills. In the Lumberton sill north of Moyie Lake, fractures with variable amounts of vein infilling and wide hydrothermally altered selvages extend from the base to the top of the 66-metre-thick sill (Figure 31).

Zones of massive siltstone, quartzite or conglomerate that cut sharply across Aldridge Formation stratigraphy are interpreted to be large-scale dewatering structures. Although it cannot be clearly demonstrated that these occur preferentially above sills, it is possible that some resulted from expulsion of pore water due to sill emplacement. They are most common in lower Aldridge and basal middle Aldridge rocks, the stratigraphic interval that hosts the Moyie sills. Their release onto the sea-floor may have formed some of the intraformational conglomerates in the lower and middle Aldridge; it has been suggested that footwall fragmental rocks at the Sullivan deposit formed by extrusion rather than by collapse of syndepositional fault scarps (D. Shaw and C.J. Hodgson, personal communication, 1977; Hamilton, 1984).

Summary and Discussion

A model for intrusion of Moyie sills into wet unconsolidated Aldridge sediments is illustrated in Figure 32. The basal contacts are locally gradational and soft-sediment deformation or obliteration of sedimentary textures occurs. High volatile content, expected with intrusion into wet sediments, is indicated by a coarse-grained marginal phase, large hornblende crystals, and extensive hydrothermal vein mineralization. Veins commonly cut vertically through sills, marking escape pathways for heated pore fluids derived from beneath the sills. Zones of crosscutting conglomerate are large dewatering structures, perhaps due to fluidization by escaping pore fluids above sills. Their extrusion onto the sea floor may have formed some of the intraformational conglomerates in the Aldridge Formation, suggesting that some sills intruded at relatively shallow depths.

Fluidization of wet sediments due to heating is unlikely to occur at depths where pressure is much greater than 31.2 megapascals (312 bars), the critical pressure for seawater (Kokelaar, 1982). This is equivalent to a depth of 1.6 kilometres of wet sediment, assuming a density of 2 grams per cubic centimetre (Kokelaar, *op. cit),* or considerably less assuming the sediments are under water; for example, beneath 1 kilometre of water, fluidization is probably restricted to sediments at depths of less than a kilometre. Over pressures, as may occur in basinal sediments, further restrict the depth at which fluidization is likely to occur. Hence, intrusion of Moyie sills that show evidence of fluidization is restricted to depths that were probably considerably less than 1.6 kilometres. As the thickness of middle Aldridge sedimentary rocks above most sills is commonly 2 to 3 kilometres, it follows that these sills were intruded during middle Aldridge time.

The sill model helps to explain the lack of major unconformities in rocks overlying the Aldridge succession. Intrusion of a cumulative thickness of greater than 2000 metres of sills into lithified rocks could only be accommodated by uplift of surface rocks with resultant erosion and deposition of coarse clastics; no such uplift is evident in the post-

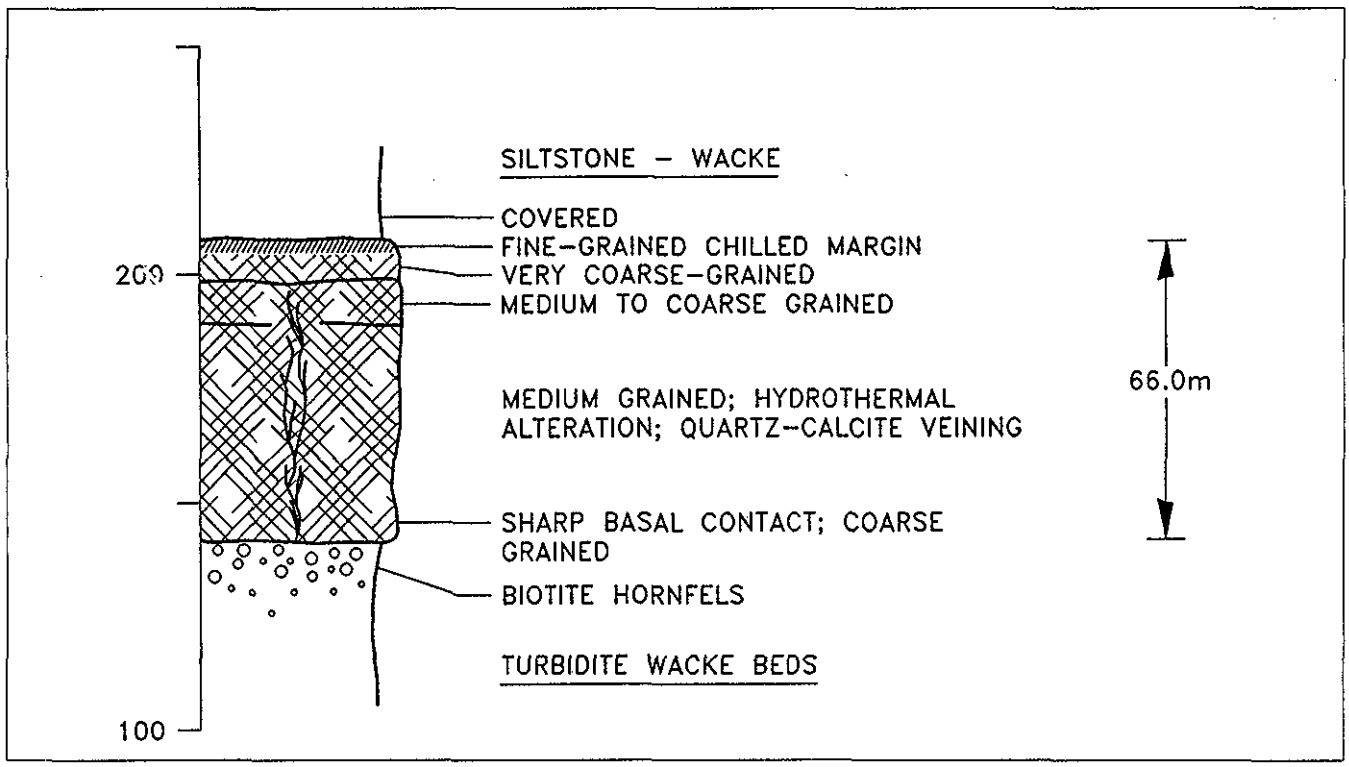


Figure 31. A section through the Lumberton sill, located 10 kilometres due north of Moyie Lake, showing unusual coarse hornblende at the base of the sill and crosscutting veins, features suggestive of intrusion into unconsolidated, water-saturated sediments (Section 7, Appendix 1).

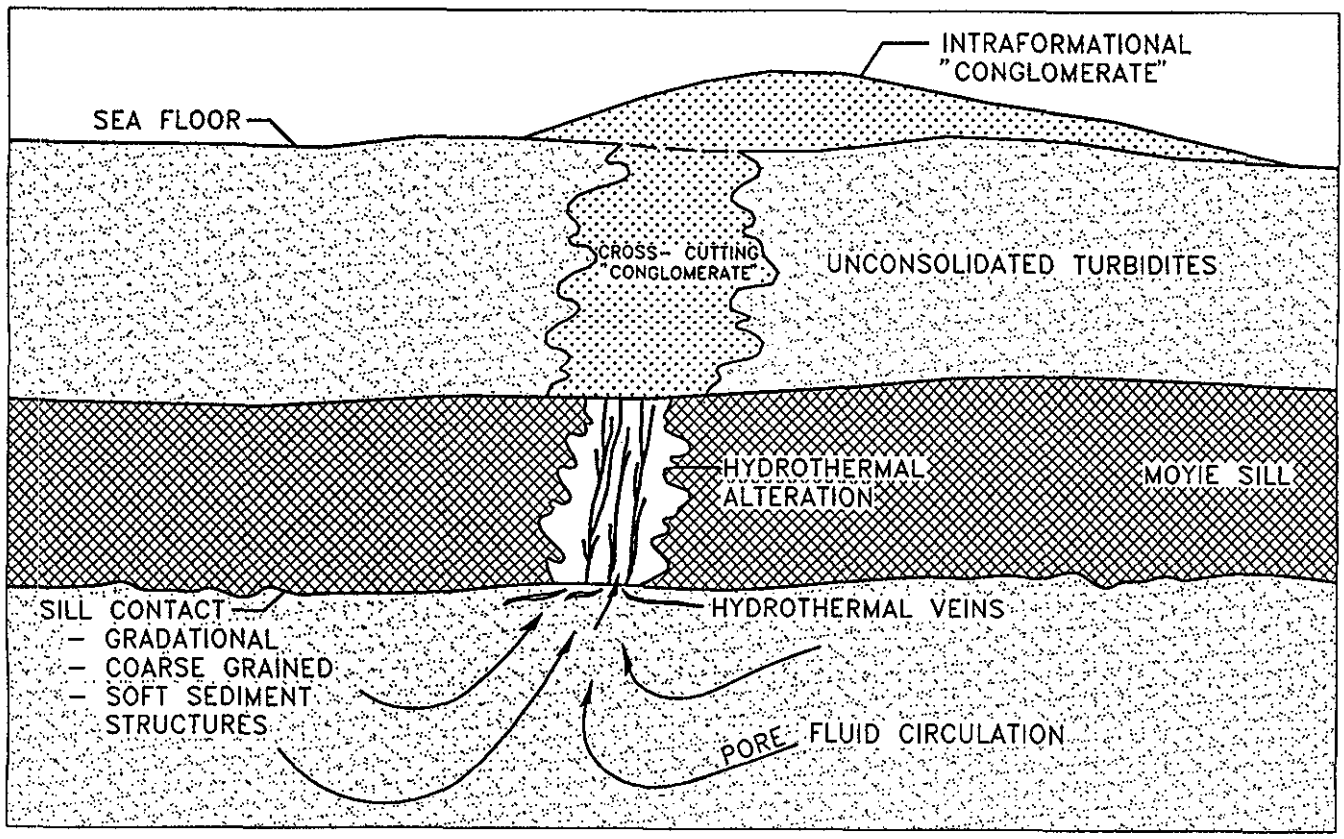


Figure 32. Model for injection of a Moyie sill into unconsolidated middle Aldridge turbidites, based on the Lumberton sill. The measured thickness of the sill is 66 metres.

Aldridge Purcell succession. Intrusion into wet, unconsolidated sediments can be accommodated by expulsion of pore fluids with little change in the relief on the sea floor.

A modern example of the Moyie sill model is the emplacement of basaltic sills in the Guaymus basin in the Gulf of California (Einsele, 1982). Some of these sills intrude unconsolidated sediments within a few tens of metres of the sediment surface. They interact with wet sediments, depositing hydrothermal minerals from heated pore fluids and, on expulsion of these fluids, create space for the intruding sill.

GEOCHRONOLOGY

A considerable number of potassium-argon dates on hornblende from Moyie sills and from biotites in contact with sills have been reported by Hunt (1962) and Zartman *et al.* (1982). The range in ages, from 679 Ma to 1084 Ma, may reflect resetting due to one or more Precambrian metamorphic events (Leech, 1962a; McMechan and Price, 1982a; Zartman *et al., op. cit).* The only previous reliable age for Moyie intrusions is a 1433 ± 10 Ma date from uranium-lead in zircons collected from the Crossport C sill in northern Idaho (Zartman *et al., op. cit).*

Samples from a number of "fresh" sills in the southeastern Purcell Mountains were collected to more closely constrain the age of Moyie sills, the host Aldridge Formation and Precambrian metamorphic events. Relatively unaltered hornblende and biotite concentrates were dated by the potassium-argon method. Zircon concentrates from the Lumberton sill were dated by uranium-lead techniques.

Potassium-Argon Dating

Potassium-argon dates of eight hornblende concentrates and one biotite concentrate from sills that intrude both lower and middle Aldridge siltstone and wacke turbidites are listed in Table 3. In contrast with potassium-argon data of Hunt (*op. cit)* and Zartman *et al.* (*op. cit),* these data have a considerably larger time span, from Early Proterozoic (Aphebian) to Cambrian. Three of the dates are older than the uranium-lead zircon dates and the interpreted age of the host Aldridge Formation. These old dates probably result from excess ^{40}Ar, perhaps derived by outgassing of older potassium-bearing minerals during ascent of the sill magma through the crust or mantle, or caused by later regional metamorphism (*see* Faure, 1977, page 152). The negative correlation between potassium content in the hornblende and resultant age in the data of Table 3 is also evidence for excess ^{40}Ar (Faure, *op. cit.*). Anomalously old potassium-argon dates for the Kiakho and Reade Lake stocks, both intrusive into Purcell Supergroup rocks are also caused by excess ^{40}Ar (Höy and van der Hayden, 1988) supporting the conclusion for excess ^{40}Ar in Moyie sill hornblendes.

The remaining potassium-argon dates range from Late Proterozoic (1094 Ma) to Cambrian (523 Ma). Although these ages do not cluster in the 800-850 Ma range of the inferred Goat River orogeny (McMechan and Price, 1982a), it is possible that they were affected by this metamorphic event. However, identification of excess ^{40}Ar in hornblendes and of dates younger than the Goat River orogeny makes any interpretation correlating potassium-argon ages with metamorphic events tenuous. Additionally, none of the potassium-argon dates from Moyie sills record an event at approximately 1350 Ma, the inferred age of the East Kootenay orogeny and termination of Belt-Purcell sedimentation (McMechan and Price, *op. cit).*

Uranium-Lead Dating

Zircons from a fresh, massive sample of the Lumberton sill in the middle Aldridge were analyzed to determine the intrusive age of the sill. Zircons were separated using standard heavy mineral separation techniques; four fractions were selected using conventional size (nylon mesh sieve) and magnetic (Frantz isodynamic separator) separations, followed by handpicking to virtually 100 per cent purity. Separated zircons were clear to pale pink. Most grains were broken and anhedral; only a few were subhedral or euhedral.

Sample dissolution and analysis were carried out using a procedure modified from Krogh (1973) and mass spec-

TABLE 3

K-Ar ANALYSES[1] OF SAMPLES OF MOYIE SILLS, SOUTHEASTERN BRITISH COLUMBIA

Lab No.	Field No.	Lat.	Long.	Mineral	K%	$^{40}Ar \times 10^{-6}$ (cc/g)	^{40}Ar(%)	Radiogenic Date (Ma)
82F/9 St. Mary								
29595	6799-1459	49°43′	116°00′15″	hornblende	0.218±0.001	21.972	97.4	1608±40
29598	6799-1642	49°43′	110°00′15″	hornblende	0.624±0.005	34.712	95.0	1054±26
29598	6799-1642	49°43′	110°00′15″	biotite	7.65±0.02	237.064	94.9	660±20
82G/5 Moyie Lake								
28150	M22-2	49°25′65″	115°52′10″	hornblende	0.206±0.001	27.381	92.0	1918±55
28152	M36-12	49°27′50″	115°54′00″	hornblende	0.270±0.001	24.730	97.7	1508±45
29556	M44-21A	49°18′10″	115°59′00″	hornblende	0.814±0.002	33.615	95.1	836±22
82G/12 Cranbrook								
28153	K23-19	49°38′50″	115°52′45″	hornblende	0.444±0.003	10.469	80.9	523±15
28154	K24-30	49°39′30″	115°52′10″	hornblende	0.250±0.001	14.613	93.2	1094±27
29597	K23-11B	49°38′25″	115°53′50″	hornblende	0.216±0.002	10.910	94.4	979±24

[1] K analyses were done by the B.C. Geological Survey Branch Analytical Laboratory.
Ar analyses were done by J. Harakal, Department of Geological Sciences, The University of British Columbia.

TABLE 4
U-Pb ZIRCON ANALYSES OF SAMPLE NEG-1, MOYIE SILL, SOUTHEASTERN BRITISH COLUMBIA

	Fractions		Concentrations		Pb Isotopic Abundance[3]				Atomic Ratios (Date, Ma)[5]		
No.	mesh size magnetic[1] properties	weight (mg)	U (ppm)	Pb[2] (ppm)		$^{206}Pb=100$		$^{206}Pb/^{204}Pb$[4]	$^{206}Pb/^{238}U$	$^{207}Pb/^{235}U$	$^{207}Pb/^{206}Pb$
A	100-200 M1.5/5°	1.6	1363	477	9.2990	66.5114	0.0144	6749	0.22998±0.00291 (1334.4±15.2)	2.8852±0.0363 (1378.1±9.3)	0.09099±7×10^{-5} (1446.4±1.5)
B	100-200 M1.8/2°	0.7	1258	438	9.2698	64.5857	0.0133	6803	0.23193±0.00167 (1344.6±8.7)	2.9050±0.0209 (1383.2±5.4)	0.09084±5×10^{-5} (1443.3±1.0)
C	200-325 NM1.5/5° M1.8/2°	0.11	945	310	9.4512	62.2798	0.0266	3556	0.22022±0.00156 (1283.0±8.3)	2.7573±0.0197 (1344.1±5.3)	0.09081±5×10^{-5} (1442.6±1.1)
D	200-325 M1.5/5° NM1.2/10°	0.4	608	201	9.6469	61.1846	0.0395	2346	0.22269±0.00158 (1296.1±8.3)	2.7929±0.0200 (13536±5.4)	0.09096±8×10^{-5} (1445.8±1.7)

Notes: [1] M,NM=magnetic, non-magnetic on Franz isodynamic separator at indicated amperage and angle of side tilt
[2] radiogenic plus common Pb
[3] radiogenic plus common Pb, corrected for 0.15% per AMU fractionation and for 120 pg Pb blank with composition 208:207:206:204=37.30:15.50:17.75:1
[4] corrected for 0.15% per AMU fractionation
[5] decay constants: $\lambda^{238}=0.155125\times10^{-9}$/yr, $\lambda^{235}=0.98485\times10^{-9}$/yr, $^{238}U/^{235}U=137.88$; ratios are corrected for U+Pb fractionation (0.15%/AMU), blank Pb, and for common Pb using the Stacey and Kramer (1975) growth curve and an initial Pb age of 100 Ma. Analyses done by P. van der Heyden, The University of British Columbia

trometric analysis was done using a VG Isomass 54R solid-source mass spectrometer in single collecter mode (Faraday cup). Precisions for $^{207}Pb/^{206}Pb$ and $^{208}Pb/^{206}Pb$ were better than 0.1 per cent and for $^{204}Pb/^{207}Pb$, better than 0.5 per cent.

The uranium-lead data are shown in Table 4 and plotted on the concordia diagram on Figure 33. An age from discordant fractions was determined by fitting data points to a straight line and extrapolating to the concordia. Errors on individual dates and on calculated intercept ages are quoted at the 2 sigma level (95 per cent confidence interval).

The upper intercept age of 1445±11 Ma is interpreted to be a minimum age for emplacement of the sill. It is close to the 1433 Ma uranium-lead age of the Crossport C sill (Zartman *et al.,* 1982) and a 1436 Ma potassium-argon date

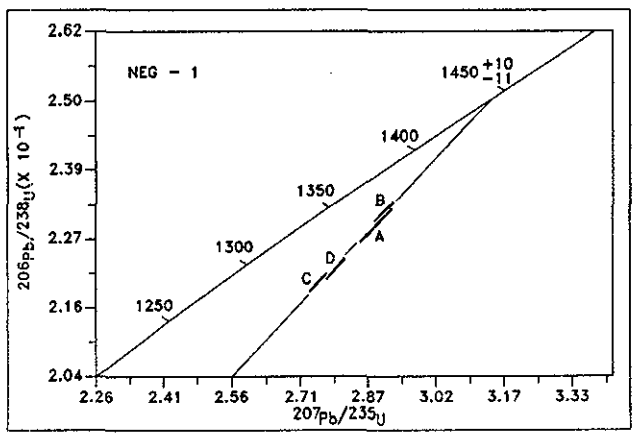


Figure 33. Uranium-lead concordia diagram for analyses of zircons, sample NEG-1, Moyie sill; (*see* Table 4 for data and explanatory notes). The zircon date is Middle Proterozoic (1445±11 Ma).

from biotite in the alteration associated with the Sullivan deposit (LeCouteur, 1979). As the Moyie sills are interpreted to have intruded during Aldridge sedimentation, the date indicates that the Sullivan deposit formed at approximately 1445 Ma and that lower and basal middle Aldridge rocks were deposited prior to 1445 Ma.

GEOCHEMISTRY

Classification

The geochemistry of Moyie sills is compared to that of volcanic rocks rather than intrusive rocks as many of the sills are interpreted to have intruded at shallow depths in unconsolidated sediments. Analyses of the sills are listed in Tables 5 and 6. Although hand samples generally appear fresh, microscopic examination indicates minor but pervasive propylitic alteration. Mobility of major elements is suggested by the amount of scatter in data plotted on conventional oxide-oxide variation diagrams. High MgO/CaO ratios in some samples (Figure 34) have been used to screen the most altered samples (de Rosen-Spence, 1976, 1985). These altered samples are removed from most major element plots that follow.

Moyie sills are generally subalkaline, although a number of samples from drill intersections in the Mount Mahon area are alkaline (Figure 35). The Mount Mahon sills are more basic with a high iron content and only 45 to 46 per cent silica. Na_2O is enriched in these sills, averaging between 2.5 and 3 per cent. The subalkaline sills are high-iron, tholeiitic basalts (Figure 36).

Plots of less mobile trace and minor elements confirm the contrast in alkalinity between the two suites of Moyie sills. For example, on Zr/TiO_2 versus Nb/Y and Nb/Y versus SiO_2 diagrams (Winchester and Floyd, 1977), Moyie sills

TABLE 5

MAJOR AND MINOR ELEMENT ANALYSES OF MOYIE SILLS IN THE FORT STEELE AND ALDRIDGE FORMATIONS, SOUTHEASTERN BRITISH COLUMBIA

Lab No.	Field No.	Host	SiO_2	Al_2O_3	Fe_2O_3	MgO	CaO	Na_2O	K_2O	TiO_2	MnO	P_2O_5	BaO	CO_2	H_2O^+	H_2O^-
28161	H83E-1	Ft Steele	52.71	13.89	11.15	5.86	9.30	0.890	2.042	1.270	0.129	0.17	—	0.23	—	—
20803	D76E-41	Ft Steele	54.40	13.98	11.32	6.44	10.96	1.435	0.687	0.736	0.180	0.16	0.01	0.15	2.44	0.16
20802	D76E6-1	Ft Steele	50.08	14.62	12.62	9.55	2.79	0.263	2.000	1.167	0.141	0.15	0.02	1.68	5.99	0.15
28162	H83E-4	Ft Steele	50.06	14.32	11.32	7.53	10.50	2.170	0.603	0.660	0.137	0.09	—	0.03	—	—
24541	M7-261	L-M Ald*	45.88	13.55	17.17	5.37	9.93	2.839	0.753	2.831	0.296	0.30	0.04	0.43	1.92	0.24
24543	M7-270	L-M Ald*	44.99	13.68	17.67	5.27	8.14	3.208	0.782	2.789	0.282	0.29	0.04	0.10	2.70	0.15
24542	M7-265	L-M Ald*	44.66	13.12	17.48	5.28	10.25	2.750	0.469	2.729	0.280	0.32	0.03	0.14	1.94	0.15
24534	M7-228	L-M Ald*	45.95	13.33	16.68	5.65	9.54	2.786	0.970	2.712	0.257	0.32	0.04	0.05	2.07	0.33
24533	M7-223	L-M Ald*	46.72	13.76	16.18	5.35	9.85	2.925	0.934	2.628	0.252	0.18	0.05	0.14	1.58	0.24
24531	M7-214	L-M Ald*	46.15	13.96	16.56	5.49	10.55	2.740	0.711	2.758	0.249	0.16	0.04	0.10	1.70	0.16
24535	M7-233	L-M Ald*	46.17	13.48	16.24	5.61	9.67	2.709	1.078	2.603	0.257	0.07	0.05	0.14	1.99	0.29
24537	M7-241	L-M Ald*	45.64	13.67	16.88	5.51	9.93	2.768	0.846	2.831	0.268	0.34	0.04	0.31	1.58	0.22
24538	M7-249	L-M Ald*	45.50	13.49	16.74	5.47	9.80	2.797	0.801	2.746	0.267	0.32	0.05	0.05	2.01	0.31
24530	M7-209	L-M Ald*	46.82	13.77	16.62	5.51	9.07	2.952	1.115	2.606	0.259	0.30	0.05	0.07	1.74	0.21
24540	M7-256	L-M Ald*	46.05	13.36	16.64	5.35	9.23	2.602	1.496	2.775	0.262	0.38	0.07	0.31	1.83	0.23
24536	M7-240	L-M Ald*	45.44	13.73	17.12	5.59	9.93	2.699	0.980	0.980	0.265	0.05	0.04	0.14	1.62	0.41
24532	M7-218	L-M Ald*	46.68	13.49	16.62	5.52	9.77	2.889	0.823	2.607	0.258	0.07	0.05	0.16	1.34	0.16
24539	M7-251	L-M Ald*	45.57	13.48	17.00	5.49	10.04	2.841	0.924	2.791	0.270	0.54	0.05	0.48	1.56	0.20
29596	M44-21A	Lower Ald	52.41	13.45	12.62	5.86	9.68	1.706	1.238	0.840	0.203	0.07	—	0.06	—	—
29597	K23-11B	Lower Ald	51.00	14.63	11.60	7.10	9.86	1.870	0.995	1.100	0.185	0.09	—	0.02	—	—
29595	6799-A	Lower Ald	52.67	13.69	11.03	6.83	9.76	1.807	0.529	0.740	0.163	0.06	—	0.46	—	—
28157	M44-19	Lower Ald	51.02	13.72	10.87	7.33	10.89	2.470	0.672	0.630	0.181	0.09	—	0.03	—	—
28156	M12-24	Lower Ald	50.90	15.06	9.56	8.43	11.62	1.490	0.421	0.550	0.162	0.09	—	0.03	—	—
28159	M60-5	Lower Ald	52.79	13.93	10.34	7.22	10.87	1.650	0.990	0.690	0.177	0.14	—	0.03	—	—
28160	K36-11	Lower Ald	52.29	14.90	8.86	7.94	11.58	1.280	0.478	0.540	0.147	0.10	—	0.03	—	—
26397	K38-4	Lower Ald	52.55	13.26	8.20	9.21	11.80	1.725	0.249	0.070	0.320	—	—	0.27	1.48	0.10
26396	K23-2	Lower Ald	51.87	14.23	8.88	7.74	9.93	1.476	1.795	0.000	0.149	—	—	—	—	—
29598	6799-B	Lower Ald	62.59	13.90	8.43	2.47	3.62	2.800	2.600	0.900	0.102	0.09	—	0.55	—	—
28158	M44-22	Lower Ald	50.46	14.70	8.21	9.21	11.98	1.310	1.303	0.430	0.158	0.09	—	0.03	—	—
22073	M12-27	Lower Ald	49.25	16.53	9.11	8.33	10.54	1.406	0.992	0.627	0.166	0.45	0.02	0.07	1.94	0.46
28151	M36-5	Middle Ald	50.78	14.11	10.71	8.25	10.33	1.620	0.713	0.713	0.194	0.09	—	0.04	—	—
28154	K24-30	Middle Ald	50.98	13.22	14.08	6.66	7.37	2.640	0.722	1.520	0.199	0.20	—	0.03	—	—
20797	E75-2	Middle Ald	52.04	13.49	11.32	6.83	6.40	2.176	0.461	0.844	0.141	0.18	0.01	5.00	4.81	0.18
28155	H83E-2	Middle Ald	52.46	13.21	12.72	6.15	7.90	2.780	0.330	1.060	0.187	0.09	—	0.11	—	—
28149	M1-7A	Middle Ald	51.73	14.81	10.35	8.55	10.77	1.790	0.832	0.790	0.156	0.30	—	0.65	—	—
20800	D76E8-15	Middle Ald	53.46	14.39	9.83	8.03	2.88	2.430	0.815	0.948	0.113	0.19	0.01	2.93	5.01	0.19
28153	K23-19	Middle Ald	51.05	13.66	13.23	5.99	7.95	2.920	0.943	1.240	0.186	0.09	—	0.15	—	—
20795	H76D3-7A	Middle Ald	43.87	14.36	12.12	6.73	10.42	2.196	2.753	2.535	0.199	0.16	0.14	1.90	2.96	0.16
24523	M20-1	Middle Ald	50.05	15.94	14.67	5.02	10.06	2.439	0.227	1.108	0.201	0.14	0.01	0.06	1.20	0.14
28152	M36-12	Middle Ald	51.43	13.78	15.65	5.35	7.03	3.290	0.328	1.720	0.230	0.12	—	0.03	—	—
28150	M22-2	Middle Ald	50.53	14.33	11.13	8.30	11.28	1.530	0.154	0.800	0.188	0.14	—	0.13	—	—
20796	M1-7	Middle Ald	50.80	14.63	9.55	8.25	11.98	1.549	0.323	0.739	0.152	0.17	0.01	0.44	2.09	0.17

— not analyzed

* drill core — Mt. Mahon area

from the Mount Mahon area plot as alkali basalts whereas most others are subalkaline basalts and andesites (Figures 37 and 38).

Tectonic Setting

The major and trace element signatures of the Moyie sills can be used to help define their tectonic setting. Most Moyie sills are low-potassium tholeiitic basalts with high iron and low aluminum content which are more typical of continental than of ocean-floor basalts (Pearce, 1976). However, the Mount Mahon sills are alkali basalts, more typical of an extensional rift environment. Barium and strontium values are high in both suites; this also is typical of continental basalts.

Plots of the relatively immobile trace elements do not clearly define the tectonic setting of Moyie sills. On a Ti-Zr-Y diagram (Pearce and Cann, 1973), the two suites are distinct (Figure 39). Mount Mahon samples plot as "within-plate" basalts, either as continental basalts or in an ocean-island setting, whereas other sills are transitional from a "plate-margin" ocean-floor or calcalkaline arc setting to a "within-plate" setting. Further discrimination on a Ti-Zr-Sr plot indicates both low-potassium tholeiites, common in arc volcanism, and ocean-floor basalts (Figure 40). Plots of other minor and trace element data, including nickel, chromium and niobium, also show characteristics of both within-plate and plate-margin ocean-floor or arc volcanism.

However, Moyie sill data define a positive slope indicative of an ocean-floor basalt trend when plotted on a TiO_2-Zr diagram (Figure 41). This diagram is based on the premise that tholeiitic magmas show an increase in titanium with differentiation whereas calcalkaline magmas do not.

TABLE 6
MINOR AND TRACE ELEMENT ANALYSES, MAFIC SILLS IN KITCHENER AND VAN CREEK FORMATIONS
(in ppm)

Lab. No.	Field No.	Host	Zr	Y	Nb	Rb	Co	Ni	Cr	Sr	Ta	Th	U
28161	H83E-1	Ft Steele	113	23	5	68	—	17	74	230	<4	4	<2
20803	D76E-41	Ft Steele	75	19	1	25	19	50	69	117	<4	15	<2
20802	D76E6-1	Ft Steele	112	22	4	45	—	79	395	23	<4	5	<2
28162	H83E-4	Ft Steele	54	13	4	20	—	78	271	126	<4	12	<2
24541	M7-261	L-M Ald*	109	22	22	36	—	30	43	374	<4	12	3
24543	M7-270	L-M Ald*	117	23	23	29	—	28	40	292	<4	1	<2
24542	M7-265	L-M Ald*	105	22	21	17	—	37	45	417	<4	8	<2
24534	M7-228	L-M Ald*	106	19	19	34	—	35	49	338	<4	4	<2
24533	M7-223	L-M Ald*	109	18	19	32	—	35	49	374	<4	9	<2
24531	M7-214	L-M Ald*	100	20	18	23	—	28	48	433	<4	—	0
24535	M7-233	L-M Ald*	106	20	21	43	18	33	50	364	<4	2	<2
24537	M7-241	L-M Ald*	100	20	19	38	—	31	46	375	<4	4	<2
24538	M7-249	L-M Ald*	103	20	18	37	—	31	46	376	<4	4	<2
24530	M7-209	L-M Ald*	113	22	24	40	21	40	47	336	<4	5	4
24540	M7-256	L-M Ald*	102	20	18	78	19	32	47	363	<4	2	<2
24536	M7-240	L-M Ald*	97	18	16	42	—	34	47	364	<4	4	<2
24532	M7-218	L-M Ald*	108	22	22	28	—	29	49	381	<4	11	<2
24539	M7-251	L-M Ald*	106	19	21	44	—	31	46	390	<4	—	<2
29596	M44-21A	Lower Ald	77	20	1	45	—	34	26	107	<4	14	<2
29597	K23-11B	Lower Ald	68	15	4	52	—	90	188	111	<4	4	<2
29595	6799-A	Lower Ald	68	16	4	21	—	50	135	112	<4	4	<2
28157	M44-19	Lower Ald	52	13	4	25	—	59	41	136	<4	4	<2
28156	M12-24	Lower Ald	50	16	6	17	—	113	423	96	<4	4	<2
28159	M60-5	Lower Ald	63	15	4	56	—	74	193	117	<4	4	<2
28160	K36-11	Lower Ald	55	13	3	18	—	121	387	91	<4	4	<2
29598	6799-B	Lower Ald	179	35	7	67	—	16	36	138	<4	8	<2
28158	M44-22	Lower Ald	41	11	4	57	—	102	367	125	<4	4	<2
22073	M12-27	Lower Ald	49	16	4	43	19	101	499	104	<4	14	<2
28151	M36-5	Middle Ald	59	15	4	31	—	116	323	113	<4	5	<2
28154	K24-30	Middle Ald	109	29	3	26	—	74	87	215	<4	2	<2
20797	E75-2	Middle Ald	68	14	1	16	—	73	148	67	<4	4	<2
28155	H83E-2	Middle Ald	85	22	1	5	—	68	61	168	<4	2	<2
28149	M1-7A	Middle Ald	62	15	2	34	—	101	325	110	<4	2	<2
20800	D76E8-15	Middle Ald	82	17	3	24	—	76	178	31	<4	3	<2
28153	K23-19	Middle Ald	91	24	4	68	—	73	100	136	<4	7	<2
20795	H76D3-7A	Middle Ald	164	20	84	59	—	74	213	1125	1	5	1
24523	M20-1	Middle Ald	81	22	2	6	—	61	43	166	<4	3	<2
28152	M36-12	Middle Ald	98	28	5	11	—	58	37	193	<4	7	<2
28150	M22-2	Middle Ald	64	14	4	9	—	101	299	127	<4	4	<2
20796	M1-7	Middle Ald	54	11	1	12	25	102	352	123	<4	6	<2

* drill core — Mt. Mahon area.

For comparative purposes, data from Moyie sills in the Mount Mahon area are also plotted on this diagram.

These diverse chemical trends, particularly the pronounced alkalic signature of Mount Mahon sills and the transient but dominantly tholeitic trend of other Moyie sills, are typical of basic volcanism in an incipient rift environment or in the early stages of continental rifting.

SUMMARY AND DISCUSSION

Moyie sills form an extensive suite of basaltic rocks that intruded lower and middle Aldridge turbidites and siltstones. Their abundance decreases up-section in the middle Aldridge as the abundance of thick-bedded A-E turbidites decreases. Although it has been proposed that Moyie sills are coeval with deposition of upper Aldridge or Creston rocks (Zartman *et al.*, 1982), or perhaps with the Nicol Creek lavas (McMechan, 1981), contact relationships between sills and Aldridge rocks indicate that some sills were extruded at very shallow depths in unconsolidated, water-saturated sediments. Others with fine-grained chilled margins have contact metamorphosed the country rocks. As these sills are interpreted to be part of a continuous magmatic event, they record an igneous/thermal event of regional extent during deposition of lower and middle Aldridge rocks. Hence, a Middle Proterozoic uranium-lead date of 1445 Ma from zircons in the Lumberton sill west of Cranbrook defines the minimum age of deposition of lower and basal middle Aldridge, and of stratiform massive sulphide deposits such as Sullivan.

Major and trace element analyses of Moyie sills indicate two distinct populations. Alkali basalts intruded the lower-middle Aldridge transition in the Mount Mahon area, whereas subalkaline tholeiitic basalts are common elsewhere. These distinct chemical trends are typical of basic volcanism in an incipient rift environment or in the early stages of continental rifting, supporting a model for development of the Belt-Purcell basin by Middle Proterozoic continental rifting (Sears and Price, 1978; McMechan, *op. cit.*). However, the chemistry of the sills

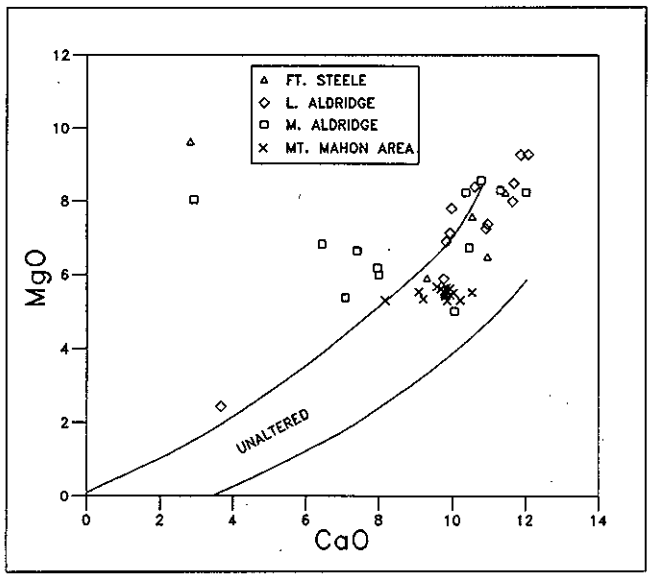


Figure 34. MgO versus CaO plot (in weight per cent) of analyses of Moyie sills in southeastern British Columbia, designed to screen altered (MgO added) from relatively unaltered samples (plot after de Rosen-Spence, 1985).

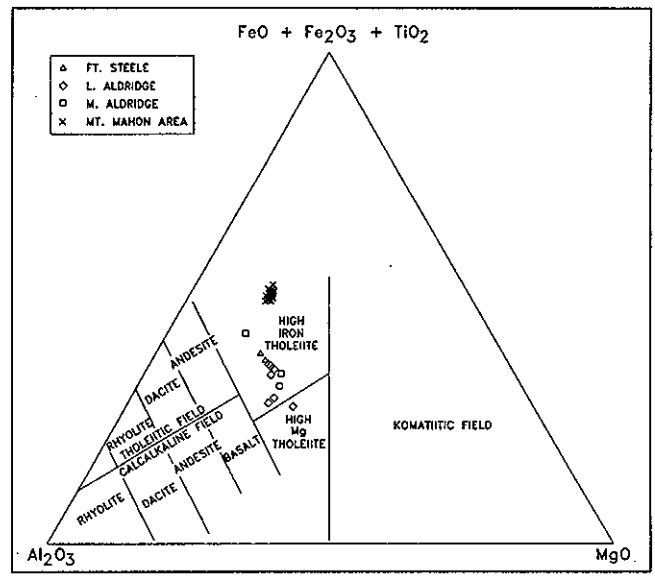


Figure 36. Jenson cation plot of relatively unaltered samples indicating that most Moyie sills are high-iron tholeiites (plot after Jensen, 1976).

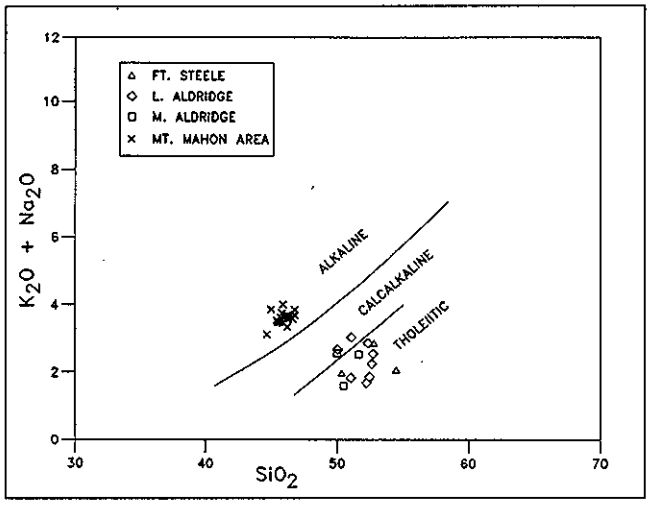


Figure 35. Alkali-silica plot (in weight per cent) of relatively unaltered samples of Moyie sills, showing the two distinct populations (plot after Irvine and Barager, 1971; Kuno, 1966). x=Mount Mahon area sills, o=other sills.

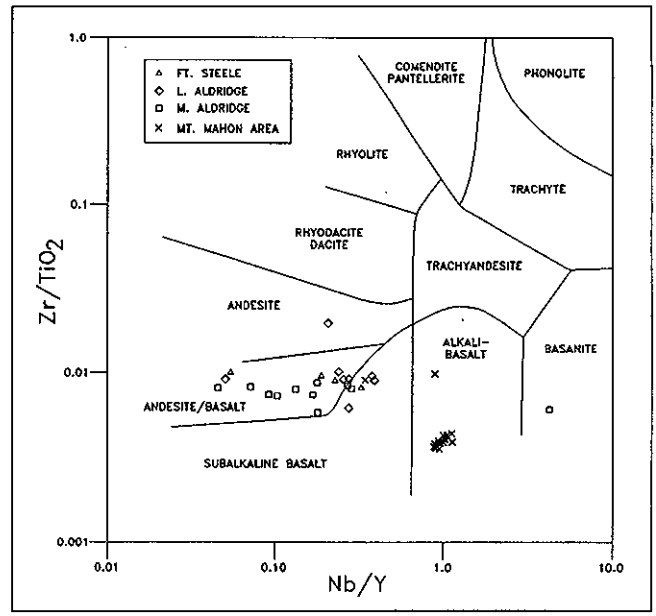


Figure 37. A Zr/Ti versus Nb/Y plot of Moyie sill samples indicating two distinct populations: subalkaline basalts and andesites, and alkaline basalts; (plot after Winchester and Floyd, 1977).

does not indicate whether host Aldridge rocks were deposited as lacustrine sediments in an intracratonic basin (Winston *et al.,* 1984) or as marine sediments in a miogeocline (Price, 1964; Harrison, 1972) that may have been floored by either continental, transitional or oceanic crust.

The age and chemistry of the Moyie sills are similar to those of a suite of dikes in continental crustal rocks in the southern Tobacco Root Mountains of Montana (Wooden *et al.,* 1978). These dikes also have trace element characteristics of both ocean-floor and continental basalts. It is probable that these dikes, located south of the margin of the Belt-Purcell basin, are cogenetic with the synsedimentary Moyie sills within the basin. They record an extensional regime that extended well beyond the limits of the basin. The similarity in chemistry between these dikes of known continental setting and the Moyie sills suggests that the Moyie sills were emplaced within a large subsiding basin above continental crust. This supports a model for deposition of Belt-Purcell rocks in an intracratonic basin formed by Middle Proterozoic rifting. However, continental separation may not have occurred until latest Proterozoic to Early Cambrian time (Devlin *et al.,* 1985, 1988).

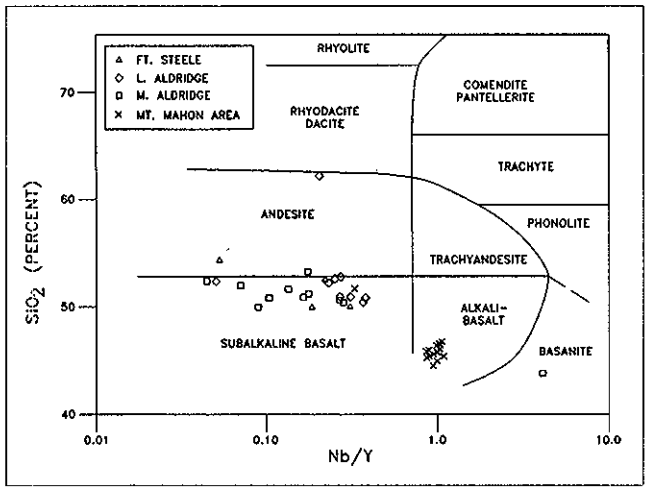


Figure 38. An SiO_2 versus Nb/Y plot of Moyie sill samples (plot after Winchester and Floyd, 1977).

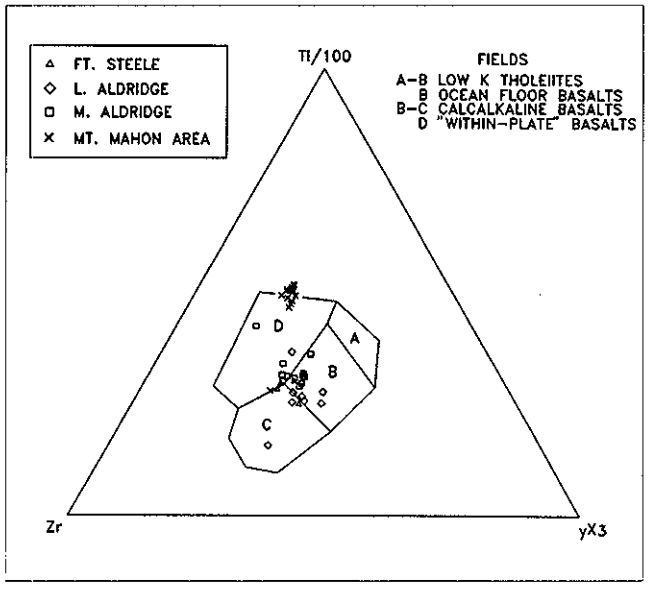


Figure 39. A Ti-Zr-Y diagram showing analyses of Moyie sills (plot after Pearce and Cann, 1973). Mount Mahon samples plot as "within-plate" basalts whereas others appear to be transitional from a "plate-margin" ocean-floor setting to a "within-plate" setting.

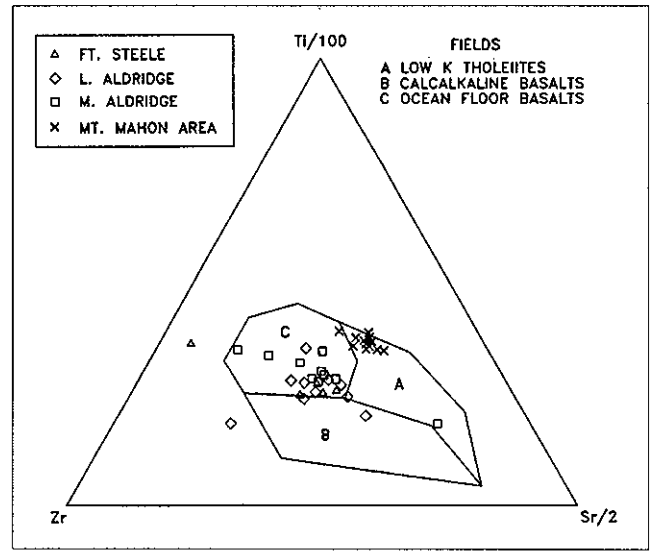


Figure 40. A Ti-Zr-Sr diagram of analyses of Moyie sills showing both low-potassium tholeiitic affinities and ocean-floor basalt affinities; (plot after Pearce and Cann, 1973).

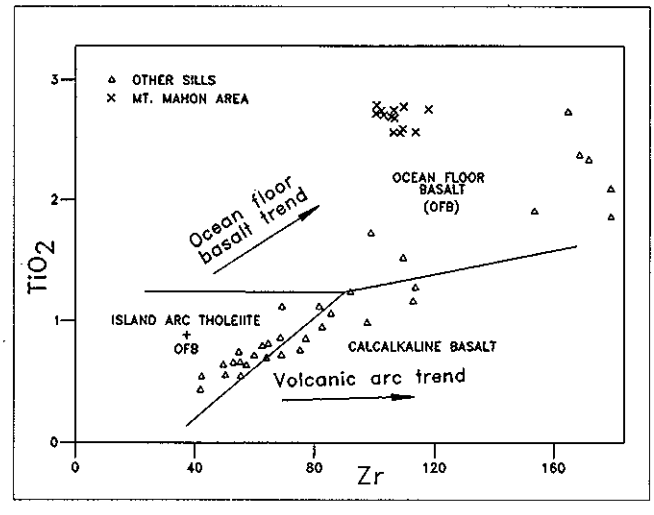


Figure 41. A TiO_2 (per cent) versus Zr (ppm) plot of Moyie sill samples (plot after Garcia, 1978). The positive slope is indicative of an ocean-floor trend.

CHAPTER 4: MESOZOIC INTRUSIVE ROCKS

INTRODUCTION

'Granitic' intrusive rocks are abundant in the Omenica crystalline belt in southeastern British Columbia but become less prominent to the east within the predominantly miogeoclinal rocks of North American provenance. Although only minor petrographic and chemical work has been done on most of these intrusive rocks, they have played an important role in unravelling the thermal and tectonic history of southeastern British Columbia (Archibald, *et al.,* 1983, 1984; Mathews, 1983). Intrusive rocks within the Purcell Supergroup near the Rocky Mountain Trench include a number of small postkinematic mesozonal quartz monzonite, monzonite and syentic plutons, numerous small quartz monzonite to syenite dikes and sills probably related to these stocks, and late mafic dikes. The Kiakho and Reade Lake stocks (Höy and van der Heyden, 1988), two of the larger of the mesozonal plutons, cut across and apparently seal two prominent east-trending faults that transect the eastern flank of the Purcell anticlinorium, and hence place constraints on the timing of latest movements on these faults. Other small intrusions of similar composition occur near the headwaters of Wild Horse River and on the flats at the mouth of the Bull River.

READE LAKE STOCK

The Reade Lake stock is exposed in small scattered outcrops on the flats north of the St. Mary River, southeast of Kimberley (Figure 42). These exposures were reported initially by Rice (1937) and appear on the maps by Leech (1960) and Höy (1984c). Bedrock is largely overlain by Quaternary sands and gravels and, as a result, defining the limits of the stock is difficult. Because of a well-defined magnetic anomaly virtually centred on the known exposures (Figure 43), the stock is inferred to underlie an area covering at least 35 to 40 square kilometres straddling the St. Mary fault. It intrudes Aldridge, Creston and Kitchener Formation rocks and, south of the St. Mary fault, Lower Cambrian siltstone of the Eager Formation. As the stock cuts across the St. Mary fault with little apparent offset, it provides a minimum age for movement on the fault.

FIELD DESCRIPTION

Exposures of the Reade Lake stock include subcrops of rounded, weathered boulders (sample number KF20-6), small isolated rounded knobs of leached rock (H84K-9), and rare, small outcrops of fresh unaltered rock (KF20-1). Where exposed, the contact of the stock is sharp, cutting at a high angle across layering in the country rock. The country rock is hornfelsed and commonly cut by widely spaced quartz, quartz-feldspar and aplite veins. These may extend several tens of metres into the intrusion, commonly through a chilled marginal phase a few metres thick.

PETROLOGY

The dominant phase of the Reade Lake stock is a grey, coarse-grained porphyritic quartz monzonite. With decrease in size of feldspar phenocrysts, this phase grades into equigranular, medium-grained quartz monzonite. Intrusive relationships between these two phases were not observed but, near the margins of the stock, aplite dikes and irregular zones a few metres thick commonly cut the porphyritic or equigranular phases. A minor quartz-augite diorite phase of the Reade Lake stock was noted by Rice (1937) and R. St. Lambert (personal communication, 1986).

The porphyritic phase has a hypidiomorphic granular texture with phenocrysts of predominantly potassic feldspar, less commonly plagioclase, and locally quartz set in a medium-grained, granular groundmass (Plate 47a). Feldspar phenocrysts, averaging 5 to 10 millimetres in diameter, commonly comprise 30 to 40 per cent of the rock. Potassic feldspar phenocrysts include both orthoclase and less commonly microcline and are generally larger and more abundant than the plagioclase phenocrysts. Orthoclase crystals are commonly perthitic and may contain cores of anhedral plagioclase (Plate 47b). Plagioclase phenocrysts are generally subhedral to euhedral (Plate 47c) and may be zoned with sericitized cores. Large, irregular quartz phenocrysts occur in only a few sections. The groundmass of the porphyritic phase comprises an intergrowth of white, anhedral to subhedral plagioclase, anhedral orthoclase, interstitial quartz, and stubby subhedral to euhedral hornblende crystals 3 to 4 millimetres long. Accessory minerals include sphene and apatite, occasional biotite intergrown with muscovite, allanite, zircon, calcite and opaques. The rock is weakly magnetic due to finely dispersed magnetite.

The equigranular phase is similar to the porphyritic phase but lacks the prominent large feldspar phenocrysts. It is a medium-grained (2 to 3 mm average grain size), pale grey quartz monzonite comprising approximately 90 per cent potassic feldspar, plagioclase and quartz, 5 per cent hornblende and 5 per cent accessory phases.

Evidence for the order of crystallization is provided by poikilitic textures with apatite, sphene and opaques enclosed in hornblende; the pronounced euhedral form of hornblende and many plagioclase grains; porphyritic textures with large anhedral potassic feldspar crystals commonly containing early euhedral growth rings; and a groundmass of interstitial intergrown quartz, orthoclase and minor plagioclase. This evidence suggests the following order: sphene, apatite and opaques, followed by hornblende, potassic feldspar and perhaps minor plagioclase, then plagioclase with continued growth of potassic feldspar and finally late concomitant growth of quartz, plagioclase and orthoclase.

KIAKHO STOCK

The Kiakho stock is exposed on the heavily wooded slopes of Kiakho Creek approximately 10 kilometres east-southeast of Cranbrook (Figure 42). It was mapped initially by Schofield (1915) and appears on subsequent maps by Leech (1960) and Höy and Diakow (1982). Exposures con-

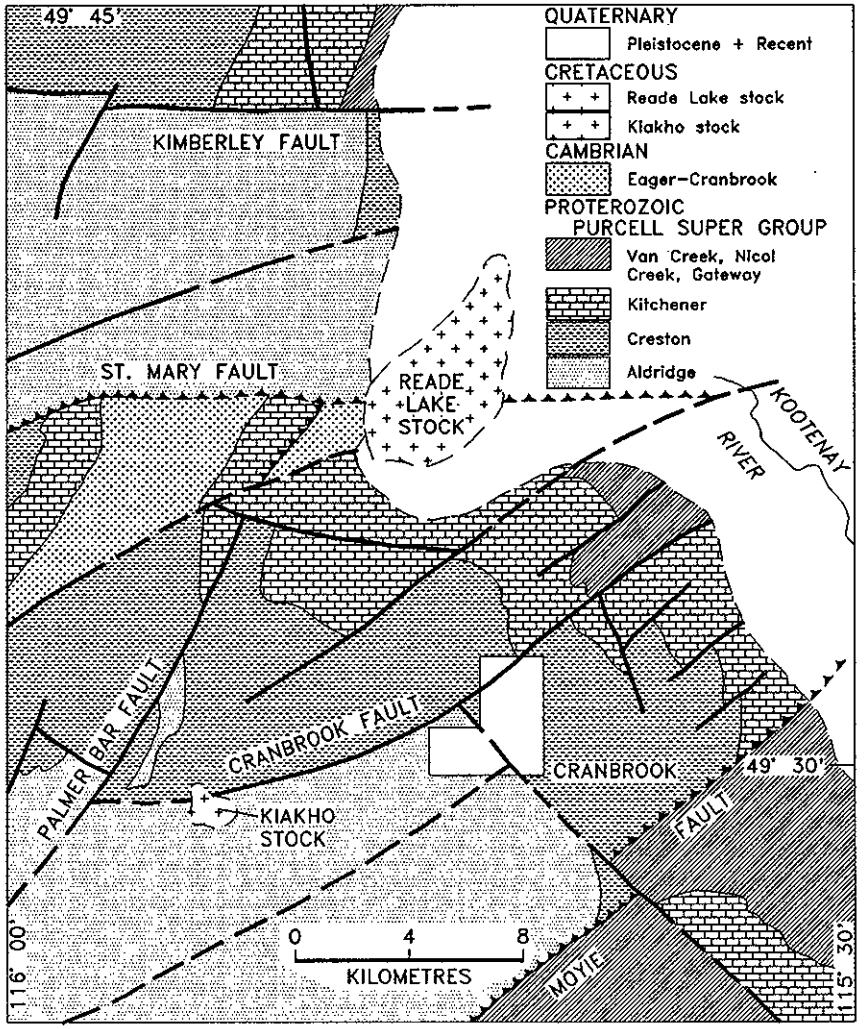


Figure 42. Geological map of the Cranbrook area, southeastern British Columbia, showing location of the Reade Lake and Kiakho stocks; the limit of the Reade Lake stock is taken as the 60 000 gamma isomagnetic line (*see* Figure 43); geology after Höy and Diakow (1981) and Höy (1984c).

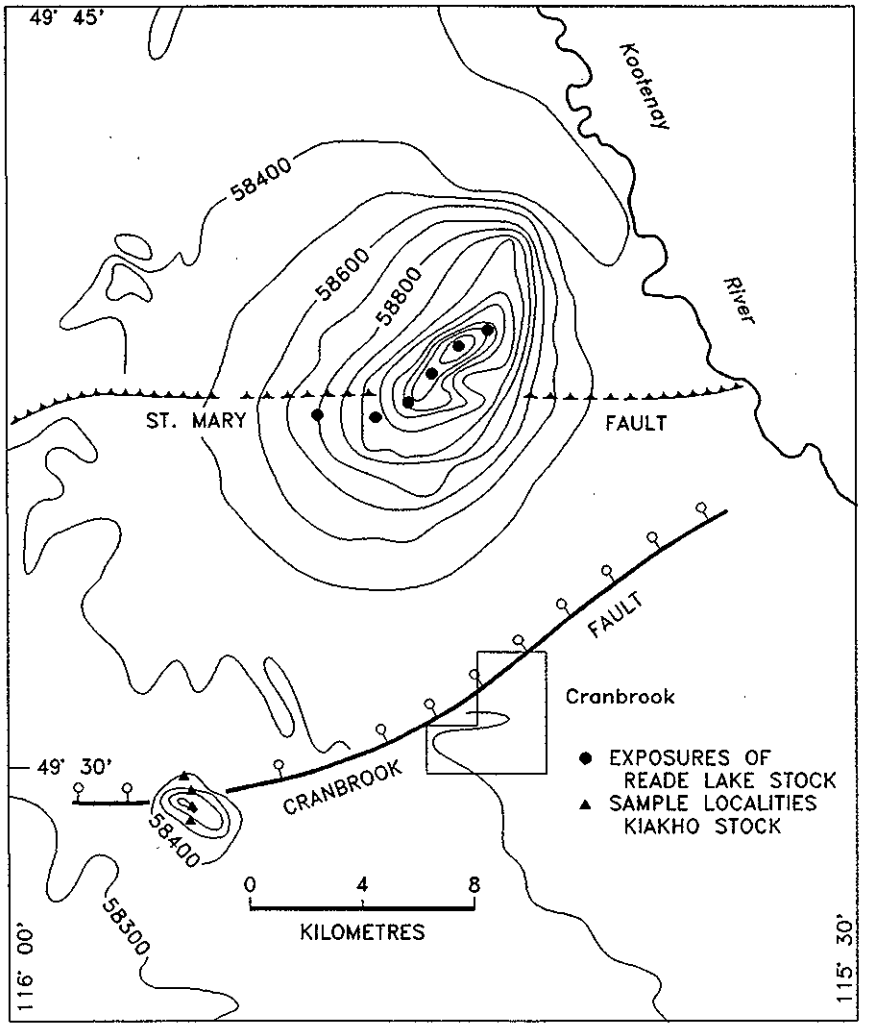


Figure 43. Map showing exposures of the Reade Lake and Kiakho stocks, traces of the St. Mary and Cranbrook faults, and isomagnetic lines (200 gamma contours); geophysical data from joint British Columbia Ministry of Energy, Mines and Petroleum Resources and Geological Survey of Canada maps 8469G (Cranbrook) and 8468G (Moyie Lake).

Plate 47. Photomicrographs of samples of Reade Lake stock; field of view is approximately 2 mm. (a) Porphyritic phase, with anhedral microcline phenocrysts in a granular matrix of quartz, plagioclase and potassic-feldspar – sample KF20-9b; crossed nicols. (b) Perthitic potassic-feldspar phenocrysts growing around a core of anhedral plagioclase – sample KF20-7c; crossed nicols. (c) Zoned, euheral plagioclase crystals, with interstitial quartz, potassic-feldspar; plane light.

sist mainly of large, fresh angular boulders or boulder fields. Although contacts with country rocks were not observed, regional mapping indicates that it intrudes clastic rocks of the Aldridge and Creston formations. The distribution of outcrops and a pronounced aeromagnetic anomaly (Figure 43) indicate that it cuts the east-trending Cranbrook normal fault with no apparent offset.

Petrology

The Kiakho stock is similar to the Reade Lake stock with the dominant phase being a light grey, medium-grained quartz monzonite. It is generally equigranular but grades into a hypidiomorphic granular porphyritic phase with prominent plagioclase and light grey to flesh-coloured potassic feldspar phenocrysts; both are up to several centimetres in diameter in a granular groundmass of white subhedral plagioclase, light grey potassic feldspar, quartz and black hornblende.

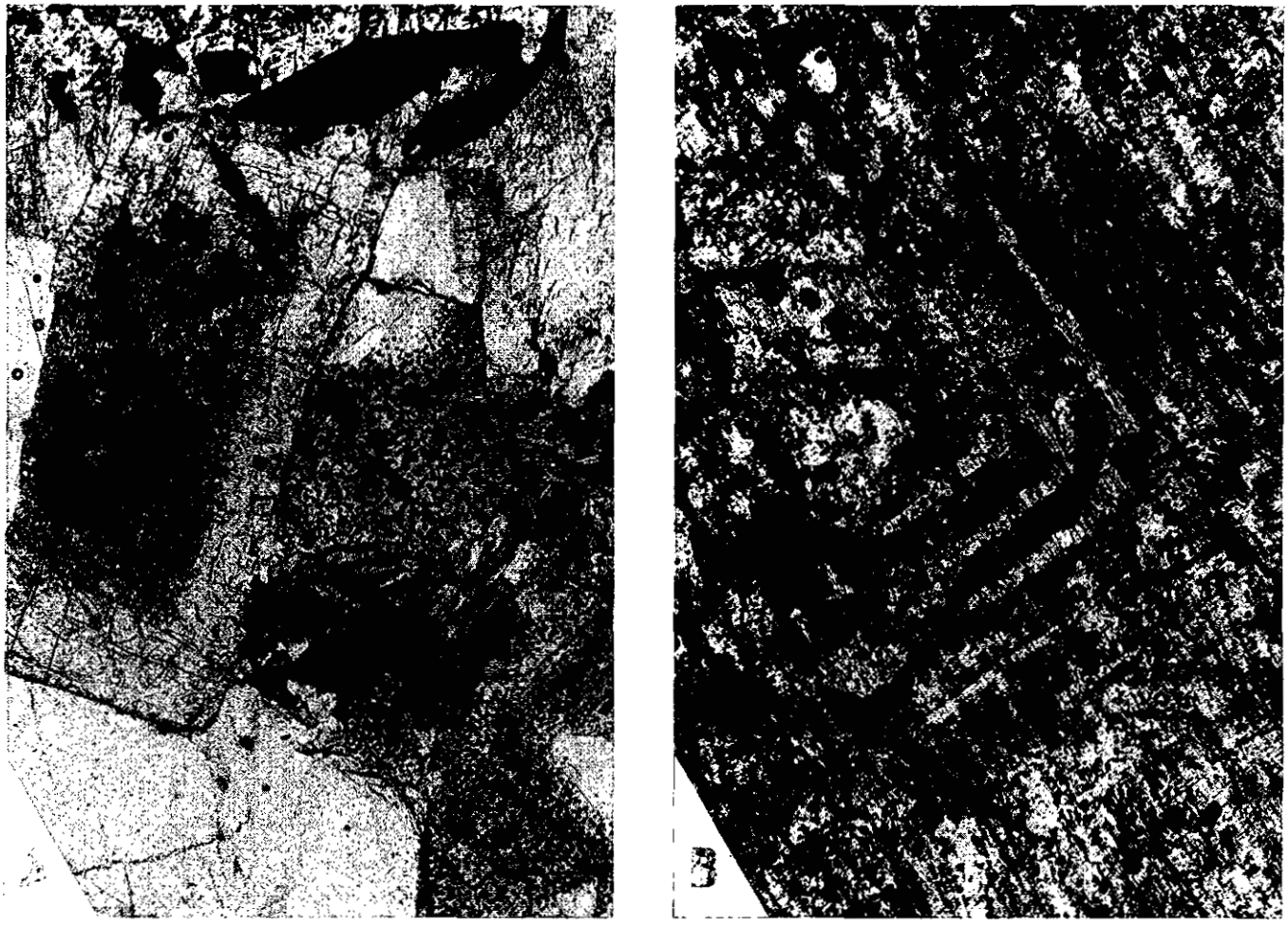


Plate 48. Photomicrographs of samples of Kiakho stock; field of view is approximately 2 mm. (a) Porphyritic phase with subhedral zoned plagioclase crystals with selective argillic alteration, potassic-feldspar (to right of plagioclase), partially altered to sericite, bladed biotite and dark euhedral sphene – sample M36-21b; plane light. (b) Large euhedral potassic-feldspar phenocrysts, with exsolved plagioclase producing perthitic texture – sample M36-21b.

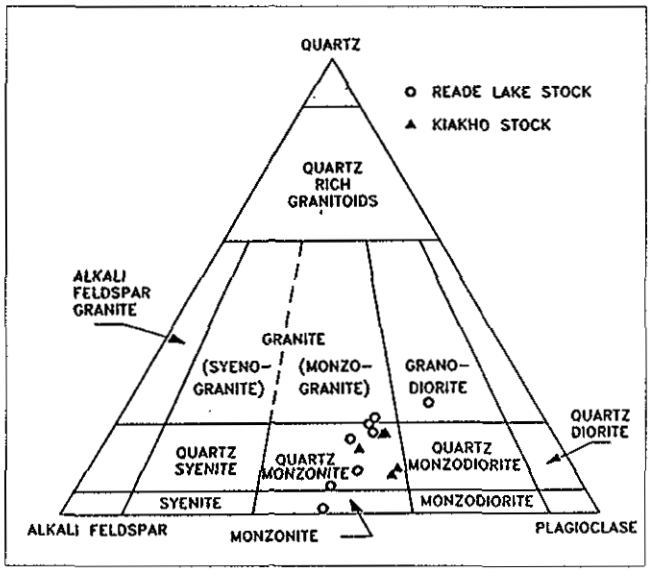


Figure 44. Ternary plot of normative quartz, potassic feldspar and plagioclase for analyzed samples of the Reade Lake and Kiakho stocks.

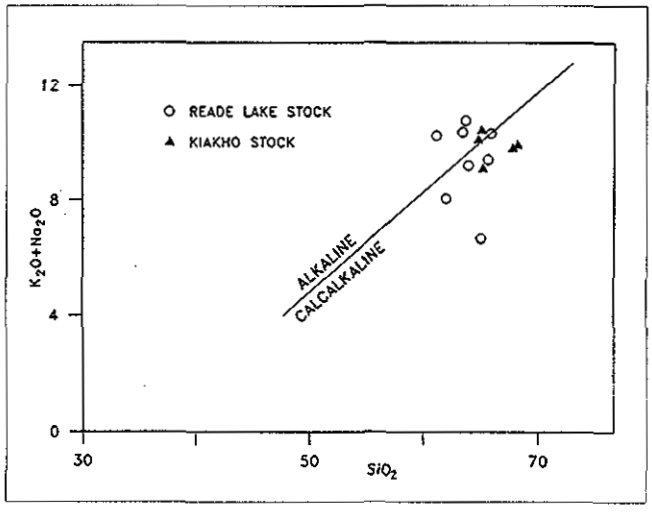


Figure 45. Alkali-silica plot of analyzed samples of the Reade Lake and Kiakho stocks; the alkaline, calcalkaline dividing line is after Irvine and Barager (1971).

TABLE 7

MAJOR ELEMENT CHEMISTRY AND CIPW NORMATIVE MINERALOGIES OF SELECTED SAMPLES OF THE READE LAKE AND KIAKHO STOCKS

Major element composition

Major-element oxide	Kiakho stock sample No.:					Reade Lake stock sample No.:							
	M36-21A	M36-21B	M36-22B	M36-22D	M36-30A	KF20-1	KF20-3	KF20-5	KF20-7A	KF20-7B	KF20-7C	KF20-7D	KH20-1
SiO_2	67.73	67.57	64.65	64.42	64.85	64.68	61.80	63.25	60.77	63.04	65.41	65.45	63.61
TiO_2	0.21	0.32	0.26	0.31	0.48	0.51	0.79	0.54	0.69	0.63	0.55	0.43	0.56
Al_2O_3	17.11	17.53	18.89	18.61	16.56	15.36	15.43	16.71	16.73	16.96	16.04	16.98	15.69
Fe_2O_3[b]	1.06	1.47	1.39	1.39	1.95	0.97	2.38	3.32	3.12	3.00	3.27	2.19	1.84
FeO	1.03	1.04	1.03	1.18	1.93	2.24	3.15	0.73	1.79	1.02	0.90	0.83	2.06
MnO	0.07	0.08	0.08	0.09	0.12	0.16	0.14	0.08	0.15	0.12	0.03	0.07	0.11
MgO	0.43	0.50	0.37	0.43	0.87	1.14	1.79	0.72	1.17	0.80	0.87	0.66	1.04
CaO	1.98	1.93	2.88	3.26	3.50	6.16	3.95	2.50	3.60	2.58	2.62	1.79	3.35
Na_2O	4.67	4.65	4.86	4.90	4.01	4.11	3.21	4.50	4.42	4.45	4.15	4.30	4.01
K_2O	5.23	5.16	5.51	5.25	5.13	2.58	4.81	6.31	5.83	5.95	5.32	6.09	5.27
P_2O_5	0.07	0.05	0.05	0.05	0.16	0.41	0.52	0.15	0.28	0.21	0.21	0.07	0.20
CO_2	0.19	0.10	0.14	0.10	0.10	1.31	0.21	0.14	0.07	0.14	0.28	0.55	1.34
H_2O^+	0.03	0.34	0.18	0.20	—	0.44	0.99	0.58	0.48	0.58	0.48	0.40	—
H_2O^-	0.11	0.12	0.03	0.03	—	0.18	0.58	0.55	0.25	0.38	0.41	0.29	—
Total	99.93	100.86	100.32	100.22	99.66	100.25	99.75	100.09	99.34	99.86	100.54	100.10	99.08

CIPW norm (volatile free)

Mineral	Kiakho stock sample No.:					Reade Lake stock sample No.:							
	M36-21A	M36-21B	M36-22B	M36-22D	M36-30A	KF20-1	KF20-3	KF20-5	KF20-7A	KF20-7B	KF20-7C	KF20-7D	KH20-1
Quartz	15.60	15.88	8.65	8.64	13.95	18.84	14.70	8.04	5.83	8.96	15.21	12.72	12.88
Corundum	0.34	0.91	—	—	—	—	—	—	—	—	—	0.24	—
Orthoclase	31.03	30.40	32.57	31.06	30.45	15.51	29.01	37.73	34.93	35.62	31.64	36.39	31.86
Albite	39.66	39.22	41.12	41.49	34.07	35.36	27.72	38.56	37.93	38.12	35.31	36.76	34.71
Anorthite	9.40	9.22	13.48	13.31	12.10	16.13	13.78	6.84	8.76	8.84	9.51	8.52	9.48
Diopside	—	—	0.40	2.08	3.49	10.11	2.24	3.67	5.85	2.13	1.70	—	5.04
Hypersthene	1.89	1.56	1.19	0.72	1.84	0.70	6.29	0.11	0.25	1.03	1.39	1.66	1.77
Magnetite	1.54	2.12	2.02	2.02	2.84	1.43	3.52	1.08	4.31	1.86	1.44	1.68	2.73
Ilmenite	0.40	0.60	0.50	0.59	0.92	0.98	1.53	1.03	1.33	1.21	1.04	0.83	1.09
Hematite	—	—	—	—	—	—	—	2.61	0.19	1.75	2.30	1.06	—
Apatite	0.16	0.12	0.12	0.12	0.37	0.97	1.24	0.35	0.66	0.50	0.49	0.17	0.48
Anorthite[a]	19.16	19.04	24.68	24.29	26.21	31.32	33.21	15.07	18.76	18.82	21.22	18.82	21.45

NOTE: Location corresponding to the sample number is given below:

Sample No.	Latitude	Longitude	Sample No.	Latitude	Longitude
M36-21A	49°29′30″	115°54′45″	KF20-3	49°36′55″	115°49′00″
M36-21B	49°29′55″	115°54′25″	KF20-5	49°37′30″	115°47′20″
M36-22B	49°30′15″	115°54′32″	KF20-7B	49°38′45″	115°45′5″
M36-22D	49°30′17″	115°54′30″	KF20-7C	49°38′30″	115°46′15″
M36-30A	49°30′23″	115°54′15″	KF20-7D	49°38′35″	115°46′20″
KF20-1	49°36′40″	115°50′50″	KH20-1	49°36′45″	115°51′10″

[a] Anorthite content in plagioclase.
[b] Total iron as Fe_2O_3.

Plagioclase (generally oligoclase) occurs as large subhedral to euhedral, reverse or normally zoned phenocrysts (Plate 48a) in the groundmass or occasionally in cores of large orthoclase grains. Orthoclase is abundant in the groundmass as perthitic intergrowths with plagioclase and as larger subhedral to anhedral phenocrysts in the porphyritic phase. Euhedral growth rings, defined by optically continuous plagioclase (Plate 48b), are abundant in some large anhedral orthoclase grains. Euhedral horneblende crystals comprise 5 to 10 per cent of the rocks and sphene, opaques (predominantly magnetite), apatite, biotite and allanite are accessory minerals.

The order of crystallization of the major mineral phases is somewhat different from that in the Reade Lake stock, probably reflecting a different initial magmatic composition. Sphene, hornblende and perhaps magnetite crystallized early, but in contrast with the Reade Lake stock, plagioclase is the dominant euhedral feldspar phenocryst, indicating early plagioclase growth, followed by orthoclase and continued plagioclase growth, and finally growth of interstitial quartz, orthoclase and minor plagioclase. Subsequent alterations, although minimal, resulted in weak argillic alteration of some plagioclase grains, sericite development in cores of potassic feldspar, and partial chlorite, epidote and carbonate replacement of some hornblende grains.

CHEMISTRY OF READE LAKE AND KIAKHO STOCKS

Samples and chemical analyses of the Reade Lake stock are few, owing to the limited number of exposures and the extensive weathering of many outcrops. Only a few sites have been sampled, but in these exposures the stock is quite homogeneous.

Major element analyses and corresponding CIPW normative mineralogies, cited in Table 7 and plotted on Figure 44, indicate that the stocks are predominantly quartz monzonites, but somewhat more alkalic than typical calc-alkaline intrusions (Figure 45).

Major element oxide trends (Figure 46), although scattered, show poorly defined negative correlations of SiO_2 with CaO, MgO and TiO_2 and positive correlation with Na_2O. These trends are similar to typical calcalkaline trends as described by Nockolds and Allen (1953) but show significantly higher K_2O content. The trends support increasing alkaline feldspar concentration with increasing magmatic differentiation.

Although composition and chemical trends of the two stocks are similar, the more siliceous Kiakho stock is relatively enriched in the alkali elements (Figure 47), aluminum and calcium and correspondingly depleted in iron, titanium and magnesium (Figure 47). This chemical distinction is enhanced on a K_2O/Na_2O plot that shows a relative Na_2O enrichment in the Kiakho stock and is further reflected on a normative plot by higher plagioclase content (Figure 44). Mineralogical and textural differences resulting from these chemical differences are also apparent; porphyritic phases of the Kiakho stock are characterized by conspicuous euhedral plagioclase phenocrysts in addition to the potassic feldspar phenocrysts, whereas the Reade Lake stock contains predominantly potassic feldspar phenocrysts.

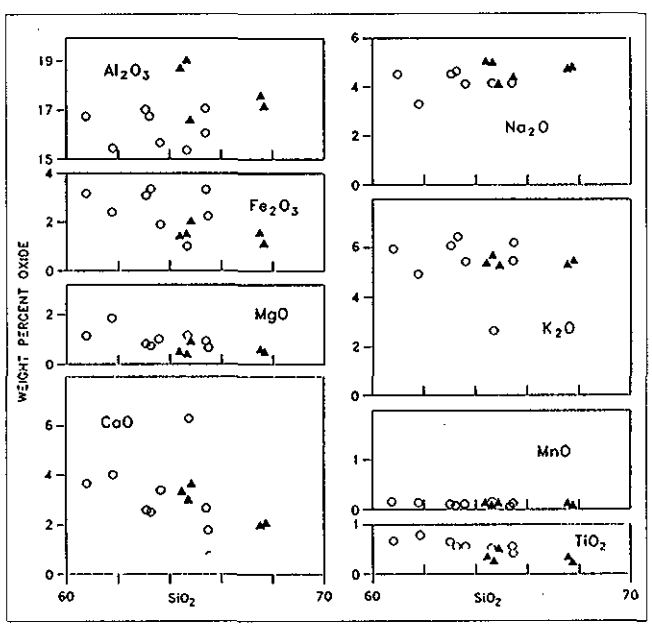


Figure 46. Harker variation diagrams for major elements in analyzed samples of the Reade Lake and Kiakho stocks (symbols as in Figure 45).

GEOCHRONOLOGY OF READE LAKE AND KIAKHO STOCKS

Potassium-Argon Dating

Conventional potassium-argon dates of hornblende concentrates from the Reade Lake and Kiakho stocks are listed in Table 8. The range in potassium-argon determinations obtained for the Reade Lake stock is difficult to interpret. Most outcrops sampled were weathered, but hornblendes were handpicked to produce a generally fresh, unaltered concentrate. It is unlikely that the age span records intrusion of successively younger phases, as all samples are mineralogically similar, no intrusive relationships between phases were observed, and the aeromagnetic anomaly pattern is well defined and uniform. It is also unlikely that the span records variable cooling rates because the samples are all

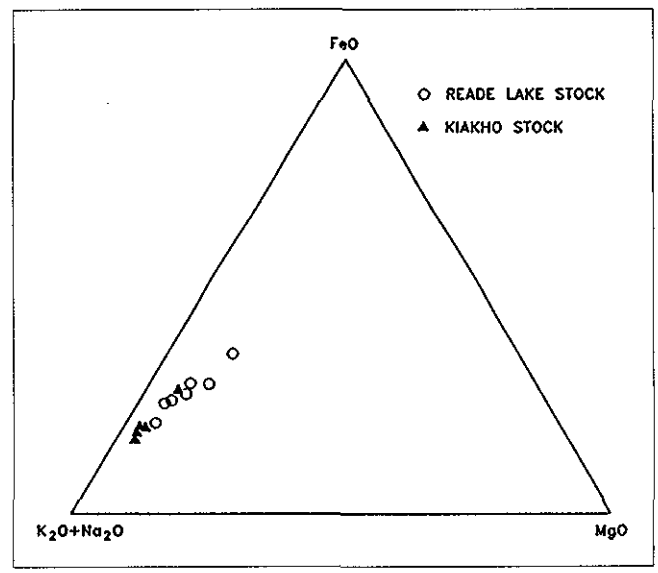


Figure 47. AFM diagram for samples of the Reade Lake and Kiakho stocks; FeO is total iron expressed as FeO.

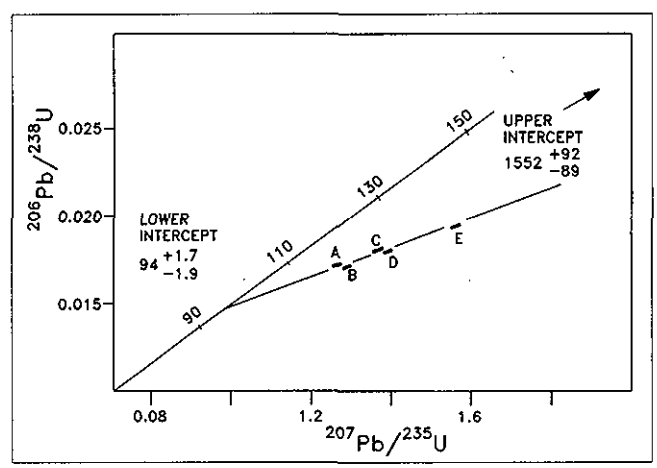


Figure 48. U-Pb concordia diagram for analyses of zircons, sample KF20-1, Reade Lake stock; *see* Table 9 for data and explanatory notes.

from near the contact of the intrusion and from similar structural levels. Rather, it is probable that it resulted from incorporation of variable amounts of excess ^{40}Ar inherited from country rock through degassing during ascent of the magma.

The analyzed sample of the Kiakho stock was unaltered and yielded a good concentration of fresh, euhedral hornblende grains; hence it is tempting to consider that the 122 Ma date (Table 8) represents a reliable intrusive age for the stock. However, as is the case for the Reade Lake stock, the presence of excess ^{40}Ar in this sample cannot be ruled out and the 122 Ma date must be considered a maximum.

Uranium-Lead Dating

In an attempt to explain the spread in potassium-argon dates obtained from the Reade Lake stock, zircons from an unaltered sample (KF20-1) were analyzed (*see* Chapter 3 for methods). Separated zircons were clear to light pink euhedral crystals; approximately 30 per cent had clear inclusions and all fractions contained grains with cloudy xenocrystic cores.

Uranium-lead data are shown in Table 9 and plotted on the concordia diagram in Figure 48. The lower intercept age of 94 Ma is interpreted to be a minimum age for emplacement of the Reade Lake stock. The upper intercept age is an older age inherited from the cloudy xenocrystic cores of many of the zircons. It is similar to uranium-lead dates from xenocrystic zircons in the Kaniksu batholith (Archibald *et al.*, 1984) and from the Precambrian basement in northern Idaho (Clark, 1973; Evans and Fischer, 1986; Armstrong, 1987), suggesting that the Reade Lake stock formed, at least in part, by partial melting of sialic basement rocks.

The span and older potassium-argon dates for the Reade Lake stock probably reflect excess ^{40}Ar in hornblende. This interpretation is supported by the inverse correlation between potassium content and increasing age; excess ^{40}Ar would cause an increasingly larger systematic discrepancy as the potassium content of hornblende decreased. The relatively high potassium content in the analyzed sample of the Kiakho stock supports the suggestion that the 122 Ma date may approach the age of emplacement.

DISCUSSION — READE LAKE AND KIAKHO STOCKS

The St. Mary fault, sealed by the Reade Lake stock, has a complex history of movement that can be documented in the Middle Proterozoic (Höy, 1982a, McMechan, 1981), Late Proterozoic (Lis and Price, 1976), and Paleozoic (Leech, 1958a). Although Price (1981) indicated a mid-Cretaceous age for the latest movement on the St. Mary fault, based on potassium-argon dates on the Bayonne batholith 70 kilometres to the west (Archibald *et al.*, 1983), recent mapping (Reesor, in preparation) has shown that the St. Mary fault is not cut by the batholith. Hence, the 94 Ma date on the Reade Lake stock provides the first reliable constraint on latest movement on the St. Mary fault, its extension east of the Rocky Mountain Trench, the Boulder Creek fault, and possible linked thrust faults in the Rocky Mountains (Benvenuto and Price, 1979; Höy and van der Heyden, 1988).

The Cranbrook fault, cut by the Kiakho stock, is a northeast-trending, north-dipping normal fault that truncates tight north-trending folds and a pronounced metamorphic fabric in its hangingwall west of Cranbrook. The Cranbrook fault, and its inferred extension east of the Rocky Mountain Trench (Benvenuto and Price, *op. cit.*), is itself cut by the Palmer Bar fault, a north-trending normal fault, at its southwestern end, and the Boulder Creek fault at its northeastern end. The 122 Ma date for the Kiakho stock is probably a reliable intrusive age and therefore constrains movement on the Cranbrook fault and the prominent deformation and regional metamorphism (Höy and Diakow, 1981) to pre-late Lower Cretaceous.

Both the Reade Lake and Kiakho stocks are postkinematic intrusions in contrast with some synkinematic intrusions of the same age in the southern Kootenay Arc (Archibald *et al.*, 1984). They were presumably emplaced east of, and at higher structural levels than these possibly comagmatic southern Kootenay Arc intrusions. Regional deformation and metamorphism preceded emplacement of the Reade Lake and Kiakho stocks; northeast-trending normal faulting and reverse movement on the St. Mary fault and the inferred linked thrust faults in the western Rocky Mountains occurred prior to 94 Ma.

ESTELLA STOCK

A small, irregular crosscutting stock is exposed in the cirque near the headwaters of Tracy Creek 10 kilometres east of Wasa Lake in the northern Hughes Range. It is informally referred to as the Estella stock because the worked-out Estella silver-lead-zinc vein occurs near its margin. The stock is in sharp intrusive contact with middle Aldridge Formation siltstone, argillite and minor quartz wacke. The country rock is hornfelsed and locally contains abundant disseminated pyrite; it may be brecciated and cut

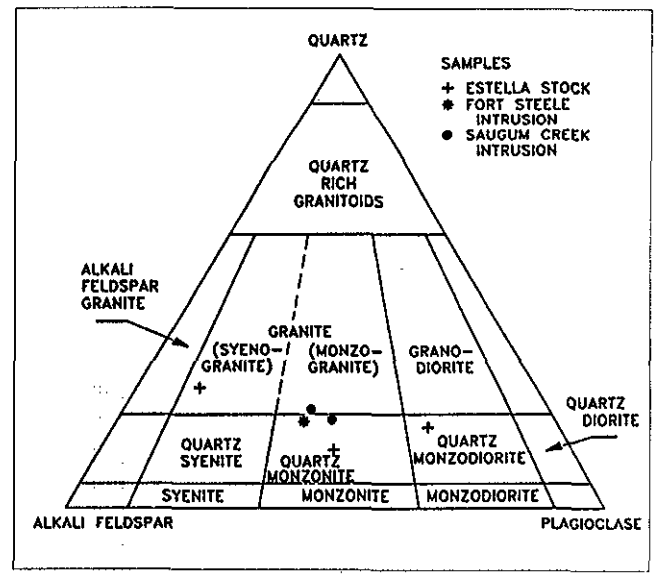


Figure 49. Ternary plot of normative quartz, potassic feldspar and plagioclase for analyzed samples of the Estella stock and a small stock that is intrusive into the Fort Steele Formation.

TABLE 8

K-Ar DATES FROM THE KIAKHO LAKES STOCK AND READE LAKE STOCK, SOUTHEASTERN BRITISH COLUMBIA

Sample No.	Mineral analyzed	Location Lat.	Long.	K (%)	$^{40}Ar \times 10^{-6}$ (cm^3/g)	Radiogenic ^{40}Ar (%)	Date (Ma)
			Kiakho lakes stock				
M36-21A	Hornblende	49°29′30″	115°54′45″	1.07±0.006	5.232	94.1	122±4
			Reade Lake stock				
KF20-1	Hornblende	49°36′40″	115°50′50″	0.855±0.025	4.962	85.8	143±6
KF20-3	Hornblende	49°36′55″	115°49′00″	0.919±0.034	4.277	89.5	116±4
KF20-7B	Hornblende	49°38′45″	115°45′ 5″	0.941±0.019	3.866	78.3	103±4
			Estella stock				
H83E3A	Biotite	49°46′15″	115°36′20″	4.78±0.01	22.008	63.8	115±4

ANALYTICAL METHOD: K analyses, carried out at the British Columbia Geological Survey Branch Laboratory, involved fusing the sample with $LiBO_2$, then dissolving the glass beads in 6% HNO_3 with 3 mL 50% HF. CsCl was added as a buffer and K abundance measured on an atomic absorption spectophotometer. Ar analyses were done at the Department of Geological Sciences, The University of British Columbia. Samples were fused and spiked with high-purity ^{38}Ar. The gas mixture as purified, and argon isotopic ratios measured on a AEI HS-10 mass spectrometer. Constants used: $\lambda_e=0.581\times10^{-10}a^{-1}$; $\lambda_\beta=4.962\times10^{-10}a^{-1}$; $^{40}K/K=0.01167$ at %.

TABLE 9

U-Pb ZIRCON ANALYSES OF SAMPLE KF20-1, READE LAKE STOCK

	Fractions		Concentrations		Pb Isotopic Abundance[3]				Atomic Ratios (Date, Ma)[5]		
No.	mesh size magnetic[1] properties	weight (mg)	U (ppm)	Pb[2] (ppm)	$^{206}Pb=100$			$^{206}Pb/^{204}Pb$[4]	$^{206}Pb/^{238}U$	$^{207}Pb/^{235}U$	$^{207}Pb/^{206}Pb$
A	−200+325 M1.7/2°	1.6	1743	29.98	11.4849	6.0992	0.0431	1903	0.01686±10 (107.8±0.7)	0.1271±9 (121.5±0.8)	0.05469±19 (399.5±7.6)
B	−200+325 NM2/1°−85% M2/1°−15%	2.4	1167	19.97	10.7246	5.7795	0.0193	3686	0.01702±11 (108.8±0.7)	0.1290±8 (123.2±0.7)	0.05497±13 (411.1±5.3)
C	200 DM2.1/−5°	3.7	1163	20.59	9.8734	5.8917	0.0204	3783	0.01771±11 (113.2±0.7)	0.1366±9 (130.0±0.8)	0.05595±13 (450.3±5.2)
D	−200+325 M1.2/5°	1.6	1833	33.00	11.1924	6.1286	0.0294	2767	0.01774±11 (113.3±0.7)	0.1394±9 (132.5±0.8)	0.05700±15 (491.5±5.7)
E	+200 NM1.2/10°	1.3	1292	24.69	10.1123	6.2323	0.0192	3199	0.01902±12 (121.5±0.8)	0.1562±10 (147.3±0.9)	0.05954±16 (586.8±5.8)

Notes: [1] M,NM,DM=magnetic, non-magnetic and diamagnetic on Franz isodynamic separator at indicated amperage and angle of side tilt.
[2] radiogenic plus common Pb
[3] radiogenic plus common Pb, corrected for 0.15% per AMU fractionation and for 120 pg Pb blank with composition 208:207:206:204=37.30:15.50:17.75:1
[4] corrected for 0.15% per AMU fractionation
[5] decay constants: $\lambda^{238}=0.155125\times10^{-9}$/yr, $\lambda^{235}=0.98485\times10^{-9}$/yr, $^{238}U/^{235}U=137.88$; ratios are corrected for U+Pb fractionation (0.15%/AMU), blank Pb, and for common Pb using the Stacey and Kramer (1975) growth curve and an initial Pb age of 100 Ma. Analyses done by P. van der Heyden, The University of British Columbia.

by quartz-carbonate-sulphide veins. Porphyry dikes, similar to the contact phase of the Estella stock, locally extend several hundred metres into the country rock.

The Estella stock is chemically, mineralogically, and texturally distinct from the Reade Lake or Kiakho stocks. Its composition is highly variable (Table 10a) and includes quartz monzonite, quartz monzodiorite and syenogranite (Figure 49). Its dominant phase is a porphyry with euhedral potassic feldspar phenocrysts (to 1-2 cm in length) and albite (generally 1 cm) in a fine-grained to aphanitic groundmass of quartz, feldspar and amphibole(?). Disseminated pyrite and quartz veinlets with bleached margins are common. A fine-grained equigranular phase is mineralogically similar to the groundmass of the porphyry phase.

The Estella stock is interpreted to be an epizonal, volatile-rich composite intrusion that was forcibly emplaced into middle Aldridge metasedimentary rocks. It contrasts markedly with the coarser grained, more homogeneous mesozonal Kiakho and Reade Lake stocks.

A biotite concentrate from a coarse-grained porphyritic syenite phase of the Estella stock has yielded a 115 Ma date (Table 8). This date is similar to dates of the Reade Lake and Kiakho stocks; however, it should be considered the maximum age of intrusion due to the possibility of excess argon. Vein mineralization at the Estella mine may be related to the stock. However, lead-lead dating of galena from these veins have yielded a Middle Proterozoic age (LeCouteur, 1973). It is possible, therefore, that the Estella

TABLE 10

MAJOR ELEMENT CHEMISTRY AND CIPW NORMATIVE MINERALOGIES OF SELECTED SAMPLES OF THE ESTELLA STOCK (10a), OTHER SMALL GRANITIC INTRUSIONS (10b) AND MAFIC DIKES (10c)

TABLE 10a

ESTELLA STOCK

Sample	Lab No.	SiO_2	Al_2O_3	$Fe_2O_{3(T)}$	MgO	CaO	Na_2O	K_2O	TiO_2	MnO	CO_2	Sum	FeO	Fe_2O_3	P_2O_5	H_2O^+	H_2O^-	S
D-4	20129	61.00	17.96	3.68	0.86	3.96	4.79	3.89	0.42	0.140	1.54	99.93	1.57	1.93	0.24	1.19	0.21	0.22
D-8J	20132	64.21	17.87	2.51	0.22	0.62	4.73	6.62	0.12	0.046	0.11	98.86	0.54	1.91	0.15	0.62	0.20	0.80
D-3	20799	57.41	21.23	3.24	0.43	2.32	1.03	8.97	0.43	0.110	1.90	100.59	0.38	—	0.22	1.82	0.24	1.22

TABLE 10b

OTHER INTRUSIONS

Sample	Lab No.	SiO_2	Al_2O_3	$Fe_2O_{3(T)}$	MgO	CaO	Na_2O	K_2O	TiO_2	MnO	CO_2	Sum	FeO	Fe_2O_3	P_2O_5	H_2O^+	H_2O^-	S
H84E2-1	29302	70.65	15.11	1.64	0.16	0.20	4.62	6.49	0.19	0.062	—	—	—	—	—	—	—	—
H84E2-2	29303	71.33	14.25	1.56	0.28	0.59	4.19	6.59	0.19	0.064	—	—	—	—	—	—	—	—
D76E10-3	20798	70.60	15.73	1.23	0.05	0.59	4.22	7.30	0.13	0.027	0.61	101.42	0.24	—	0.06	0.30	0.10	0.44

TABLE 10c

MAFIC DIKES

Sample	Lab No.	SiO_2	Al_2O_3	$Fe_2O_{3(T)}$	MgO	CaO	Na_2O	K_2O	TiO_2	MnO	CO_2	Sum	FeO	Fe_2O_3	P_2O_5	H_2O^+	H_2O^-	S
H84E-3	29304	43.13	14.33	9.50	8.57	12.71	1.58	3.31	2.56	0.197	—	—	—	—	—	—	—	—
H84E-4	29305	42.75	14.52	9.79	8.62	11.97	1.69	3.65	2.50	0.200	—	—	—	—	—	—	—	—
E55-4	20130	50.30	14.53	9.52	8.13	11.43	1.56	0.43	0.69	0.154	0.11	—	6.96	—	0.15	2.73	0.11	—

deposit records Proterozoic mineralization, remobilized by the Middle Cretaceous Estella stock.

OTHER "GRANITIC" INTRUSIONS

A large L-shaped stock intrudes limestone and shale of the McKay Group east of the Rocky Mountain Trench near the divide between Tanglefoot Creek and the east fork of Horsethief Creek (Figure 2, in pocket). The following description is summarized from Leech (1960). The southern part of the stock is a pink porphyritic monzonite and quartz monzonite with medium to coarse subhedral grains of perthitic orthoclase and minor hornblende in a fine-grained groundmass of plagioclase, orthoclase and quartz. The northern part is more varied, with compositions of grab samples taken from a dump below old adits on a tributary of Tanglefoot Creek, 400 metres south of the southeast corner of the stock, ranging from almost equigranular to markedly porphyritic.

Two zones of granitic rocks intrude the Gateway and Jubilee formations and the McKay Group just east of the headwaters of Wildhorse Creek. They range in composition from quartz monzonite to monzonite and minor syenite and vary from medium-grained equigranular phases to porphyritic phases. The porphyritic phases are most common, with phenocrysts of potassic feldspar, plagioclase, and less commonly hornblende in a fine to very fine grained groundmass. Contact metamorphism has hornfelsed clastic country rocks and has locally produced skarns in Jubilee Formation dolomite.

A number of small outcrops of altered monzonite or granodiorite porphyry are exposed on the east side of the trench near the mouth of the Bull River (Leech, 1960). Contacts are not exposed but the stocks are assumed to be intrusive into Devonian and Mississippian rocks. Many dikes and small irregular granitic intrusions are also exposed on the east side of the trench between Lewis Creek and Wild Horse River. Only one area, located just north of the headwaters of Saugum Creek, has been visited and sampled. Here, weathered, rounded outcrops of pink to grey intrusive rock occur within hornfelsed siltstone and quartzite of the Fort Steele Formation. Chemical analyses (Table 10b), recalculated to norms and plotted on Figure 49, indicate that the intrusion is a quartz monzonite to monzogranite. It is porphyritic with subhedral phenocrysts of perthite, commonly overgrown by plagioclase, in a groundmass of anhedral perthite, microcline, plagioclase and quartz. Accessory minerals include apatite, biotite, sphene and opaques; minor secondary minerals include chlorite, epidote and carbonate, and probably replacements of hornblende. Porphyritic dikes of similar composition, 1 to 2 metres thick, cut orthoquartzites of the Fort Steele Formation up to 1 kilometre south of the main intrusive zone.

MAFIC DIKES

Narrow mafic dikes, referred to as minette (McClay, 1983) or lamprophyres (LeCouteur, 1979) were noted occasionally during field mapping. A number have been analyzed (Table 10); no other work has been done on them. LeCouteur (*op. cit.*) reports an Early Cretaceous age (~130 Ma) for lamprophyre dikes that cut the Sullivan orebody.

CHAPTER 5: STRUCTURE AND TECTONICS

INTRODUCTION

The Fernie west-half map area is within the most eastern of the physiographic belts in the Canadian Cordillera, the Foreland thrust and fold belt (Monger *et al.*, 1982). This belt is characterized by shallow, easterly verging thrust faults and broad open folds in Proterozoic (generally west of the Rocky Mountain Trench) and Phanerozoic miogeoclinal rocks. Locally, as in this area, the Proterozoic Purcell and Windermere Supergroup rocks are exposed in thrust sheets east of the trench.

The structure of the western part of the Foreland thrust belt is dominated by the Purcell anticlinorium, a broad, generally north-plunging structure that is cored by rocks of the Purcell and Windermere supergroups and flanked by Paleozoic miogeoclinal rocks. The anticlinorium is allochthonous, carried eastward and onto underlying cratonic basement by thrusts that lie close to or at the basement contact (Price, 1981). Structures within the anticlinorium include easterly verging thrust faults, northeast-trending, right-lateral reverse faults and open to tight folds. A complex array of normal faults that trend dominantly northward, parallel to the Rocky Mountain Trench, or northeasterly, cut the earlier thrust faults and folds.

The northeast-trending structures are within or parallel to a broad structural zone that cuts the Purcell anticlinorium, crosses the Rocky Mountain Trench and extends northeastward across the Foreland thrust belt. The zone is marked by a conspicuous change in the structural grain, from northward north of the zone to northwestward to the south, and by pronounced and fundamental changes in thickness and facies of sedimentary rocks that range in age from Middle Proterozoic to early Paleozoic.

This chapter summarizes the dominant structures and the tectonic evolution of the Fernie west-half map area. It stresses the influence of early structures in shaping the Purcell basin, largely detailed in Chapter 2, and the resultant effect these early structures had in modifying the pattern of later thrusts and normal faults. The control that many of these structures had in localizing some of the mineral deposits in the area is summarized in Chapter 6.

PROTEROZOIC TECTONIC EVENTS

Purcell Supergroup rocks have been affected by several episodes of deformation in Middle and Late Proterozoic time (Figure 50). The earliest events are recorded in the Purcell stratigraphy. Extensional tectonics resulted in prominent block faulting along the margin of the Purcell basin during deposition of the Fort Steele and Aldridge formations. Continued extension in late Purcell time, particularly during deposition of the Nicol Creek and Gateway formations, was also accompanied by block faulting.

LOWER PURCELL TECTONICS

The earliest tectonic event recorded in Purcell Supergroup rocks occurred during deposition of the Aldridge and

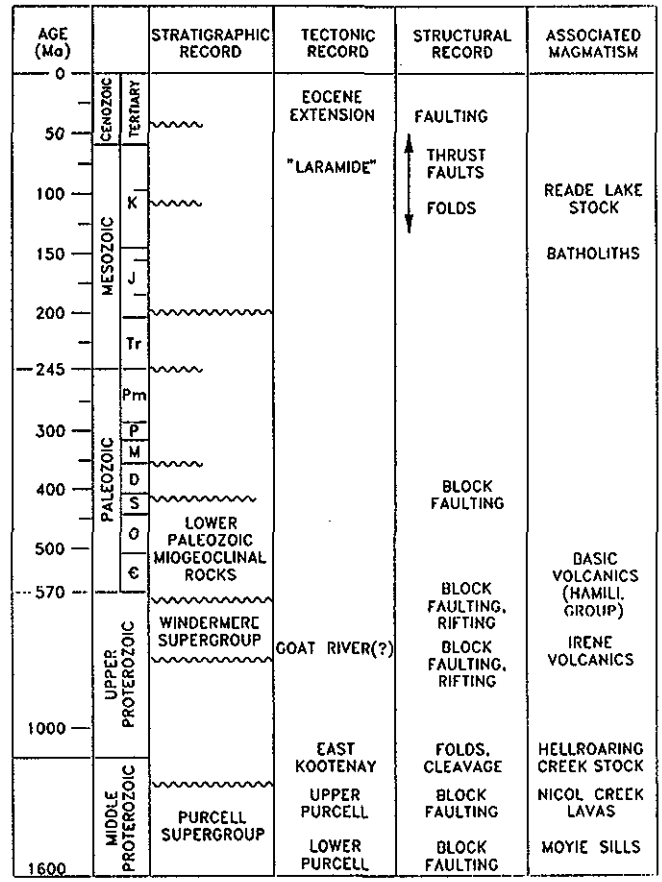


Figure 50. Table showing the major tectonic events that affected Purcell Supergroup rocks in southeastern British Columbia.

Fort Steele formations. The Boulder Creek fault and the segment of the Rocky Mountain Trench fault north of the Boulder Creek fault coincide with a marked change in the character of lower Purcell rocks, from dominantly fluvial (Fort Steele), shallow-water and minor turbidite deposits in the northern Hughes Range to a thick succession of middle Aldridge turbidites in the southern Hughes Range and the Purcell Mountains west of the Rocky Mountain Trench (Figure 51). Thus, the Boulder Creek fault and the segment of the Rocky Mountain Trench fault north of the Boulder Creek fault outline a block of Purcell rocks in the northern Hughes Range that marks the northern and eastern edge of the Purcell basin.

In the northern Hughes Range, dramatic southward thickening of coarse-grained units in the Aldridge Formation, interlayered with thinly laminated siltstone and argillite, suggests that deposition of the coarse-grained units was influenced by growth faults located near the basin margin (Figure 51b). In late middle Aldridge time, turbidite deposition extended over the basin edge into the area of former shelf or platformal deposits represented by the Fort Steele and lower part of the Aldridge formations (Figure 51b, c).

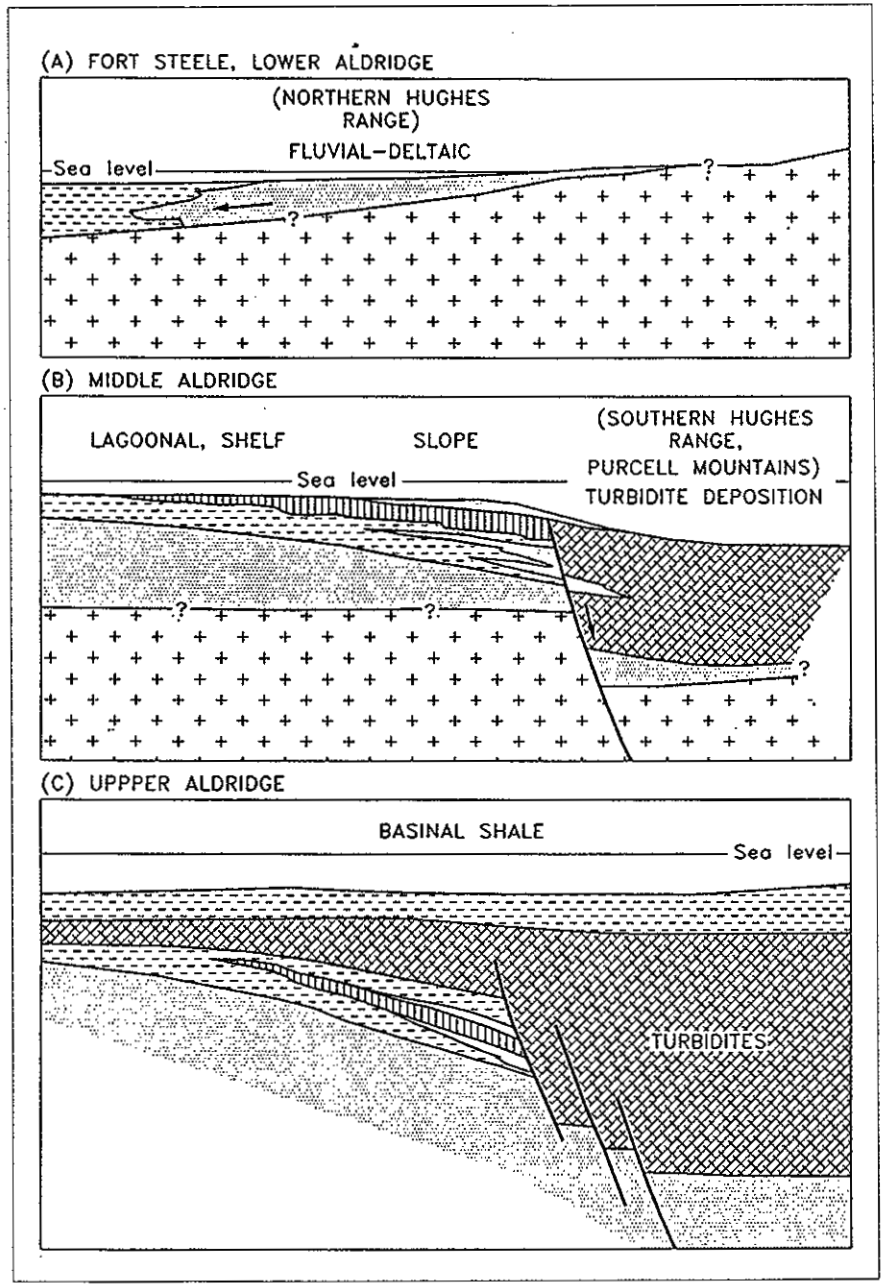


Figure 51. Tectonic evolution of the northeastern margin of the Purcell basin in Fort Steele and Aldridge times.

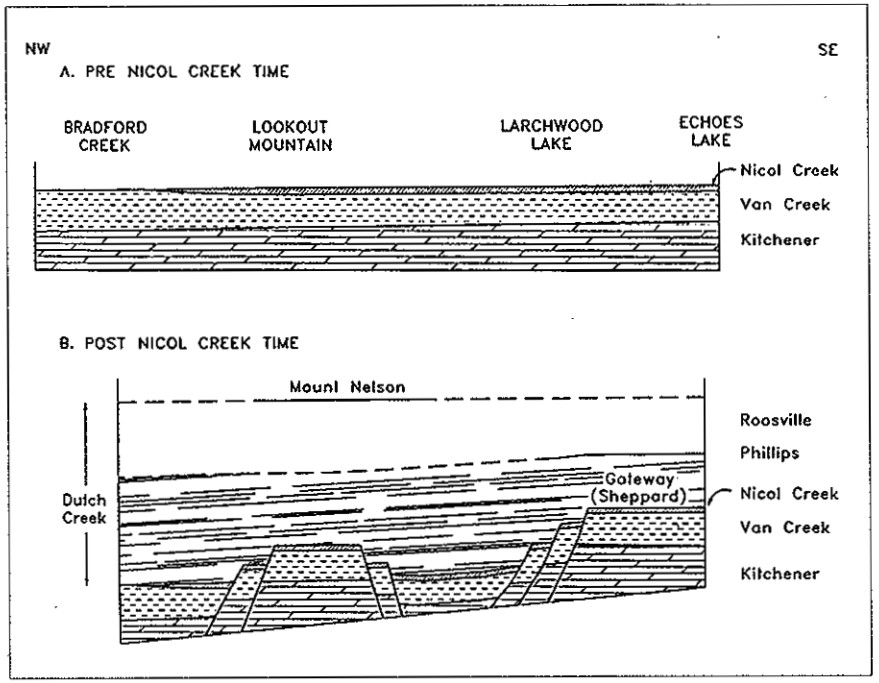


Figure 52. Postulated model for deposition of upper Purcell rocks, Skookumchuck area, showing effects of late Purcell tectonism (after Carter and Höy, 1987a); *see* Figure 57 for locations.

Lack of turbidites in upper Aldridge siltstone and argillite, and similar thicknesses and facies across the basin margin, indicate movement on marginal growth faults had effectively ceased by then (Figure 51c).

Growth faults along the basin margin record extensional tectonics that initiated development of the Purcell basin. Similar growth faults are recognized near the southern margin of the Belt basin in Montana (McMannis, 1963; Winston, 1986a). Intrusion of the basaltic Moyie sills during Aldridge sedimentation is also evidence of extensional tectonics. The Lumberton sill, which is intrusive into the lower part of the middle Aldridge Formation, has yielded a 1445 Ma uranium-lead zircon date (Höy, 1989; Chapter 3, this report). This date provides a minimum age for the earliest recognized tectonism in the Purcell basin in Canada.

Upper Purcell Tectonics

An isopach map of the Nicol Creek Formation, which records the first indication of renewed tectonic activity, shows that the most voluminous extrusion of basaltic lava occurred along the eastern margin of the Purcell basin (Figure 22). However, the most pronounced disturbance is recorded in the overlying Sheppard and Gateway formations.

In the Skookumchuck area, dramatic changes in thickness and facies of both the Sheppard and Gateway formations are caused by extensional growth faults and resultant differential subsidence. The Sheppard and Gateway formations thicken from approximately 800 metres at Echoes Lake to 2500 metres in the Larchwood Lake area, 10 kilometres farther north (Chapter 2, this report; Carter and Höy, 1987a). This increase in thickness is accompanied by prominent facies changes, indicative of deeper water conditions to the north. The overlying Phillips Formation, a regional marker succession comprising red, hematitic argillite and siltstone, also dies out here, supplanted to the north by green "reduced" facies. Faults mapped just south of Skookumchuck, that cut and offset Nicol Creek lavas and perhaps part of the Sheppard Formation but not the Gateway Formation, are growth faults that developed near the margins of the block-faulted terrain in upper Purcell time (Figure 52). A tectonic high within the down-dropped block is indicated by a thinned statigraphic succession north of Larchwood Lake at Lookout Mountain.

Tectonic instability in Sheppard time is also evident in the Moyie Lake area (Höy and Diakow, 1982). A prominent fluviatile conglomerate, up to 9 metres thick, has locally cut through and removed up to several hundred metres of the Nicol Creek Formation (Chapter 2). Elsewhere, the Sheppard Formation is more typical, with a stromatolitic and oolitic dolomite, quartzite and siltstone succession up to 75 metres thick. It is possible that these locally varied facies result from block faulting similar to that in the Skookumchuck area, with erosion and deposition of coarse conglomerates on and at margins of tectonic highs and shallow-water, turbulent carbonate facies deposited in adjacent small basins.

The absolute age of this late Purcell-age block faulting is not known. Attempts to date the Nicol Creek lavas, the first expression of renewed extensional tectonics, have been unsuccessful. It was hoped that dating of fine to medium-grained pink intrusive boulders, prominent in some sections of the Sheppard conglomerate, would provide a minimum age for this event. The uranium-lead data of zircons in these boulders is shown in Table 11 and plotted on the concordia diagram in Figure 53. An isochron for the coarse non-magnetic abraded zircon fractions gives a maximum age of 1554 Ma; isochrons for all three fractions give a minimum age limit of 1514 Ma. Hence, these boulders are from a magmatic event that happened prior to deposition of all Purcell Supergroup rocks and therefore cannot constrain the

TABLE 11
U-Pb ZIRCON ANALYSES OF COBBLES AND BOULDERS IN THE SHEPPARD FORMATION CONGLOMERATE, CHIPKA CREEK, SOUTHEAST OF CRANBROOK

	Fractions		Concentrations		Pb Isotopic Abundance[3]				Atomic Ratios (Date, Ma)[5]		
No.	mesh size magnetic[1] properties	weight (mg)	U (ppm)	Pb[2] (ppm)		$^{206}Pb=100$		$^{206}Pb/^{204}Pb$[4]	$^{206}Pb/^{238}U$	$^{207}Pb/^{235}U$	$^{207}Pb/^{206}Pb$
A	+200 abraded NM2A/1°	2.2	127.3	34.07	9.3256	23.2683	0.0142	6629	0.23392±0.00095 (1355.0±5.0)	2.94387±0.01313 (1393.3±3.4)	$0.09128\pm1\times10^{-4}$ (1452.4±2.1)
B	−325 abraded M2A/1°	0.8	362.3	89.13	9.1221	26.7401	0.0090	9605	0.20997±0.00090 (1228.7±4.8)	2.60459±0.01212 (1301.9±3.4)	$0.08997\pm1\times10^{-4}$ (1424.8±2.1)
C	+125 abraded NM2A/1°	0.9	119.9	34.22	9.5844	22.7541	0.0167	5313	0.24974±0.00086 (1437.1±4.4)	3.22030±0.01272 (1462.1±3.1)	$0.09352\pm1\times10^{-4}$ (1498.4±2.5)

Notes: [1] M,NM=magnetic, non-magnetic on Franz isodynamic separator at indicated amperage and angle of side tilt
[2] radiogenic plus common Pb
[3] radiogenic plus common Pb, corrected for 0.15% per AMU fractionation and for 120 pg Pb blank with composition 208:207:206:204=37.30:15.50:17.75:1
[4] corrected for 0.15% per AMU fractionation
[5] decay constants: $\lambda^{238}=0.155125\times10^{-9}$/yr, $\lambda^{235}=0.98485\times10^{-9}$/yr, $^{238}U/^{235}U=137.88$; ratios are corrected for U+Pb fractionation (0.15%/AMU), blank Pb, and for common Pb using the Stacey and Kramer (1975) growth curve and an initial Pb age of 100 Ma. Analyses done by J. Gabites, The University of British Columbia
[6] *sample location – Moyie Lake 1:50 000 map sheet; 49°20'N, 115°30'51"E)*

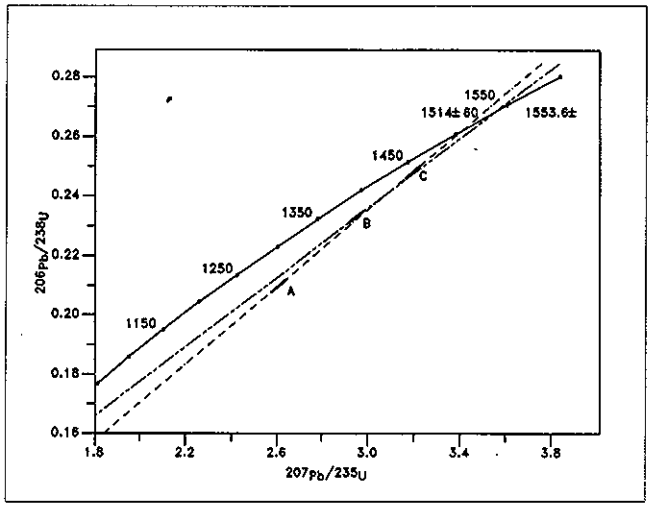


Figure 53. Uranium-lead concordia diagram for analyses of zircons from an intrusive boulder in the basal Sheppard Formation southeast of Cranbrook. *See* Table 11 for explanatory notes.

age of Sheppard Formation and the late Purcell block faulting.

East Kootenay and Goat River Orogenies

Evidence for deformation and metamorphism of Purcell Supergroup rocks prior to deposition of overlying lower Paleozoic strata is widespread. This metamorphism and deformation have been attributed to one tectonic event, the "East Kootenay orogeny" (White, 1959). However, McMechan and Price (1982a) suggested that it occurred during two tectonic events. The earlier, for which the term East Kootenay orogeny was retained, was restricted to the period 1300 to 1350 Ma, and supposedly terminated Belt-Purcell sedimentation. The later event occurred during deposition of the Windermere Group, 800 to 900 Ma, and was referred to as the "Goat River orogeny".

The **East Kootenay orogeny** (Figure 50) was a compressive tectonic event that produced folds and associated cleavage and was associated with granitic intrusions (White, *op. cit.;* Leech, 1962a). Evidence for the orogeny, as summarized by McMechan and Price, includes:

- Northeast of Cranbrook and south of Kimberley, between the St. Mary and Moyie faults, Purcell Supergroup rocks are considerably more metamorphosed than unconformably overlying Lower Cambrian rocks (Leech, *op. cit.*).
- In the Mathew Creek area west of Kimberley, the Hellroaring Creek stock, dated at 1305±52 Ma by rubidium-strontium whole-rock analyses (Ryan and Blenkinsop, 1971), cuts structures in Purcell Supergroup rocks (Leech, *op. cit.*).
- In the Coeur d'Alene district of Idaho, uraninite mineralization dated at 1190±30 Ma (Eckelman and Kulp, 1957) crosscuts folded and cleaved lower Belt strata (Hobbs *et al.,* 1965).
- In the Moyie Lake area, biotite that forms a penetrative cleavage in Aldridge Formation argillites has been dated at 995±34 Ma (Leech, 1967).

East of the Rocky Mountain Trench in the Sand Creek block, a spaced cleavage defined by aligned phyllosilicate minerals is folded about the axis of the Late Cretaceous - Paleocene Lizard segment of the Hosmer nappe (McMechan and Price, 1982a). This cleavage may also have formed during the East Kootenay orogeny as it locally has a similar orientation to the early biotite cleavage near Moyie Lake (McMechan and Price, *op. cit.*). A coarse muscovite fraction from the Aldridge Formation in the Sand Creek block has a date of 1318±41 Ma (Leech, 1962a) and may record this metamorphic event (McMechan and Price, *op. cit.*) or may reflect older detrital muscovite that has been partially replaced by younger metamorphism (Leech, *op. cit.*).

However, potassium-argon dates of micas and hornblendes in Purcell Supergroup rocks vary widely and do not provide reliable ages for either intrusive or metamorphic events (see Chapter 3). The 1305 Ma uranium-lead date for the post-tectonic (East Kootenay) Hellroaring Creek stock does establish a minimum age for the East Kootenay orogeny and is compatible with the suggested 1300 to 1350 Ma time span. Augen gneiss near Red River, Idaho, interpreted to be about 1370 Ma, is contemporaneous or later than intense deformation, also indicating a tectonic event at this time (Evans and Fischer, 1986).

The inference that the East Kootenay orogeny terminates Belt-Purcell sedimentation is controversial as other estimates for the upper age limit of these rocks are generally younger. Magnetostratigraphic studies by Elston and Bressler (1980) suggest deposition of Belt-Purcell rocks occurred between 1500 and 1250 Ma, and geochronological studies by Obradovich and Peterman (1968) and Obradovich *et al.* (1984) indicate deposition occurred until approximately 900 Ma.

The **Goat River orogeny** (Figure 50) was an extensional tectonic event, characterized by large-scale block faulting during and perhaps immediately prior to deposition of the Late Proterozoic Windermere Supergroup. The Windermere Supergroup (Young *et al.,* 1973) comprises a basal conglomerate, the Toby Formation, overlain by generally immature clastic rocks and carbonates of the Horsethief Creek Group. Continental basalts of the Huckleberry Formation in Washington, which are correlative with the Irene Formation at or near the base of the Windermere Supergroup, have yielded a samarium-neodymium mineral/whole-rock age of 762±44 Ma (Devlin *et al.,* 1988) and hence restrict the age of deposition of these rocks and the inferred Goat River orogeny.

The best documented evidence for large-scale block faulting in Windermere time is recorded in the Toby Formation. The formation comprises predominantly conglomerates and breccias, interpreted to have been deposited in fan sequences adjacent to active fault scarps in large structural basins (Bennett, 1985; Bennett and McClay, in preparation). Locally, up to 2000 metres of underlying Belt-Purcell rocks have been eroded from uplifted blocks, providing a sediment source for the Toby Formation in adjacent basins.

Bennett and McClay (*op. cit.*) suggest that the widespread distribution of fanglomerates along the entire length of the Cordillera, and their association with mafic volcanics, is evidence of initiation of continental rifting. Final rifting and generation of oceanic crust may not have occurred until latest Proterozoic to Early Cambrian time (Devlin *et al.*, 1985; 1988).

Additional evidence for Windermere-age block faulting occurs along the southwestern extension of the St. Mary fault (Lis and Price, 1976). Northwest of the fault, an increasingly thicker succession of Windermere rocks is exposed beneath a Lower Cambrian unconformity as the fault is approached. At the southwest end of Kootenay Lake, the Windermere Supergroup is more than 9 kilometres thick and includes a number of polymict conglomeratic units that contain locally derived clasts of the underlying Purcell Supergroup. This implies that the Windermere Supergroup was deposited in a deep, block-faulted structural basin north of an uplifted source terrain (Lis and Price, *op. cit.*). South of the St. Mary fault, the Cambrian unconformity cuts lower Purcell Creston and Kitchener formations, implying a sub-Cambrian tectonic high. The Late Proterozoic displacement along the antecedant of the St. Mary fault involved relative subsidence and northwest tilting of the northern block.

LATE PROTEROZOIC AND EARLY PALEOZOIC TECTONICS

The record of periodic extensional tectonics in southeastern British Columbia, evident in the stratigraphic record during Purcell and Windermere times, continued in Late Proterozoic and early Paleozoic times. The earlier tectonic events may record incipient rifting, with development of block-faulted, intracratonic structural basins, whereas by early Paleozoic time continental separation had occurred as platformal and miogeoclinal sediments were deposited on a western continental margin (Monger *et al.*, 1982). Renewed extension is evident in Cambrian time: the extensive Lower Cambrian platform foundered and the platformal edge, exposed near Kootenay Lake in Early Cambrian time, occurs in the Rocky Mountains in the Middle Cambrian (Höy, 1982b).

Within the Fernie map area, north of the Moyie and Dibble Creek faults, a sub-Cambrian unconformity truncates Windermere and Purcell rocks at a slight angle, indicative of tilting prior to deposition of Cambrian rocks. East of the Rocky Mountain Trench in the Lussier River area, the Toby Formation is exposed, whereas in the Boulder Creek and Cranbrook areas, the unconformity cuts upper Purcell rocks.

Detailed mapping of the eastern extensions of the Mount Stephens and Nicol Creek faults in the Lussier River area indicates pre to syn-Cambrian movements (Welbon and Price, 1992). These faults truncate and offset basal Jubilee Formation rocks, but die out up-section within the Jubilee. An unnamed transverse fault is truncated by the sub-Cambrian unconformity and overlain by the Cranbrook Formation indicating faulting prior to deposition of the Cranbrook Formation (Welbon and Price, *op. cit.*).

A tectonic high, referred to as "Montania" (Deiss, 1941), occurred south of the Moyie - Dibble Creek faults in pre-Devonian time. North of these faults, a thick sequence of Cambrian through Silurian beds is exposed; to the south, Devonian rocks unconformably overlie upper Purcell rocks (Figures 2 and 3). Norris and Price (1966) suggested Montania was uplifted along steep faults or flexures. A reconstruction of sub-Devonian units across the northwestern flank of Montania indicates that it was marked by a northwest-dipping monoclinal flexure, referred to as the "Dibble Creek monocline" (Benvenuto and Price, 1979). North of the flexure, now the approximate locus of the Dibble Creek and Moyie faults, was a basin filled with lower Paleozoic rocks. Truncation of the flexure and stratigraphic relief of 2 to 5 kilometres on the unconformity east of the trench in "folded" Cambrian through Ordovician rocks indicates the extent of uplift of Montania in early Paleozoic time (McMechan and Price, 1982b).

MESOZOIC-CENOZOIC TECTONICS

The dominant structures in the Purcell Mountains and Western Ranges of the Rocky Mountains developed during a period spanning almost 100 Ma, from Late Jurassic to Paleocene time, as Purcell and Windermere rocks and overlying Paleozoic and Mesozoic miogeoclinal rocks were horizontally compressed, tectonically thickened and displaced eastward (Bally *et al.*, 1966; Price and Mountjoy, 1970; Price, 1981). A complex pattern of thrust faults, normal faults and broad to relatively tight folds developed during this time. Easterly verging thrust faults typically followed bedding glide zones, then cut up-section along ramps producing anticlinal structures. Earlier, more western thrust sheets were carried piggyback by younger, generally deeper thrusts producing imbricate zones and stacked sheets. Back thrusts, with displacement directions opposite to that of the main thrust, and normal faults cutting thrust faults and associated faults, developed during and after thrusting.

Structural patterns in the Fernie map area are controlled, in part, by prominent facies and thickness changes in Purcell and younger rocks and by earlier structures. The Boulder Creek fault, one of the more prominent structural features that crosses the generally north-trending structural grain, coincides approximately with a pronounced change in Purcell rocks (Chapter 2, this report; Höy, 1982a). The St. Mary fault, the southwestern extension of the Boulder Creek fault, follows the southern edge of a late Proterozoic (Windermere) structural basin. To the south, the northeast-trending Moyie - Dibble Creek fault system coincides with the northwestern flank of Montania, a lower Paleozoic tectonic high.

These prominent northeast-trending faults segment the Hosmer thrust sheet into a number of fault-bounded blocks, the Hall Lake, St. Mary and Moyie blocks on the west side of the trench and the Wildhorse, Tanglefoot and Boulder blocks and Hosmer nappe on the east side (Benvenuto and Price, 1979). Differential movements occurred on these blocks as the Hosmer nappe first moved northeastward approximately 8 kilometres and then southeastward 12 kilometres (Benvenuto and Price, *op. cit.*). These blocks define the boundaries of the structural domains illustrated in Figure 54).

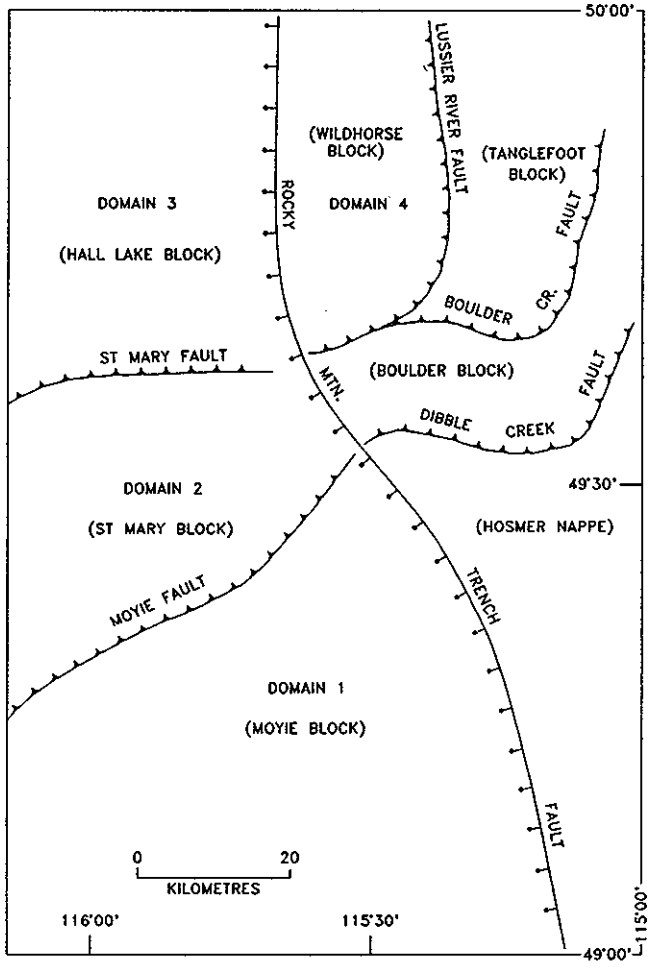


Figure 54. Structural domains in the Fernie west-half map area.

Structures along the eastern edge of the Purcell anticlinorium are dominated by large, north to northeast-plunging anticlinal folds (Dahlstrom, 1970). Although generally open, minor folds on their limbs are locally tight and overturned, particularly adjacent to faults. The folds, associated cleavages and northeast-trending reverse faults formed during compression and eastward displacement of the Hosmer thrust sheet in Late Cretaceous to Paleocene time (Benvenuto and Price, 1979).

Northeast-trending normal faults are prominent in Domain 1 in the core of the Moyie anticline southeast of Moyie (Figure 2). They are cut by northwest to north-trending, west-dipping normal faults such as the Rocky Mountain Trench fault and the Gold Creek fault.

Many of these structures have been described in considerable detail elsewhere (*see*, for example, McMechan, 1981; Benvenuto, 1978) and hence their geometry and history will be only summarized here.

Moyie and Dibble Creek Faults

The Moyie fault and its extension east of the Rocky Mountain Trench, the Dibble Creek fault, is a right-lateral reverse fault with an estimated displacement of 12 kilometres (Benvenuto and Price, 1979).

The Moyie fault follows, in its footwall, a Devonian gypsum horizon that unconformably overlies the northwest limb of the Moyie anticline (Leech, 1962b). Elsewhere, scattered outcrops of conglomerate, similar to those that underlie the gypsum unit southwest of Bull River, are exposed in the footwall of the Moyie fault (Leech, *op. cit.*). These exposures extend southwest to the Lamb Creek area near the western edge of the map sheet (Figure 2, in pocket).

The Moyie fault is a zone of intense shearing, up to several hundred metres wide, that dips northwest at 60° to 70°. Splays within the fault zone in the Lamb Creek area isolate small lenses of lower Aldridge siltstone and Moyie sill in pale green limy siltstone of the Kitchener Formation (Figure 55a). Northeast along the fault, near Monroe Lake, rusty weathering lower Aldridge siltstones in the hangingwall are folded into a series of moderately tight and locally overturned, northeast-plunging folds (Figure 55b). A similar structural level is repeated farther northeast in the Peavine Creek area (Figure 55c). These tight folds and an associated penetrative cleavage formed as the hangingwall was thrust southeastward over the northern edge of the Montania high. Farther away from the Moyie fault, folds are considerably more open.

The Dibble Creek fault on the east side of the trench truncates structures and Purcell Supergroup units in its hangingwall, but closely follows the basal Devonian succession in its footwall (Figure 2, Leech, 1960; Benvenuto and Price, 1979; McMechan and Price, 1982b). It merges eastward, through a series of splays, with the Gypsum fault and the underlying Hosmer thrust (Benvenuto and Price, *op. cit.*).

St. Mary and Boulder Creek Faults

The St. Mary fault has been traced or projected eastward from the Grassy Mountain and St. Mary sheets (Reesor, 1981; Leech, 1957), crossing the St. Mary River south of Kimberley and extending onto the flats along the western edge of the Rocky Mountain Trench (Figure 2, in pocket). East of the trench, it is referred to as the Boulder Creek fault; farther east, it merges with the Galbraith thrust.

The St. Mary fault is a right-lateral reverse fault with an estimated displacement of 11 kilometres (Benvenuto and Price, 1979). The age of this displacement is constrained by a date of 94 Ma on the Reade Lake stock which truncates the fault south of Kimberley (Chapter 4, this report; Höy and van der Heyden, 1988). However, minor shearing in the stock along the projection of the fault indicates some post-intrusive movement. North-trending, lower Aldridge through Creston Formation rocks and a number of west-dipping thrust faults are sharply truncated by the St. Mary fault. In the footwall, younger Purcell rocks and Lower Cambrian siltstones and argillites of the Eager Formation are truncated.

East of the trench, displacement of the St. Mary fault is accommodated by reverse displacement on the western part of the Boulder Creek fault, where Aldridge rocks in the hangingwall are juxtaposed against Kitchener rocks on Lone Hill, and by reverse displacements on northern splays of the Boulder Creek fault, including the Wild Horse fault. Other north-trending faults in the immediate area with apparent net normal movement were originally thrust or

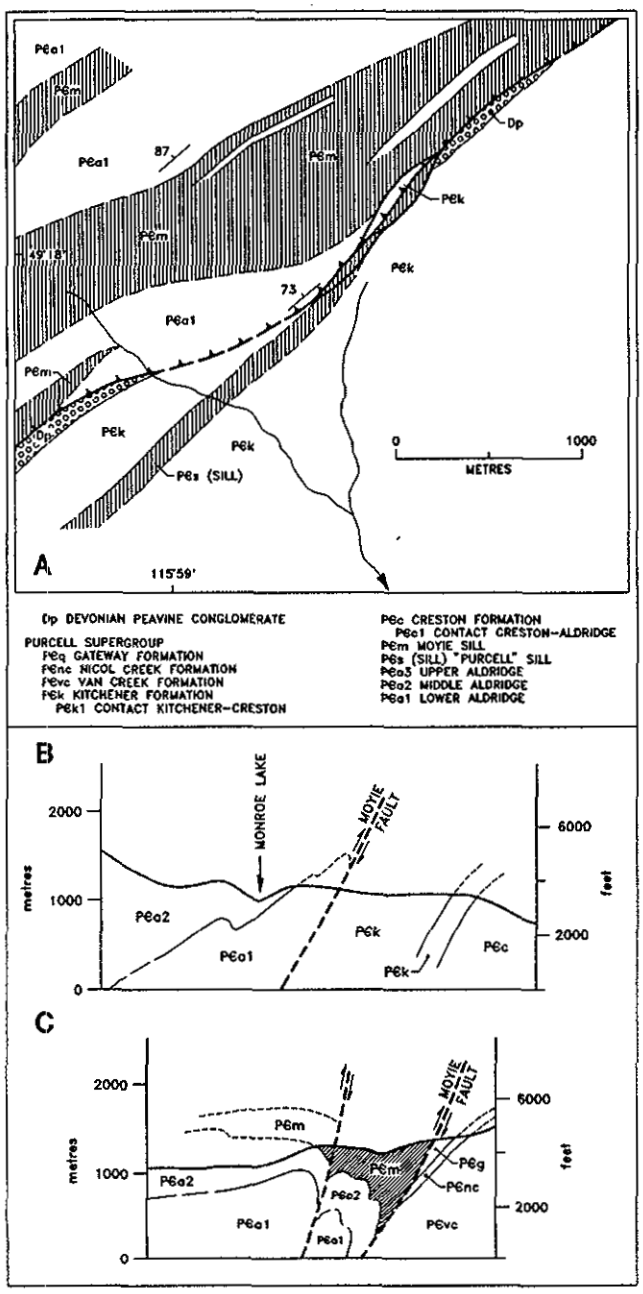


Figure 55. (a) Geology along the Moyie fault, Lamb Creek area; (b) vertical structure sections across the Moyie fault in the Monroe Lake area and (c), the Peavine Creek area; (after Höy and Diakow, 1982); *see* Figure 2, in pocket, for location of map and sections.

reverse faults on which displacement changed. Apparent net normal movement on the Boulder Creek fault, between reverse movements at its western end and on the Galbraith fault at its eastern end, has also been attributed to local normal faulting that followed initial reverse movement (Benvenuto and Price, *op. cit.*).

Domain 1 — The Moyie Block

The structure of the Moyie block is dominated by the Moyie anticline. Aldridge, Creston and Kitchener rocks are exposed in the core of the anticline and upper Purcell rocks, including the Nicol Creek lavas, are exposed in its eastern limb (Figure 3). Part of its western limb is truncated by the Moyie fault.

The Moyie anticline is an open, upright fold with a steep west-dipping axial surface and a shallow northerly plunge. A widely spaced fracture cleavage in more competent beds, or a slaty cleavage, defines the axial surface. Locally, adjacent to Moyie sills, aligned fine-grained biotite parallels axial surfaces. This biotite apparently formed as a contact alteration mineral during sill emplacement and may have been transposed during folding. Biotite in argillite in the Moyie anticline, dated by potassium-argon at 995±35 Ma (Leech, 1967; McMechan and Price, 1982a) may have a similar origin rather than be the result of a Middle Proterozoic deformation and metamorphic event.

Farther south, the Moyie anticline plunges to the south forming a culmination in the hinge line near the Canada - United States border. A number of north-plunging synclines and anticlines, disrupted by numerous north-trending normal faults, occur to the east in the gently east-dipping east limb of the Moyie anticline.

Northwest-trending, west-dipping normal faults repeat the Nicol Creek lavas near the hinge of the Moyie anticline south of Cranbrook. The cumulative displacement on these faults is approximately 1500 metres. They are parallel to the Gold Creek fault but are earlier as they are truncated by the Moyie fault which is displaced by the Gold Creek fault.

Domain 2 — The St. Mary Block

Structures within the St. Mary block, between the Moyie and St. Mary faults, are considerably more complex. The Creston-Kitchener contact defines a broad north-plunging anticlinal fold, dismembered by an array of dominantly northeast and north-trending faults (Figures 2 and 3).

West of Cranbrook, tight overturned, variably plunging folds with well-developed axial planar foliation are outlined by units in the upper Aldridge and lower Creston formations (Figure 56). The sense of vergence on these folds, on both the hangingwall and footwall of the Palmer Bar fault, suggests development during initial reverse movements on the fault. Subsequent west-side-down displacement on the Palmer Bar fault has resulted in net normal movement.

The Cranbrook fault is an east-trending normal fault that is younger than folding associated with initial reverse displacement on the Palmer Bar fault, but is later than normal movement. The Cranbrook fault juxtaposes Creston Formation in its hangingwall against middle Aldridge turbidites. It is cut by the Kiakho stock which has been dated by potassium-argon at 122 Ma (Chapter 4). Due to possible excess argon in the hornblendes, this date is interpreted to be a maximum age of emplacement of the stock.

Domain 3

Domain 3 is bounded by the St. Mary fault on the south and the Rocky Mountain Trench fault on the east (Figure 54). It includes Aldridge formation rocks around the Sullivan mine at Kimberley and a large north-plunging anticlinal fold in upper Purcell rocks west of Skookumchuck.

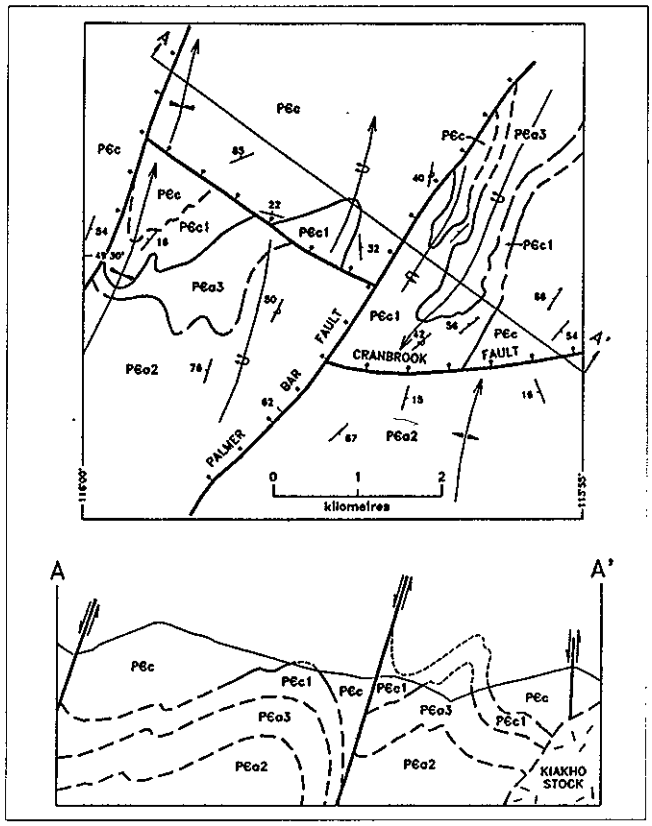
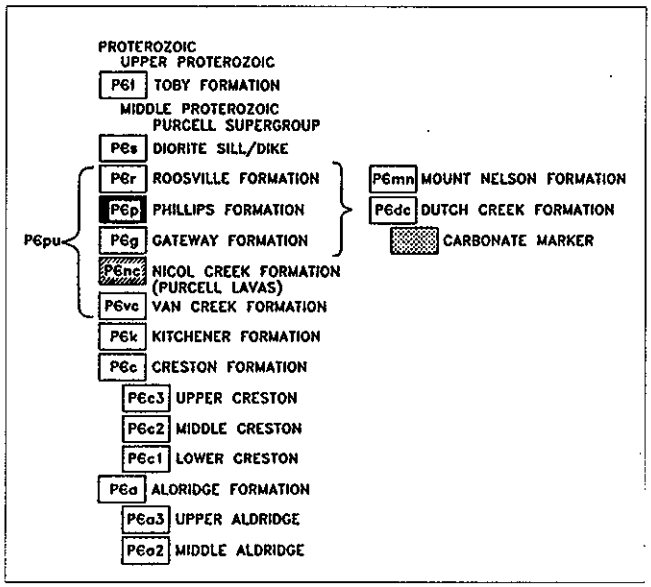


Figure 56. Geology in the vicinity of the Palmer Bar and Cranbrook faults (after Höy and Diakow, 1982).



Legend for Figures 56, 57, 58 and 59.

The structure of the Skookumchuck area is well illustrated on the geological map in Figure 57 and by cross-sections A-A', B-B' and E-E' in Figure 58. In the northern part of the Skookumchuck area, the regional structure is dominated by two north-plunging anticlines separated by a syncline with a prominent fault, the "McIntosh fault", in its hinge (Carter and Höy, 1987a, 1987b). Folds in the area are essentially concentric or parallel and a refraction or fan cleavage is observable in outcrops as well as on cross-sections. Poles to cleavage, plotted on equal-area nets (Figure 59) are distributed within an elongate cluster illustrating the refraction cleavage pattern. Cleavage-bedding intersection lineations are somewhat scattered, but generally trend north.

Northeast-trending normal faults produce an apparent sinistral fault movement on the map (Figure 57). These faults dip steeply to the northwest, with the west side downthrown. A minor strike-slip component may also produce the sinistral displacement. The largest of these faults, the Mather Creek fault, places lower Kitchener rocks against middle Creston strata. Farther northwest, the large normal displacement on the fault is accommodated by a set of small north-trending normal faults. Their position and sense of movement are known with confidence due to measured displacements of the Nicol Creek lavas. Locally the faults are marked by a zone of intense, coarse hematitic alteration, most commonly displayed in the light green siltstone-argillite units of the Gateway Formation. Several regional thrust faults and listric reverse or thrust faults merge to the south of the Canal Flats map sheet (Leech, 1958a; Foo, 1979; Carter and Höy, 1987b). One of these, the Buhl Creek fault, transects the northwest corner of the Skookumchuck map area and places lower to middle Dutch Creek strata above upper Dutch Creek stratigraphy. Farther west, the "Copper Lake" thrust carries an overturned panel of Creston to lower Dutch Creek strata over Dutch Creek rocks.

The west-trending Kimberley fault separates the Skookumchuck area from the Kimberley area (Figure 2). The Kimberley fault dips steeply north and along its eastern end juxtaposes Creston and Kitchener rocks in the northern hangingwall against Aldridge rocks to the south. Here, an apparent left-lateral displacement of up to 10 kilometres is indicated by offset of the upper Aldridge. However, farther west, deep drilling in the northern block has intersected what is interpreted to be the western edge of the faulted northern extension of the Sullivan lead-zinc-silver deposit at a depth of 2500 metres, and indicates a net left-lateral displacement of only 3.5 kilometres (Hagen *et al.*, 1989). It is possible that some of the left-lateral and normal displacement of the eastern segment was accomodated by normal movements on north-trending, west-dipping faults that intersect or merge with the Kimberley fault between the two segments (Figure 60) and by the pre-thrust normal movement along the Mathew Creek fault (Hagen *et al., op. cit.*).

The north-trending faults referred to as "Sullivan-type" dip steeply to the west in the Kimberley area and generally have west-side-down offsets of only a few tens of metres (Figure 61) (Hamilton *et al.*, 1983a; McClay, 1983). Those east of the deposit are drawn schematically; they may in fact involve cumulative movements on a number of smaller northeast-trending faults as shown on Figure 2-4 of Hamilton *et al.*, 1983b; Hamilton, 1984). Sullivan-type faults appear to cut the east-trending, north-dipping faults, including the Kimberley fault.

These two prominent fault sets cut gently plunging, broad open folds (Figure 61) with steep, generally west-dipping axial planar cleavage. The cleavage is widely spaced (approximately 5 cm) in competent quartz wacke beds, is

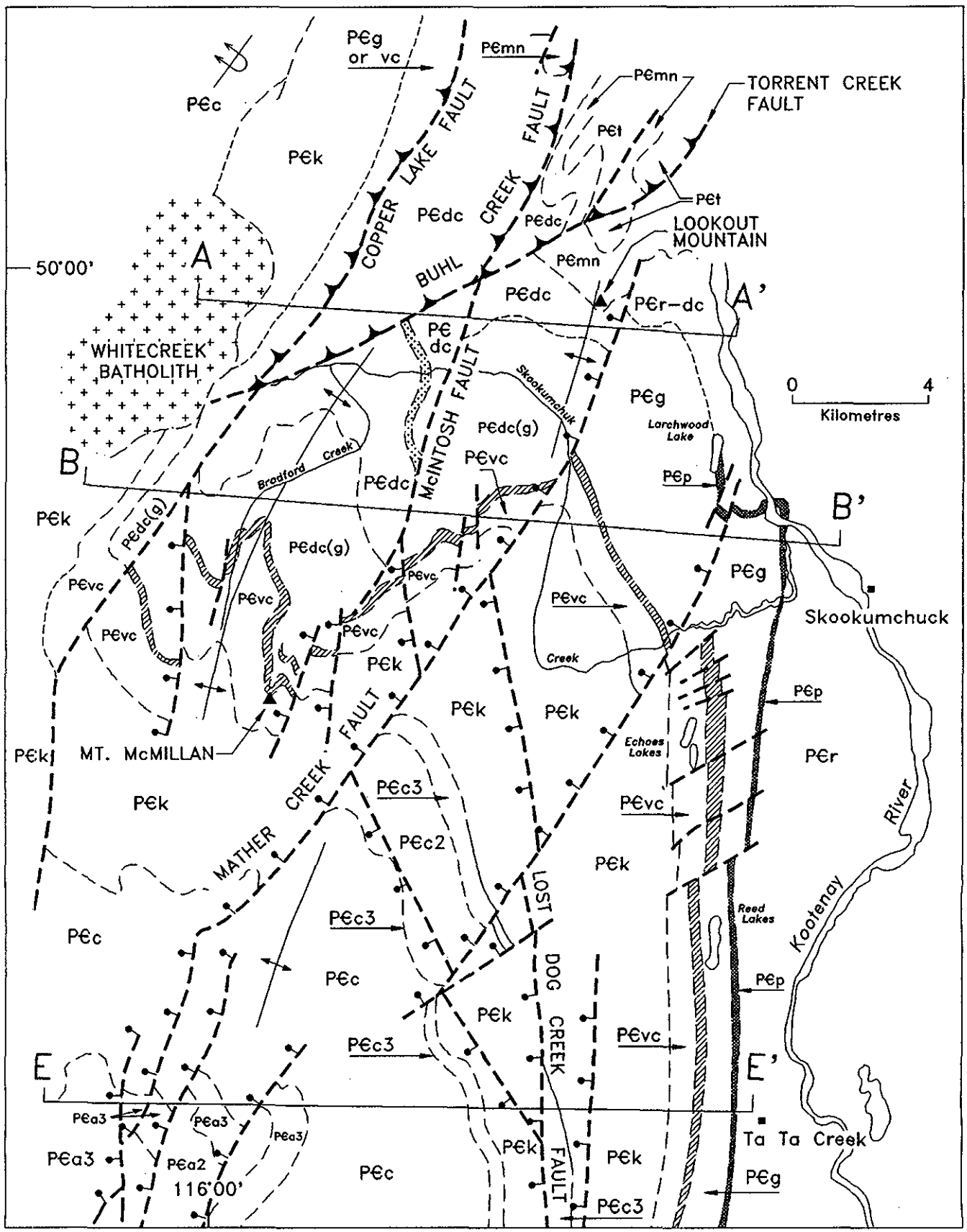


Figure 57. Geology of the Skookumchuck area (after Carter and Höy, 1987b; Leech, 1958b; Reesor, 1958; Foo, 1979; and P.W. Ransom, personal communication, 1986; 1992).

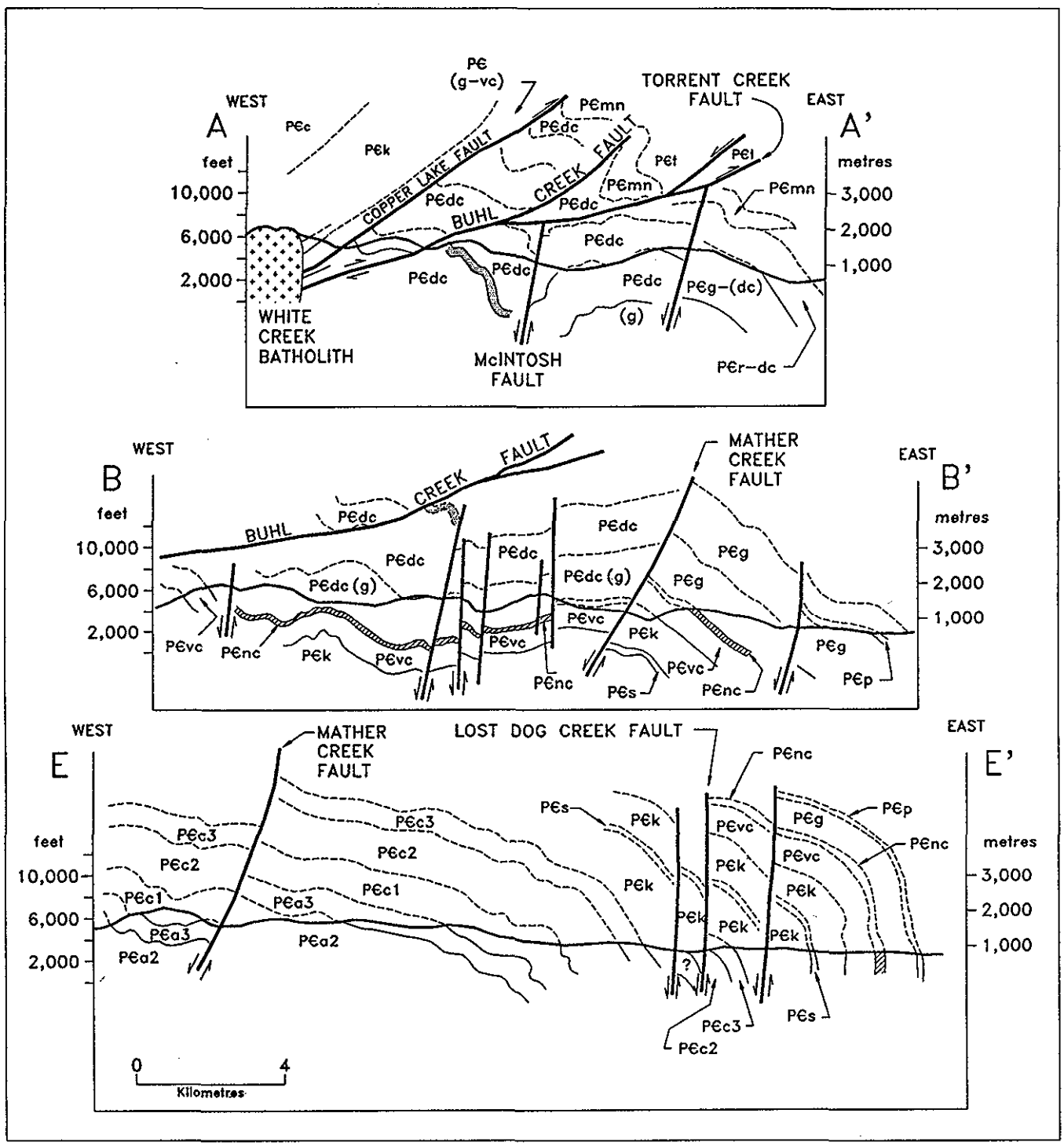


Figure 58. Vertical structural sections through the Skookumchuck map area (for locations and references, *see* Figure 57).

more closely spaced in siltites, and locally comprises a penetrative foliation in phyllite (near the southwest corner of the map in Figure 60). Southwest of the Sullivan deposit, on North Star Hill (Domain 3a, Figure 62), folds are locally tight with fold hinges that plunge variably to the north or south. In general, however, bedding is relatively flat lying to east dipping, cleavage dips steeply west, and bedding-cleavage intersections plunge at low angles to the north or south, parallel to fold hinges. In the Sullivan mine area (Domain 3b, Figure 62), regional bedding is also relatively flat lying to east dipping, cleavage dips variably to the west, and cleavage-bedding intersections and fold axes, although scattered, generally trend north-northeasterly or south-southwesterly; plunges are up to a few tens of degrees. These folds and associated cleavage are correlative with Phase 2 structures described by McClay (1983) in the Sullivan deposit. The greater scatter of structural elements in the deposit is undoubtably due to the lower competency of

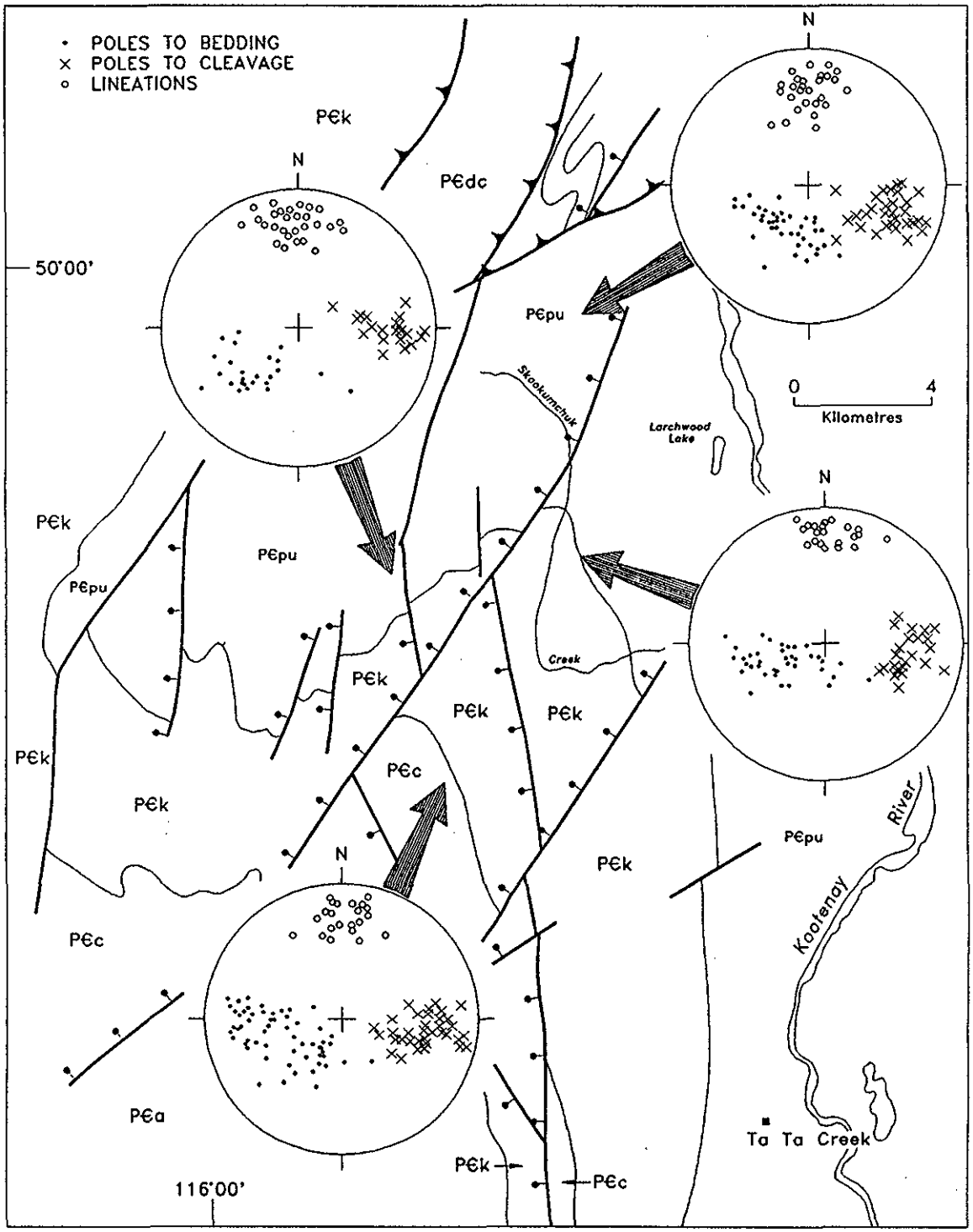


Figure 59. Equal-area projections of structural data, Skookumchuck area (from Carter and Höy, 1987a).

the thinly laminated sulphides (compare Figure 17 of McClay with Domain 3b of Figure 62). East of the Sullivan deposit and in the Concentrator Hill area (Domain 3c) bedding trends north and dips 20° to 30° east. Cleavage dips steeply west-northwest; lineations and bedding-cleavage intersections plunge at low angles to the north-northeast.

A late crenulation cleavage locally overprints the pronounced regional folds and associated cleavage.

Domain 4

Domain 4, the Wildhorse block of Benvenuto and Price (1979), is bounded by the Lussier River thrust and Wildhorse reverse faults on the east and south and the Rocky Mountain Trench fault on the west. It comprises Purcell Supergroup rocks and an unconformably overlying succession of Cambrian through Silurian carbonate and clastic miogeoclinal rocks.

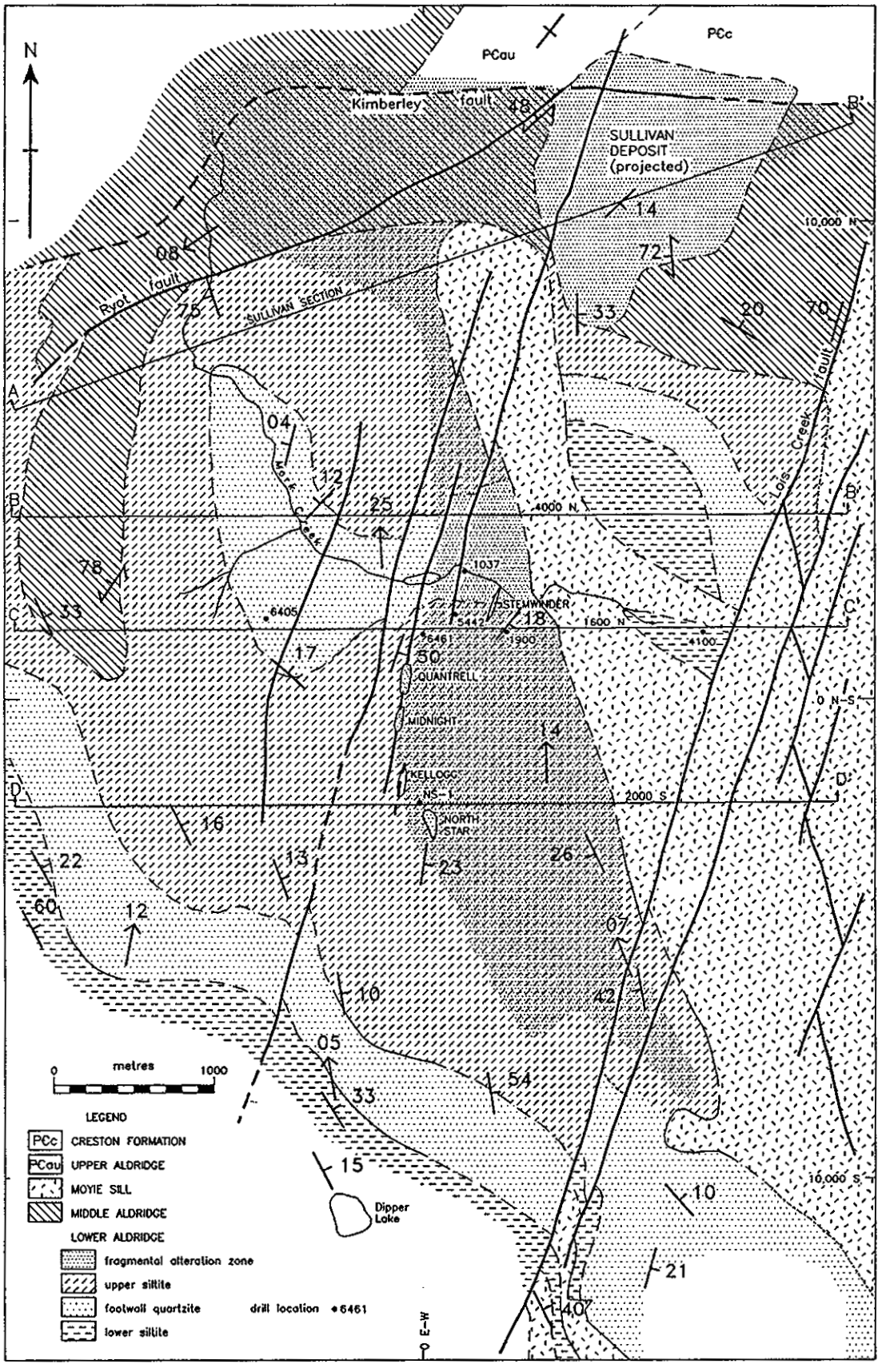


Figure 60. Geology in the vicinity of the Sullivan deposit, Kimberley (after Höy, 1984a and internal Cominco Ltd. reports).

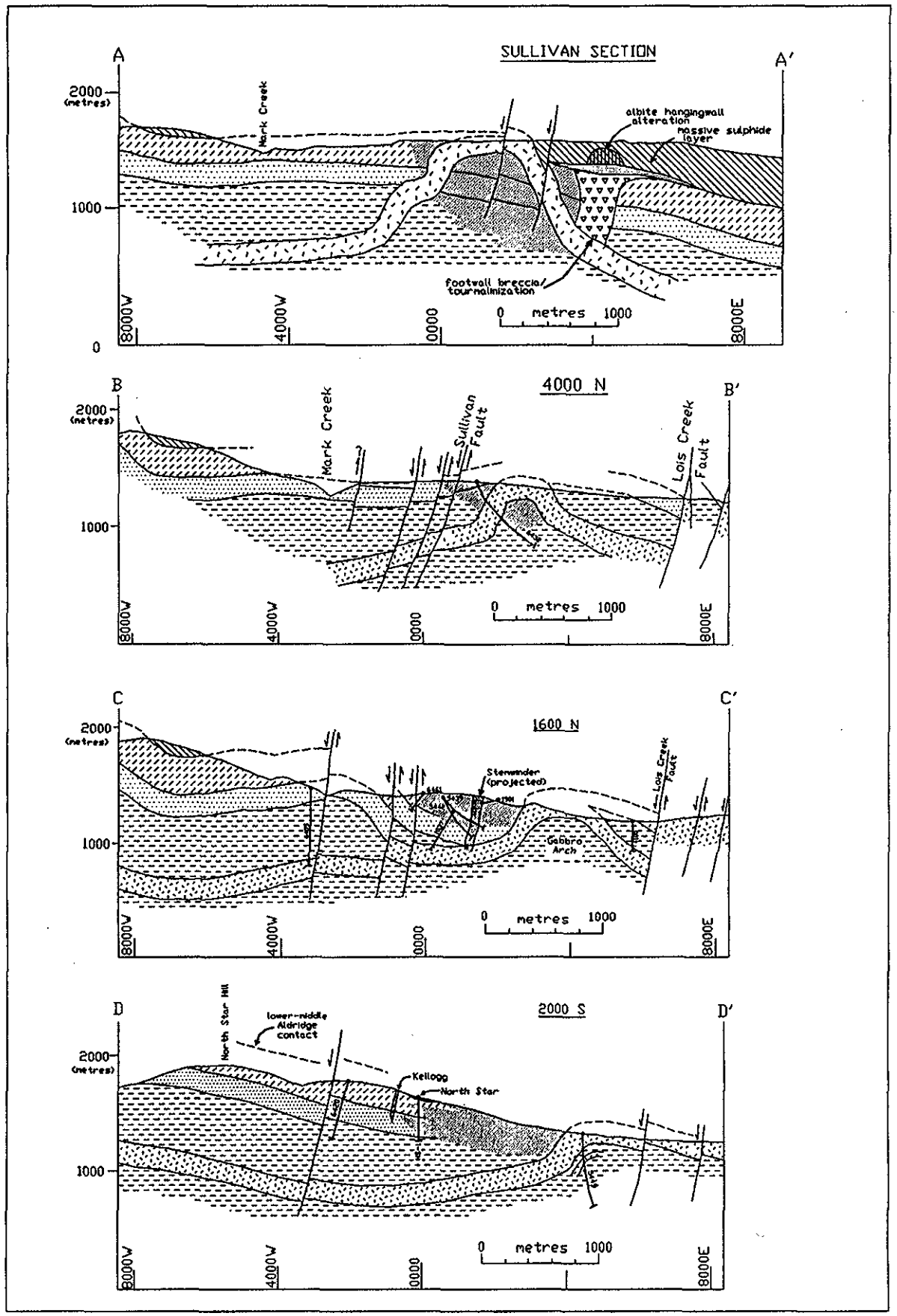


Figure 61. Vertical structural sections, Sullivan deposit area (*see* Figure 60 for locations).

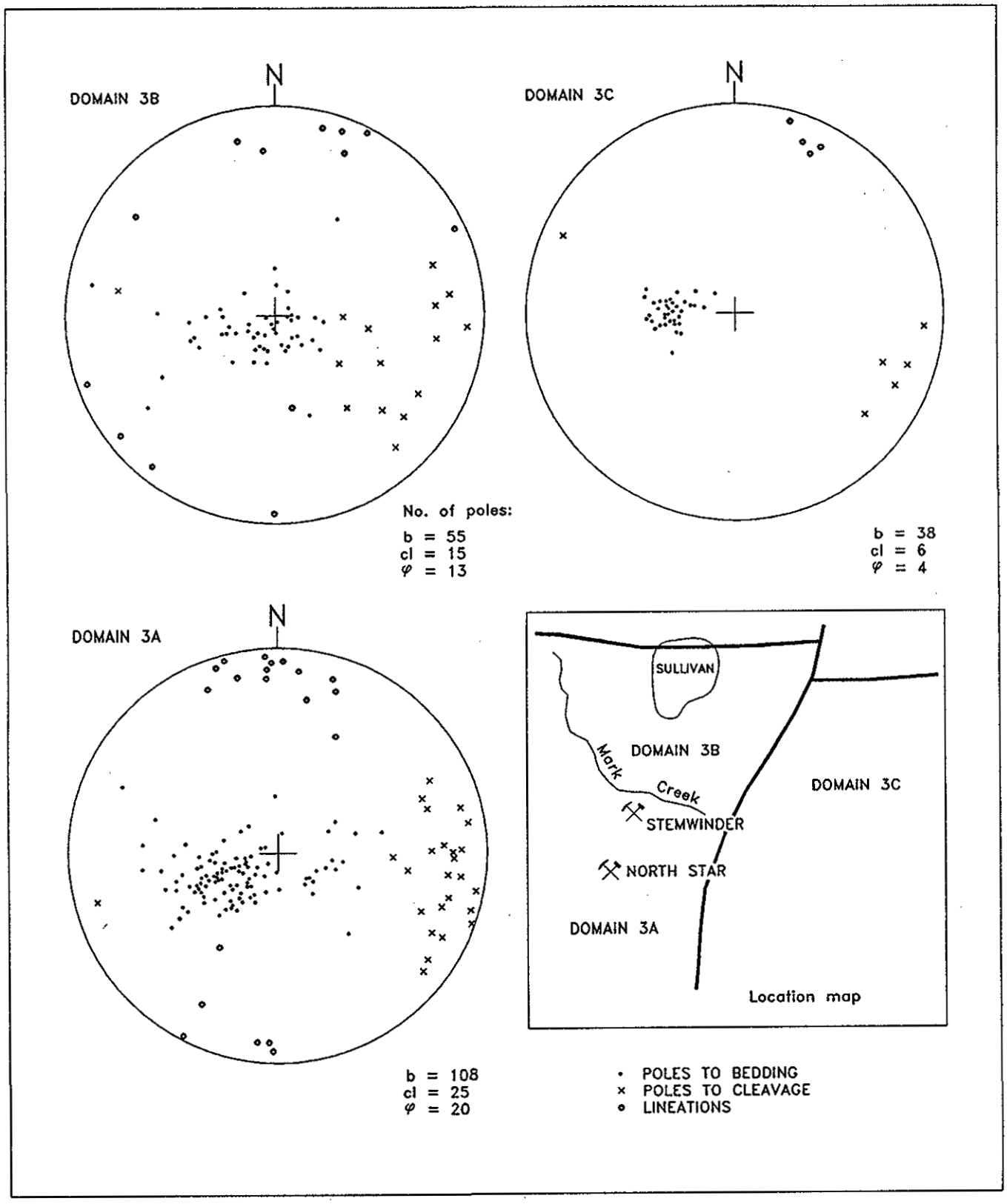


Figure 62. Equal-area projections of structural data, Sullivan deposit area.

A large, open recumbent anticline dominates the structure of Domain 4. It plunges to the north and its axial plane dips to the west. Bedding in its upper limb, in the western part of Domain 4, dips to the east whereas bedding in its lower limb is overturned and dips to the west. In fine-grained units, a fracture or slaty cleavage and a mineral lineation are developed parallel to the axial plane and fold axis (Plates 49 and 50).

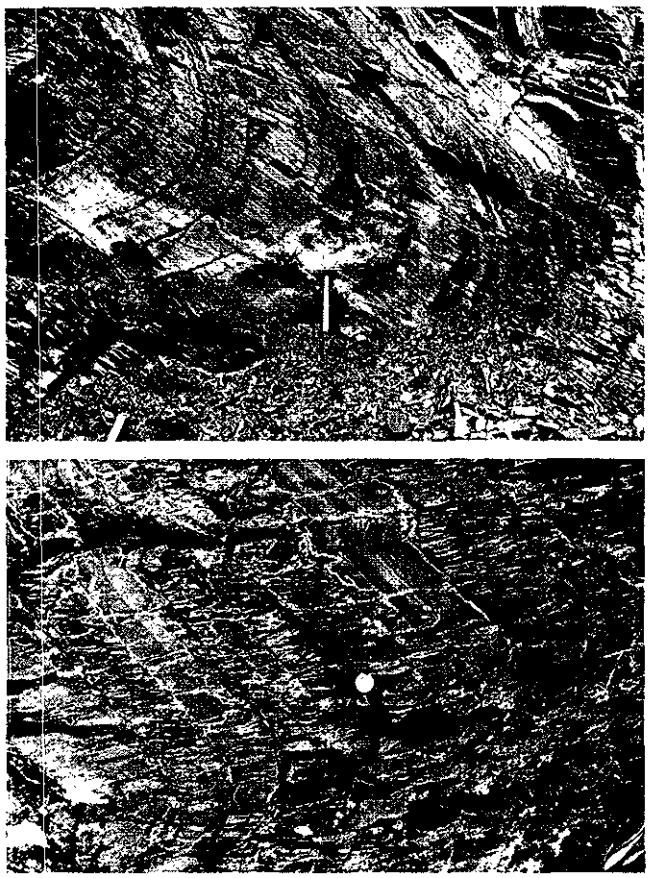


Plate 49. (a) Axial planar cleavage in concentrically folded middle Aldridge siltstone, Estella road, northern Hughes Range; (b) Detail of fold closure.

Plate 50. Concentric folds in thin-bedded Creston Formation quartzite and siltstone; (field of view, approximately 2 metres).

A number of north-trending faults in the eastern part of the area, including the West and East Tackle Creek faults, repeat the upper part of the Aldridge, the Creston and the Kitchener formations (Figure 2; Höy, 1979). These are west-dipping, high-angle listric faults with either reverse or normal movements. All may originally have been thrust faults that developed in the overturned eastern limb of the anticline, along which subsequent normal movements resulted in local net normal displacements. Other north-trending, essentially layer-parallel faults result in apparent thinning of units or loss of stratigraphy. Between the Nicol Creek and Lewis Creek faults, the middle division of the Aldridge Formation, Unit A2, is juxtaposed against the Creston Formation and the upper Aldridge is missing entirely. These faults are difficult to recognize in the field, yet their recognition and interpretation are vital in measuring sections or determining lateral facies variations. Southeast of Mount Stevens, a northwest-dipping, low-angle normal fault is offset by the east-trending Mount Stevens fault (Figure 63; Plate 51). South of the Nicol Creek fault, it forms a klippe of Creston and Kitchener rocks (Figure 63). Farther north in the Premier Lake area, a similar northwest-dipping fault has a net normal displacement of about 1.5 kilometres. It is possible that these faults were also originally thrusts on which later normal displacement has occurred.

East-trending, crosscutting faults, such as the Lewis Creek, Nicol Creek and Mount Stevens faults, are recognized more easily in the field than the north-trending, essentially layer-parallel faults. Bedding attitudes are commonly disrupted within several tens of metres of these structures and the north-south continuity of units is broken. The latest movements on these faults are usually dip-slip.

Domain 5 — Mount Fisher Area.

The structure of Domain 5, south and east of the Boulder Creek fault and the Rocky Mountain Trench fault, has been described in detail by McMechan (1979), McMechan and Price (1982b) and Benvenuto and Price (1979). Within Domain 5, the generally north-trending structural grain in Domain 4 to the north and in the Galton Range to the south swings northwesterly. This change in trend is accompanied by numerous northeast-trending structures, including faults such as the Bull Canyon and Dibble Creek faults and some broad open folds. As described earlier, these transverse trends reflect Proterozoic and early Paleozoic structures and accompanying facies and thickness changes of sedimentary successions.

LATE TERTIARY NORMAL FAULTS

North-trending, west-dipping normal faults cut and offset structures related to the thrust and fold belt. The most prominent are within or along the edges of the Rocky Mountain Trench, including the Rocky Mountain Trench fault and the Gold Creek fault (Figure 2). Farther south, many similar north-trending faults with west-side-down displacements are inferred to be west-dipping normal faults (Leech, 1960).

The largest of these faults, the Rocky Mountain Trench fault, is a listric normal fault with dip-slip separation of at least 5 to 10 kilometres. As many structures and units can be correlated across the trench, strike separation must be minimal (Leech, 1966; Benvenuto and Price, 1979). The fault occurs along the eastern margin of the trench, forming a half-graben filled with up to 1500 metres of Miocene and

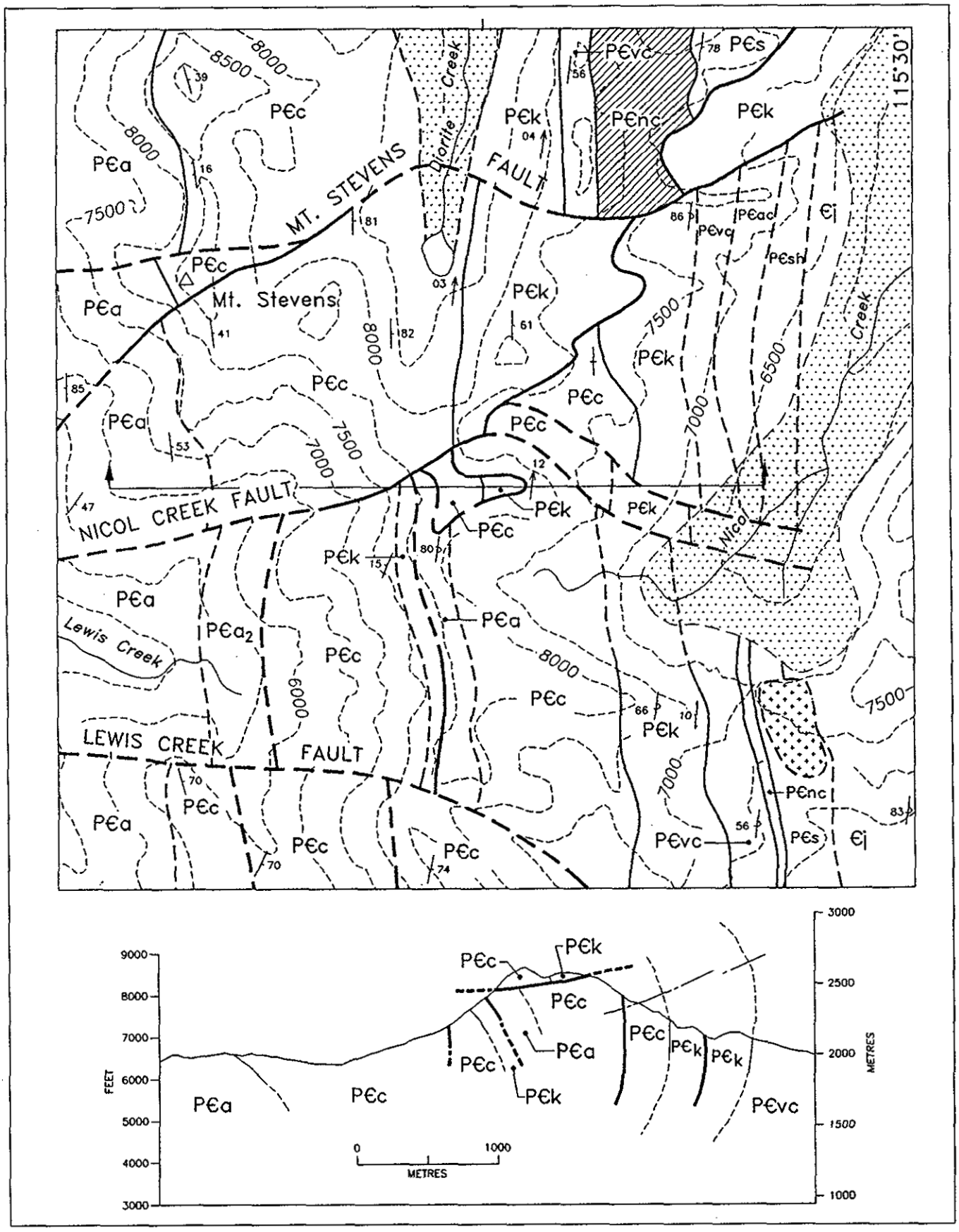
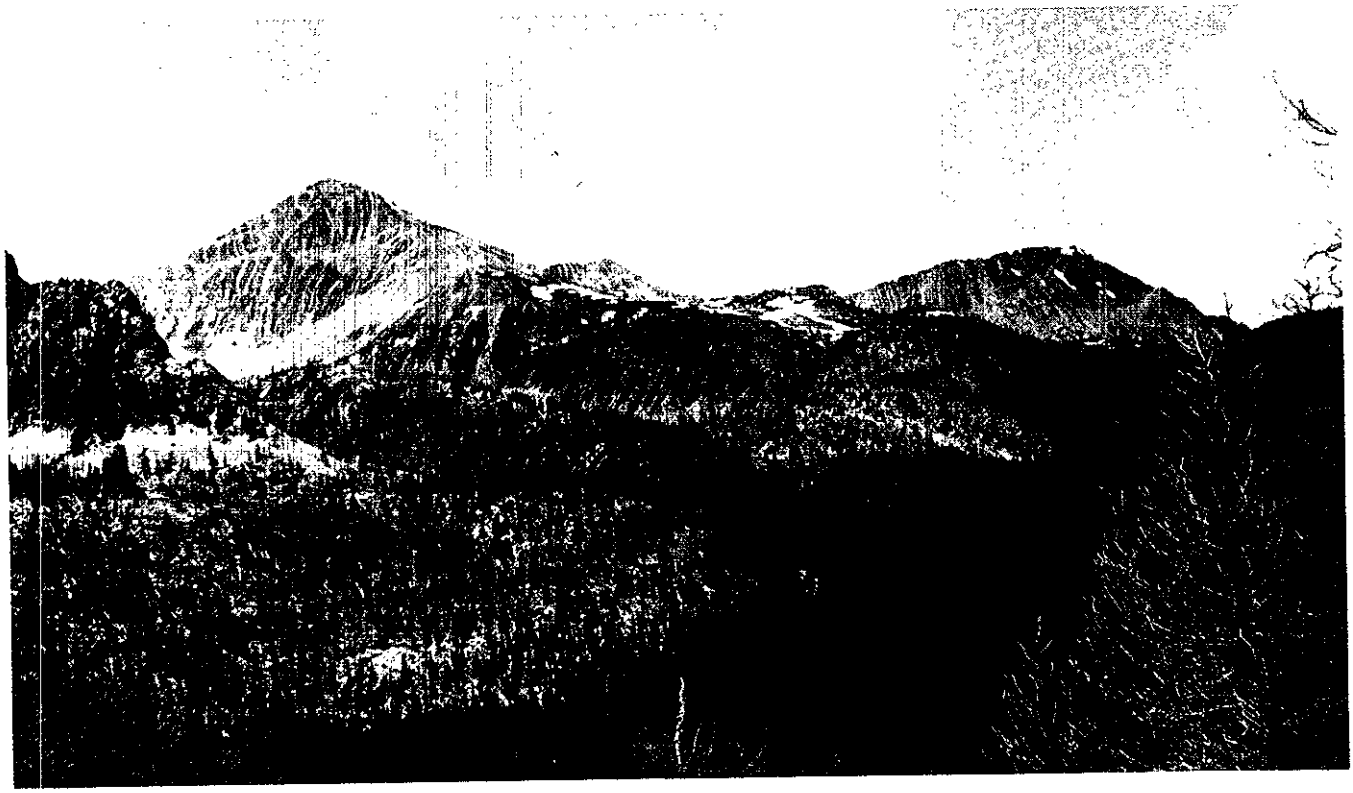


Figure 63. Geology of the Mount Stephens area, northern Hughes Range (after Höy, 1979 and Welbon and Price, 1992).



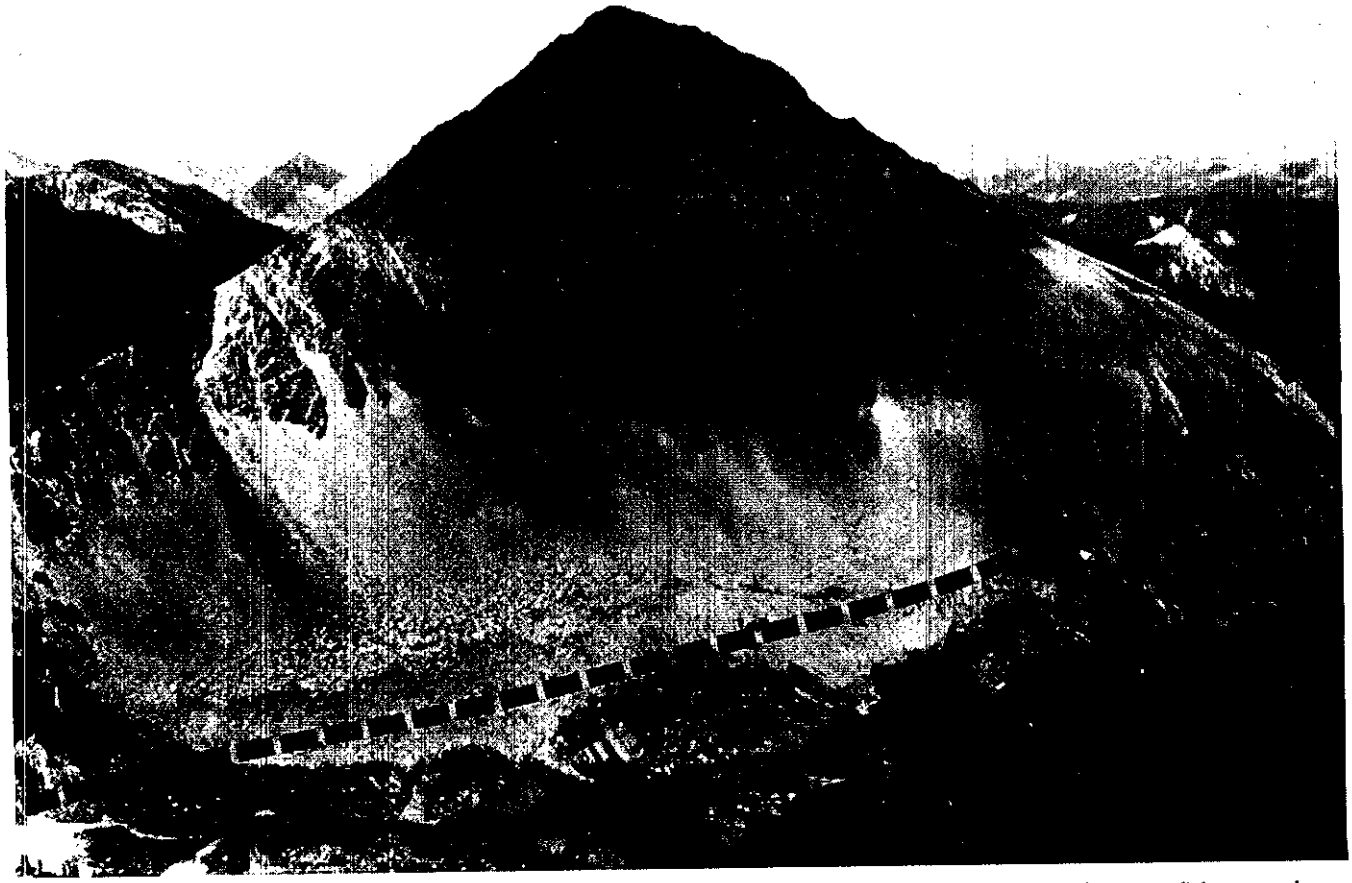


Plate 51. Steeply dipping Kitchener Formation (skyline) in thrust panel overlying Creston Formation (foreground) between the Mt. Stephens and Nicol Creek faults, northern Hughes Range (*see* Figure 63); note latest movement on fault (shown on lower plate) has resulted in net normal displacement.

older Tertiary sediments (Leech, *op. cit.;* Clague, 1974). The age of displacement of the fault is thus restricted to post-Paleocene thrusting and pre to syn-Miocene sediment fill. Comparison with a similar structure in the Flathead valley, filled with late Eocene and Oligocene sediments, suggests normal faulting in the trench began in Eocene time (Price, 1962). Eocene extensional tectonics in southern British Columbia are well documented to the west, resulting in tectonic uplift and denudation of "core complexes" along the eastern margin of the Shuswap Metamorphic Complex (Parrish *et al.,* 1988).

SUMMARY — TECTONIC EVOLUTION

The Rocky Mountain Trench, a north-trending valley that extends from Montana to the Yukon Territory, divides the Fernie map area and separates two physiographic elements, the Purcell Mountains on the west from the Western Main Ranges of the Rocky Mountains on the east.

The Purcell Mountains are underlain by the Purcell anticlinorium, a large, north-plunging structure cored by Purcell Supergroup rocks and flanked by Windermere and younger rocks. It formed as the thick succession of Purcell Supergroup rocks were thrust eastward onto the western cratonic edge of North America in late Mesozoic and early Cenozoic time (Price, 1981). The structurally highest and most western of the thrust sheets, the Hosmer sheet, includes rocks along the southwestern edge of the Purcell anticlinorium and in the Rocky Mountains east of the trench. The Hosmer sheet was segmented into discrete blocks, bounded by right-lateral reverse faults, as it was displaced eastward (Benvenuto and Price, 1979). Two prominent northeast-trending faults, the St. Mary and Moyie faults and their extensions east of the trench, the Boulder Creek and the Dibble Creek faults, continued their long and varied history as reverse tear faults during this eastward displacement. These faults coincide spatially with pronounced changes in Middle Proterozoic, Late Proterozoic and early Paleozoic successions. As well, large, upright, north-plunging folds developed during this compression and eastward displacement. Adjacent to the faults, folds are locally tight, overturned and have well-developed axial planar foliations. The age of the compressive deformation is resticted by a 94 Ma uranium-lead date on the Reade Lake stock which cuts and appears to seal the St. Mary fault.

Later normal movements occurred on many thrust faults, commonly resulting in net normal displacements. The Palmer Bar fault west of Cranbrook; low-angle, northwest-dipping normal faults in the northern Hughes Range; and a segment of the Boulder Creek fault with normal displacement, were originally thrusts along which displacements changed. As well, a complex array of high-angle normal faults developed between the St. Mary and Moyie faults and south of the Moyie fault. McMechan and Price (1982b) attribute some of this extension to gravitational spreading after displacement of the Hosmer thrust sheet across ramps and the lower Paleozoic monocline along the footwall of the Moyie - Dibble Creek fault.

West and southwest-dipping normal faults, including the Rocky Mountain Trench fault, the Gold Creek fault and many parallel northwest-trending faults within and adjacent to the Rocky Mountain Trench, cut and offset the fold and thrust structures. These faults record a period of extension in Early Tertiary time.

CHAPTER 6: MINERAL DEPOSITS AND OCCURRENCES

INTRODUCTION

The Fernie west-half map area is within an important lead-zinc metallogenic province in southeastern British Columbia (Table 12; Figure 64). Within the province are massive stratiform deposits of Middle Proterozoic age, such as the Sullivan orebody, the Shuswap massive sulphide deposits of probable Late Proterozoic to early Paleozoic age (Fyles, 1970; Höy, 1987) and massive lead-zinc deposits in Lower Cambrian marbles in the Kootenay Arc (Fyles and Hewlett, 1959; Fyles, 1964, 1966; Höy, 1980, 1982b). Middle Cambrian lead-zinc deposits, including the Monarch and Kicking Horse, occur in platformal carbonates in the Rocky Mountains.

The distribution of massive sulphide deposits in southeastern British Columbia is closely tied to tectonic events. Stratabound Middle Proterozoic deposits in the Purcell Supergroup are concentrated near the contact between lower and middle Aldridge rocks, a contact that is marked by a change in character of turbidite deposits from "distal" to more "proximal" and probably results from an increase in tectonic activity in the Purcell basin. They also appear to be concentrated near the eastern margin of the Purcell basin, a margin that was tectonically active during deposition of lower Purcell rocks. Some Shuswap deposits, in particular the Cottonbelt deposit, record deposition in shallow-marine platformal rocks on a tectonic high in Early Cambrian time (Höy, 1987; Höy and Godwin, 1988). The Kootenay Arc deposits are near the western edge of an extensive Early Cambrian carbonate platform that developed on the rifted cratonic margin of North America. The platform foundered, probably due to continued extensional tectonics, and the Middle Cambrian platform edge is now exposed in the Rocky Mountains nearly 200 kilometres to the east; the Middle Cambrian carbonate-hosted lead-zinc deposits are along this edge.

This chapter describes some of the various mineral deposits that are known in both Belt Supergroup rocks in the United States and Purcell Supergroup rocks in Canada. Stratabound clastic-hosted and silica-hosted deposits are the earliest formed; they are part of the host succession and hence their origin is tied closely to the depositional and tectonic environment of the Belt-Purcell supergroups. Stratabound carbonate-hosted deposits are "replacement" deposits; their distribution is controlled by both favourable lithologies and by later tectonic events. Vein deposits are structurally controlled and some are related to intrusive activity: copper veins more commonly with early, mafic Moyie intrusions and lead-zinc with more felsic Mesozoic intrusions.

Although some deposit types are not recognized in the Fernie west-half map area, they are reviewed briefly as they are a viable exploration target. They include stratabound copper-cobalt deposits and stratabound silica-hosted deposits in Montana and Idaho, carbonate-hosted lead-zinc deposits in the Toby Creek area and shear-related gold deposits in the Nelson east-half sheet.

DEPOSIT TYPES

A variety of metallic deposit types occur in Purcell Supergroup rocks in southeastern British Columbia and in

TABLE 12
PRODUCTION FROM MINERAL DEPOSITS, FERNIE WEST-HALF AND EASTERN PART OF NELSON EAST-HALF MAP SHEETS

MINFILE Number	Name	Years	Type	Au(g)	Ag(g)	Cu(kg)	Pb(kg)	Zn(kg)	Cd(kg)	Tonnes
082GNW002	Bull River	1972-74	Cu vein	126,123	6,353,628	7,256,050				450,325
082GNW006	Copper King	1924,1928	Cu vein	31	3,266	411				12
1,4082GNW008	Estella	1951-67	Au-Pb vein	2,052	6,392,849	1,198	5,181,020	9,834,293	10,243	109,518
082GNW009	Kootenay King	1952-53	stratiform	715	882,299		710,866	881,383	985	13,260
082GNW012	Park	1916-1923	Pb vein		22,674		10,631			131
082GNW019	Dardennelle	1974,1975	Pb vein	1,372	5,355		4,040	65		87
082GNW022	Midas	1968	Pb vein		684		804			9
082GNW045	Emily-Tiger	1917	Cu vein		1,866		168			1
082GSW013	Burton	1916-1918	Cu vein		124	7,757				207
082GSW017	Peacock Copper	1925-26	Cu vein		1,182	5,317				22
082GSW021	Midway	1933-62	Au vein	9,082	85,534	108	2,549	1,701		1,168
082GSW023	Aurora	1900-1927	Ag vein		411,463		274,307	512,674		3,763
082GSW025	St. Eugene	1899-1929	Ag vein	78,846	182,690,658		113,034,479	14,482,913		1,475,266
082GSW027	Guindon	1919-1927	Ag vein		3,328		3,312	3,494		28
082GSW030	Society Girl	1900-1952	Pb vein		432,052		499,655	23,914		2,984
082GSW037	Pay Roll	1907	Au vein	187	715					16
082GNW003	Dibble	1895,1934	Cu vein	342	37,479	109				29
082GNW004	Victor	1921	Pb vein	31	5,350		2,416			6
082FNE052	Sullivan	1900-1989	stratiform	174,863	8,653,679,700	5,106,742	7,508,700,089	6,533,819,615		123,431,895
082FNE053	Birdie L	1937	Ag vein	31	15,054		3,452			23
082FNE053	North Star	1895-1929	stratiform		41,674,193		21,775,030	6,304		61,330
082FNE116	Stemwinder	1926	Ag-Pb vein	1,306	1,955,197		945,317	3,990,900		25,620

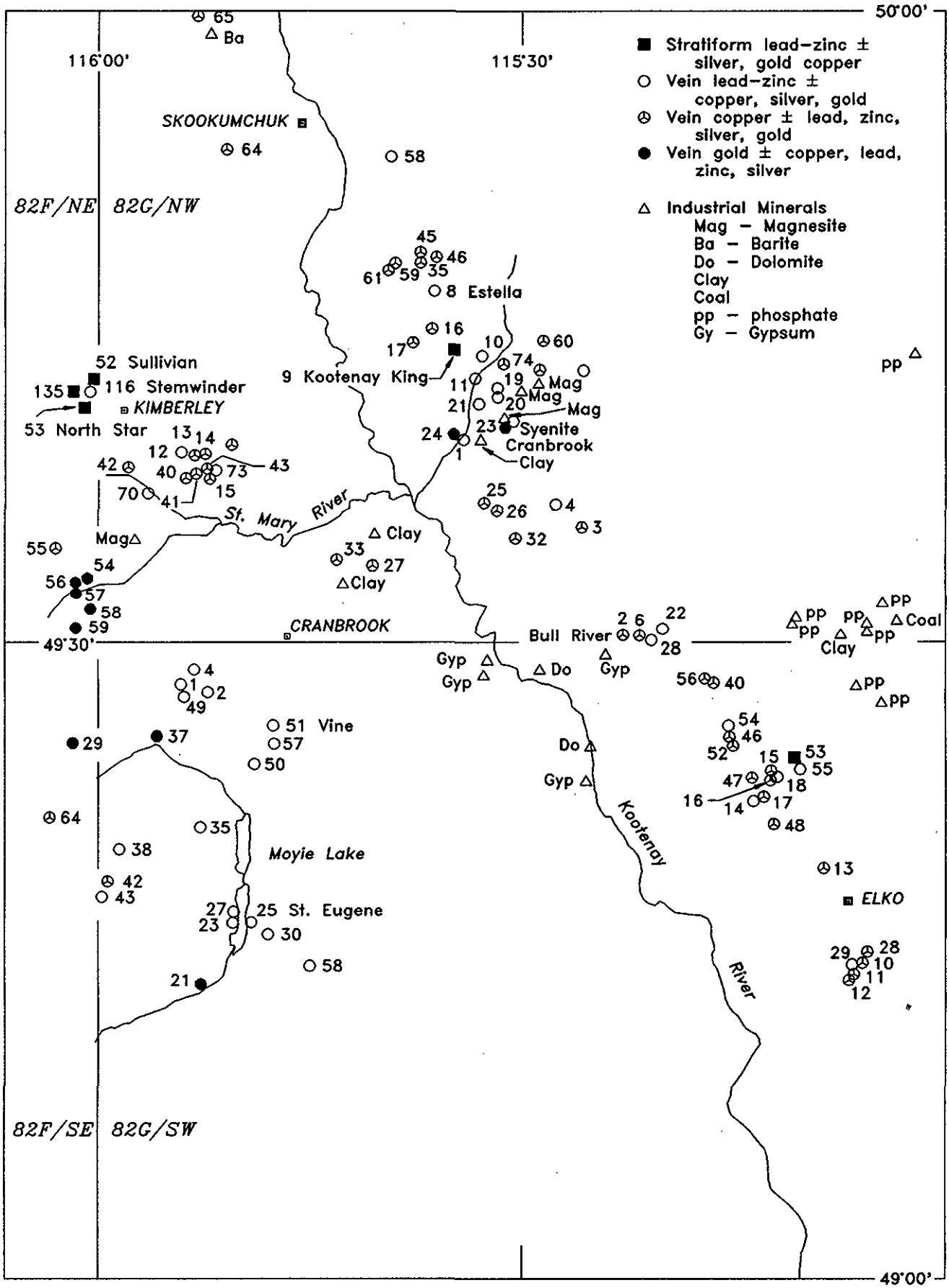


Figure 64. Location of mineral deposits in Fernie west-half map-sheet (from MINFILE data).

correlative Belt Supergroup rocks in the United States. They have been subdivided into five main types (Table 13).

- Stratabound clastic-hosted deposits are dominantly syngenetic or formed immediately after deposition of the hostrocks. They include stratiform lead-zinc deposits such as the Sullivan, copper-cobalt deposits in Montana, and sedimentary copper-silver deposits such as Spar Lake at Troy, Montana.
- Stratabound silica-hosted deposits refer to fine-grained siliceous layers that contain gold; the only known examples are in lower Belt rocks in the United States.
- The stratabound carbonate-hosted category includes replacement lead-zinc deposits in carbonate rocks of the Mount Nelson and possibly Dutch Creek formations.

The fourth type, vein deposits, are further subdivided based on vein mineralogy. Copper veins are most common in the Creston Formation or in the Aldridge Formation adjacent to Moyie sills; lead-zinc veins occur in Aldridge rocks, either in late structures or adjacent to late felsic intrusions; and gold veins occur in the Aldridge Formation and in sheared Creston Formation rocks in the Perry River area.

Shear-related gold deposits occur in silicified shear zones in Middle Aldridge turbidites west of the Fernie map sheet.

STRATABOUND CLASTIC-HOSTED DEPOSITS

Stratiform Lead-Zinc Deposits

Stratiform lead-zinc deposits occur in Middle Proterozoic rocks throughout the world. They are concordant bodies of massive or laminated lead, zinc and iron sulphides in fine to, less commonly, medium-grained sedimentary rocks. Some, such as the Sullivan deposit, have well-developed footwall zones comprising stockwork, disseminated or vein mineralization. This crosscutting mineralization is generally interpreted to be the conduit zone for mineralizing solutions for the overlying stratiform sulphides.

Many stratiform lead-zinc deposits are zoned, either vertically or laterally. The most common vertical zoning is copper-zinc-lead-(barium); lateral zoning from the central part to the distal fringes of the deposit is commonly copper-lead-zinc. For example, the Pb/Zn ratio decreases towards the periphery of the Sullivan deposit (Freeze, 1966).

Stratiform lead-zinc deposits in the Purcell Supergroup, such as the Sullivan, North Star and Kootenay King, are restricted to the deep-water facies of the lower and possibly middle Aldridge Formation (Table 14).

The Sullivan and North Star deposits are within a large zone of intensely altered and fragmental rock, approximately 6000 metres in length and 1000 to 2000 metres in width, that trends south from Sullivan (*see* Figure 60, Plate 52). The zone has been extrapolated to a depth of 1500 metres beneath the Sullivan orebody (Hamilton, 1984) and has been intersected in drill holes to depths exceeding 200 metres on North Star Hill (D.H. Olson, personal communication, 1983; Hagen, 1985; Figure 61).

The alteration zone appears to be restricted to lower Aldridge rocks; that is, rocks that stratigraphically underlie the Sullivan deposit. It is a district-scale alteration zone, distinct from the smaller footwall pipe, and may be comparable to the semiconformable alteration zones that have been recognized in volcanogenic massive sulphide deposits (Morton and Franklin, 1987). The zone is characterized by:

TABLE 13
MINERAL DEPOSIT CLASSIFICATION
PURCELL/BELT SUPERGROUP, SOUTHEASTERN BRITISH COLUMBIA AND NORTHWESTERN UNITED STATES

Deposit Type	Description	Commodities	Host	Examples
I				
Stratabound Clastic-hosted	Stratiform Pb-Zn	Pb-Zn-Ag	Lower Aldridge Middle Aldridge	Sullivan Kootenay King
	Stratabound Cu-Co	Cu-Co±Pb Zn,Ag,Ni,Ba	Newland Fm Yellowjacket	Sheep Creek, Mont. Blackbird, Idaho
	Sedimentary copper	Cu-Ag±Pb,Zn	Revett Fm Grinnell Fm, *etc.*	Spar Lake, Mont. Sage Creek area
	Iron formation	Fe	Creston Formation	Iron Range
II				
Stratabound Silica-hosted	Chert gold Orthoclase gold	Au±Pb,Zn,Ag,Ba, Au-Cu	Prichard Fm Yellowjacket Fm	York, Mont. Ulysses, Idaho
III				
Stratabound Carbonate-hosted	Replacement Pb-Zn	Pb-Zn-Ag-Ba ±Au	Mt. Nelson Fm (?)	Mineral King Paradise
IV				
Vein	Copper veins	Cu-Ag-Au±Pb,Zn Cu-Ag-Au	Aldridge-Moyie sill Creston	Bull River Dibble
	Lead-zinc veins	Pb-Zn-Ag±Au,Cu	Aldridge Aldridge-porphyry	St. Eugene Estella
	Gold veins	Au±Ag,Pb,Zn Au±Ag,Pb,Zn	Creston Aldridge	Perry Creek area Midway
V				
Shear-related	Gold	Au±Ag,Pb,Cu	Aldridge	David-Lew

TABLE 14
STRATIFORM LEAD-ZINC DEPOSITS, OCCURRENCES; PURCELL SUPERGROUP, SOUTHEASTERN B.C.

MINFILE Number	Name	Commodities	Host	Status
082GNW009	Kootenay King	Ag-Pb-Zn-Cd-Au-Cu	Unit A1d-M. Aldridge	Past Producer
082GSW051	Vine 17 (?)	Pb-Zn	L. Aldridge	Drill intersection
082GSW053	Ross 2	Pb	L. Aldridge	Showing
082FNE052	Sullivan	Pb-Zn-Ag-Au-Cu-Cd-Sn	L. Aldridge	Producer
082FNE053	North Star	Pb-Zn-Ag	L. Aldridge	Past Producer
082FNE135	Dean/All Over (?)	Pb-Zn-Ag	L. Aldridge	Prospect

Plate 52. View of North Star Hill (with ski slopes) and open pit of Sullivan deposit in foreground.

- A marked increase in the abundance of disseminated and irregularly laminated pyrrhotite and, to a lesser extent, pyrite. Surface exposures are typically strongly oxidized.
- An increase in the number of pyrite, galena and sphalerite-bearing veins, including the Stemwinder, Kellogg and Quantrell occurrences, and small veins on the Dean and All Over claims.
- An increase in the number of small massive sulphide occurrences.
- Zones of pervasively tourmalinized rock, similar to those in the footwall of the Sullivan deposit. These are commonly irregular in outline with either sharp or gradational contacts; they cross lithologic boundaries. Locally, thin tourmaline-rich laminations occur in siltstone. The tourmalinite is a dark, hard rock that breaks with a conchoidal fracture. Chemical analyses of North Star and other tourmalinites are given in Table 15 and they are illustrated in Plates 53 and 54.
- Mineralogical changes (Leitch *et al.,* 1991): the zone is characterized by destruction of detrital feldspar, with concommittant development of muscovite producing typically a muscovite-pyrite assemblage. This assemblage grades to tourmalinite with increasing tourmaline and pyrrhotite, and decreasing muscovite. Manganiferous garnet within the zone records early introduction of hydrothermal manganese.

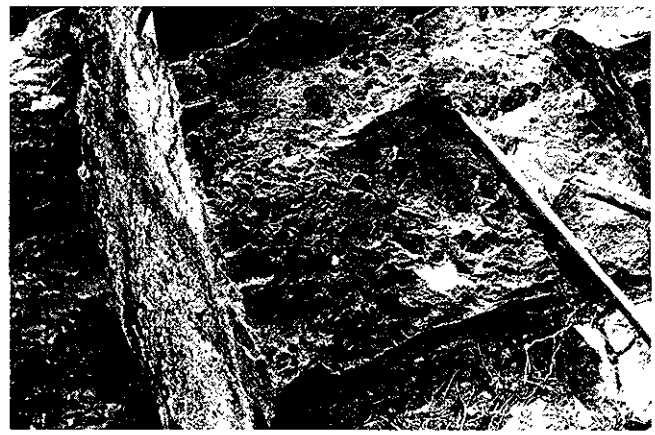


Plate 53. Tourmalinite breccia, Neg property, Negro Lake area west of Cranbrook; note clasts of angular dark tourmalinite in a silty tourmalinized matrix.

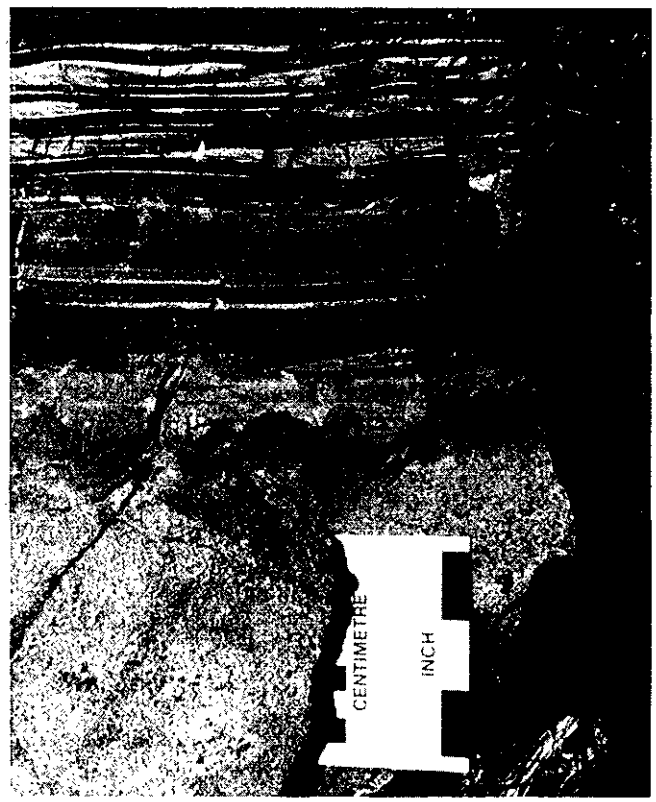


Plate 54. Interlayered tourmalinite (dark) and siltstone, middle Aldridge Formation, Mount Mahon area.

TABLE 15A
MINOR ELEMENT ANALYSES — TOURMALINITE SAMPLES

Lab No.	Field No.	Aldridge Host	Ag ppm	Cr ppm	Sb ppm	Ni ppm	Cu ppm	Pb ppm	Zn ppm	Co ppm
26399	K38-34 (F)[1]	Lower	—	—	—	—	—	—	—	—
26400	K38-36 (F)[1]	Lower	—	—	—	—	—	—	—	—
31624	SULL-1 (H)[2]	Lower	6	21	—	24	880	367	73	45
31625	SULL-2 (H)[2]	Lower	2	—	—	5	56	158	63	62
31626	NORST1 (H)[3]	Lower	—	57	—	14	240	50	70	60
31627	SULL-20 (H)[2]	Lower	—	10	—	4	79	83	83	43
31628	SULL-21 (H)[2]	Lower	—	36	15	4	16	20	188	18
31844	NORTHSTAR1 (H)[3]	Lower	—	—	—	10	9	260	960	48
31845	NORTHSTAR2 (H)[3]	Lower	—	—	—	5	21	—	330	69
28777	GOATFEL (H)[4]	Middle	—	—	—	—	2	—	5	46
31621	GOATFEL1 (H)[4]	Middle	—	—	—	4	5	140	30	87
31622	NEG.1 (H)[5]	Middle	—	30	36	20	3	12	60	60
31623	NEG.2 (H)[5]	Middle	—	44	24	21	8	10	52	45

(F)=Float
(H)=Hand

[1] float-North Star Hill
[2] footwall alteration zone, Sullivan deposit
[3] North Star deposit area
[4] Goatfel occurrence at Goatfel (82F/1)
[5] Neg occurrence at Negro Lake (82G/5)

TABLE 15B
MAJOR ELEMENT ANALYSES

Field No.	SiO_2 %	Al_2O_3 %	Fe_2O_3 %	FeO %	MgO %	CaO %	Na_2O %	K_2O %	TiO_2 %	MnO %	P_2O_5 %	SrO %	BaO %
K38-34 (F)	74.95	11.73	4.14	3.00	2.23	1.60	0.57	0.70	0.40	0.08	0.21	0.01	0.03
K38-36 (F)	75.07	11.83	3.32	2.50	1.84	0.53	0.44	1.81	0.41	0.14	0.18	0.01	0.15
SULL-1 (H)	47.32	9.60	30.16	26.44	2.35	0.42	0.59	0.01	0.31	0.03	—	—	—
SULL-2 (H)	76.36	9.65	6.14	3.57	2.69	8.03	4.37	4.48	0.14	0.32	—	—	—
NORST1 (H)	65.63	11.95	10.58	8.77	2.20	0.41	0.72	0.04	0.52	0.03	—	—	—
SULL-20 (H)	70.87	8.88	9.36	8.20	3.49	1.47	0.43	0.01	0.31	0.09	—	—	—
SULL-21 (H)	62.91	11.50	5.38	4.28	6.01	4.78	0.43	0.01	0.43	0.34	—	—	—
NORTHSTAR1 (H)	63.06	18.21	6.26	0.00	2.11	2.77	0.92	1.26	0.74	1.00	0.08	—	—
NORTHSTAR2 (H)	74.22	10.83	5.65	2.12	0.98	0.68	0.20	0.20	0.32	0.10	0.07	—	—
GOATFEL (H)	65.34	18.56	1.65	1.40	0.54	0.50	11.83	0.06	0.54	0.01	0.35	0.76	0.95
GOATFEL1 (H)	90.01	4.09	1.30	0.80	0.30	0.04	0.14	0.42	—	—	—	—	—
NEG.1 (H)	74.59	13.40	3.63	2.86	1.68	0.53	1.37	0.49	—	—	—	—	—
NEG.2 (H)	71.63	14.44	3.56	2.43	1.77	0.54	1.49	0.94	—	—	—	—	—

(F)=Float
(H)=Hand

- Irregular zones of breccia or fragmentals. The fragmentals are generally diamictites with subrounded siltite clasts up to 2 centimetres in diameter in a granular siltstone matrix. Pyrite and pyrrhotite with minor amounts of sphalerite and galena occur in the matrix. The conglomerate often grades into massive (lacking bedding) siltstone or quartzite. The conglomerates may be bedded but also occur as crosscutting zones. Similar rocks in the footwall of the Sullivan orebody, termed "fragmental", are interpreted to have formed by injection and local surface extrusion, rather than by collapse of fault scarps (Hamilton, *op. cit.*). However, a crude layering in some North Star Hill fragmentals, occassional normal grading and interlayering with bedded lower Aldridge siltstones suggests that the fragmentals may represent, in part, slump conglomerates related to marginal growth faults.
- Obliteration of bedding by intense sulphide alteration, tourmalinization, or development of "fragmental".

Some of the features of the regional footwall alteration zone extend beyond the obvious mappable limits of the zone. For example, thin laminations of tourmalinite occur 3 to 4 kilometres south of the North Star Hill (A. Hagen, personal communication, 1983). As well, anomalous numbers of sulphide laminae occur at the lower-middle Aldridge transition (the Sullivan horizon) on Concentrator Hill, 5 kilometres east of Sullivan. And finally, mineralogical changes, particularly the destruction of albite and the presence of epidote, are more widespread than the fragmental zone.

NORTH STAR (82FNE053)

The North Star deposit is located on the east slope of North Star Hill at an elevation of approximately 1560 metres. It underlies the North Star ski slope and many of the original showings in the area have been covered by this development. The deposit has high silver and lead grades; during the life of the mine, from 1895 to 1929, it produced 41 674 kilograms of silver and 21 775 tonnes of lead from 61 330 tonnes of ore (Table 12).

The deposit is hosted by strongly altered lower Aldridge siltstone and wacke, near or at the lower-middle Aldridge contact and the stratigraphic position of the Sullivan

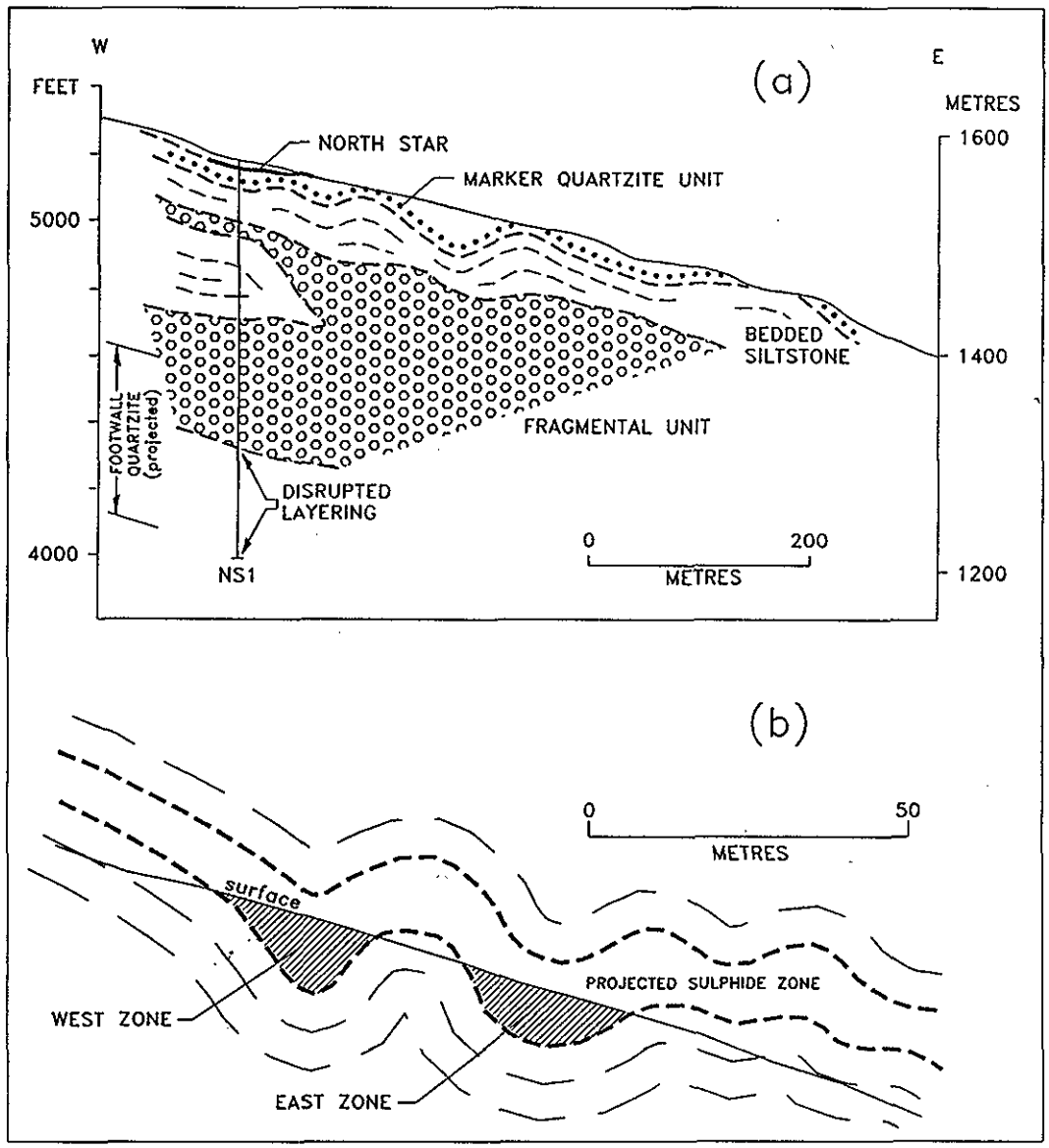


Figure 65. (a) East-west section through the North Star deposit area, lower Aldridge Formation, North Star Hill (after Hagen, 1985); (b) Diagrammatic cross-section of the North Star orebodies (after Schofield, 1915); for location and surface geology, *see* Figure 60).

deposit. It lies near the western edge of the Sullivan - North Star alteration zone and a drill hole (NS-1, Figure 65a) intersected altered fragmental units and disrupted bedding beneath the sulphide layer. Two orebodies were mined, the "West" and the "East". These were interpreted by Schofield (1915) to be the remnant parts of a larger massive sulphide layer, preserved in the cores of two synclines (Figure 65b). The orebodies trended northward, parallel to the prominent structural grain. The West orebody was approximately 130 metres long, 23 metres wide and 16 metres thick; the East, 60 metres long and 12 metres wide (Schofield, 1915).

The ore was primarily massive, fine-grained argentiferous galena with minor sphalerite, pyrrhotite, pyrite and chalcopyrite. Drill core (NS-1) logged by C.H.B. Leitch and R.J.W. Turner (personal communication, 1991) indicates that the massive sulphide layer is locally banded and, near its base, interbedded with laminated siltstone and argillite. It is underlain by laminated siltstone that contains pyrrhotite laminae, irregular quartz, galena, sphalerite veins, and abundant manganiferous garnet.

In the upper parts of the orebodies, close to the erosional surface, the ore was extensively oxidized. It comprised reddish brown, black and yellow oxides and lead and zinc carbonates; beautiful specimens of wire silver and cerussite were reported in the oxidized ore (Schofield, *op. cit).*

SULLIVAN (82FNE052)

The Sullivan deposit is one of the largest base metal massive sulphide deposits in the world. It has been described in a number of papers, more recent ones including Ethier *et al.* (1976) and Hamilton *et al.* (1982, 1983a) and in guidebooks (Höy *et al.,* 1985) and is treated only briefly here. Details of the structure in the vicinity of the deposit

Plate 55. Highly contorted basal part of the A band, eastern part of the Sullivan orebody. The A band here overlies approximately 2 metres of siltstone waste, then the main band sulphide layer; medium grey layers, pyrrhotite; light grey layers, galena. Plate width – 1.4 metres.

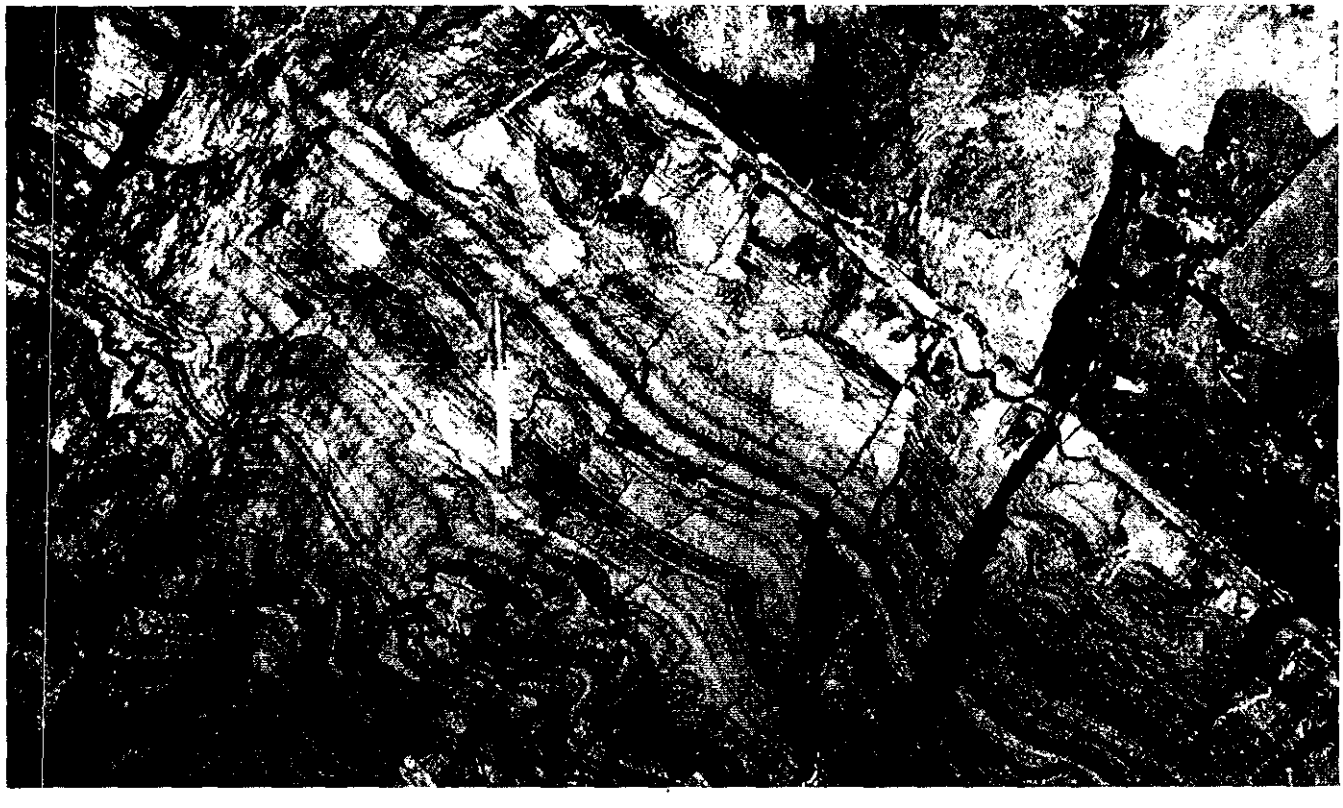


Plate 56. Top of the A band, Sullivan deposit, in contact with overlying graded quartz wacke waste bed; photo overlaps Plate 55; plate width – 1.3 metres.

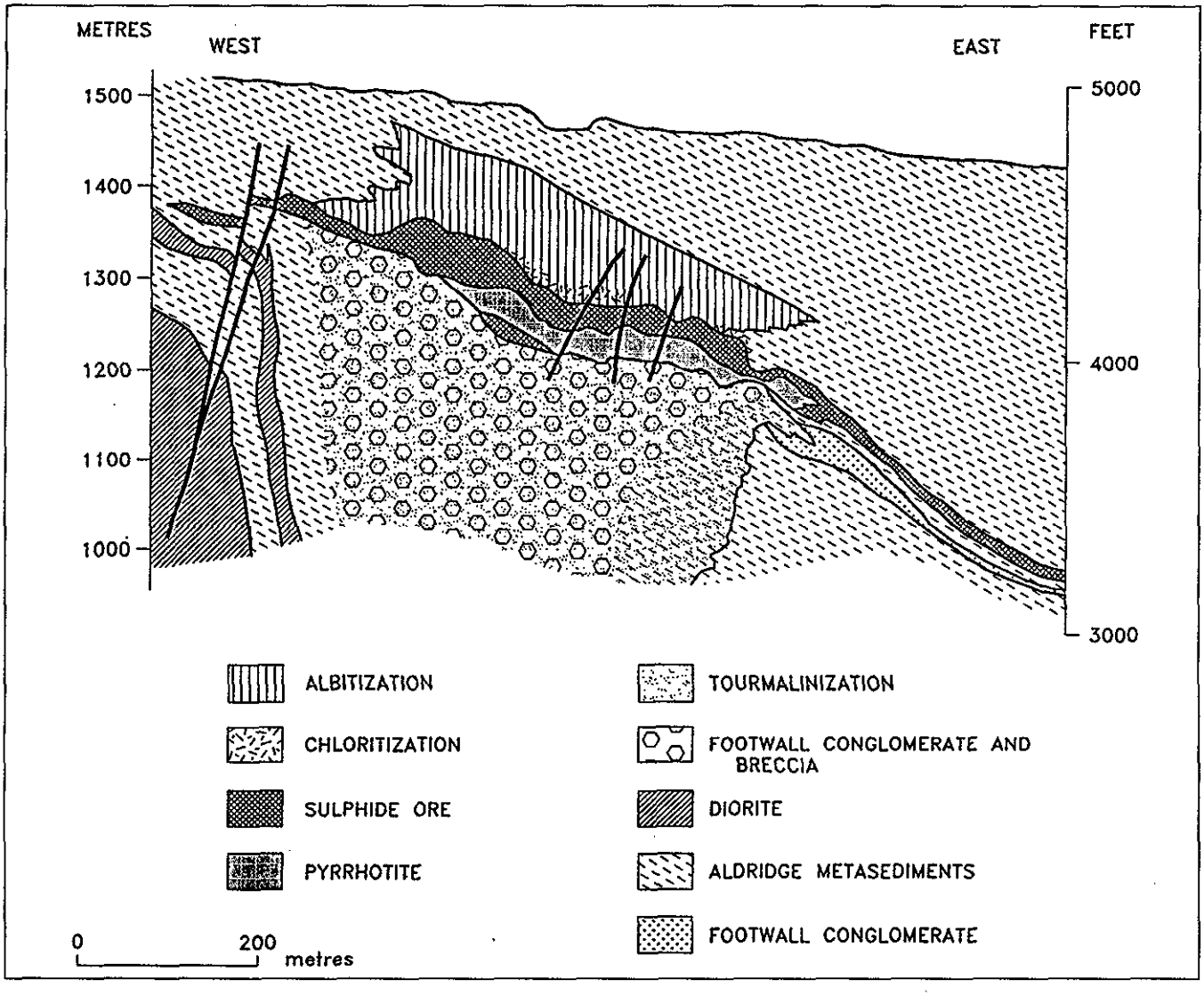


Figure 66. A schematic east-west vertical section through the Sullivan orebody (modified from Hamilton *et al.*, 1982, 1983; Ransom *et al.*, 1985); (for location and surface geology, *see* Figure 60).

Plate 57. B band triplets, Sullivan deposit, separated from underlying A band by 1 to 1.5 metres of waste siltite. Note sharp contacts between well-laminated sulphide band and waste beds. The top sulphide band of the triplet, at top of photo, is 25 centimetres thick; the two lower bands of triplets appear in lower left of photo.

are described in Chapter 5. The deposit has produced in excess of 125 million tonnes of ore from an original reserve of more than 160 million tonnes that contained 6 per cent lead, 6 per cent zinc, 28 per cent iron and 67 grams per tonne silver (Ransom *et al.*, 1985).

The western part of the orebody is approximately 1000 metres in diameter and up to 100 metres thick (Figure 66). It comprises massive pyrrhotite with occasional wispy layers of galena, overlain by layered galena, pyrrhotite and sphalerite, which in turn is overlain by pyrrhotite, sphalerite, galena and minor pyrite that is intercalated with clastic layers. Its eastern part, separated from the more massive western part by an irregular transition zone, includes five distinct conformable layers of generally well-laminated sulphides separated by clastic rocks (Plates 55-58). The sulphide layers thin to the east away from the transition zone. Sub-ore-grade sulphide layers of pyrite and pyrrhotite with subordinate sphalerite and galena persist beyond the eastern limits of the ore-grade sulphides.

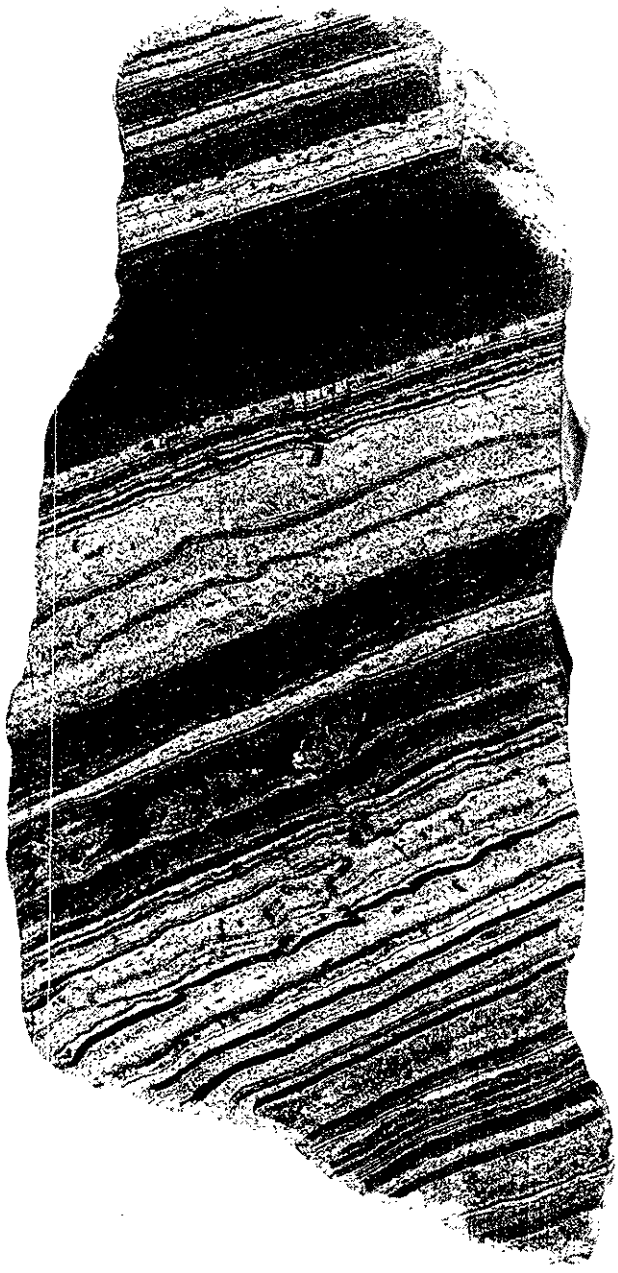


Plate 58. Detail of finely laminated sulphide bed, Sullivan deposit. Thin dark laminations are dominantly sphalerite; medium grey, pyrrhotite; and light laminations, galena. Thick dark layer at top is siltite bed with disseminated sphalerite in its base; sample width - 5 centimetres.

An extensive brecciated and altered zone underlies the massive western part of the orebody (Shaw and Hodgson, 1980). Linear north-trending breccia zones, disseminated and vein sulphides, and extensive alteration to a dark, dense chert-like tourmaline-rich rock are conspicuous features of the altered footwall. Albite-chlorite-pyrite alteration is also restricted to the western part of the orebody, occurring in crosscutting zones in the footwall tourmalinite, in the orebody itself and up to 100 metres into the hangingwall (Hamilton *et al.*, 1982; Shaw and Hodgson, *op. cit.*).

The deposit is zoned, with lead, zinc and silver values decreasing toward the margin in the eastern part. Tin is concentrated in the western part. In general, metal distribution patterns are directly related to proximal chaotic breccia; higher absolute values and higher Pb/Zn and Ag/Pb ratios overlie the breccia zones (Freeze, 1966; Hamilton *et al.*, 1982; Ransom *et al.*, 1985).

Sullivan is interpreted to be a hydrothermal synsedimentary deposit (sedex deposit) that formed in a small submarine basin. The western part lies directly above the conduit zone, the brecciated and altered footwall of the deposit.

KOOTENAY KING (82GNW009)

The Kootenay King deposit is located at an elevation of approximately 2200 metres on a steep south-facing slope in the northern Hughes Range (Plate 59). It is accessible by a narrow gravel road that climbs northward along the western slope above Wild Horse River.

Kootenay King was discovered in the late 1890s. It was acquired by the Kootenay King Mining Company in 1928 and, after considerable diamond drilling, a small orebody was outlined. Drilling by subsequent owners, Britannia Mining and Smelting Company Ltd. and the Mining Corporation of Canada Ltd. continued in 1929 and 1942 respectively. In 1951, a road was built to the deposit, a mill built just east of Fort Steele, and considerable underground exploration undertaken. A 50-tonne per day concentrator and a mine camp were also constructed at the mine site. Production, in 1952 and 1953, was approximately 13 260 tonnes with recovery of 715 grams of gold, 882 kilograms of silver, 710 866 kilograms of lead and 881 383 kilograms of zinc (Table 12).

Kootenay King is a stratiform lead-zinc massive sulphide layer in rocks correlative with the lower part of the middle Aldridge Formation. In contrast with dominantly thick-bedded A-E turbidites in the Purcell Mountains, the succession in the Kootenay King area comprises dominantly buff-coloured dolomitic siltstone, dolomitic argillite and dark grey argillite. A prominent thick-bedded "quartzite", referred to as the Kootenay King quartzite, contains the stratiform sulphide layer. It comprises a sequence of interbedded wacke, arenite and minor argillite up to 250 metres thick. It generally becomes thicker and coarser grained to the south, and appears to thin and eventually pinch out northward (Höy, 1979). The sulphide layer is near the top of the Kootenay King quartzite, in an impure, fine-grained dolomitic facies.

The Kootenay King stratigraphic succession is on the steeply east-dipping upper limb of a large recumbent anticline; east of the deposit, beds are inverted on the lower eastern limb. Small, generally open, north-northeasterly trending folds with shallow east-dipping upper limbs and steep to overturned lower limbs (Figure 67) are minor folds near the hinge of the large anticline. Local shearing and faulting occurs near the hinges of these minor folds.

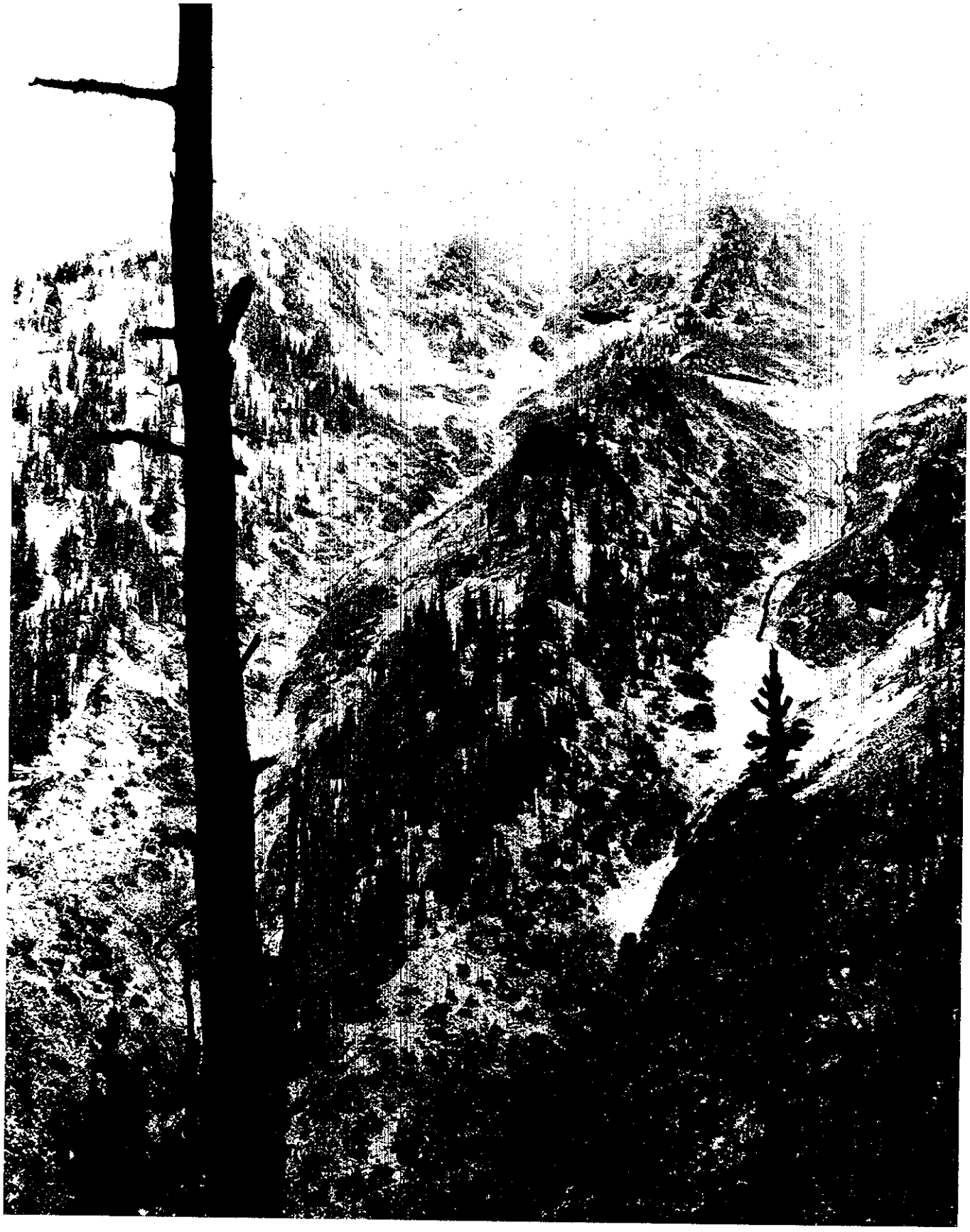


Plate 59. View of Kootenay King deposit and access road, top left of photo, northern Hughes Range.

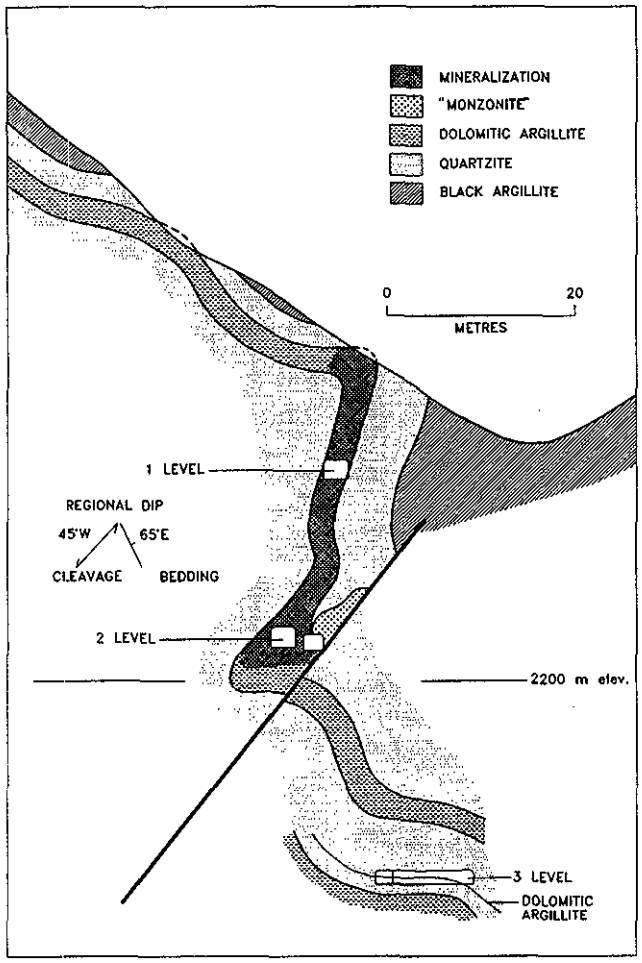


Figure 67. A generalized cross-section, looking north, through the Kootenay King deposit, middle Aldridge Formation, northern Hughes Range (from Ney, 1957).

Plate 60. Laminated sulphide layers (dark) in dolomitic siltstone, Kootenay King deposit; sample width approximately 20 centimetres.

Mineralization comprises fine-grained, laminated pyrite, galena and an unusual pale grey to green sphalerite (Plate 60). North of the deposit, the Kootenay King horizon is represented by a few metres of laminated silty argillite within quartzite that contains up to 60 per cent pyrite and anomalous but minor lead, zinc and silver values (I.D. McCartney, personal communication, 1980).

The lack of either a footwall stringer zone or hangingwall alteration, and the finely laminated nature of the mineralization suggests either that the deposit is distal, well-removed from its vent source or that much of it is eroded, including evidence of a conduit in the footwall.

Stratabound Copper-Cobalt Deposits

Stratabound copper-cobalt deposits occur in rocks correlative with the Aldridge Formation in Montana and Idaho. No examples of this type of deposit are known in the Purcell Supergroup in Canada.

The **Sheep Creek** deposit in central Montana comprises two main zones: an upper zone with reserves of approximately 4.5 million tonnes containing 2.5 per cent copper and 0.12 per cent cobalt, and a lower copper-rich zone of 1.8 million tonnes containing 6 per cent copper (Himes and Petersen, 1990; Zieg, 1989).

Mineralization is hosted by the Newland Formation, a thick succession of noncalcareous to calcareous or dolomitic shale overlain by dolomite, limestone and siltstone. The property lies along the northern edge of the Helena embayment, adjacent to the Volcano Valley fault. This fault, and others in the area, were active during deposition of the Newland Formation and may have controlled sulphide deposition (Zieg, *op. cit.*).

Mineralization occurs within at least two zones in the lower part of the Newland Formation. These zones are within a thick (approximately 350 metres) pyrite-rich succession, with pyrite content ranging from disseminated grains to massive beds several metres thick. They are associated with silicification, primarily as quartz veins, and both grade laterally into pyrite zones with anomalous lead-zinc content. The upper zone is high in copper, cobalt, nickel, barium, arsenic, lead and silver whereas the lower zone is higher in copper, nickel and gold but lower in cobalt, arsenic, lead and silver.

The upper zone averages 35.7 metres in thickness but ranges up to 65 metres thick (Himes and Petersen, 1990). It comprises sheets of finely bedded chalcopyrite, pyrite, barite and tennantite, with minor marcasite and various cobalt minerals, separated by grey, laminated barite-rich shale or conglomerate. These sheets are overlain by coarse-grained, silver-bearing barite.

The lower sulphide zone is at least 850 metres in length and averages 7 metres in thickness. It comprises bedded pyrite and chalcopyrite in a silica and/or dolomite gangue; barite is not recognized and the silver and cobalt contents are low. It is overlain by dolomitized shales and conglomerates, and separated from the upper zone by the Volacano Valley fault.

Fluid inclusion studies of barite in the upper zone indicate that the fluids were hot (>250°C) and moderately saline (6 to 17 per cent NaCl equivalent; Himes and Petersen, 1990). It is suggested that these fluids deposited sulphides and sulphates onto the sea floor during deposition of the Newland Formation in a locally developed, down-dropped faulted basin (Zieg, *op. cit.;* Himes and Petersen, *op. cit).*

The **Blackbird** mine in Idaho includes a number of copper-cobalt orebodies in the Yellowjacket Formation. The Yellowjacket Formation comprises garnet schist, phyllite, argillite, quartzite and quartz-mica schist, and is probably correlative with Prichard Formation in Montana (Hughes, 1982).

The deposits were mined intermittently from 1917 to 1960; total remaining reserves are estimated to include approximately 5.8 million tonnes containing 0.55 per cent cobalt and 1.31 per cent copper (Hanna Mining Company report, 1977).

Cobalt-copper orebodies at the Blackbird mine are irregular, varying from tabular to pod-like (Anderson, 1947; Vhay, 1948). Sulphides are dominantly pyrite, with minor pyrrhotite, cobaltite and chalcopyrite, and occur as disseminations, small veins and stratabound layers. In addition to copper and cobalt, the deposits contain gold, bismuth, nickel and silver. Gangue minerals include quartz in veins and veinlets, biotite amd tourmaline; hornblende, chlorite, muscovite, ankerite, siderite and calcite are less common gangue minerals.

Sedimentary Copper Deposits

Stratabound copper mineralization, referred to as sedimentary copper occurrences, occurs either in quartzites or in many of the red and green beds that overlie the deeper water Aldridge or Prichard formations. The more important deposits occur in rocks of the Appekunny and Grinnell formations in the Clark Range in southeastern British Columbia and southwestern Alberta and in Revett Formation quartzites at Spar Lake, Montana. Stratabound copper mineralization also occurs in carbonate facies of the Siyeh Formation in southwestern Alberta (Koopman and Binda, 1985) and in the Helena Formation in Montana (Lange and Eby, 1981).

The origin of these sedimentary copper deposits is debatable. Hamilton and Balla (1983), Lange and Sherry (1983) and Hayes (1984) have suggested that the Spar Lake orebody is diagenetic, with sulphides forming after sedimentation but before lithification, perhaps controlled by proximity to syndepositional, basement-controlled faults (Lange and Sherry, *op. cit.).* Garlick (1988) favours a syngenetic origin, with sulphides precipitating at the time of deposition of the host sediments. Harrison (1972), however, has argued that small red-bed copper occurrences are structurally controlled, epigenetic deposits.

Stratabound copper deposits and occurrences in Belt-Purcell rocks have a number of features in common with other stratabound, clastic-hosted copper deposits, such as those of the Zambian Copper Belt, the Permian copper deposits in Oklahoma and the Coppermine deposits in the Northwest Territories. They commonly formed in a tectonically active, intracratonic setting; there appears to be only an indirect association, if any, with volcanic rocks; and the hostrocks are usually fine-grained clastic sediments, commonly green, reduced beds that immediately overlie more oxidized red beds. At Spar Lake, however, the hostrocks are white to pinkish quartzites within grey siltites. Mineralization in these deposits is stratabound, localized in specific favourable units; it is usually not stratiform as it cuts across both sedimentary units and structures. Metals include copper and silver, less commonly uranium, and occassionally lead and zinc. Mineral and metal zoning is common.

The **Spar Lake** deposit near Troy, Montana, is in white, crossbedded quartzite of the Revett Formation (Hayes, 1984). Sulphides occur as disseminations, clots and fracture fillings, commonly closely related to bedding planes, crossbeds and scour-and-fill structures (Lange and Sherry, *op. cit.).* The sulphides are zoned with essentially a lower chalcopyrite zone, overlain by chalcopyrite-bornite-chalcocite, bornite-chalcocite, chalcopyrite-bornite-galena, galena-pyrite, and pyrite zones. Silver values correlate with copper values, with better grades in the thicker parts of the deposit. Evidence for structural control of mineralization includes: the spatial association with an early growth fault, the East fault; zonation of minerals and elements away from the fault; and vertical stacking of mineralized lenses in the Revett Formation.

STRATABOUND SILICA-HOSTED DEPOSITS

Stratabound silica-hosted deposits are chert (or, less commonly, orthoclase) deposits that contains anomalous amounts of gold. They are recognized in Montana and Idaho, in rocks that are correlative with the Prichard (Aldridge) Formation. Some of these deposits were originally described as "bedded" gold-quartz veins and it is possible that other similar veins may be stratabound silica-hosted gold deposits (W.W. Boberg, personal communication, 1988). They may be syngenetic or diagenetic, with gold (± pyrite) accumulating in siliceous exhalites.

The historic **Ulysses** gold mine in Idaho occurs in weakly metamorphosed siltites and fine-grained quartzites of the Yellowjacket Formation (Chevillon and Herberger, 1989). Gold is associated with a number of units, including strat-

iform quartz, pyritic quartz and chlorite-biotite-amphibole-magnetite schists. These units were derived from metamorphism of chert, pyritic chert and mafic tuffs (Chevillon and Herberger, *op. cit.).*

The **York** showings in Montana are in orthoclase and gold-rich zones in mudstones and siltites of the Greyson Formation (Baitis *et al.,* 1989). The zones are less than a metre to greater than 30 metres thick and are exposed over a strike length of approximately 10 kilometres. They contain gold values that typically average 450 ppb, and low concentrations of copper, lead, zinc, silver, arsenic, mercury, chromium and tellurium.

STRATABOUND CARBONATE-HOSTED DEPOSITS

Stratabound carbonate-hosted deposits are replacement lead-zinc deposits in upper Purcell carbonate rocks. The two most important are the Mineral King and the Paradise, located in the Toby Creek area of the Lardeau east-half map sheet (Reesor, 1973).

The **Mineral King** mine operated intermittently until 1974, producing 90 370 tonnes of zinc, 37 440 tonnes of lead, 662 tonnes of copper, 299 tonnes of cadmium and 57 723 kilograms of silver from 2.1 million tonnes of ore.

The Mineral King orebodies are hosted by massive to mottled, light grey and white dolomite in the lower part of the Mount Nelson Formation (Fyles, 1960) Dolomite breccias occur locally and their proximity to faults indicates that they are tectonic breccias (Fyles, *op. cit.*). Some are mineralized which suggests that the orebodies may be structurally controlled. The orebodies conform generally to fold structures within the dolomite, and some faults are mineralized, also suggestive of structural control.

The principal sulphides are sphalerite, galena, pyrite and minor bournonite in a dolomite, barite and quartz gangue (Fyles, *op. cit.*). The barite is white, fine to medium grained and has a sugary texture. Since closure of the lead-zinc mine, 66 000 tonnes of barite have been recovered from underground workings and the tailings pond.

During the intermittent life of the **Paradise** mine, from 1901 to 1953, it produced 7250 tonnes of lead, 3624 tonnes of zinc and 22 929 kilograms of silver. The ore zones are in grey siliceous magnesium limestone and dolomite of the Mount Nelson Formation, commonly near the hinges of broad open folds (Hedley, 1950). An important structural control appears to be the proximity to a high-angle fault that truncates folds in the Mount Nelson Formation and juxtaposes the formation against the Toby and Horsethief Creek Groups (McClay, personal communication, 1986). The ore comprises dominantly galena, sphalerite and pyrite; in the upper levels, it was very oxidized, consisting typically of "sand carbonate" with zinc and lead sulphates in addition to the sulphides.

VEIN DEPOSITS AND OCCURRENCES

Vein occurrences are numerous throughout the area (Figure 64). Although most are small showings or prospects, a number have historical production of lead, zinc, copper, silver, gold and, from the Estella deposit, cadmium (Table 12). Metals recovered from vein deposits total approximately 219 400 grams gold, 198 418 kilograms silver, 7270 tonnes copper, 119 962 tonnes lead and 28 850 tonnes zinc. Nearly all of this production came from four deposits, the Bull River, Estella, St. Eugene and Stemwinder mines. Most others produced less than 100 tonnes of ore each.

Most veins carry pyrite, pyrrhotite, chalcopyrite, galena or sphalerite in a quartz-carbonate gangue. Veins hosted by Purcell Supergroup rocks are subdivided into three main types, those with copper, those with silver, lead and zinc, and those with gold as their primary commodities. Although this classification is somewhat arbitrary, it does help emphasize a number of diagnostic characteristics of each type.

Copper Veins

Copper veins carry copper with variable amounts of lead, zinc, silver and gold. They are listed in Table 16 and located on Figure 64. The principal sulphide minerals are chalcopyrite, pyrite and pyrrhotite; galena and sphalerite occur in numerous veins and tetrahedrite is reported in a few. The principal gangue is quartz, commonly with calcite or siderite. Chlorite and epidote are uncommon, and barite occurs in a number of copper veins hosted by upper Purcell rocks in the Skookumchuck area.

Two groups of copper veins are recognized: those hosted by middle Aldridge or, less commonly, lower Aldridge or Fort Steele rocks and those hosted by clastic rocks of the upper Purcell Supergroup (Table 16). Many of the veins in the Aldridge Formation occur in shear or fault zones that cut across the lower Purcell stratigraphy. Others are associated with Moyie sills, either in metasediments immediately adjacent to a sill or in vertical fractures in sills. It is suggested (Chapter 3) that some of these sills were emplaced in unconsolidated or only partially consolidated wet sediments. Convective hydrothermal cells, derived from circulation of heated pore fluids and driven by heat of the intruding sill, leached base and precious metals from underlying sediments and sills. These metals were then deposited in hydrothermal veins in or adjacent to the sills, probably in response to decreased pressure or temperature as a sill fractured and allowed the escape of fluids.

Veins in overlying upper Purcell rocks may be largely derived from remobilization of metals originally deposited in shallow-water clastic or carbonate facies. A few of these veins (for example, Wilda, Green and Silver King) are in wacke or arenite that contains finely disseminated chalcopyrite or pyrite. This disseminated mineralization may be similar to, but far less concentrated than stratabound copper occurrences in arenaceous facies of the Grinnell and Appekunny formations in the Clark Range (Morton *et. al.,* 1973; Collins and Smith, 1977) or the Revett Formation in Montana (Hamilton and Balla, 1983; Lange and Sherry, 1983).

A number of other copper vein occurrences are closely associated with small mafic or alkalic stocks or dikes. These

TABLE 16
COPPER VEIN OCCURRENCES IN PURCELL SUPERGROUP ROCKS

MINFILE Number	Name	Commodities	Host Rock	Status
082GNW017	Try Again	Cu-W	Ft. Steele	Showing
082GNW059	Lazy 19	Cu-Ag	Ft. Steele, Moyie Sill	Showing
082GNW061	Lazy 32	Cu	Ft. Steele, Moyie Sill	Showing
082GNW06	Copper King	Cu-Ag-Au-Pb	M. Aldridge, Moyie Sill	Past producer
082GNW035	Golden Fleece	Cu-Au-Ag-Pb	Aldridge, Moyie Sill	Showing
082GNW045	Emily Tiger	Cu-Au-Ag-Pb	Aldridge, Moyie Sill	Past producer
082GNW046	Wanda B	Cu-Au-Ag-Pb	M. Ald., Moyie Sill	Showing
082GSW015	Empire	Cu-Pb-Ag-Au	M. Aldridge	Showing
082GSW016	Blue Grouse	Cu	M. Aldridge	Showing
082GSW047	Mountain	Cu-Pb-Ag	M. Aldridge	Showing
082GNW02	Bull River	Cu-Ag-Au	M. Ald., Moyie Sill	Past producer
082GNW014	Grey Copper	Cu-Au-Ag	M. Ald., Moyie Sill	Showing
082GNW015	Yankee Girl	Cu-Au-Ag-Pb-Zn	M. Ald., Moyie Sill	Showing
082GNW016	Kootenay Selkirk	Cu-Pb-Ag	M. Ald., Moyie Sill	Showing
082GNW025	Eagle Plume	Cu-Ag-Au	M. Aldridge	Showing
082GNW026	Eagle's Nest	Cu	M. Ald., Moyie Sill	Showing
082GNW032	Eagle Too	Cu-Au	M. Ald., Moyie Sill	Showing
082GNW040	Sylvia	Cu-Pb-Zn	M. Ald., Moyie Sill	Showing
082GNW075	Kim 3	Cu-Pb-Zn	M. Ald., Moyie Sill	Showing
082GSW040	Great Western	Cu-Ag-Pb-Zn-Au	M. Aldridge	Showing
082GSW046	Pit	Cu	M. Aldridge	Showing
082GSW052	Ross I	Cu-Zn	M. Aldridge	Showing
082FSE064	Royal Crown	Pb-Cu	M. Ald., Moyie Sill	Showing
082GNW013	Luke	Cu-Au	Moyie sill	Showing
082GNW041	Blue Dragon	Cu	Moyie sill	Showing
082GNW043	Black Hills	Cu-Pb	Moyie sill	Showing
082GNW03	Dibble	Cu-Ag-Au	Creston	Past producer
082GNW074	Olivia	Cu	Creston	Showing
082GSW056	Viking	Cu-Pb-Ag	Creston	Showing
082FNE055	Rice	Cu-Au-Ag-Pb-Zn	Creston	Prospect
082GNW027	Copper Belt	Cu-Ag-Au	Kitchener	Showing
082GNW033	King	Cu	Kitchener, mafic sill	Showing
082GNW060	Cedar	Cu-Ag-W-Mo	Kitchener, monzonite	Showing
082GNW064	Federal	Cu	Kitchener	Showing
082GSW019	Wilda	Cu-Ba-Zn	Sheppard	Showing
082GSW020	Green	Cu-Zn-Ba	Sheppard	Showing
082GSW010	Ramshorn	Cu	Gateway, mafic sill	Showing
082GSW011	Jennie	Cu	Gateway, K-spar sill	Showing
082GSW012	Sweet May	Cu	Gateway, K-spar sill	Showing
082GSW017	Peacock Copper	Cu-Ag	Gateway, K-spar	Showing
082GSW048	Don	Cu-Ba	Gateway, K-spar sill	Showing
082GSW013	Burton	Cu-Ag-Au	Roosville	Past Producer
082GSW028	Silver King	Cu	Roosville	Showing
082GNW065	Brenda	Cu-Au-Ag-Ba	Dutch Creek	Showing

include the King showing, hosted by a mafic sill in the Kitchener Formation, and the Jennie and Sweet May, in a potassic feldspar sill in the Gateway Formation (Table 16).

BULL RIVER (82GNW002)

The Bull River deposit is located at an elevation of 1067 metres, 7 kilometres upstream from the settlement of Bull River (Figure 64). It was operated by Placid Oil Co. from 1971 to 1974, producing approximately 7256 tonnes of copper, 126 000 grams of gold and 6.3 million grams of silver. Approximately 450 000 tonnes of ore were mined from two open pits, with an average grade of 1.46 per cent copper, 0.232 gram per tonne gold and 11.7 grams per tonne silver. An attempt was made in 1974 to develop an underground mine on one of a number of other mineralized zones that are known on the property but was abandoned because adverse mining conditions made production unprofitable.

Mineralization occurs in at least seven zones of strongly sheared and fractured rock that dip steeply to the south, cutting across lower Aldridge siltstone and wacke at or near a contact with a Moyie dike (McMechan, 1979; Grieve, 1980). Each zone comprises one or more quartz-siderite veins with disseminated or massive pods of chalcopyrite, pyrite and pyrrhotite.

LEAD-ZINC VEINS

Lead-zinc veins carry lead and zinc as their primary commodity with variable amounts of copper, silver and gold. The main sulphide minerals are similar to those in copper veins, dominantly galena, sphalerite, pyrite and pyrrhotite but with only minor chalcopyrite; arsenopyrite and tetrahedrite occur locally. The gangue in most lead-zinc veins is quartz, occasionally quartz-calcite and less commonly quartz-siderite. Accessory minerals in the veins may

TABLE 17
LEAD-ZINC VEIN OCCURRENCES IN PURCELL SUPERGROUP ROCKS

MINFILE Number	Name	Commodities	Host Rock	Status
082FNE116	Stemwinder	Zn-Pb-Ag	L. Aldridge	Past Producer
082GNW058	Pic	Pb-Zn-Cu	Aldridge	Showing
082GSW014	Jessie	Pb-Cu-Zn	L. Aldridge	Showing
082GSW042	Pu Pu 50	Pb	L. Aldridge	Showing
082GSW043	Pu Pu 55	Pb-Zn-Ag	L. Aldridge	Showing
082GSW053	Rozz 2	Pb	L. Aldridge	Showing
082GNW010	Palmayra	Pb	M. Aldridge	Showing
082GNW070	Rigel	Pb-Zn	M. Aldridge	Showing
082GSW001	Nord	Ag-Pb-Zn-Cu-Au	M. Aldridge	Showing
082GSW004	B & V	Pb-Zn-Ag	M. Ald, Moyie sill	Showing
082GSW021	Midway	Au-Ag-Pb-Zn, Cu	M. Aldridge	Past Producer
082GSW023	Aurora	Pb-Zn-Ag	M. Aldridge	Past Producer
082GSW025	St. Eugene	Ag-Pb-Zn-Au	M. Aldridge	Past Producer
082GSW027	Guindon	Ag-Pb-Zn	M. Aldridge	Past Producer
082GSW030	Society Girl	Pb-Zn-Ag	M. Aldridge	Past Producer
082GSW038	Pee Pee	Pb	M. Aldridge	Showing
082GSW049	Vine SS	Pb-Zn-Cu	M. Aldridge	Showing
082GSW050	Vine 1	Pb-Zn-Ag-Cu-Ag	M. Aldridge	Showing
082GNW001	Magnet	Pb-Zn	M. Aldridge-Ald	Showing
082GNW008	Estella	Ag-Pb-Zn-Cd-Cu-Ag	M. Aldridge-Ald	Past Producer
082GNW011	Lily May Ext	Pb-Cu	M. Aldridge-Ald	Showing
082GNW012	Park	Pb-Ag	M. Aldridge-Ald	Past Producer
082GNW021	St. Tresa	Pb-Ag	M. Aldridge-Ald	Showing
082GNW028	Cucko	Pb-Cu-Ag	M. Ald, Moyie sill	Showing
082GNW051	Box	Pb-Cu	M. Aldridge-Ald	Showing
082GNW072	Trilby	Pb-Zn-Ag-Au	M. Ald, Moyie sill	Showing
082GNW073	BC	Pb-Zn-Cu	M. Aldridge	Showing
082GSW018	Burt	Zn-Pb-Ag-Cu	M. Aldridge	Showing
082GSW035	Helg	Pb-Zn-Ag	M. Aldridge	Showing
082GSW037	Payroll	Au-Ag-Cu-Pb	M. Aldridge	Past Producer
082GSW054	Cedar	Pb-Ag	M. Aldridge	Showing
082GSW055	OK	Pb-Ag	M. Aldridge	Showing
082GSW057	Ranch	Pb-Zn	M. Aldridge	Showing
082GNW004	Victor	Pb-Zn-Ag-Au	Creston	Showing
082GNW019	Dardenelle	Pb-Au-Ag-Zn-Cu	Creston	Past Producer
082GNW020	Lily May	Au-Ag-Pb-Zn	Creston	Showing
082GSW058	Silver Pipe	Pb-Ag-Cu	Gateway	Showing
082GSW029	Leah	Ag-Pb	Gateway	Showing

include biotite and apatite (the Pee Pee occurrence); weathered veins commonly contain anglesite, jamesonite and limonite. The Society Girl vein, a higher level oxidized extension of the St. Eugene vein systems, also contains cerussite and pyromorphite.

Nearly all lead-zinc vein occurrences are within the Aldridge Formation (Table 17), most commonly in the middle Aldridge or in rocks correlative with the middle Aldridge rocks (Unit Ald) east of the Rocky Mountain Trench. Middle Aldridge rocks are deep-water clastic facies with relatively high background metal values that provide a source for metals in the veins. They are commonly thick-bedded and competent, and hence fracture readily. In contrast with copper veins, only a few lead-zinc veins appear to be associated with the Moyie sills. A number, however, occur near the margins of more felsic intrusions, such as the Estella deposit in the northern Hughes Range.

Despite the variety of lead-zinc vein deposits in Aldridge rocks, most have very similar lead isotopic ratios (LeCouteur, 1973; Andrew *et al.*, 1984; Godwin *et al.*, 1988). These ratios are similar to those of stratiform deposits such as Sullivan and Kootenay King, indicating a common lead source, presumably the host Aldridge succession. Metals were initially deposited together with Aldridge sediments, remobilized during intrusive or later tectonic events and deposited as lead-zinc veins. Examples of these veins are described below.

STEMWINDER (82FNE116)

The Stemwinder deposit is located on Mark Creek, 2 kilometres south of Sullivan. It produced approximately 25 000 tonnes of ore containing 3.7 per cent lead, 15.6 per cent zinc and 76.3 grams per tonne silver (Table 12). It is hosted by altered siltstone and wacke in the upper part of the lower Aldridge Formation.

The deposit is a steeply west-dipping vein structure within the Sullivan - North Star alteration zone. It is parallel to prominent north-trending, west-side-down normal faults located just to the west (Figure 60 and Section C-C', Figure 61). The deposit is within a crosscutting fragmental unit comprising granule to pebble-sized clasts in a sulphide matrix. It has a maximum thickness of 38 metres and a strike length of approximately 300 metres (Hagen, 1985).

The deposit is zoned, with a central portion of fine-grained sphalerite and galena, an intermediate zone of pyr-

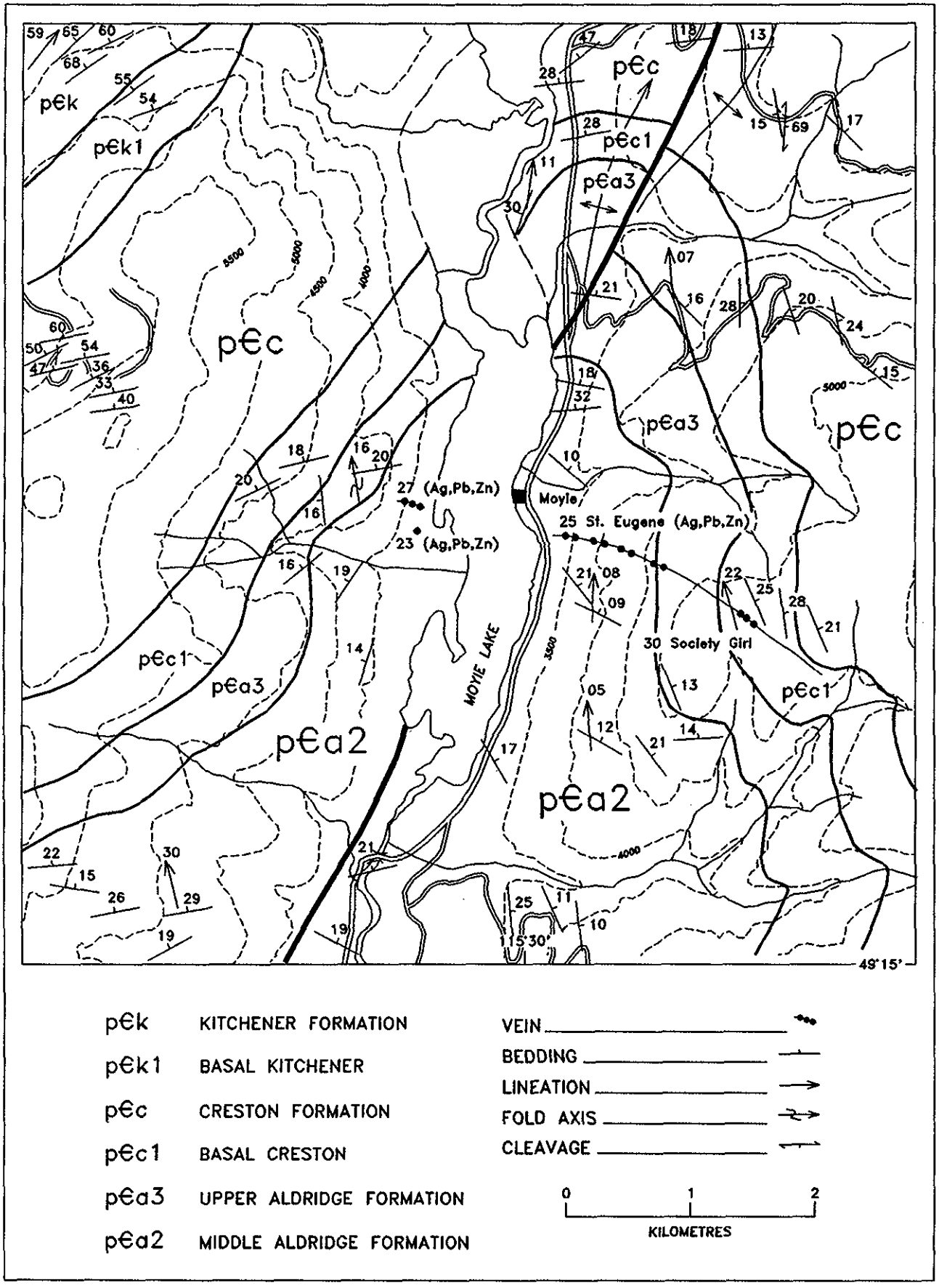


Figure 68. Regional geology in the vicinity of the St. Eugene deposit, Moyie Lake area (from Höy and Diakow, 1982).

Plate 61. Headframe of the abandoned St. Eugene deposit, Moyie Lake, photographed in 1978.

rhotite, sphalerite and galena, and an outer zone, comprising the bulk of the deposit, of dominantly pyrrhotite. A high-grade zone within the central part is approximately 85 metres long and 3 metres thick that contains 20 per cent zinc, 1 per cent lead and 32 grams per tonne silver (D.H. Olsen, personal communication, 1983). Tourmalinite alteration, referred to as a cherty layer (Schofield, 1915), flanks the steeply dipping vein-breccia deposit.

ST. EUGENE (82GSW025)

The St. Eugene vein system is located at the town of Moyie, approximtely 35 kilometres southwest of Cranbrook (Plate 61). It includes the St. Eugene deposit and extensions to the east (Society Girl) and to the west on the east shore of Moyie Lake (Aurora and Guindon).

The St. Eugene was discovered in the late 1890s by a Kootenay Indian and acquired by the owners of the Trail smelter in 1905 to supplement diminishing supplies of concentrates. It produced until 1916 when reserves were exhausted at 620 metres below the shaft collar. It is the largest vein deposit in the Purcell Supergroup, with total production of approximately 78 846 grams gold, 182 691 kilograms silver, 113 034 tonnes lead and 14 483 tonnes zinc from 1.47 million tonnes of ore (Table 12).

Regional Geology

The St. Eugene veins are controlled by a large fracture system that cuts across the nose of the north-plunging Moyie anticline (Figure 68). It trends 110° and dips 65° southwest, approximately perpendicular to the axis of the anticline. Other fractures with similar trends and net normal displacements occur farther southwest in the Moyie anticline (Figure 2) and may represent faults that have been reactived along AC joints. Although Schofield (1915) reports little displacement on the St. Eugene fractures, slickensided walls, gouge and, locally, small drag folds indicate at least some movement with the south block down-dropped relative to the north block.

The fracture system is extensive, with a strike length of appoximately 3300 metres and a vertical extent of 1300 metres, from the Society Girl at an elevation of 1586 metres above sea-level to more than 600 metres beneath Moyie Lake. At deeper structural levels, in the St. Eugene, Aurora and Guindon deposits, the veins cut shallow-dipping, thick-bedded quartz wacke and arenite turbidite beds of the middle Aldridge Formation. At higher levels, in the upper workings of the St. Eugene deposit, they are in thin-bedded siltstone and wacke of the upper part of the middle Aldridge and in the upper Aldridge, and at the Society Girl, in the transition between the upper Aldridge and the Creston Formation.

Deposit Geology

The St. Eugene deposits are controlled by at least two subparallel fracture zones, referred to as the North and South fractures. The North fracture, known as the Main vein, was most productive with ore mined in three main shoots, the Lakeshore, Moyie and St. Eugene. Mineralization in the North fracture decreased to the west, where mineralization in the South fracture becomes more prominent. At the Lakeshore, where the North and South fractures converged slightly, ore was found in both fractures as well as in parallel veins ("parallels") and crossveins ("avenues") between the fractures (A. Smith, Falconbridge Nickel Co. Ltd., internal report, 1949).

The deposits occured as tabular ore shoots up to 10 metres thick, with one or more bands of near-massive galena up to 1.3 metres thick. The average mineable widths were in the order of 2 to 3.5 metres.

The location of the ore shoots within the main fracture was apparently controlled by intersection of the fracture with north-south zones of fracturing and small folds. Extensive areas along the fractures where wallrock strata dip regularly were explored and found to be barren (A. Smith, *op. cit.*). Host lithology was an important secondary ore control. Thick-bedded, more competent quartzite produced steeper dipping, clean fractures that favoured mineralization. Thin-bedded quartzite-siltstone interbeds higher in the succession were less favourable hosts, and siltstones and argillites in the upper Aldridge were generally unmineralized. The Society Girl is in more competent quartzite of the overlying Creston Formation.

The dominant vein minerals were galena and sphalerite, associated with pyrite, pyrrhotite, and minor magnetite,

chalcopyrite and tetrahedrite. Gangue minerals included garnet, calcite, quartz, chlorite, amphibole and biotite. Typically, the vein chlorite formed fine-grained felted masses that enclose subhedral to euhedral manganiferous garnet, actinolite and fine-grained biotite. Epidote, grunerite and fluorite were found locally. Wallrocks contain finely dispersed chlorite and biotite, and small subhedral garnet and magnetite porphyroblasts. Vein margins are locally brecciated and late, barren quartz veinlets cut the earlier mineralized veins and hostrocks.

ESTELLA (82GNW008)

The Estella deposit is located in a large, north-facing basin at an elevation of 1830 metres in the northern Hughes Range (Plate 62). It is accessible by a well-maintained gravel road that follows the south fork of Lewis Creek.

The deposit was discovered in the 1890s and two adits, the Rover and the Estella, driven to intersect the vein mineralization (Hedley, 1952, 1964). The property was optioned to the Consolidated Mining and Smelting Company of Canada, Limited in 1927, drilled and then dropped.

Estella Mines Ltd. was formed in 1950, the mine camp was re-established, and a 135 tonne per day mill built at Wasa. Milling commenced in 1951 and continued in 1952 and 1953. In 1962, the property was purchased by Copper Soo Mining Company and a downward extension of the orebody subsequently discovered and brought into production in August, 1963. Giant Soo Mines Ltd. was formed in 1965 and again the property was put into production. During the intermittent life of the mine, from 1951 to 1967, a total of 109 518 tonnes of ore was milled, yielding approximately 6393 kilograms of silver, 5181 tonnes of lead, 9834 tonnes of zinc and very minor gold in concentrates (Table 12).

Plate 62. Location of the Estella deposit in a cirque just north of Mount Bill Nye. The access road to the 6250 level is located at the base of the resistant hill in the centre of the photo (*see* Figure 73).

Regional Geology

The Estella deposit is a silver-lead-zinc vein in siltstone, argillite and wacke of the Aldridge Formation. The vein occurs adjacent to a small porphyritic to equigranular composite stock, informally referred to as the Estella stock (Figure 69). A large, irregular diorite body is exposed just west of the deposit, and a similar diorite exposed underground is presumed to be the "over-all controlling feature" for the Estella veins (Hedley, 1964, p. 84). The diorites are part of the suite of Moyie intrusions exposed throughout the lower and basal middle Adridge succession east of the Rocky Mountain Trench and in the Purcell Mountains.

The hostrocks, Units A1c and A1d of the Aldridge Formation, consist largely of finely laminated silty argillite and buff-weathering dolomitic siltstone. Sedimentary structures in Unit A1d suggest deposition as distal turbidites, possibly in a slope or small-basin setting. Unit A1d is also host to the stratiform Kootenay King deposit, approximately 5 kilometres to the south.

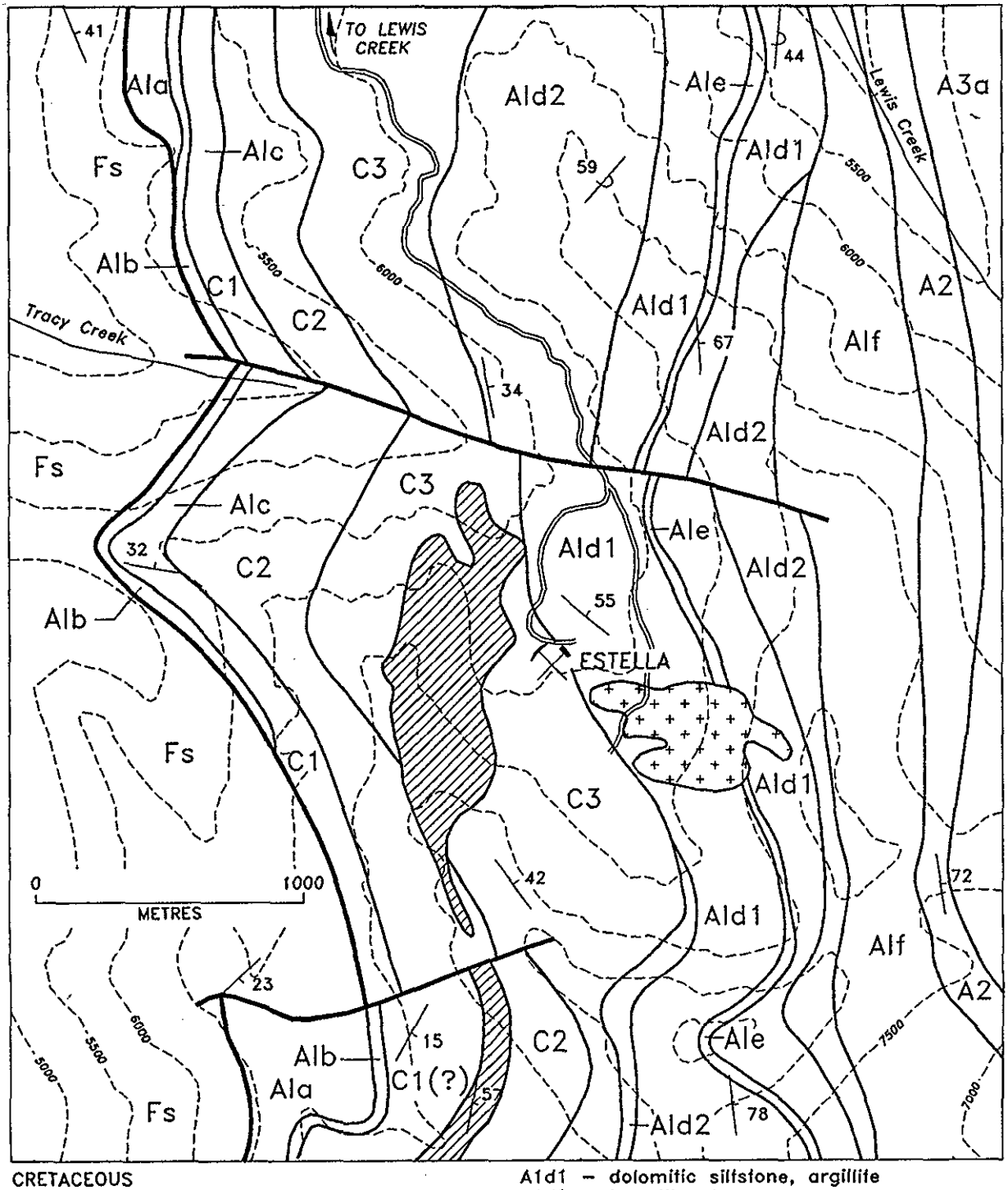
Deposit Geology

The description of the Estella deposit is largely summarized from the reports by Hedley (1952; 1964). The lode is a zone of fracturing and light shearing, dipping to the southwest at angles between 40° and 70°. The main ore zone rakes at a low angle to the southeast, following the general trend of a diorite contact. It ranges in width from a thin, barren fracture to a zone 5 to 7 metres wide. The ore is described as a "replacement" by sphalerite, galena and pyrite accompanied by varying amounts of silica. Vein quartz is not abundant, except in diagonal veins that usually contain few if any sulphides (Hedley, 1952, p. 187).

At the deeper "Estella" level (Figure 70), a poorly mineralized quartz stringer zone approximately 30 metres in width occurs in the hangingwall of the lode. It also coincides with the contact zone between diorite and sedimentary rock. Mineralization increases southeastward in Aldridge metasediments, and has been mined over a strike length of approximately 100 metres. Within this block are a number of steep quartz stingers that diverge from or cross the vein. A few parallel mineralized stringers are present in the footwall.

VINE (82GNW050)

The Vine property, located approximately 12 kilometres south-southwest of Cranbrook, is accessible by gravel road leading north from Highway 3/95. Lead-zinc float boulders



CRETACEOUS

Estella Stock – monzonite, syenite

MIDDLE PROTEROZOIC

Moyie Sill

Aldridge Formation

A3a – dark grey, finely laminated argillite
A2 – quartzite, siltstone; minor argillite
A1f – medium–dark grey argillite, siltstone
A1e – thick-bedded quartzite
A1d1 – dolomitic siltstone, argillite
A1d2 – transitional zones
A1c3 – rusty-weathering, dark grey argillite
A1c2 – light grey, tan, green siltstone, argillite
A1c1 – black graphitic argillite
A1b – silty dolomite, argillite
A1a – grey to black siltstone, argillite

Fort Steele Formation

Fs – quartzite, siltstone; cross-bedded, mud-cracked

Figure 69. Regional geology in the vicinity of Estella deposit, northern Hughes Range (from Höy, 1979).

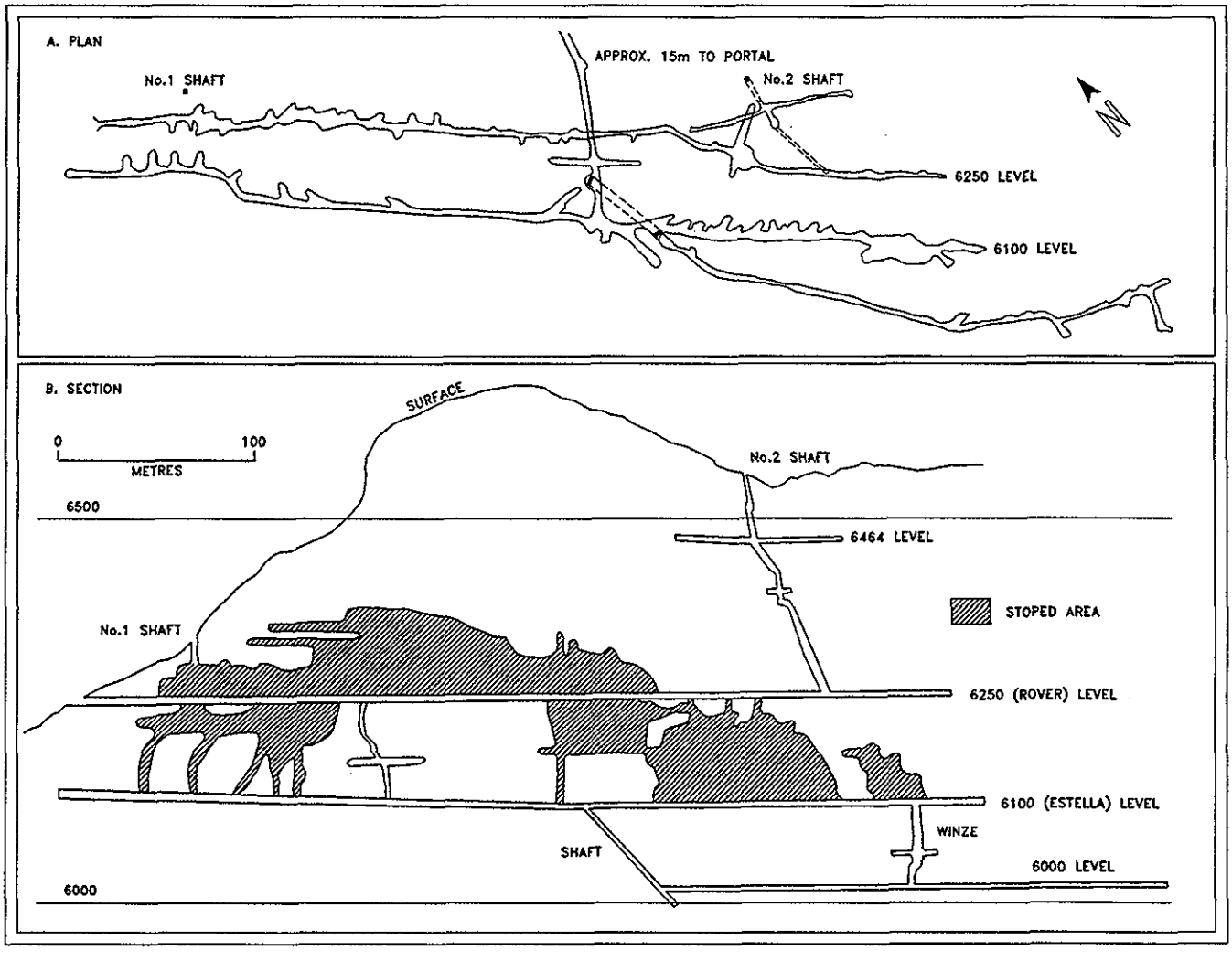


Figure 70. Plan and section, Estella deposit, northern Hughes Range (from Hedley, 1964).

were discovered initially in the vicinity of the massive sulphide vein in 1976 by Cominco Ltd. Since then, considerable trenching, geophysical and geochemical surveys and diamond drilling have extended the vein to a depth of at least 700 metres and a strike length of greater than 1000 metres. The current owner, Kokanee Explorations Ltd., has continued mapping, sampling and drilling the vein system. Drill-indicated geological reserves total 1.9 million tonnes containing 3.76 per cent lead, 1.07 per cent zinc, 0.13 per cent copper, 2.3 grams per tonne gold and 39.8 grams per tonne silver (company news release, June, 1990).

The Vine vein is within a fault that strikes 120° and dips 65° to 75° west. On surface, it cuts gently northwest-dipping quartz wackes and siltstones in the lower part of the middle Aldridge Formation; at depth, it cuts the lower-middle Aldridge contact and lower Aldridge siltstones and wackes.

The vein comprises massive pyrrhotite with minor galena, arsenopyrite, chalcopyrite, pyrite and sphalerite (Stephenson, 1990). The arsenopyrite may be coarse grained, commonly euhedral, or occurs disseminated throughout the pyrrhotite. Gangue minerals include quartz, commonly as clear, rounded grains within the massive sulphides, and minor calcite. Chlorite-biotite-quartz veinlets commonly cut the massive sulphide vein.

Brecciation and shearing within and along the margins of the vein are common. The hostrocks include metasediments of the Aldridge Formation and chloritic altered gabbro/diorite of the Moyie sill intrusive suite.

OTHER VEIN OCCURRENCES

Although many of the copper veins and some of the lead-zinc veins contain minor gold (Tables 16 and 17), a number of veins in the Perry Creek area contain gold as their primary commodity (Table 18). They are gold-quartz veins controlled by northeast-trending faults that cut Creston Formation quartzite and siltstone. Shearing and fracturing are extensive, commonly occuring in a zone several hundred metres wide on either side of the faults. Many of the veins are also associated with mafic dikes. They vary in thickness from a few centimetres to greater than 10 metres (Cairnes, 1933). They comprise massive, white to occassionally pink quartz, minor calcite, disseminated pyrite, and occassionally trace chalcopyrite and galena. They are commonly severely fractured or sheared and locally cut and offset by crossfaults. Others cut the prominent schistosity, which

suggested to Cairnes (*op. cit.*) that they formed during and immediately following deformation.

A number of small veins in the Fernie west-half area are hosted by Cambrian rocks and are commonly associated with small faults or intrusions. These include the Fisher, Coronado and Jolly-Molly (Table 18).

SHEAR-CONTROLLED GOLD DEPOSITS

Significant gold mineralization has been discovered recently in northeast-trending shears in the middle Aldridge Formation on tributaries of the Moyie River 30 kilometres southwest of Cranbrook. The prospect, referred to as the **David** property, is accessible by Lumberton, Moyie North and Kutlits Creek logging roads. It is currently (1991) under option to Dragoon Resources Ltd. and has undergone recent airborne and ground geophysical surveys, soil and rock geochemical surveys, geological mapping, trenching and diamond drilling. The following report is summarized from Klewchuck (1991).

The property is underlain by northeast-trending, west-dipping middle Aldridge siltstones and quartz wackes that are intruded by a number of Moyie sills. These sills locally contain anomalous magnetite concentrations near the mineralized zones. North-northeast-trending shears and faults, including the Baldy Mountain fault which juxtaposes Creston Formation on the west against the Aldridge Formation, are prominent in the area.

Gold mineralization, associated with galena and chalcopyrite, occurs in zones of intense silicification within a number of these shear zones. Small crosscutting quartz tension veins and stockwork breccia zones occur within the

TABLE 18
GOLD VEINS, PURCELL SUPERGROUP

MINFILE Number	Name	Commodities	Host	Status
082GNW024	Dougherty	Au	Aldridge-Ald	Showing
082FNE056	Anderson	Au-Ag-Pb	Creston	Past Producer
082FNE057	Birdie Lake	Pb-Ag-Au	Creston	Past Producer
082FNE058	Roone & Valley	Pb-Au	Creston	Past Producer
082FNE059	Running Wolf	Au	Creston	Past Producer
082FNE054	Janet	Au	Creston	Prospect
082FSE029	Prospectors Dream	Au	M. Aldridge	Prospect
082GNW023	Fisher	Au-Ag-Pb	Cranbrook	Showing

TABLE 19
INDUSTRIAL MINERALS, FERNIE WEST-HALF SHEET

MINFILE Number	Name	Commodities	Host	Status
082GNW037	Cranbrook	Clay	Tertiary (?)	Showing
082GNW039	Fort Steele	Clay	Tertiary	Showing
082GNW048	Fernie	Clay	Tertiary	Showing
082GNW056	Eager Station	Clay	Eager Fm	Showing
082GSW005	Elko	Clay	Eager Fm	Showing
082GNW005	Marysville, Perry Creek	Magnesite	Cranbrook Fm	Showing
082GNW036	Boulder Creek	Magnesite	Cranbrook Fm	Showing
082GNW047	Wallinger	Magnesite	Cranbrook Fm	Showing
082GNW053	Fort Steele, Red Mountain	Magnesite	Cranbrook Fm	Showing
082GSW032	Bull River	Dolomite	Palliser Fm	Showing
082GSW036	Wardner	Dolomite	Palliser Fm	Showing
082GNW031	Island Lake Two	Phosphate	Fernie Fm	Showing
082GNW034	Island Lake One	Phosphate	Fernie Fm	Showing
082GNW054	Fairy Creek	Phosphate	Ranger Canyon Fm	Showing
082GNW055	Mutz Creek	Phosphate	Fernie Fm	Showing
082GNW068	Upper Mutz Cr.	Phosphate	Sulpher Mt.	Showing
082GNW069	North Sulphur Cr.	Phosphate	Showing	
082GSW059	Lizard	Phosphate	Fernie	Prospect
082GSW060	Fernie Ski Hill	Phosphate	Johnson Canyon	Showing
082GNW052	BBX	Barite	Dutch Creek	Showing
082GSW009	Chipka Creek	Gypsum	Fairholme	Showing
082GSW031	Bull River	Gypsum	Banff	Prospect
082GSW044	Mayook Quarry	Gypsum	Gateway	Past Producer
082GSW045	Sunrise Cave	Gypsum	Gateway	Past Producer

shears. Although pyritic, these generally have low gold values. Chlorite, pyrite and associated bleaching occur within and marginal to the shears.

One of the zones is 1 to 2 metres thick and has been traced on surface for 950 metres. Drill-hole intersections include 1.5 metres assaying 26.76 grams per tonne gold and 1.8 metres assaying 8.02 grams per tonne gold.

The David discovery is significant not only because it is new, but also because it represents a new exploration target model in the Purcell Supergroup. The discovery is also important as it may help explain concentrations of placer gold in creeks and rivers that drain catchment areas underlain by the Aldridge Formation. Queenstake Resources and a number of private individuals have active placer operations on the Moyie River.

INDUSTRIAL MINERALS

Twenty-four industrial mineral occurrences are plotted in Figure 64 and listed in Table 19. The principle commodities include clay, magnesium compounds, phosphate, barite and gypsum.

Clay deposits are of two types: calcareous, porous, and cream to buff-burning, suitable for common and scouring brick, drain tile, flower pots and crude pottery; and red-burning with high shrinkage, suitable for facebrick and tile.

Magnesium and magnesium compounds are mined from deposits rich in magnesite, hydromagnesite, dolomite, brucite and olivine (Grant, 1987). Both magnesite and dolomite deposits are known in the Fernie west-half map area. Deposits of magnesite occur as creamy grey, coarse to fine-grained, massive beds from 15 to 45 metres thick in the Cranbrook Formation. Carbonate deposits occur in sedimentary layers 2 to 10 metres thick which vary from pure calcium limestone to high-manganese dolomitic limestone. Some of the dolomite grades up to 37 per cent MgO but much contains hard, blue chert nodules. Commercial applications for magnesium compounds include refractory bricks, fertilizers, ceramics and magnesium alloys.

Phosphate deposits occur primarily in the Fernie Formation in the eastern part of the map area (Butrenchuck, 1987). Two types are recognized: phosphorite and phosphatic siltstone, sandstone and shale beds from 0.5 to 3.5 metres thick and with up to 13.3 per cent P_2O_5; and phosphate nodules, pellets, partings along bedding, and cement, in clastic units with up to 1.5 per cent phosphate (Butrenchuck, *op. cit.*). Phosphate is used mainly in fertilizer production.

Barite occurs economically as relatively pure, coarsely crystalline vein material and subeconomically associated with quartz, siderite and sulphides in stratiform and vein deposits. The BBX showing is a massive barite vein in the Dutch Creek Formation northeast of Skookumchuck. The main uses of barite are as "heavy mud" in oil and gas-well drilling as a filler in high-quality paper and as lithopone in paint.

Gypsum deposits occur in the central part of the map area as layers 5 to 15 centimetres thick within light grey to black limestones of the Fairholme Group. The deposits typically have a CaO content ranging from 20 to 30 per cent and MgO from 1 to 7 per cent. Gypsum is used for the production of plaster wallboard, as a retarder in cement, and as a soil conditioner in fertilizers.

COAL

There is only one coal occurrence in the Fernie west- half map area, the Fernie prospect (82GSW066) located at the town of Fernie. At least 13 coal seams of medium volatile bituminous rank, from 0.3 to 6.1 metres thick, are interbedded with shale, sandstone and siltstone of the Mist Mountain Formation. Analyses of coal samples indicate values ranging from 9.5 to 42.7 per cent ash, 17.9 to 27.1 per cent volatiles, 29.1 to 71.2 per cent fixed carbon and 0.3 to 0.5 per cent sulphur.

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APPENDIX 1
MEASURED STRATIGRAPHIC SECTIONS

Fort Steele Formation; Premier Lake

Location: 4.5 km south-southwest of south end of Premier Lake, elev. 945 m (3100 ft); NTS Skookumchuck 82G/13E; UTM grid 594750E-5526500N (base) to 595100E-5526625N (top)

Measured by T. Höy (1978), field section H78E54

Unit	Description	Thickness (metres)	Height above base (metres)
Fort Steele Formation (228.1 m - incomplete)			
36	siltstone, light brown, 10-15 cm thick beds, channels; argillite, dark grey, interlayered with siltstone, flaser and lenticular bedded; quartzite, planar bedded, tangential crossbeds, ripple crosslaminated.	7.6	228.1
35	argillite and siltstone, dark grey, lenticular bedded, mud cracks, scour channels.	9.1	220.5
34	quartzite, silty and siltstone, 10-15 cm thick beds, ripple crosslaminated, planar laminated, lenticular bedded, flaser bedding	7.0	211.4
33	quartzite, white to light grey, thick to very thick bedded, broad channels at base; quartzite, finer grained, parallel bedding, medium bedded, tangential crossbeds; siltstone, brown to grey interlayers near top.	6.7	204.4
units 33 to 35 are a fining-upward sequence			
32	siltstone and argillite, light brown to grey, thin to medium bedded, parallel laminations, minor ripple crosslaminations.	6.1	197.7
31	quartzite, white, very thick bedded, large tangential crossbeds, irregular discontinuous bedding; sharp contact with unit 30 below; quartzite, silty, thin to medium bedded at top, gradational contact with unit 32 above.	7.9	191.6
units 31 to 32 are a fining-upward sequence			
30	siltstone, tan coloured, medium bedded with medium grey argillite or fine-grained siltstone caps, parallel laminations, very low angle tangential crossbeds, ripple crosslaminations.	3.6	183.7
29	quartzite, white, very thick bedded, massive at base, tangential crossbedding throughout, broad scouring channels; grades upward into quartzite, pure to silty, medium to thick bedded, crosslaminations; gradational contact with unit 30 above, forming a fining-upward sequence.	11.6	180.1
28	quartzite, white, massive at base in irregular, discontinuous beds that may form broad channels; grades upward into silty quartzite, planar bedded, tangential crossbeds common.	15.2	168.5
27	quartzite, pure to silty, medium bedded, massive tangential crossbeds; generally poorly exposed.	10.7	153.3
26	siltstone, medium bedded, planar bedding with even-parallel laminations and planar-tabular crossbeds.	3.0	142.6
25	generally covered; few exposures of quartzite, white, thin bedded.	2.1	139.6
24	quartzite, white, medium to thick bedded, low-angle tangential crossbeds above massive beds; minor siltstone interlayers.	2.7	137.5
23	covered.	1.2	134.8
22	quartzite, medium bedded; commonly cyclical with tangential crossbeds near base, planar-tabular crossbeds above and planar-laminated beds at top of cycle; quartzite with carbonate-cemented quartzite concretions; quartzite, thick bedded, planar beds with tangential crossbedding, irregular, wavy bedded, minor ripple crosslaminations at top of more massive beds.	53.3	133.6
21	quartzite, white, medium to thick bedded, broad channels, herringbone crossbeds, tangential crossbeds; quartzite, medium bedded, ripple crosslaminations at base of bed, parallel laminations at top.	9.1	80.3
20	siltstone, medium bedded, massive, or crossbedded; quartzite, medium bedded, massive.	1.5	71.2
19	quartzite, silty, crossbedded, minor scours and irregular, discontinuous beds; interlayered with siltstone and argillite, rippled surfaces, mud cracks, lenticular beds.	18.3	69.7

18	quartzite, feldspathic, medium thick beds with crossbedding at base, parallel laminations or ripple laminations in middle and siltstone or argillite tops; units 18 to 20 form a fining-upward sequence.	3.0	51.4
17	covered.	4.3	48.4
16	siltstone, lenticular bedded, ripple crosslaminations, parallel laminations; interlayered with approximately 20% argillite and silty argillite, finely laminated, mud cracks, commonly with silt lenticles; graded siltstone-argillite couplets.	5.2	44.1
15	siltstone, thin to medium bedded, crossbeds, massive or thinly laminated.	4.5	38.9
14	siltstone, thin bedded, ripple crosslaminated, minor scours, thinly laminated; interbedded with silty argillite, dark grey, mud cracks; siltstone-argillite couplets, thin bedded.	1.2	34.4
13	quartzite, thick bedded at base, broad channels, graded beds common with crossbedding at base, planar laminations to irregular laminations near centre and ripple crosslaminations at top; silty quartzite near top, ripple crossbedded, gradational contact with unit 14, forming a fining-upward sequence.	5.2	33.2
12	covered.	1.5	28.0
11	siltstone, thin bedded, massive, or graded beds with laminated bases and ripple crosslaminated tops; silty argillite interbeds.	1.5	26.5
10	quartzite, white, thin bedded to medium bedded, broad scours; graded beds common with crossbedding at base and parallel laminations near base.	1.8	25.0
9	quartzite, silty, thin bedded, commonly graded, channels; siltstone-argillite graded couplets, very thin bedded, comprise 10% of unit; quartzite, thin bedded, graded, some crossbedding.	2.7	23.2
8	quartzite, silty, coarser grained than unit 9, medium bedded, massive to graded beds; minor siltstone, thin bedded, some ripple crosslaminations.	4.5	20.5
7	quartzite, white, thick to very thick bedded, generally massive to discontinuous wavy bedded, broad channels, minor crossbedding; occasional thin siltstone partings; units 7 to 9 form a fining-upward sequence.	5.5	16.0
6	siltstone, thin to medium bedded, graded beds with wavy to irregular laminations at base and massive to finely laminated siltstone at top; argillite, minor partings.	0.9	10.5
5	quartzite, pure to feldspathic, medium to thick bedded, massive to faint irregular laminations, occasional reverse grading, minor ripple crosslaminations; rare siltstone partings.	3.3	9.6
4	quartzite, silty, thin bedded at base, coarsening upward to quartzite, thick bedded with broad channels, low-angle crossbedding and herringbone crossbedding; rare siltstone laminations near base.	2.1	6.3
3	quartzite, silty, thin bedded, low-angle crossbedding, graded and reverse graded beds.	1.5	4.2
2	quartzite, medium bedded, generally massive, broad scours, faint tangential crossbedding near tops of beds.	1.5	2.7
1	quartzite, white, medium bedded, coarse (1 mm) grained, occasional crossbeds, broad scours, occasional argillite partings; units 1 to 3 form a coarsening-upward cycle.	1.2	1.2

Fort Steele Formation; Lazy Lake

Location: 3.5 km west of Lazy Lake, elev. 975 m (3200 ft); NTS Skookumchuck 82G/13E; UTM grid 595400E-5519525N (base) to 595800E-5519400N (top)

Measured by T. Höy (1978), field section H78E55

Unit	Description	Thickness (metres)	Height above base (metres)
Fort Steele Formation (651.0 m - incomplete)			
30	quartzite, rusty weathering, poorly exposed.	6.0	651.0
29	covered.	17.8	645.0
28	siltstone, thin bedded, lenticular bedded; interlayered with argillite, dark brown, laminated; minor silty quartzite, thick to medium bedded.	30.0	627.2
27	covered.	24.0	597.2
26	quartzite, medium bedded, graded, planar-tabular, crossbedded or massive; graded quartzite-siltstone beds at top of unit.	7.6	573.2
25	covered.	13.7	565.6
24	quartzite, medium bedded, planar-tabular surfaces, crossbedded (partially covered).	6.0	551.9
23	covered.	9.0	545.9
22	quartzite, white, thick bedded, massive, irregular, commonly scoured surfaces.	6.1	536.9
21	covered.	29.0	530.8
20	quartzite, white, very thick bedded; coarse grained, even to discontinuous bedded, occasional large high-angle crossbeds, not graded.	9.1	501.8
19	covered.	30.0	492.7
18	quartzite, thick bedded, broad channels, discontinuous beds, massive or with trough crossbeds	30.0	462.7
17	quartzite, silty, interlayered with thin-bedded siltstone at base of unit, lenticular bedded; grades upward into silty quartzite, thin to medium bedded, planar bedded, with tangential crossbedding; quartzite, medium bedded at top of unit, broad scours, high-angle crossbeds, or massive.	26.0	432.7
16	siltstone (feldspathic) interbedded with argillite; graded siltstone-argillite couplets, thin bedded, with mud-cracked surfaces; silt scours cutting argillite are common, lenticular bedding.	13.7	406.7
15	diorite sill, green, fine grained.	15.0	393.0
14	covered.	62.5	378.0
13	quartzite, silty, thin bedded, thinly laminated, minor ripple crosslaminations; siltstone, light brown, thin bedded, commonly graded with dark grey argillite tops.	62.0	315.5
12	quartzite, feldspathic, thick bedded, brown weathering, tangential and trough crossbedding.	7.6	253.5
11	quartzite, feldspathic, medium bedded, brown weathering, tangential crossbedding and ripple crosslaminations.	18.3	245.9
10	quartzite, feldspathic, thick bedded, large trough and planar crossbeds.	4.6	227.6
9	covered.	7.6	223.0
8	quartzite, medium bedded, even-parallel beds with parallel laminations, ripple crossbeds, tangential crossbeds; quartzite, thick bedded, massive or trough crossbedding.	7.6	215.4
7	covered.	9.0	207.8
6	quartzite, silty (?), thick bedded, massive, some large tangential crossbeds (partially covered).	16.8	198.8
5	quartzite, white, thick bedded, massive, or large-scale crossbedding (partially covered); somewhat thinner bedded and finer grained at top.	25.9	182.0

4	quartzite, thin to medium bedded, tangential and trough crossbedding common; thinner bedded, more silty quartzites near top; thick bedded, massive or trough crossbedded quartzite near base; unit 4 is a gradational fining-upward sequence.	27.4	156.1
3	quartzite, feldspathic, brown weathering, generally massive.	107.0	128.7
2	quartzite, medium to thick bedded with planar and tangential crossbedding.	6.7	21.7
1	quartzite, light to dark grey, thick bedded, abundant trough crossbedding that grades upward to ripple crosslaminated bedding, broad scours, climbing ripples, reverse graded bedding is common; siltstone, thin bedded, interlayered with quartzite, mud-chip breccias, silt scours.	15.0	15.0

Fort Steele Formation, Aldridge Formation; Mount Bill Nye

Location: Mount Bill Nye, north of Herbert and Tackle creeks, elev. 1082 m (3550 ft) at base; NTS Cranbrook 82G/12; UTM grid 598200E-5509925N (base) to 602600E-5513350N (top)

Measured by T. Höy (1978), field sections H78E58, H78E62

Unit	Description	Thickness (metres)	Height above base (metres)
Aldridge Formation (3058.6 m)			
Unit PCa3 (upper Aldridge) (324.5 m)			
106	argillite, silty, dark grey, rusty weathering, containing minor light green silt lenticles; siltstone-argillite graded beds, buff to pink, approximately 1 cm thick, lenticular bedded; minor light green, graded siltstone.	131.0	4 286.8
105	generally covered; dark grey argillite scree.	117.3	4 155.8
104	argillite, dark grey, massive to faintly laminated; scattered outcrops.	76.2	4 038.5
unit PCa2 (564.4 m)			
103	siltstone, buff, massive, sharp contact with unit 104.	24.4	3 962.3
102	quartzite, silty, and siltstone, light brown, buff weathering, medium bedded, flute casts, massive near base of beds with ripple crosslaminated tops.	13.7	3 937.9
101	siltstone, argillaceous, buff coloured to light green; minor argillite, dark grey.	41.1	3 924.2
100	covered; massive siltstone scree.	61.0	3 883.1
99	siltstone, light grey, buff weathering, thin bedded, massive to faintly laminated.	76.2	3 822.1
98	quartzite, silty, medium to thick bedded, commonly graded with dark grey argillite tops.	38.1	3 745.9
97	siltstone and silty quartzite, medium bedded, commonly graded; interbedded with siltstone, buff to pale green, thin bedded and laminated.	82.3	3 707.8
96	covered; buff-weathering siltstone scree.	16.8	3 625.5
95	siltstone, argillaceous, light brown, thin bedded; minor quartzite, medium bedded, graded.	15.2	3 608.7
94	argillite, dark grey; siltstone, light brown to pale green, laminated, minor quartzite, medium to thick bedded, massive to graded.	29.0	3 593.5
93	quartzite, light grey, thick bedded, generally massive, with thin argillite partings; siltstone, medium bedded, buff weathering near base of unit.	33.5	3 564.5
92	argillite, dark grey, rusty weathering, massive to faintly laminated.	76.2	3 531.0
91	quartzite, light grey, thick bedded; grading upward through unit into quartzite, silty, buff weathering, finer grained, medium bedded with dark grey argillite partings.	4.6	3 454.8
90	argillite, dark grey, rusty weathering; with some siltstone, buff weathering, medium bedded, massive layers.	21.3	3 450.2
89	siltstone and arkosic wacke; light grey to green, medium to thick bedded, generally massive or graded; minor light green argillite interlayers.	4.6	3 428.9
88	argillite, dark grey, massive to faintly laminated.	8.2	3 424.3
87	feldspar porphyry dike, pink, aphanitic groundmass.	3.0	3 416.1
86	siltstone, buff coloured, thick bedded; interlayered with dark grey argillite and silty, laminated argillite.	15.2	3 413.1
unit PCa1f (294.8 m)			
85	argillite, dark grey; minor siltstone, buff coloured, generally massive, somewhat granular.	35.0	3 397.9
84	argillite, dark grey; interlayered with siltstone, buff coloured, somewhat dolomitic, massive or containing numerous sedimentary structures including ripple crosslaminations, well-layered graded beds, lenticular bedding with dolomitic buff siltstone lenticles in darker grey argillaceous siltstone or argillite.	53.3	3 362.9

83	argillite, dark grey, rusty weathering.	18.3	3 309.6
82	siltstone, buff coloured, laminated or massive, dolomitic in part, mud-chip breccias, graded beds, ripple crosslaminations are common.	12.2	3 291.3
81	quartz wacke, quartz arenite, medium to thick bedded; siltstone, buff coloured, medium bedded, generally massive to graded, interbedded with argillaceous siltstone, green, laminated to massive at top of unit; unit 81 is a fining-upward sequence.	9.1	3 271.9
80	siltstone, buff coloured.	6.0	3 270.2
79	argillite, dark grey to black, laminated.	30.5	3 264.0
78	argillite, dark green, massive to faintly laminated.	24.4	3 233.5
77	argillite, dark grey, parallel laminated, interbedded with siltstone, light brown, medium bedded, massive to faintly laminated; minor quartz wacke layers approximately 30 cm thick, massive.	30.5	3 209.1
76	argillite, dark grey, rusty weathering, laminated; minor buff-weathering argillaceous and dolomitic siltstone layers.	13.7	3 178.6
75	argillite, silty, medium grey, laminated; interbedded with buff-weathering argillaceous and dolomitic siltstone.	22.8	3 164.9
74	siltstone, feldspathic wacke, green to brown tinged, thick to very thick bedded, commonly graded; minor siltstone, thin bedded and laminated.	13.7	3 142.1
73	siltstone, buff to medium grey weathering, generally massive.	24.4	3 128.4
72	porphyritic feldspar dike.	0.9	3 104.0

unit PCa1d (283.4 m)

71	siltstone, massive, thick bedded, slightly dolomitic; interlayered dark argillite and laminated dolomitic siltstone.	32.9	3 103.1
70	porphyritic feldspar dike.	1.2	3 070.2
69	dolomitic argillite and siltstone, buff weathering, dark grey, laminated argillite.	42.7	3 069.0
68	dolomitic siltstone, buff weathering.	6.0	3 026.3
67	dolomitic siltstone; quartzite, graded beds with rip-up clasts at base.	15.2	3 020.3
66	feldspathic arenite, quartz arenite, light grey to white, generally massive, thick bedded, with rare flute casts; grades upward to 3 m of laminated, buff-weathering dolomitic siltstone; (unit PCa1e).	19.8	3 005.1
65	dolomitic siltstone, buff weathering, thick bedded, interbedded with dark grey, laminated argillite.	19.8	2 985.3
64	dolomitic siltstone, buff weathering, medium bedded.	10.7	2 965.5
63	porphyritic feldspar-hornblende dike.	2.4	2 954.8
62	dolomitic siltstone, argillite, thinly laminated.	22.8	2 952.4
61	dolomitic siltstone, buff weathering, minor graded siltstone-argillite beds.	20.0	2 929.6
60	siltstone, grey weathering to buff weathering, dolomitic in part.	53.3	2 909.6
59	dolomitic siltstone, buff weathering; ripple crosslaminated, tangential crossbeds, silt scours, irregular discontinuous laminations, graded beds; argillite beds grading up to dolomitic argillite are common; lenticular bedded.	36.6	2 856.3

unit PCa1c (1399.5 m)

58	siltstone, buff to grey weathering, thin bedded and parallel bedded; massive, rusty weathering, grey siltstone near top.	106.7	2 819.7
57	porphyritic feldspar dike.	6.1	2 713.0
56	siltstone, grey to slightly buff weathering, thin to medium bedded, generally massive or with faint irregular laminations.	22.9	2 706.9
55	siltstone, grey to slightly buff weathering, thin to medium bedded; interlayered with minor dark grey laminated argillite; basal half of unit is predominantly argillite, rusty weathering, lenticular bedded with grey siltstone laminations, grey to buff weathering, ripple crosslaminated.	126.5	2 684.0
54	siltstone, grey to buff weathering, medium to thick bedded, minor ripple crosslaminations in thinner beds.	50.3	2 557.5
53	argillaceous siltstone, grey, blocky, thin bedded, minor lenticular bedding; rare thin, dark limestone layers; grades upward into dark grey, rusty weathering laminated argillite with only minor blocky argillaceous siltstone.	134.1	2 507.2
52	fault zone, sheared, calcite veining; thin porphyritic dike.	1.5	2 373.1

51	siltstone, grey, with fine white laminations; rare silty lenticular bedding.	7.6	2 371.6
50	argillite, dark grey to medium grey, rusty weathering, massive to finely laminated.	94.5	2 364.0
49	siltstone, grey to tan coloured; interlayered with dark grey argillite; at 1051 m, limestone, limestone pods in siltstone, irregular (algal ?) laminations, crossbedding.	35.0	2 269.3
48	argillite, well bedded, dark grey, rusty weathering.	71.6	2 234.5
47	limestone, dark grey to black; dolomite; silty dolomite; dolomitic siltstone; massive siltstone; limestone rip-up clasts in silty matrix.	18.9	2 162.9
46	siltstone, light green, massive, thin to medium bedded, hornfelsed.	45.7	2 144.0
45	Moyie sill - gabbro.	27.4	2 098.3
44	siltstone, hornfelsed.	6.1	2 070.9
43	Moyie sill - gabbro.	205.0	2 064.8
42	siltstone, pink to light grey to green (hornfelsed), laminated.	107.0	1 859.8
41	dike, felsic, aphanitic.	1.5	1 752.8
40	calcareous and dolomitic siltstone, grey to buff weathering, crosslaminated; calcareous argillite, dark grey, with cleavage commonly formed by thin discontinuous white calcite veinlets.	61.0	1 751.3
39	argillite, shale, black, calcareous in part, pyritic.	134.0	1 690.3
38	partly covered; few outcrops of black shale, argillite.	60.0	1 556.3
37	argillite, shale, black, massive or thinly laminated, carbonaceous, well bedded.	70.0	1 496.3
36	dike, felsic.	1.5	1 426.3
35	covered.	4.6	1 424.8
unit PCa1b (51.8 m)			
34	dolomitic siltstone, green, even-parallel bedding, generally massive; chert, thin bedded, well layered or as pods in dolomitic siltstone.	51.8	1 420.2
unit PCa1a (140.2 m)			
33	siltstone, buff weathering, very fine laminations.	27.4	1 368.4
32	dike, felsic.	25.9	1 341.0
31	siltstone, dark grey, very thin bedded, laminated, commonly forms thin graded siltstone-argillite couplets.	86.9	1 315.1
30	argillite, dark grey, somewhat silty, lenticular bedding, abundant mud cracks (or syneresis dewatering structures); graded siltstone-argillite couplets.	96.0	1 228.2
29	quartz arenite, white, massive, thick bedded; somewhat thinner bedded and finer grained at top.	6.1	1 132.2
28	quartz arenite, white, massive, very thick to thick bedded.	6.0	1 126.1
27	quartz wacke, buff coloured, medium bedded, some trough crossbeds and scour channels; interbedded with dark grey argillite; mud cracked, lenticular bedded; graded siltstone-argillite couplets.	53.3	1 120.1
26	argillite, dark grey, thin bedded, abundant mud cracks, silt scours, graded couplets, silt lenticles; siltstone, thin bedded, tan coloured.	64.0	1 066.8
25	argillite, dark grey, graded beds, mud cracks, silt scours.	32.0	1 002.8
24	argillite, black, lenticular bedded, interlayered with thin-bedded silty quartzite, forms base of unit; these coarsen upward to thin-bedded quartz wacke, then thin to medium-bedded tangentially crossbedded quartz wacke and arenite; top two-thirds of unit fines upward to thin-bedded, tangentially crossbedded quartz wacke and siltstone.	39.6	970.8
23	quartz arenite, white to tan, thick bedded, with abundant crossbedding, rare argillite partings.	30.5	931.2
22	covered.	13.7	900.7
21	quartz arenite, white, grey, green tinged, medium to thick bedded; abundant crosslaminations, tangential crossbeds, wavy non-parallel bedding (broad channels); minor interlayered siltstone.	40.0	887.0
20	covered.	16.8	847.0
19	quartz arenite, white, thick bedded; similar to unit 21.	27.4	830.2

18	covered	7.6	802.8
17	quartz arenite; similar to unit 21 above; fairly abrupt change from unit 16 below.	50.3	795.2
16	siltstone, buff coloured, crosslaminated; interlayered with argillite, dark grey, containing abundant silt lenticular beds.	70.1	744.9
15	siltstone-argillite, similar to unit 16 above; grades upward to predominantly argillite, mud cracks; lenticular silt beds, interlayered with minor thin-bedded siltstone, crosslaminated.	61.0	674.8
14	argillite, black, mud cracks abundant; with minor thin-bedded siltstone, ripples, crosslaminations.	25.9	613.8
13	fining-upward unit (to include unit 14 at top), from 2-3 m of quartz arenite, thick bedded, massive; to medium-bedded quartz arenite and wacke, parallel laminations, tangential crossbeds; to quartz wacke and siltstone, thin bedded with thin black argillite interlayers.	36.6	587.9
12	argillite, dark grey to black, abundant mud cracks, lenticular silt beds, silt scours; siltstone-argillite graded beds, thin bedded; siltstone, thin bedded, cross-laminations.	21.3	551.3
11	quartz arenite, light grey to white, very thick bedded, generally massive, broad irregular surfaces defining channels.	30.5	530.0
10	quartz arenite, medium to thick bedded, non-parallel bedding surfaces, massive or with broad tangential crossbeds, trough crossbeds.	25.9	499.5
9	quartz arenite, quartz wacke, white to grey, thick to medium bedded, irregular bedding surfaces, tangential and trough crossbeds,. rare rippled surfaces, commonly massive; siltstone interlayers near top.	54.8	473.6
8	quartz arenite, white, very thick to thick bedded, irregular indistinct bedding surfaces, large irregular tangential and trough crossbeds with steeply inclined (30-40°) foreset beds.	106.7	418.8
7	covered.	213.4	312.1
6	quartz arenite, thick to medium bedded at base, crossbeds; largely covered in top part.	13.8	98.7
5	covered.	6.0	84.9
4	quartz arenite, thick bedded, irregular indistinct bedding surfaces, broad trough crossbeds.	36.6	78.9
3	quartz wacke and arenite, feldspathic arenite, medium to thick bedded, parallel-laminated beds alternate with planar-tabular crossbeds, minor trough crossbeds.	9.0	42.3
2	quartz arenite, feldspathic arenite, medium bedded, planar-tabular crossbeds, tangential crossbeds; unit coarsens upward.	25.8	33.3
1	feldspathic arenite, dark grey, thick to medium bedded, parallel laminations, planar and tangential crossbeds; coarsening-upward beds with sharp lower contact, tangential crossbeds at base, and parallel laminations at top are common.	8.0	8.0

Aldridge Formation; Wasa Creek Section

Location : 1.3 km north-northwest of confluence of Wasa Creek and Wolf Creek, elev. 1520 m (5000 ft) at base; NTS Skookumchuck 82G/13E; UTM grid 598750E-5523770N (base) to 601760E-5525400N (top)

Measured by T. Höy (1978), field section H78E63

Unit	Description	Thickness (metres)	Height above base (metres)
Creston Formation (219.5 m - incomplete)			
38	quartzite, white, thin to medium bedded, generally massive; minor siltstone, green.	22.9	2 107.4
37	argillite, dolomitic, buff weathering; interlayered with siltstone, green, laminated.	16.8	2 084.5
36	argillaceous siltstone, grey-green, thin bedded, laminated to massive; argillite, dark grey, with greater than 50% siltstone lenses and layers.	91.4	2 067.7
35	siltstone-argillite graded beds, thin bedded, green to grey; dolomitic siltstone.	61.0	1 976.3
34	siltstone, light green, very thin to thin bedded, interlayered with argillite, dark grey, mud cracks; siltstone-argillite graded beds common.	27.4	1 915.3
Aldridge Formation (1887.9 m - complete)			
unit PCa3 - upper Aldridge (173.4 m)			
33	argillite, dark grey, rusty weathering, occasional green siltstone interlayers; 3 m of buff to pink-weathering dolomitic siltstone at base.	61.0	1 887.9
32	argillite, dark grey, rusty weathering; rare green siltstone laminations.	61.0	1 829.6
31	argillite, similar to unit 32; thin bedded, siltstone layers and lenses are common.	30.0	1 765.9
30	siltstone, thick bedded, with dark grey argillite interbeds.	10.7	1 735.9
29	covered (argillite scree).	10.7	1 725.2
unit PCa2 (242.2 m)			
28	quartz wacke, medium to thick bedded, basal scours, load casts and flute casts; thin-bedded siltstone and silty argillite interbeds (comprises approximately 20% of unit 28).	77.7	1 714.5
27	argillite, dark grey, rusty weathering; minor siltstone layers.	18.3	1 636.8
26	quartz wacke, thin bedded; argillite, dark grey, rusty weathering (approximately 35% of unit 26).	33.5	1 618.5
25	generally covered; few outcrops of thin-bedded siltstone and black argillite.	70.0	1 585.0
24	argillite, black, rusty weathering, laminated.	6.1	1 515.0
23	feldspathic arenite, thick bedded, massive; minor siltstone, light grey, laminated; unit 23, fines upward to feldspathic wackes, thin to medium bedded, with increasingly greater proportion of interbedded siltstone and silty argillite.	36.6	1 508.9
unit PCa1f (553.9 m)			
22	argillite, black, generally rusty weathering; green siltstone lenses and layers common near base.	204.2	1 472.3
21	siltstone, tan weathering, well layered; medium bedded; three quartz arenite layers, 30-40 cm thick, occur near base.	32.0	1 268.1
20	argillite, dark grey, rusty weathering, thinly laminated, in 12-15 m thick sections; argillaceous and dolomitic siltstone, buff weathering, with green silt lenses and layers, scours, graded beds.	240.0	1 236.1
19	argillite, dark grey to black, finely laminated to irregular bedded, minor graded siltstone-argillite lenses; minor buff-weathering dolomitic siltstone and argillite.	77.7	996.1

unit PCa1d (342.6 m)

18	siltstone, argillaceous siltstone, thin bedded, grey to buff weathering, somewhat dolomitic, thinly laminated, massive, or graded siltstone-argillite layers; rare crosslaminations, scours.	67.0	918.4
17	silty argillite, light brown to pink, thin bedded, thin parallel laminations and thin wavy laminations, scours at base of unit; argillaceous siltstone, dark grey-brown, thinly laminated; siltstone, pink, massive, thin bedded, minor graded beds, scours; feldspathic wacke (2 m thick), white to pink tinged, massive to thinly laminated, medium bedded.	137.0	851.4
16	siltstone, pink tinged, massive to finely laminated, contains rusty weathering dolomitic siltstone pods with crossbeds.	103.6	714.4
15	argillaceous and dolomitic siltstone, buff weathering, thin bedded, thin wavy laminations, graded beds, tangential crossbeds, silt scours, lenticular beds, brown-weathering dolomitic siltstone pods.	35.0	610.8

unit PCa1c (325.9 m)

14	partially covered; argillite, dark grey, rusty to grey weathering, thinly laminated, silty in part.	45.7	575.8
13	argillite, dark grey to black, rusty weathering, laminated with abundant irregular and discontinuous white calcite streaks.	91.4	530.1
12	argillite, light to medium grey, well-defined thin beds, thinly laminated; thin interbeds of tan-coloured graded siltstone layers and lenses.	48.8	438.7
11	argillite, phyllite, dark grey, rusty weathering, sections are very carbonaceous, massive to thinly laminated.	140.0	389.9

unit PCa1b (158.5 m)

10	argillite, medium to dark grey, with thin irregular laminations of dolomite; up section, dolomitic and limy layers 3-4 cm thick are common.	61.0	249.9
9	argillite, light green to buff coloured, dolomitic, soft and fissile; argillite, dark grey, brown weathering, massive, with thin irregular laminations and pods of calcite.	13.7	188.9
8	dolomite, argillaceous, brown weathering, thinly laminated.	13.7	175.2
7	shale, light grey-green, very thin bedded, buff to brown weathering, with thin dolomite partings; interbedded with thinly laminated argillaceous dolomite; grades upward from predominantly shale at base to carbonate at top.	15.2	161.5
6	quartzite, white (vein ?), widely spaced layering with thin shale horizons; includes angular, irregular disoriented fragments of brown-weathering dolomite.	7.6	146.3
5	argillite, black, thinly laminated, no carbonate, white quartz 'sweats' are common.	7.6	138.7
4	argillaceous dolomite, buff to brown weathering, thick laminations; argillite, light grey-green; thin (1-2 cm) chert layers are interlayered with dolomite and argillite.	16.8	131.1
3	dolomitic siltstone, grey, buff to brown weathering, thin bedded, thinly laminated to irregularly laminated; argillite, grey-green, thin bedded, is interlayered with dolomitic siltstone; dolomite and dolomitic siltstone increases higher in unit at expense of siltstone; dark brown weathering silty dolomite pods occur near top.	22.9	114.3

unit PCa1a (91.4 m)

2	argillite, grey-green to dark grey higher in unit, massive to thin to very thin laminations.	45.7	91.4
1	quartz wacke, dark grey; siltstone, dark grey, rusty weathering, dolomitic cement; argillite, medium grey-green, massive to laminated, medium bedded; argillaceous siltstone, thin bedded, commonly graded, even-parallel laminations, some lenticular beds.	45.7	45.7

Lower Aldridge – Middle Aldridge Contact; Rabbit Foot Creek

Location: Rabbit Foot Creek area, straddling the Moyie Lake sheet (82G/5) and the Grassy Mountain sheet (82F/8); UTM grid 572900E-5462200N, elev. 1930 m (6340 ft) at base, to 572400E-5463100N at top

Measured by T. Höy (1983), field section H83M60

Unit	Description	Thickness (metres)	Height above base (metres)
Middle Aldridge (178.5 m - incomplete)			
45	Moyie sill – massive, medium to coarse-grained diorite.	33.0	618.0
44	largely covered; quartz wacke, thick bedded, occurs near base and at top.	21.0	585.0
43	Moyie sill – massive, medium to coarse-grained diorite; basal contact shows evidence of soft-sediment deformation, including flame structures, load structures, and diorite fragments in quartzite matrix; large amphibole crystals and quartz veining also occur at base of diorite.	4.5	564.0
42	quartz wacke, rusty weathering, thin to medium bedded, graded with siltstone tops, generally laminated (DE and AD turbidites).	9.0	559.5
41	quartz wacke, grey, thick bedded, commonly graded with laminated siltstone at top (AD turbidites); top of unit, thinner bedded (DE turbidites).	7.5	550.5
40	quartz wacke, siltstone, thin bedded, grey, recessive weathering.	6.0	543.0
39	quartz arenite, quartz wacke, thick bedded, grey, commonly graded; siltstone, somewhat rusty weathering, laminated.	13.5	537.0
38	gap.	10.5	523.5
37	quartz arenite, grey, medium to thick bedded, braided with laminated siltstone tops; siltstone, thin bedded, laminated.	6.0	513.0
36	gap.	3.0	507.0
35	quartz wacke, grey, medium bedded; minor siltstone, thin bedded, rusty weathering, laminated; latter is more pronounced at top of unit.	13.5	504.0
34	quartz wacke, siltstone, grey to rusty weathering, thin to medium bedded, laminated; occasional grey quartz wacke beds 15 cm thick.	15.0	490.5
33	quartz wacke, grey to rusty weathering, thin bedded; siltstone (approximately 10%), thin bedded, rusty weathering, laminated.	12.0	475.5
32	similar to unit 33; occasional grey quartz wacke beds 15-20 cm thick.	3.0	463.5
31	siltstone, grey, rusty weathering, thin bedded; occasional graded, rusty weathering wacke beds 8-10 cm thick.	10.5	460.5
30	siltstone, argillaceous, medium grey, well laminated; phyllite; grades up section to a grey quartz wacke unit 1 m thick, thick bedded.	4.5	450.0
29	quartz wacke, grey, medium to thick bedded, graded beds; minor argillaceous siltstone, dark to medium grey, laminated.	6.0	445.5
Lower Aldridge (439.5 m - incomplete)			
28	siltstone, rusty weathering, thin bedded; occasional thin (7-10 cm) rusty weathering quartz wacke beds.	6.0	439.5
27	quartz wacke, grey, graded, very thick bedded.	1.5	433.5
26	quartz wacke, grey, grey weathering, thick bedded near base (420-425 m); quartz wacke, siltstone, rusty weathering, graded beds, interlayered with few thin (15-20 cm) grey quartz wacke beds (425-428 m); siltstone, rusty weathering, grey, thin bedded, cleaved, graded beds at top (428-432 m); unit 26 is a fining and thinning-upward sequence.	15.0	432.0
25	quartz wacke, quartz arenite; light grey weathering; thick bedded at base, grading upward to siltstone, rusty weathering, thin bedded at top.	4.5	417.0
24	siltstone, grey, rusty weathering, thin to medium bedded.	4.5	412.5
23	gap.	10.5	408.0
22	siltstone, light grey to rusty weathering, massive to vague irregular bedding, structurally deformed; very minor argillite, dark grey, thinly laminated.	52.5	397.5

21	siltstone, argillaceous, rusty weathering, thin to medium bedded, vague discontinuous wavy bedding.	30.0	345.0
20	scattered outcrop; quartz wacke and argillaceous siltstone similar to unit 21.	16.5	315.0
19	quartz and feldspathic wacke, rusty weathering, thick, but irregular and discontinuous bedding, irregular non-parallel laminations; siltstone, grey, rusty weathering, thin bedded with few thick-bedded, grey quartz wacke beds at top of unit.	13.5	298.;5
18	siltstone, grey, rusty weathering, thick bedded, discontinuous vague bedding, thin laminations to massive; minor thin-bedded, graded siltstone; gap from 265.5 to 277.5 m.	48.0	285.0
17	gap.	13.5	237.0
16	quartz and feldspathic wacke, generally rusty weathering, graded with laminated siltstone tops; phyllite, rusty weathering, crenulation cleavage imposed on sericite foliation.	13.5	223.5
15	siltstone, grey, rusty weathering, even medium bedded, massive.	9.0	210.0
14	quartz wacke, grey to slightly rusty weathering, thick bedded, non-graded, massive; siltstone interbeds, grey, rusty weathering, thin bedded.	10.5	201.0
13	siltstone, grey, medium bedded; siltstone, rusty weathering, thin bedded.	10.5	190.5
12	Moyie sill - diorite, medium grained, massive, generally pervasive chlorite alteration; sharp contact with overlying siltstone; 60 cm chilled, finer grained, more mafic margin at top.	19.5	180.0
11	gap.	12.0	160.5
10	quartz wacke, grey, thick bedded, massive to vague irregular laminations.	3.0	148.5
9	siltstone, very rusty weathering, thin bedded, commonly graded, occasional crossbeds.	7.5	145.5
8	siltstone, grey, very rusty weathering, thin bedded and well cleaved (crenulation cleavage imposed on sericite foliation); grades up through fine-grained quartz and feldspathic wacke, grey, medium bedded; to thick-bedded grey quartz wacke at top of unit.	18.0	138.0
7	siltstone, feldspathic wacke, white to rusty weathering, medium bedded, parallel to discontinuous irregular laminations, crossbeds.	3.0	120.0
6	siltstone, rusty weathering, thin bedded, laminated, recessive weathering.	19.5	117.0
5	quartz wacke, rusty weathering, thick bedded at base; grades up through siltstone, rusty weathering, well cleaved with interbeds of quartz wacke 15-20 cm thick; to thin-bedded, very rusty weathering, massive to laminated siltstone.	19.5	97.5
4	siltstone and phyllite, rusty weathering, thin bedded, interbedded with rusty weathering feldspathic wacke 5-8 cm thick.	4.5	78.0
3	quartz wacke, grey, rusty weathering, medium bedded, massive to graded; minor siltstone, thin bedded, laminated; (AE turbidites).	18.0	73.5
2	quartz and feldspathic wacke, grey, rusty weathering, medium bedded with well-defined bedding planes, massive to laminated; siltstone, rusty weathering, massive to only faintly laminated throughout, but more pronounced at top; crenulation cleavage and early foliation are pronounced.	37.5	55.5
1	siltstone, quartz wacke, grey, rusty weathering, thin to medium bedded, graded with finer grained laminated siltstone tops; phyllite, crenulation cleavage.	18.0	18.0

'Kootenay King Quartzite', Middle Aldridge Formation; Lakit Mountain

Location : 1 km east of Lakit Mountain; NTS Cranbrook 82G/12;UTM grid 601550E-5507800N, elev. 2286 m (7500 ft) at base to 602250E-5508200N, elev. 1980 m (6500 ft) at top

Measured by T. Höy (1978), field section H78E75

Unit	Description	Thickness (metres)	Height above base (metres)
Kootenay King Member, Middle Aldridge Formation (250.9 m - incomplete)			
16	argillite, dark grey, medium bedded, generally massive, or graded with silty argillite at base and black argillite at top.	16.8	250.9
15	argillite, dark grey, well layered; argillaceous siltstone (largely covered).	13.7	234.1
14	quartz arenite, wacke, dark grey, massive.	9.7	220.4
13	largely covered; siltstone, dark grey to tan coloured in scree.	9.8	210.7
12	quartz arenite, wacke, dark grey, generally massive.	8.2	200.9
11	covered; dark grey quartzite and siltstone scree.	9.1	192.7
10	quartz arenite, white to tan coloured, well bedded to irregular bedded surfaces; quartz wacke, generally tan coloured, medium bedded at base of unit.	6.1	183.6
9	gabbro/diorite sill.	1.5	177.5
8	quartz wacke, medium grey, thin to medium bedded; minor siltstone.	13.7	176.0
7	argillite, dark grey, laminated; minor dolomitic siltstone, medium grey, buff to grey weathering.	54.9	162.3
6	quartz arenite, wacke, dark grey, medium bedded.	22.9	107.4
5	siltstone, buff coloured.	35.0	84.5
4	quartz arenite, white, thick bedded; fines upward through thinner bedded quartz wacke to siltstone of unit 5.	6.1	49.5
3	fining-upward unit; basal 4 m - quartz arenite, white, massive, with no discernible bedding surfaces; grades upward through quartz wacke and siltstone, buff coloured, massive to medium to thick bedded, to fissile, laminated shale at top.	12.2	43.4
2	quartz arenite, wacke, dark grey, thick bedded, graded beds with dark grey, fissile, laminated tops; breccia with large (to 30 cm) angular siltstone and argillite clasts suspended in medium to coarse-grained quartz wacke.	5.2	31.2
1	siltstone, buff coloured, ripple crosslaminated, massive or well laminated.	26.0	26.0

Moyie Sill, Middle Aldridge Formation; Lumberton

Location: Just east of Highway 3/95 at turn-off to Lumberton 13 km south of Cranbrook, elev. 1006 to 1160 m (3300 to 3800 ft); NTS Moyie Lake 82G/5; UTM grid 582000E-5475200N at base to 582200E-5475400N

Measured by T. Höy (1983), field section H83M61

Unit	Description	Thickness (metres)	Height above base (metres)
13	siltstone, quartz wacke, thick bedded, generally massive, interbedded with dark grey argillaceous siltstone.	146.25	438.75
12	covered	84.0	292.5
Moyie sill (66.0 m)			
11	gabbro, coarse grained with bladed hornblende crystals several centimetres long; gabbro becomes finer grained near top, with a chilled margin from 204-208.5 m.	13.5	208.5
10	gabbro, medium grained, to coarse grained at top; abundant quartz-calcite veining.	6.0	195.0
9	gabbro, variable grain size; commonly hydrothermally altered with associated quartz-calcite veining; sharp irregular basal contact with a very coarse grained phase at contact; vertical fractures with quartz-calcite veining and associated hydrothermal alteration cut across sill.	46.5	189.0
8	siltstone, wacke, medium to thin bedded, graded; hornfelsed; biotite overgrows cleavage.	6.0	142.5
7	covered (gabbro ?)	29.25	136.5
6	siltstone, argillaceous, thin bedded, dark grey; occasional medium-bedded wacke; euhedral biotite cuts across cleavage.	14.25	107.25
5	covered.	60.0	93.0
4	argillite, silty, dark grey, well cleaved.	3.0	33.0
3	quartz arenite, quartz wacke, massive, thick bedded.	7.5	30.0
2	quartz wacke, massive, thick bedded; interbedded with two thick sections of siltstone, dark grey, well cleaved, with euhedral biotite overgrowths.	9.0	22.5
1	quartz wacke, grey, thick bedded, massive, with well-defined basal flute casts; 350°, 008°, 352° current directions; generally becomes finer grained up section, to siltstone, fine grained, dark grey, thinly laminated, well cleaved.	13.5	13.5

Middle Aldridge, Upper Aldridge; Midway Mine Area

Location: 3.5 km west of south end of Moyie Lake above Midway mine; NTS Moyie Lake 82G/5; UTM grid 580750E-5456200N, elev. 1506 m (4940 ft) at base; 580150E-545700N, elev. 1768 m (5800 ft) at top

Measured by T. Höy (1982), field section H82M5

Unit	Description	Thickness (metres)	Height above base (metres)
Upper Aldridge (421.5 m - complete)			
44	quartz wacke, feldspathic wacke, grey, medium bedded, massive to commonly graded with dark grey argillite tops, syneresis cracks in argillite.	4.5	687.0
43	gap; scattered outcrops of grey siltstone.	9.0	682.5
42	quartz arenite, wacke, grey, fine grained, very thin to thin bedded, massive or graded; siltstone, tan with lenticular coarser siltstone lenses.	3.0	673.5
41	siltstone, grey weathering to somewhat rusty weathering, thin bedded, thinly laminated to massive.	28.5	670.5
40	gap.	51.0	642.0
39	siltstone, medium grey, rusty weathering, generally thin bedded; argillite, dark grey, very thinly laminated, forms partings or layers up to 1 mm thick between siltstone layers; thick (0.6 m) grey siltstone bed with planar-tabular crossbed occurs at 590 m.	6.0	591.0
38	gap.	18.0	585.0
37	siltstone, argillaceous, medium grey, rusty weathering, well bedded, thinly laminated; argillite, dark grey, forms partings and very thin (approximately 1 mm) layers.	52.5	567.0
36	gap.	1.5	514.5
35	siltstone, grey, rusty weathering, very thin to thin bedded with widely spaced light tan lenticular siltstone lenses, 1-2 mm thick.	13.5	513.0
34	siltstone, argillaceous, dark grey, rusty weathering, very thin bedded, lenticular bedded; minor argillite.	54.0	499.5
33	siltstone, argillaceous in part, light to medium grey, rusty weathering, very thin bedded, lenticular bedded.	28.5	445.5
32	quartz wacke, grey, rusty weathering, thin bedded, laminated.	3.0	417.0
31	siltstone, grey, rusty weathering, very thin bedded, graded with fine-grained siltstone or argillite tops; argillaceous siltstone, rusty weathering, laminated.	85.5	414.0
30	argillaceous siltstone, dark grey, rusty weathering, with thin 1-2 mm white siltstone layers.	18.5	328.5
29	siltstone, medium grey, rusty weathering, thin laminations, bedded, graded with thin 1-2 mm dark grey argillite tops, thinly laminated; quartz wacke, grey, thin bedded, graded.	44.5	310.0
Middle Aldridge (265.5 m - incomplete)			
28	quartz wacke, grey, rusty weathering, thin to medium bedded, graded; argillaceous siltstone, dark grey, rusty weathering; minor quartz arenite, grey and thick bedded.	9.0	265.5
27	gap; small exposure of grey quartz wacke at 222 m.	40.5	256.5
26	quartz wacke, grey weathering, thin to medium bedded, minor grading at tops of beds.	3.0	216.0
25	argillaceous siltstone, medium or dark grey, rusty weathering, medium bedded, thinly laminated; minor grey quartz wacke.	12.0	213.0
24	quartz wacke, feldspathic wacke, argillaceous siltstone, rusty weathering, thin to medium bedded.	3.0	201.0
23	quartz wacke, siltstone, grey, rusty weathering, medium to thick bedded near centre of unit.	4.5	198.0
22	argillaceous siltstone, rusty weathering, thinly laminated.	25.5	193.5
21	quartz wacke, siltstone, rusty weathering, thin bedded, commonly graded with argillite tops; minor dark grey, rusty weathering argillite is more pronounced at top.	7.5	168.0

20	gap.	6.0	160.5
19	quartz arenite, grey, thick bedded, massive; grades upward to medium-bedded, rusty weathering quartz wacke; units 19 to 22 form a fining-upward sequence.	4.5	154.5
18	gap.	15.0	150.0
17	siltstone, argillaceous, dark grey, rusty weathering, thin bedded; siltstone, medium grey, forms thin (2-3 cm) lenses.	3.0	135.0
16	gap.	7.5	132.0
15	quartz and feldspathic wacke, medium grey, rusty weathering, thin bedded, laminated; grades upward to argillaceous siltstone, rusty weathering, thinly laminated.	4.5	124.5
14	gap; small exposure of rusty weathering argillaceous siltstone.	7.5	120.0
13	argillaceous siltstone, dark grey; quartz wacke, grey, graded beds; rusty weathering, thin bedded.	3.5	112.5
12	gap.	10.5	109.0
11	argillaceous siltstone, dark grey, rusty weathering, very thin to thin bedded.	1.5	98.5
10	quartz arenite, grey, medium to thick bedded, graded; minor grey siltstone interlayers.	4.5	97.0
9	gap; small (1 m) exposures of interbedded quartz wacke and argillaceous siltstone, rusty weathering, thin bedded.	9.0	92.5
8	quartz arenite, wacke, grey, thick bedded, massive or with thin discontinuous dark argillaceous streaks near tops of beds.	9.0	83.5
7	quartz arenite, grey, medium to thick bedded, massive to minor grading at top of beds; grades up section through quartz wacke, grey, thin to medium bedded, with thin (3-4 cm) dark siltstone interlayers; to argillaceous siltstone, dark grey, rusty weathering, thin to very thin bedded with only 10-20% thin quartz wacke beds; sharp basal contact with unit 6.	19.5	74.5
6	argillaceous siltstone, dark grey, rusty weathering, very thin bedded; very thin dark laminations.	15.0	55.0
5	quartz arenite, wacke, grey, medium to thick bedded, massive or with minor graded tops; interbedded quartz wacke, medium grey, and argillaceous siltstone, rusty weathering, generally thin bedded at top of unit.	17.5	40.0
4	gap.	4.5	22.5
3	quartz arenite, grey, thick bedded, massive at base; quartz wacke, medium bedded, with thin (2-3 cm) siltstone layers at top of unit.	13.5	18.0
2	gap.	3.0	4.5
1	argillaceous siltstone, dark grey, rusty weathering, very thin bedded, laminated; minor medium grey siltstone layers 2-3 cm thick.	1.5	1.5

Creston Formation; Premier Lake

Location: 1 to 2 km north of Premier Lake, elev. approximately 1070 m (3500 ft); NTS Skookumchuck 82G/13; UTM grid 597250E-5533950N at base to 597100E-5535950N at top

Measured by T. Höy (1979), field sections H79E52, H79E59

Unit	Description	Thickness (metres)	Height above base (metres)
Creston Formation (1213.7 m - virtually complete, from basal Creston to near Creston-Kitchener transition zone)			
44	siltstone, pale watery green colour, calcareous, thin bedded, massive in part; poorly exposed.	38	1 213.7
43	silty quartzite, siltstone, green, thin bedded; interbedded with silty argillite, dark grey, laminated.	23.0	1 175.7
42	argillaceous siltstone, dark grey, thinly laminated.	12.2	1 152.7
41	quartzite and siltstone, interbedded, white and light green.	15.2	1 140.5
40	diorite sill, fine to medium grained, generally massive.	80.0	1 125.3
39	quartzite, white to pale green, interbedded with siltstone, green.	7.6	1 045.3
38	covered.	4.6	1 037.7
37	generally covered; some exposures of siltstone, green, generally massive beds, asymmetrical ripple marks; few thin white quartzite layers.	13.7	1 033.1
36	siltstone, green, fine grained, somewhat argillaceous, parallel bedded, small fining-upward cycles.	12.2	1 019.4
35	quartzite, white, thick bedded; siltstone, green, thin bedded, scour channels, ripple marks.	20.0	1 007.2
34	covered.	20.0	987.2
33	similar to unit 35.	18.3	967.2
32	fining-upward cycle; quartzite, white, thick bedded, massive at base; grading up to interbedded siltstone, light green thin to medium bedded, and white quartzite.	21.3	948.9
31	interbedded silty quartzite, light green, crosslaminated; siltstone, green; dolomite-cemented white sandstone layer, 15 m thick, planar crossbedded.	45.4	927.6
30	siltstone, argillaceous; phyllite.	7.0	882.2
29	fining-upward cycle; quartzite, white to pale green, thick bedded, massive to vague tangential crossbeds, minor rip-up clasts at base; grading up to interbedded siltstone and quartzite, green, thin to medium bedded.	10.7	875.2
28	fining-upward cycle; siltstone, green, thick to medium bedded, commonly graded beds with some basal scours; grading up to silty argillite and well-cleaved phyllite.	22.9	864.5
27	covered.	5.5	841.6
26	silty quartzite, green to white, thin-bedded, rip-up clasts, crossbedded, scours.	18.3	836.1
25	siltstone, purple, mauve, green, fine grained, synereses cracks, minor ripple crosslaminations; interbedded with quartzite layers near top.	32.0	817.8
24	coarsening-upward cycles, 3-10 m thick, with purple and green siltstones near base; grading up through ripple crosslaminated siltstones and quartzites; to massive, thick-bedded quartzite at top of some cycles, and at top of unit 24.	46.0	785.8
23	quartzite, white, medium to thick bedded, broad trough crossbeds, tangential crossbeds, rip-up clasts; minor siltstone, purple to green, laminated and ripple crosslaminated.	70.0	739.8
22	generally covered; minor interbedded siltstone and quartzite, purple and green, tangential crossbeds, rip-up clasts, scours; minor white quartzite.	95.0	669.8
21	covered.	30.0	574.8
20	siltstone, purple, green, interbedded with quartzite, green; crossbeds, rip-up clasts, scours.	27.4	544.8
19	siltstone, purple, generally massive or finely laminated, small crossbeds; minor quartzite, green, discontinuous beds.	55.0	517.4

18	quartzite, purple, white; crossbedded.	6.0	462.4
17	siltstone, purple, green, massive, thin bedded, vague laminations; minor white quartzite at top.	77.6	456.4
16	siltstone, brown, purple, laminated; minor quartzite, scours.	7.6	448.8
15	coarsening-upward cycle; massive to laminated purple and green siltstones near base, with some broad scours, grading upward to thin-bedded purple siltstone interbedded with some white quartzite layers; crossbeds, rip-up clasts, graded beds, and scour-and-fill structures common in top of unit.	21.3	441.2
14	coarsening-upward cycle, similar to unit 15.	75.0	419.9
13	siltstone, green, irregular and discontinuous bedding; minor white quartzite.	23.0	344.9
12	siltstone, green, thinly laminated; minor thin, brown-weathering silty dolomite layers, occasional rip-up clasts.	12.2	321.9
11	covered.	12.2	309.7
10	siltstone, green, grey, thin bedded, graded beds; minor lenticular beds, silt scours, reverse graded beds.	15.2	297.5
9	partially covered; argillite, dark grey to black, with thin siltstone lenticles; siltstone, grey, thin bedded; graded siltstone-argillite beds, lenticular bedding, occasional scours and syneresis cracks.	67.0	282.3
8	siltstone, thick to medium bedded, with dark grey argillite partings; dark grey argillite sequence near centre.	33.5	215.3
7	siltstone, green, medium to thick bedded, thinly laminated; rare argillite laminations, graded.	22.8	181.8
6	argillite, dark grey, faintly laminated; minor green siltstone interbeds.	3.6	159.0
5	siltstone, green, medium to thick bedded; beds commonly graded with light green siltstone at base and darker green phyllite at top; very thin bedded siltstone-argillaceous siltstone couplets occur near top.	27.4	155.4
4	siltstone, olive green, thin bedded, laminated; minor dark grey argillite.	30.5	128.0
3	siltstone, dark grey to green, thin bedded, syneresis cracks throughout.	10.7	97.5
2	argillite, grey to dark grey, thin bedded; minor lenticular-bedded siltstone.	21.3	86.8
1	siltstone, grey, green, thin bedded, commonly graded with dark grey argillite caps, syneresis cracks.	65.5	65.5

Upper Aldridge, Creston Formation; Moyie Lake

Location : Ridge northwest of Moyie, west side of Moyie Lake; NTS Moyie Lake 82G/5; elev. 991 m (3250 ft) at base to 1326 m (4350 Ft) at top; UTM grid 584100E-5460750N at base to 582000E-5463800N at top

Measured by T. Höy (1982), field section H82M3

Unit	Description	Thickness (metres)	Height above base (metres)
Kitchener Formation (37.5 m - incomplete)			
92	siltstone, dolomitic, watery green, tan to grey weathering; 5 m thick silty dolomite, watery green, brown weathering, occurs at base.	19.5	2 562.5
91	siltstone, dolomitic, pale watery green, grey to pale tan weathering.	18.0	2 543.0
Creston Formation (2208 m - complete)			
90	siltstone, green, graded beds, thinly laminated; siltstone with dolomitic cement near top.	31.5	2 525.0
89	siltstone, pale green, generally massive, thin bedded; minor interbedded purple and green siltstone at top.	9.0	2 493.5
88	siltstone, argillaceous, green, commonly graded.	18.0	2 484.5
87	siltstone, green, grading up to purple siltstone; commonly graded with green siltstone bases and purple argillaceous tops, mud cracks; argillaceous siltstone, purple, mud-chip breccias, mud cracks; possible fault, with units 87 to 92 a repetition of 79 to 86.	45.0	2 466.5
86	gap; small outcrop of pale green, dolomitic siltstone.	24.0	2 421.5
85	siltstone, pale watery green, grey to brown weathering; dolomitic in part; argillaceous siltstone, grey to brown weathering with minor green siltstone layers.	13.5	2 397.5
84	argillaceous siltstone, watery green, dolomitic, finely laminated; minor thin brown-weathering dolomitic siltstone layers.	7.5	2 384.0
83	gap.	4.5	2 376.5
82	quartz wacke, grey, thick bedded.	3.0	2 372.0
81	partial exposure; siltstone, green, thinly laminated, grey weathering; dolomitic near top.	18.0	2 369.0
80	quartz arenite, white, coarse grained, with scours and channels, in green argillaceous siltstone; up section, siltstone, green, thin bedded, graded, mud cracks.	10.5	2 351.0
79	siltstone, green, thinly laminated; minor quartz wacke beds, green; at top, argillacous siltstone, purple, laminated, mud cracked.	18.0	2 340.5
78	fining-upward sequence; at base, siltstone, green, thin bedded, with minor darker green wacke beds; grading up to purple argillaceous siltstone, thin bedded, mud cracks, with minor silt wacke beds throughout.	13.5	2 322.5
77	argillaceous siltstone, dark grey to purple, thin bedded; with minor mauve silt wacke beds; mud cracks, mud-chip breccias, (well cleaved).	61.5	2 309.0
76	siltstone, grey to mauve, medium bedded, competent, with dark purple, irregular and discontinuous laminations, mud cracks; siltstone, green, medium bedded, competent, interlayered with thin-bedded, tan and mauve siltstone and argillaceous siltstone.	13.5	2 247.5
75	gap.	11.0	2 234.0
74	siltstone, pale mauve to light green, thin bedded, in part, slightly dolomitic; overlain by more competent silt wacke, mauve, thicker bedded, with darker purple, irregular, discontinuous laminations; minor quartz arenite beds; mud cracks, mud-chip breccias.	12.0	2 223.0
73	siltstone, green, competent, thin to medium bedded, generally graded; mauve silt wacke beds 10-15 cm thick; up section, thin-bedded mauve quartz wacke, graded.	50.0	2 211.0
72	gap.	6.0	2 161.0

71	argillaceous siltstone, dark grey to dark purple, thin bedded; thin light grey quartzite layers throughout, mud-chip breccias, mud cracks (scattered exposures).	46.5	2 155.0
70	gap.	13.5	2 108.5
69	siltstone, mauve, thick bedded; white quartz arenite lenses, 5 cm thick throughout (similar to unit 67).	4.5	2 095.0
68	gap.	7.5	2 090.5
67	siltstone, mauve to greyish purple, thin bedded, graded, mud cracks, ripple marks; interbedded with thin quartz arenite beds, white, crossbedded, scour-and-fill structures, commonly graded with green tops and capped by dark grey, mud-cracked argillaceous siltstone.	30.0	2 083.0
66	gap.	13.5	2 053.0
65	coarsening-upward sequence; base, argillaceous siltstone, dark purple, irregular discontinuous bedding, with thin white quartz arenite lenses throughout; grading up through green siltstone, thin bedded, rusty weathering; to quartz wacke and siltstone, medium bedded, mauve coloured with purple lenses throughout.	10.5	2 039.5
64	gap.	15.0	2 029.0
63	scattered exposures; argillaceous siltstone, purple to grey, irregular bedding; thin white quartz arenite lenses and layers throughout.	7.5	2 014.0
62	gap; small exposure, quartzite, white, thin bedded; in dark grey to purple argillaceous siltstone.	28.5	2 006.5
61	siltstone, wacke, mauve, competent, medium bedded, darker purple irregular laminations throughout, mud cracks; minor green siltstone; grades upward to dark grey argillaceous siltstone.	15.0	1 978.0
60	quartz wacke, grey to green, thick bedded, at base; grades upward to siltstone, pale green, thin bedded, mud cracks, ripple marks, interbedded with more massive, mauve siltstone.	28.5	1 963.0
59	quartz wacke, siltstone, purple, mauve, minor green, mud cracks, mud-chip breccias, crossbedding, scour-and-fill structures, well laminated.	39.0	1 934.5
58	quartz wacke, siltstone, mauve to grey, thin to medium bedded, large trough crossbeds, convoluted bedding, ball-and-pillow structures, load casts, mud cracks; sequence generally fines upward.	45.0	1 895.5
57	quartz wacke, medium green, massive, competent, thick bedded, with no siltstone interlayers; grades upward to unit 58.	9.0	1 850.5
56	gap.	25.5	1 841.5
55	argillaceous siltstone, dark grey, thin bedded, graded siltstone to mud-cracked argillite beds throughout.	3.0	1 816.0
54	graded sequence; quartz arenite, coarse grained, grey, thick bedded, massive to faintly laminated at base; quartz arenite, mauve, medium to thick bedded, graded beds with siltstone tops, minor interbedded siltstone layers.	46.5	1 813.0
53	unit 53 consists generally of a number of fining-upward cycles 10-15 m thick; base of cycles, quartz arenite, thick bedded, grey, massive to irregularly laminated; grading up through quartz wacke, pale grey to mauve, crosslaminated; into interbedded dark purple argillaceous siltstone and grey siltstone, thin purple argillaceous siltstone and grey siltstone, thin bedded, mud cracks, crosslaminated, graded.	81.0	1 766.5
52	feldspathic arenite, medium green, medium to thick bedded, generally massive; minor thin, light green siltstone interbeds; minor quartz arenite, white, medium bedded.	15.0	1 685.5
51	siltstone, quartz wacke, dark grey to purple, thin bedded, laminated, mud cracks, mud-chip breccias, silt scours; top, argillaceous siltstone, purple, laminated, mud-chip breccias, mud cracks; minor white quartz arenite beds 15-20 cm thick.	16.5	1 670.5
50	siltstone, quartz wacke, mauve, medium to thick bedded, crossbeds, commonly graded with rippled, mud-cracked siltstone tops.	27.0	1 654.0
49	quartz wacke, feldspathic arenite, tan to light grey, thick bedded, coarse grained, graded with thin siltstone tops, high-angle crossbeds, asymmetrical ripples; mauve, laminated siltstone at top, ripple marks, minor thin, white quartz arenite beds.	45.0	1 627.0
48	siltstone, feldspathic wacke, mauve to grey, medium bedded, commonly graded, mud cracks, crossbeds; quartz wacke, mauve, thick bedded, massive, broad scours at base; unit includes a number of thin fining-upward cycles.	51.0	1 582.0
47	unit includes a number of fining-upward sequences, and two prominent coarsening upward sequences; fining-upward sequences - quartz arenite, quartz wacke, mauve, medium to thick bedded, crossbeds defined by darker streaks, irregular laminations, minor silt interbeds, graded at base; grading up to thin to medium-bedded siltstone, interbedded with mauve to purple mud-cracked argillite.	63.0	1 531.0
46	coarsening-upward sequence; siltstone, tan and minor mauve coloured, thin bedded, crosslaminated; to coarser grained, medium-bedded siltstone.	48.0	1 468.0

45	quartz arenite, coarse grained, white, thin bedded, graded with thin purple siltstone tops, mud cracks, scour-and-fill structures, channels, crossbeds; overlain by siltstone, mauve, very thin bedded, graded, mud cracks.	13.5	1 420.0
44	argillaceous siltstone, siltstone, mauve to purple, thin bedded; grades upward to thin to medium-bedded green and mauve siltstone; unit 44 is base of coarsening-upward cycle that includes base of 45.	15.0	1 406.5
43	siltstone, mauve, thin bedded, graded with dark argillite tops, mud cracks, mud-chip breccias; interbeds of quartzite, white, graded, coarsens upward with quartzites predominating over siltstone at top.	54.0	1 391.5
42	siltstone, tan, grey, mauve, light green, thin bedded, graded, mud cracks, mud-chip breccias; minor quartz wacke.	45.0	1 337.5
41	siltstone, light grey to mauve, minor tan; thin bedded, mud cracks; approximately 10-20% interbedded green, graded siltstone beds.	73.5	1 292.5
40	siltstone, mauve, with dark purple argillaceous partings; siltstone, green; argillaceous siltstone, grey with thin mauve streaks; thin bedded, mud cracks.	30.0	1 219.0
39	siltstone, green, minor tan, thin bedded.	25.5	1 189.0
38	siltstone, tan, medium bedded; minor thin-bedded green siltstone.	27.0	1 163.5
37	gap; minor exposure of green siltstone.	33.0	1 136.5
36	siltstone, light green to grey, thin bedded, occasional scours and crossbeds.	16.5	1 103.5
35	siltstone, green, very thin to thick bedded; siltstone, tan, irregular thin to medium bedded, massive; minor thin-bedded, green quartz wacke.	63.0	1 087.0
34	siltstone, tan, thin bedded, massive to thinly laminated.	40.5	1 024.0
33	siltstone, quartz wacke, green to grey-green, thin bedded, laminated, massive.	70.5	983.5
32	siltstone, quartzite, thin bedded, grey-green, massive or graded, crossbeds, lenticular beds.	45.0	913.0
31	quartz wacke, grey, massive, medium bedded, with thin discontinuous siltstone partings.	12.0	868.0
30	wacke, grey thin, wavy bedding, massive or scours, rare crossbeds.	24.0	856.0
29	gap; thin bedded, grey siltstone and wacke scree.	54.0	832.0
28	siltstone, grey, thin to medium bedded, wavy bedding, generally massive.	4.5	778.0
27	siltstone, quartz wacke, light grey-green; argillaceous siltstone, medium grey, thin bedded, laminated, lenticular bedded.	40.5	773.5
26	argillite, dark grey, thinly laminated, with thin 1-2 mm siltstone lenticles near top.	50.0	733.0
25	siltstone, tan, thin bedded; very minor dark grey argillaceous siltstone.	31.5	683.0
24	siltstone, tan, thin bedded; minor dark grey argillaceous siltstone.	12.0	651.5
23	argillaceous siltstone, dark grey, mud cracks, lenticular bedded; siltstone, tan, very thin bedded, graded.	28.5	639.5
22	siltstone, tan to light grey, thin to medium bedded, graded with dark grey argillite tops, mud cracks.	18.0	611.0
21	gap.	30.0	593.0
20	siltstone, grey to pale grey-green, medium bedded, graded; argillaceous siltstone, rusty, dark grey, thin bedded with 30-40% light grey siltstone lenticles, irregular laminations, syneresis cracks.	78.0	563.0
19	gap.	64.5	485.0
18	argillaceous siltstone, rusty weathering, dark grey, thin bedded, lenticular bedded, syneresis cracks, commonly graded with basal scouring siltstone units; minor thin, graded siltstone beds.	70.5	420.5
17	gap.	7.5	350.0
16	argillaceous siltstone, dark grey, rare syneresis cracks.	4.5	342.5
15	argillaceous siltstone (similar to unit 16), with thin grey siltstone beds.	6.0	338.0
14	siltstone, grey, thick bedded, massive, ball-and-pillow structures; medium bedded near top.	15.0	332.0

Upper Aldridge (240.0 m - complete)

13	gap.	16.5	317.0
12	argillaceous siltstone, medium grey, laminated.	67.5	300.5
11	argillaceous siltstone, dark grey, irregular bedding.	40.5	233.0

10	argillaceous siltstone, dark grey, rusty weathering; rare white or tan, thin siltstone lenses.	52.5	192.5
9	argillite, dark grey, with thin 1-3 mm graded siltstone lenses throughout, rare crosslaminations in siltstone.	7.5	140.0
8	argillaceous siltstone, dark grey, rusty weathering, laminated.	42.0	132.5
7	argillaceous siltstone (similar to unit 8) with rare thin (10 cm) tan siltstone layers.	13.5	90.5

Middle Aldridge (77.0 m - incomplete)

6	argillaceous siltstone (similar to unit 8); minor siltstone, grey, thin bedded, rare crossbeds, graded; siltstone, laminated.	17.0	77.0
5	gap.	13.5	60.0
4	siltstone, quartz wacke, tan, light grey, medium bedded; argillaceous siltstone (similar to unit 8).	10.5	46.5
3	gap.	9.0	36.0
2	siltstone, quartz wacke, tan, grey, thick bedded, massive or graded.	3.0	27.0
1	argillaceous siltstone, dark grey, rusty weathering, finely laminated.	24.0	24.0

Creston and Basal Kitchener Formations; Cranbrook

Location: Approximately 3 km northeast of Cranbrook, elev. 1020 m (3350 ft) at base; NTS Cranbrook 82G/12; UTM grid 592750E-5487150N (base) to 594200E-5487350N (top)

Measured by T. Höy (1982), field section H82K1

Unit	Description	Thickness (metres)	Height above base (metres)
Kitchener Formation (292.5 m - incomplete)			
42	siltstone, light green, laminated, contains calcite pods; silty dolomite, light grey weathering; dolomite predominates at top of unit.	24.0	1 075.5
41	gap.	21.0	1 051.5
40	siltstone, dolomitic in part, light green to watery green, minor buff weathering; silty dolomite, brown weathering.	48.0	1 030.5
39	scattered outcrops; similar to unit 38.	18.0	982.5
38	siltstone, green, laminated; minor brown-weathering dolomitic siltstone at top.	12.0	964.5
37	gap.	22.5	952.5
36	siltstone, green, thin bedded, laminated, graded beds, generally fissile; minor tan-weathering dolomitic siltstone.	39.0	930.0
35	siltstone, green, thin bedded, laminated, graded beds.	40.5	891.0
34	siltstone, green, laminated; some beds of dolomitic siltstone, tan to buff weathering.	51.0	850.5
33	siltstone, green, graded beds or laminated; dolomitic siltstone, green, brown weathering.	16.5	799.5
Creston Formation (783.0 m - incomplete)			
32	siltstone, light green, graded, thin bedded, finely laminated in part; minor watery green dolomitic siltstone.	93.0	783.0
31	gap.	45.0	690.0
30	siltstone, green, thin bedded, graded, mud cracks, mud-chip breccias; minor thin white quartzite beds; at base, purple siltstone, laminated, mud cracks, with thin white discontinuous quartzite layers.	30.0	645.0
29	gap.	45.0	615.0
28	gap; boulders of laminated green siltstone.	69.0	570.0
27	siltstone, mauve to grey, thin bedded, irregular, uneven laminations; minor dark grey siltstone, fissile, laminated.	7.5	501.0
26	gap.	10.5	493.5
25	siltstone, grey, thinly laminated, fissile.	6.0	483.0
24	gap.	27.0	477.0
23	quartzite, light grey, thin bedded, generally massive or with discontinuous wavy laminations.	3.0	450.0
22	gap.	13.5	447.0
21	quartzite, white to green, thin bedded, discontinuous beds; minor silty quartzite, dark grey, fine grained, mud cracks.	22.5	433.5
20	gap.	10.5	411.0
19	siltstone and silty quartzite, mauve to medium grey, thin bedded, wavy, discontinuous laminations.	25.5	400.5
18	silty quartzite, grey to mauve, medium bedded; minor thin-bedded siltstone, grey to purple, mud cracks.	76.5	375.0
17	siltstone, purple to mauve, thin bedded, mud cracks, minor green siltstone.	16.5	298.5
16	quartzite, grey, massive, medium to thick bedded, minor siltstone interbeds.	25.5	282.0

15	gap.	9.0	256.5
14	massive grey quartzite bed.	3.0	247.5
13	quartzite, light grey, thick bedded, generally massive; at top, beds are thinner, massive or discontinuously laminated.	3.0	244.5
12	silty quartzite, grey, thin to medium bedded, massive to graded; minor fissile sandstone beds.	60.0	241.5
11	fining-upward sequence, from quartzite, green, thick bedded, massive; through quartzite, grey to mauve, medium bedded, commonly graded with dark grey laminated siltstone tops; to fissile, light green slate at top.	13.5	181.5
10	siltstone, argillaceous, light grey-green, fissile, laminated	7.5	168.0
9	silty quartzite, generally grey, some mauve, medium bedded; minor white quartzite layers.	51.0	160.5
8	quartzite, white, thin bedded, irregular, discontinuous beds, scours; minor dark grey to purple, well-laminated siltstone.	1.5	109.5
7	silty quartzite, light green to grey, medium bedded, massive, competent.	15.0	108.0
6	gap; few exposures of thin-bedded, mauve, purple to dark grey siltstone.	13.5	93.0
5	silty quartzite, grey, thin bedded, parallel laminations or discontinuous, wavy laminations; minor fissile, mauve siltstone.	7.5	79.5
4	fining-upward sequence; white quartzite at base, thin bedded; grades up through grey silty quartzite, greenish grey silty quartzite, to argillaceous siltstone at top, purple, fissile, thin bedded, laminated.	12.0	72.0
3	siltstone, pale green, only minor mauve, discontinuous laminations, thin to medium bedded.	22.5	60.0
2	quartzite, green, thin bedded; white quartzite beds, commonly crossbedded, throughout.	13.5	37.5
1	siltstone, light grey to green, generally massive, thin bedded; minor silty quartzite, minor green fissile, laminated siltstone.	24.0	24.0

Kitchener Formation; Hughes Range

Location : On western slope and ridge, Hughes Range, approximately 4 km east of Premier Lake; NTS Skookumchuck 82G/13; UTM grid 600700E-553100N, elev. 1860 m (6100 ft) at base, to 601750E-5530920N, elev. 2560 m (8400 ft) at top

Measured by T. Höy (1979), field section H79E65 and base of H79E66

Unit	Description	Thickness (metres)	Height above base (metres)
Van Creek Formation (30.5 m - incomplete; see Section 15 for continuation)			
35	siltite, argillaceous, commonly graded to argillite producing thin-bedded, finely laminated siltite-argillite couplets commonly with basal scours; siltite, dolomitic graded beds, thinly laminated, occur occasionally in sections 0.5-1 m thick, buff weathering.	30.5	1 058.1
Kitchener Formation (926.4 m - complete)			
34	dolomite, silty in part, light green, thinly laminated, scours at base of beds; with siltite, light green, dolomitic, and argillite, light green to buff, dolomitic, lenticles and thin discontinuous layers; generally light green to buff weathering.	10.7	1 027.6
33	limestone, grey beds, 1-2 m thick; dolomite, silty, irregular wavy laminations, broad scours, buff weathering; dolomite, finely laminated, buff weathering; minor siltstone, grey, graded with argillite tops.	41.1	1 016.9
32	siltstone, tan to pale green, overlain by dark grey, mud-cracked argillite, broad scours; silty dolomite, buff weathering, scours, crossbeds, 'molar tooth' structures, overlain by tan, graded siltstone, thin black argillite.	42.7	975.8
31	gap.	54.9	933.1
30	silty dolomite, tan to grey, basal scours, wavy irregular bedding, crossbeds, graded beds, minor siltstone partings; includes a layer of dolomite 2 m thick, oolitic dolomite.	45.7	878.2
29	dolomite, silty dolomite, buff weathering, current structures include crossbeds, rip-up clasts; minor fragmental limestone beds; rare thin argillite laminations.	40.0	832.5
28	dolomite, buff to brown weathering, light to medium grey calcite veinlets; generally massive, some argillite partings.	21.3	792.5
27	silty dolomite, buff weathering, graded beds, wavy irregular bedding, broad silt scours, molar tooth structures; interbedded with grey siltstone, minor grey limestone.	21.3	771.2
26	siltstone, dark grey weathering, very thin bedded, graded, with argillite tops.	7.6	749.9
25	dolomitic siltstone, grey to buff weathering, "molar tooth" structures; silty dolomite, with very thin argillite layers (partings); minor grey limestone.	24.4	742.3
24	argillite, dark grey to black; grey limy siltstone.	6.1	717.9
23	silty dolomite, tan to light grey weathering, scours, "molar tooth" structures; minor dolomite, buff weathering, thinly laminated; limestone, grey, rip-up clasts.	36.5	711.8
22	siltstone, dolomitic siltstone, grey, tan weathering, graded couplets, "molar tooth" structures; phyllite, grey, laminated, with silty quartzite layers approximately 15 cm thick; minor grey limestone layers 15-30 cm thick with clear quartz grains, oolitic limestone 30 cm thick at top.	42.7	675.3
21	dolomitic siltstone, silty dolomite, light buff to tan, very irregular weathered surfaces, calcite pods are common, "molar tooth" structures, scours.	62.5	632.6
20	siltstone, tan to light grey weathering, graded beds, scours; minor silty dolomite.	35.0	570.1
19	dolomite, brown, very irregular weathered surfaces, limestone pods; some graded siltstone to dolomite beds, broad scours.	45.7	535.1
18	silty dolomite, light tan to green, broad scours, lenticular bedding, graded siltstone-dolomite beds; minor limy siltstone.	18.3	489.4
17	scattered exposures; dolomite, dark brown, rusty weathering, with limestone pods or fragments, graded siltstone-dolomite beds, "molar tooth" structures; minor quartzite layers throughout.	50.3	571.1
16	dolomite, dark reddish brown weathering, massive to well layered; quartzite layers with scouring basal contacts, tangential crossbeds; minor dark argillite at top of graded dolomite-argillite beds.	38.0	420.8
15	gap.	13.7	382.8

14	diorite dike.	7.6	369.1
13	dolomite, somewhat argillaceous, dark grey, irregular wavy laminations, minor scours; thin (5-10 cm) graded quartzite layers throughout; tangential crossbeds, scours.	24.4	361.5
12	dolomite, dark grey, rusty weathering, massive to wavy bedded, broad scours; dark grey, argillite interbeds 40-50 cm thick .	30.5	337.1
11	argillaceous dolomite, dolomitic argillite, dark grey, rusty weathering, finely laminated, abundant scours and broad channels; occasional graded quartzite layers 5-10 cm thick.	7.6	306.6
10	dolomite, buff weathering, thinly laminated; quartz grains are common near base; minor 'phyllitic' dolomite beds.	50.3	299.0
9	siltstone, pale green, laminated; minor dolomite interbeds, massive, or with wavy bedding, rip-up clasts; zone of interbedded, thin-bedded, massive to laminated dolomite, green siltstone, and oolitic limestone.	20.0	248.7
8	dolomite, argillaceous dolomite, tan to grey, buff weathering; grading up through light green silty dolomite, siltstone, with abundant current structures; to siltstone, light green, with limestone pods, dolomite interlayers, thin bedded.	46.0	228.7
7	dolomite, buff weathering, massive to wavy layering, minor scours, crossbeds; interbedded (on a 1-2 m scale) with dolomitic siltstone, pale green; in general, the relative proportion of siltstone increases up section.	40.0	182.7
6	dike.	1.5	142.7
5	dolomite, light grey, buff weathering, thinly laminated or with abundant current structures, including small ripple marks, crossbeds, scours; interbeds of dolomitic siltstone, 1-1.5 m thick, buff to light green, composed of thin, graded siltstone - dolomitic siltstone couplets; outcrop has a pronounced, large-scale green-brown striped appearance.	40.0	141.2

Creston Formation (101.2 m - incomplete)

4	dolomitic siltstone, siltstone, light to pale green, buff weathering.	24.4	101.2
3	siltstone, light green, well bedded, graded siltstone-argillite beds 0.5 cm thick; occasional thin, white quartzite layers; rare buff-weathering dolomitic siltstone layers.	48.8	76.8
2	siltstone-argillite graded beds, thin bedded, light green; minor buff-weathering green siltstone.	13.7	28.0
1	siltstone, green, graded beds; minor white quartzite layers to 10 cm thick.	14.3	14.3

Kitchener – Van Creek Contact; Cranbrook Area

Location: 3.5 km north of junction of Highways 3/95 and 95A, elev. 1040 m (3400 ft); NTS Cranbrook 82G/12; UTM grid 591650E-5491850N

Measured by T. Höy (1982), field section H82K2-23

Unit	Description	Thickness (metres)	Height above base (metres)
Van Creek (5.0 m - incomplete)			
8	siltstone, mauve, thin bedded, thin laminations, mud-chip breccias; minor dolomitic siltstone, light grey-green, brown weathering.	5.0	30.9
Kitchener (25.9 m - incomplete)			
7	siltstone, light green, thin to medium laminations; minor silty dolomite, tan weathering.	11.0	25.9
6	siltstone, pale green, rusty weathering, thin laminations; occasional darker green, coarse siltstone laminations.	3.6	14.9
5	siltstone, silty dolomite, tan to pale green, buff weathering, thinly laminated, graded beds.	4.6	11.3
4	stromatolitic dolomite.	0.3	6.7
3	dolomitic siltstone, tan to pale green, slightly rusty weathering, graded beds, mud cracked.	1.5	6.4
2	silty dolomite, dark brown to medium grey, thin bedded; cryptal algal structures.	0.3	4.9
1	siltstone, silty dolomite, tan to pale green, rusty weathering, thinly laminated, cryptal algal structures; some mud-chip breccias.	4.6	4.6

Kitchener – Van Creek Contact; Bloom Creek

Location: Southwest of Bloom Creek, 1.7 km north of U.S.A. border; elev. 1829 m (6000 ft) at base to 1920 m (6300 ft); NTS Yahk River 82G/4; UTM grid 607200E-5430100N (base) to 607400E-5430100N

Measured by L. Diakow (1982), field section D82Y1

Unit	Description	Thickness (metres)	Height above base (metres)
Van Creek Formation (47.0 m - incomplete)			
10	siltstone, interbedded maroon, green and minor dark green, thin to medium bedded, thinly laminated, mud-chip breccias; rare light grey quartzite beds up to 20 cm thick.	6.0	152.0
9	siltstone, dark green, thin bedded, thinly laminated; gradational contact with Kitchener Formation.	41.0	146.0
Kitchener Formation (105.0 m - incomplete)			
8	siltstone, dark green, thinly laminated, interbedded with paler green, tan-weathering dolomitic siltstone in beds to 1 m thick.	3.0	105.0
7	siltstone and argillaceous siltstone, green, medium bedded.	6.0	102.0
6	dolomitic siltstone, maroon; overlain by siltstone, mauve to maroon, interbedded with green siltstone, mud-chip breccias; rare pale grey quartzite beds up to 18 cm thick.	12.0	96.0
5	siltstone and argillaceous siltstone, green, thin to medium bedded, thinly laminated.	12.0	84.0
4	gap.	27.0	72.0
3	argillaceous siltstone, siltstone, slightly dolomitic, mauve to maroon, mud-chip breccias.	6.0	45.0
2	siltstone, pale green, pyritic, thin bedded, thinly laminated; rare quartz arenite lenses, fine grained.	19.0	39.0
1	siltstone, mauve to purple, thin to medium bedded, interbedded with dolomitic siltstone beds, maroon, 0.5-2 m thick, mud cracks, crosslaminations, mud-chip breccias, ripple marks; rare quartzite beds up to 18 cm thick, pale grey to red tinged; rare coarse-grained dolomitic quartz arenite lenses.	20.0	20.0

Reference Section of the Nicol Creek and Van Creek Formations; Hughes Range

Location: Along the northeast-trending ridge, just north of unnamed lake, 4.5 km east of the south end of Premier Lake, and 35 km north of Fort Steele; NTS Skookumchuck 82G/13; elev. 2560 m (8400 ft), UTM grid 601700E-5530730N (base) to elev. 2350 m (7700 ft), 602900E-5531950N (top)

Measured by T. Höy (1979), field section H79E66

Unit	Description	Thickness (metres)	Height above base (metres)
Sheppard Formation (106.7 m - incomplete)			
20	siltite, green, maroon, commonly graded to argillite, lenticular bedding, argillite partings, locally mud cracked, light green to grey weathering; siltite, dolomitic, light green to tan, commonly graded, buff weathering; minor quartzite, grey to white, thin layered, crossbedded; argillite, medium to dark grey, commonly mud cracked.	106.7	534.2
Nicol Creek Formation (168.5 m - complete)			
19	lava, dark green, porphyritic and amygdaloidal flows, 1-2 m average thickness.	36.6	627.5
18	siltite, light to dark green, minor maroon coloured; commonly graded with lighter green, more argillaceous tops, lenticular bedding and silt scours common; minor siltite, dolomitic, light tan coloured, buff weathering.	7.0	390.9
17	covered, abundant siltite fragments, green and maroon.	10.7	383.9
16	argillite, red to medium to dark grey, thinly laminated, very thin bedded (1-2 cm).	7.6	373.2
15	lava, dark green, flows 1-2 m thick; character of flows changes through unit from fine to medium grained, equigranular massive to microporphyry at base; through porphyritic lava flows, to coarser grained, porphyritic and amygdaloidal (quartz-chlorite filled) flows at top.	33.5	365.6
14	lava, dark green, porphyritic flows.	7.6	332.1
13	lava, dark green, porphyritic and amygdaloidal flows.	30.5	324.5
12	lava, dark green, porphyritic, with large feldspar phenocrysts in fine-grained groundmass.	13.7	294.0
11	lava, dark green, fine to medium grained, equigranular to microporphyry, massive flows, 0.5-1 m thick.	21.3	280.3
Van Creek Formation (207.2 m - complete)			
10	siltite, light tan, fine grained, dolomitic, broken and oxidized, buff weathering.	16.8	259.0
9	argillite, dolomitic, finely laminated, buff weathering.	3.0	242.2
8	siltite, light green, thin bedded, thinly laminated; commonly forms small 1-2 m coarsening-upward cycles; commonly irregularly bedded.	44.2	239.2
7	siltite, argillaceous, tan, finely laminated, mud cracked, buff weathering; argillite, silty, finely laminated, rippled surfaces, buff weathering.	4.5	195.0
6	siltite, light green, thin beds, generally 1-2 cm thick, but occasionally to 10 cm; finely laminated, small coarsening upward cycles common, some coarser grained, discontinuous, irregularly bedded siltite lenses.	18.3	190.5
5	argillite, silty dark grey, thin bedded, finely laminated.	32.0	172.2
4	siltite, argillite, quartzite; this unit is a coarsening-upward cycle, from argillite, silty, green, finely and regularly laminated at base; to siltite, thin bedded (5-10 cm), green, rip-up clasts, mud-chip breccia layers, mud cracked; to quartzite, silty, beds 10-20 cm thick, green, regularly to discontinuously bedded at top.	57.9	140.2
3	siltite, argillaceous, commonly graded to argillite producing thin-bedded, finely laminated siltite-argillite couplets commonly with basal scours; siltite, dolomitic, graded beds, thinly laminated, occur occasionally in sections 0.5-1 m thick, buff weathering.	30.5	82.3

Kitchener Formation (51.8 m - incomplete; see Section 12)

2	dolomite, silty in part, light green, thinly laminated, scours at base of beds; with siltite, light green, dolomitic, and argillite, light green to buff, dolomitic, lenticles and thin discontinuous layers; generally light green to buff weathering.	10.7	51.8
1	limestone, grey, beds 1-2 m thick; dolomite, silty, irregular wavy laminations, broad scours, buff weathering; dolomite, finely laminated, buff weathering; minor siltstone, grey, graded with argillite tops.	41.1	41.1

Van Creek Formation; Bloom Creek Area

Location: 3 km west of south end of Bloom Creek, elev. approximately 1890 m (6200 ft); NTS Yahk River 82G/4; UTM grid 606900E-5432600N at base to 607500E-5432600N at top

Measured by L. Diakow (1982), field section D82Y2

Unit	Description	Thickness (metres)	Height above base (metres)
Nicol Creek Formation (see Section 20)			
14	lava, dark green, fragmental at base, overlain by porphyritic lava.		
Van Creek Formation (791.0 m - incomplete)			
13	siltstone, argillaceous siltstone, green to dark green, thin bedded, thinly laminated, basal scours, truncated beds.	21.0	791.0
12	quartzite, white to light grey, thick bedded, ripple marks, crosslaminated.	2.0	770.0
11	siltstone, dark green, thin bedded.	28.0	768.0
10	dolomitic siltstone, green to grey, reddish brown weathered surface, thin bedded; very minor thinly laminated green siltstone.	3.0	740.0
9	siltstone, green, thin bedded.	15.0	737.0
8	dolomitic siltstone, grey to green, weathers tan-brown, thin bedded, thinly laminated; basal part cut by fine calcite veinlets, producing irregular, uneven weathered surfaces.	2.0	722.0
7	siltstone, green to grey-green, very thin to thin bedded, thinly laminated, weathers to a dullish red-brown colour; overlain by interlayered siltstone and silty quartzite, generally green, weathering to light brown, medium to thick bedded, thin to medium laminations, ripple marks, mud-chip breccias; overlain by siltstone, dark green, thin bedded, thinly laminated.	268.0	720.0
6	dolomitic siltstone, similar to unit 10, green to grey, reddish brown weathered surface, thin bedded; interbedded with thinly laminated green siltstone.	3.0	452.0
5	siltstone, greenish grey, green, thin graded beds, 2-5 cm thick.	77.0	449.0
4	gap.	37.0	372.0
3	siltstone, dark green, thin bedded, thin to medium lamellae, interbedded with medium-bedded siltstone; silty quartzite, siltstone, dark green, medium to thick bedded; siltstone, thin bedded, interbedded mauve and green beds; cross-laminations, ripple marks, cut-and-fill structures, rare magnetite grains near top.	234.5	335.0
2	gap.	96.0	100.5
1	siltstone, light green with slight orange cast, thin bedded, thinly laminated.	4.5	4.5

Nicol Creek Formation; Northeast of Cranbrook

Location: 1.5 km west of junction of Highways 3 and 95, elev. 1300 m (3300 ft); NTS Cranbrook 82G/12; UTM grid 593800E-5491800N

Measured by T.Höy (1982), field section H82K3-24

Unit	Description	Thickness (metres)	Height above base (metres)
Nicol Creek Formation (217.5 m - incomplete)			
11	siltstone, tan to olive green, thin bedded, massive or graded with tan-coloured coarse fractions and dark green finer fractions.	27.0	217.5
10	lava, dark green, massive or amygdaloidal.	4.5	190.5
9	wacke, lithic tuff, purple, coarse-grained volcanic fragments.	4.5	186.0
8	covered.	15.0	181.5
7	lithic tuff, crystal tuff, volcaniclastic siltstone, green, fissile.	6.0	166.5
6	partially covered; siltstone, graded tan to olive green, thin-bedded layers.	28.5	160.5
5	covered.	16.5	132.0
4	similar to unit 6.	9.0	115.5
3	lava, medium green, massive or with occasional chlorite-filled amygdules.	7.5	106.5
2	lava, dark green, massive, amygdaloidal; covered from 40.5-55.5 m and 69.0-91.5 m.	58.5	99.0
1	lava, dark green, 1.5-2.5 m flows, abundant amygdules.	40.5	40.5

Sheppard, Nicol Creek and Van Creek Formations; St. Mary River

Location: 4 km south of Marysville, elev. 1189 m (3900 ft); NTS Cranbrook 82G/12W; UTM grid 575075E-5494700N

Measured by T. Höy (1982), field section H82K45

Unit	Description	Thickness (metres)	Height above base (metres)
Sheppard Formation (36.0 m - incomplete)			
11	siltstone, sandstone, green, thin bedded, commonly graded; dolomitic siltstone, buff weathering.	19.5	69.0
10	sandstone, green, thin bedded.	9.0	49.5
9	dolomitic sandstone, pale green, buff weathering, very thin bedded.	1.5	40.5
8	covered; probable dolomitic sandstone (as unit 4).	6.0	39.0
Nicol Creek Formation (3.0 m - complete)			
7	lava, green, amygdaloidal, quartz filled.	3.0	33.0
Van Creek Formation (30.0 m - incomplete)			
6	siltstone, quartzite, green, thin to medium bedded, commonly graded, rare flute casts, rare syneresis cracks in finer grained and thinner bedded siltstone near base of unit.	18.0	30.0
5	dolomitic sandstone, light green, thin bedded.	2.0	12.0
4	covered.	4.0	10.0
3	dolomitic sandstone, light green, graded with green phyllite tops, thin bedded.	1.0	6.0
2	siltstone, sandstone, green, very thin to thin bedded, thinly laminated, commonly graded, no mud cracks.	4.0	5.0
1	dolomitic sandstone, light green, thin bedded, silty quartzite, green, thin bedded.	1.0	1.0

Sheppard, Nicol Creek and Van Creek Formations; St. Mary River

Location: 4 km south of Marysville, elev. 1189 m (3900 ft); NTS Cranbrook 82G/12W; UTM grid 575100E-5494900N

Measured by T. Höy (1982), field section H82K46

Unit	Description	Thickness (metres)	Height above base (metres)
Sheppard Formation (6.0 m - incomplete)			
5	sandstone, light to dark green, chloritic, thin bedded; minor dolomitic sandstone, tan to green, buff weathering.	4.5	60.0
4	phyllite, dark green; minor dark green quartz sandstone lenses.	1.5	55.5
Nicol Creek Formation (36.0 m - complete)			
3	lava, dark green, massive or amygdaloidal flows, quartz-filled amygdules; phyllite, dark green, probable tuff.	16.5	54.0
2	lava, dark green, quartz-filled amygdules are abundant in top flows; underlain by 2-3 m of massive dark green lava flows, commonly well cleaved; amygdaloidal lava at top of lower flow units that overlie massive or cleaved flows.	19.5	37.5
Van Creek Formation (18.0 m - incomplete)			
1	siltstone, silty argillite,, light green, thin bedded, graded couplets; siltstone, light green, chloritic, with thin (2-3 mm) sandstone lenses or layers; no mud cracks or syneresis cracks, very thinly laminated.	18.0	18.0

Nicol Creek Formation; Bloom Creek Area

Location: 2-3 km west of south end of Bloom Creek, elev. 1890-1676 m (6200-5500 ft); NTS Yahk River 82G/4; UTM grid 607500E-5432600N at base to 608450E-5432600N at top

Measured by L. Diakow (1982), field section D82Y3

Unit	Description	Thickness (metres)	Height above base (metres)
Gateway Formation (incomplete)			
7	siltstone, dark green, weathers reddish orange, thin to thick bedded; siltstone, purple, with disseminated magnetite octahedra, 1 m thick layer approximately 4 m above base of unit; sharp basal contact.	8.0	380.0
Nicol Creek Formation (372.0 m - complete)			
6	lava, dark green, massive or quartz-filled amygdules.	157.0	372.0
5	siltstone, dark green, medium to thick bedded, thinly laminated.	27.0	215.0
4	crystal and lapilli tuff, predominantly quartz (to 3 mm) and fewer plagioclase (to 1.5 cm) crystals, dark green matrix; lateral facies change to lava, dark green, vesicular, interlayered with dark green volcaniclastic siltstone.	21.0	188.0
3	siltstone, dark green, weathers orange, thin to thick bedded, paleocurrent direction - 100°.	57.0	167.0
2	lava flows, dark green, commonly massive grading through feldspar-porphyritic lava into amygdaloidal lava with occasional feldspar phenocrysts; vesicular lava; chert, light green, interlayered with lava; minor lapilli tuff near base, with large angular fragments, grades up into massive dark green lava.	110.0	110.0
Van Creek Formation (see Section 16)			
1	siltstone, dark green, siliceous, thin bedded.	-	-

Van Creek Formation and Nicol Creek Formation; Cherry Lake

Location: 3 km northwest of Cherry Lake; NTS Yahk River 82G/4; UTM grid 602250E-5451050N, elev. 1875 m (6150 ft) at base, to 604750E-5450550N, elev. 1740 m (5700 ft) at top

Measured by L. Diakow (1982), field section D82Y4

Unit	Description	Thickness (metres)	Height above base (metres)
Gateway Formation (40.0 m - incomplete)			
28	siltstone, sandstone, purple, mauve, green, thin to medium bedded, thin to medium laminae, commonly graded with argillite tops, abundant sedimentary structures including mud-chip breccias, flaser bedding, ripple crosslaminations, ripple marks and graded bedding; sharp contact with unit 27.	40.0	1 395.0
Nicol Creek Formation (420.0 m - complete)			
27	basaltic lava, dark green, generally amygdaloidal (quartz and minor chlorite), minor massive flows, pipe vesicles.	188.0	1 355.0
26	coarse volcanic breccia (at base of unit 27), with large (to 1 m) amygdaloidal lava fragments in massive, dark green lava; thin, laminated mauve to tan lapilli tuff layers.	4.0	1 167.0
25	covered.	23.0	1 163.0
24	siltstone, argillaceous siltstone, dark green, volcaniclastic and tuffaceous, thin bedded.	2.0	1 140.0
23	lava, dark green, amygdaloidal; volcanic breccia, amygdaloidal lava fragments in light green to tan siliceous matrix.	2.0	1 138.0
22	covered.	35.0	1 136.0
21	tuffaceous siltstone, argillaceous siltstone, dark green, thin bedded.	6.0	1 101.0
20	covered.	37.0	1 095.0
19	lava, dark green, masive, thin to medium bedded; siltstone, dark green or mauve, very thin bedded; minor maroon, laminated argillite.	12.0	1 058.0
18	basalt lava, dark green, massive or amygdaloidal; flows commonly grade upward from massive to amygdaloidal (chlorite filled).	48.0	1 046.0
17	lava, dark green, massive to porphyritic (with plagioclase crystals up to 4 cm); gradational contacts with units 16 below and 18 above.	41.0	998.0
16	lapilli tuff, green, thin to very thin bedded, graded beds, commonly contains lithic, dark green volcanic fragments to 1 cm across.	22.0	957.0
Van Creek Formation (926.0 m - complete)			
15	siltstone, dark green to mauve, very thin to thin bedded, thinly laminated.	12.0	935.0
14	covered.	117.0	923.0
13	siltstone, medium green, thin bedded, magnetite crystals throughout.	3.-	806.0
12	covered.	285.0	803.0
11	partially covered; siltstone, dark green, thin to medium bedded, pyritic, thinly laminated, mud cracked.	75.0	518.0
10	covered.	68.0	443.0
9	siltstone, yellow, tan, green, thin bedded, with small, orange oxide spots (weathered pyrite ?).	9.0	375.0
8	covered.	64.0	366.0
7	siltstone, green, very thin to thin bedded; rare mauve argillite beds a few mm thick; occasional green siltstone beds with disseminated magnetite, mud cracked.	23.0	302.0
6	covered.	72.0	279.0
5	siltstone, dark green, thin bedded, thinly laminated, mud cracked.	12.0	207.0

4	covered.	115.5	195.0
3	siltstone, siliceous, dark green, thin to medium bedded, weathers orange coloured, white mica on bedding surfaces, mud cracked, mud-chip breccias, ripple marks.	4.5	79.5
2	covered.	66.0	75.0

Kitchener Formation (9.0 m - incomplete)

1	siltstone, pale green, calcareous, thin bedded, thinly laminated; thin argillite bed, maroon to light green.	9.0	9.0

Nicol Creek and Sheppard Formations; Galton Range

Location: 1.5 km southeast of confluence of Raymon Creek and Elk River, elev. 1067 m (3500 ft); NTS Lake Koocanusa 82G/3; UTM grid 638700E-551500N

Measured by T. Höy (1982), field section H82Y5

Unit	Description	Thickness (metres)	Height above base (metres)
Sheppard Formation (49.5 m - incomplete)			
24	quartzite, white, dolomitic siltstone, tan to buff weathering, thick bedded.	3.0	165.0
23	dolomitic sandstone, brown and quartzite, white; dolomite, brown weathering, massive, medium to thick bedded.	7.0	162.0
22	silty dolomite, tan, fine grained, thin to medium bedded; grades upward through dolomitic siltstone into fine-grained quartzite.	1.0	155.0
21	dolomite, brown weathering, algal, stromatolitic.	7.0	154.0
20	quartzite, grey, well bedded, low-angle tangential crossbeds, irregular laminations; thick bedded at base, thinner bedded near top.	7.5	147.0
19	partially covered; few exposures of brown-weathering dolomite, silty dolomite.	2.0	139.5
18	quartzite, white, medium to thick bedded, massive to vague irregular bedding.	6.5	137.5
17	dolomite, grey, brown weathering, cryptal algal mats; capped by massive brown-weathering dolomite.	4.0	131.0
16	quartzite, white, thick bedded.	1.0	127.0
15	sandstone, dolomitic, buff weathering, medium bedded, graded beds with quartzite at base and dolomitic siltstone at top.	1.5	126.0
14	dolomite, brown weathering, cryptal algal mats; rare stromatolites.	4.5	124.5
13	silty dolomite, thin bedded, tan coloured.	1.5	120.0
12	covered.	3.0	118.5
Nicol Creek Formation (115.5 m - incomplete)			
11	lava, green to maroon, massive to amygdaloidal flows; minor calcareous volcaniclastic sandstone.	18.0	115.5
10	lava, green, thin flows, abundant calcite-filled amygdules, some vesicles; lava, medium to thick flows, calcite-filled amygdules.	3.0	97.5
9	lava, green, chlorite-filled amygdules in fine to medium-grained groundmass, some vesicular lava flows; 2 m thick pillow lava flows at 91.5 m, pillows are massive with approximately 1 cm chilled margins; they overlie chert-filled amygdaloidal flow with a thin (2 cm) pale green chlorite-altered top.	22.5	94.5
8	poorly exposed; lava flows, green, massive or porphyritic.	22.5	72.0
7	poorly exposed; lava flows, porphyritic, massive, vesicular and amygdaloidal, calcite filled.	16.5	49.5
6	lava flows, porphyritic grading upward to massive, fine to medium-grained basalt.	5.0	33.0
5	lava flows, green, massive.	7.0	28.0
4	lava flows, green, 1-2.5 m thick, flows near base of unit are fine grained, massive, grading upward through porphyritic flows with small vesicles to coarsely porphyritic, vesicular flows at top.	9.0	21.0
3	lava, green, fine to medium-grained massive flows.	2.75	12.0
2	lava, 0.5-1 m flows, coarse grained, porphyritic.	6.25	9.25
1	lava, dark green, medium grained, massive.	3.0	3.0

Phillips, Gateway and Nicol Creek Formations; Skookumchuck Area

Location: 5 km south of Skookumchuck, elev. 884 m (2800 ft); NTS Skookumchuck 82G/13; UTM grid 586450E-5525600N at base to 587550E-5524000N

Measured by L. Diakow (1982), field sections D82S1, D82S2

Unit	Description	Thickness (metres)	Height above base (metres)
Phillips Formation (67.5 m - incomplete)			
51	siltstone, quartzite, green, micaceous, thinly laminated.	15.0	939.0
50	siltstone, maroon and green, thinly laminated.	4.5	924.0
49	siltstone, quartzite, argillite interbeds, maroon, micaceous, thinly laminated.	16.5	919.5
48	siltstone, silty quartzite, generally green, minor maroon, micaceous, thinly laminated.	20.0	903.0
47	quartzite, maroon, thick bedded; interbedded with siltstone and minor argillite, maroon, thinly laminated; mud-chip breccias.	11.5	883.0
Gateway Formation (802.5 m - complete)			
46	siltstone, silty quartzite, light to dark green, orange weathering, thick bedded, thinly laminated, micaceous bedding surfaces.	34.5	871.5
45	siltstone, quartzite, green to grey, medium to thick bedded, thinly laminated, scour-and-fill structures, ripple marks.	21.0	837.0
44	siltstone, argillite, black to dark grey, micaceous, thin to medium bedded, thinly laminated.	9.0	816.0
43	covered.	111.6	807.0
42	dolomite, buff to light grey, medium to thick bedded; rare orange to red-weathering dolomite lenses to 0.5 m thick; minor thinly laminated grey dolomite; 'fish scale' textures, 'cross-webbing' (differential weathering of crosscutting, more siliceous veinlets).	92.4	695.4
41	dolomite, light grey, tan weathering, flaggy, grading upward to more massive, grey dolomite with 'cross-webbing' on weathered surfaces.	9.3	603.0
40	siltstone, light grey weathering, medium to thick bedded, ripple marks.	15.9	593.7
39	dolomite, grey to white, thinly laminated, 'sugary textured' and 'cross-webbed' surfaces, rare pisolites to 1 cm diameter.	3.3	577.8
38	siltstone, green or faint mauve tinge, medium to thick bedded, micaceous; minor dolomite, grey, thinly laminated; rare salt-crystal casts.	33.0	574.5
37	dolomitic siltstone, green, interbedded with light grey to white dolomite with 'cross-webbed' surfaces.	18.0	541.5
36	dolomite, pale pink to light grey, thinly laminated, minor crosslaminations, oolites, nodular in part.	6.0	523.5
35	siltstone, green, medium to thick bedded.	4.5	517.5
34	dolomite, light grey to white, finely crystalline, weathers to flaggy buff to tan fragments.	2.1	513.0
33	siltstone, green, medium to thick bedded, micaceous; rare dolomitic siltstone, light green to orange weathering.	17.4	510.9
32	covered.	192.0	493.5
31	siltstone, maroon, thinly laminated; overlain by interbedded stromatolitic dolomite and minor green siltstone.	12.5	301.5
30	siltstone and minor quartzite, purple and green; overlain by dolomite, lamellar and stromatolitic; minor interbedded white quartzites near top.	14.5	289.0
29	dolomite, lamellar.	2.3	274.5
28	dolomite, stromatolitic, buff weathering; dolomite, white, finely granular.	2.2	272.2
27	quartzite, white, pyritic.	3.7	270.0
26	dolomite, stromatolitic, lamellar.	2.3	266.3
25	stromatolitic dolomite overlain by purple quartzite, siltstone, ripple marks, salt-crystal casts.	3.0	264.0

24	dolomite, massive, overlain by stromatolitic dolomite; thin interbeds of grey to green quartzite, medium to thick bedded.	7.5	261.0
23	quartzite, white, thick bedded, ripple marks, crosslaminations.	3.0	253.5
22	dolomite, cream to white, massive.	0.7	250.5
21	quartzite, white, thick bedded.	3.8	249.8
20	stromatolitic dolomite, thinly laminated dolomite, tan coloured, crossbeds, oolites.	1.5	246.0
19	quartzite, white, medium to thick bedded.	21.0	244.5
18	stromatolitic dolomite, large pronounced stromatolite to 1.5 m diameter; quartzite, purple, medium to thick bedded; minor purple siltstone, ripple marks.	1.5	223.5
17	quartzite, green, pyritic, medium to thick bedded; siltstone, light green, 'slabby' weathering; minor silty dolomite and rare, isolated stromatolites.	37.5	222.0
16	siltstone, light green to mauve, thin to medium bedded.	2.5	184.5
15	silty dolomite, light green, thinly laminated; quartzite, light green, resistant, medium to thick bedded; siltstone, light green, medium bedded, ripple marks.	11.0	182.0
14	quartzite, grey-green, medium bedded, thinly laminated, white micaceous bedding surfaces.	25.5	171.0
13	quartzite, grey-green, medium bedded, thinly laminated; interbedded with dolomitic siltstone, ripple marks.	10.5	145.5
12	dolomite, light grey-green, weathers tan to reddish brown, sugary textured.	13.5	135.0
11	dolomite interbedded with dolomitic siltstone, ripple marks, crosslaminations.	1.5	121.5
10	quartzite, dark green, thick bedded; interbedded with dolomitic siltstone, medium bedded, thinly laminated.	10.5	120.0
9	dolomitic siltstone, light green, weathers to buff flaggy fragments, thin bedded, thinly laminated; minor medium-bedded coarse sandstone layers, cut-and-fill structures.	12.0	109.5
8	sandstone, dark green, rusty weathering, fine grained with disseminated pyrite (?), well bedded, medium bedded.	24.0	97.5
7	siltstone, light green, interbedded with dark green argillite, thin bedded, graded beds throughout, ripple marks, mud-chip breccias.	4.5	73.5
Nicol Creek Formation (69.0 m complete)			
6	lava, dark green, fine grained, massive or amygdaloidal (siderite filled).	42.0	69.0
5	lava, dark green to faint purple tinge, quartz amygdules rimmed by chlorite.	16.5	27.0
4	covered (lava).	1.5	10.5
3	lava, dark green, massive, fine grained, orange oxide spots on weathered surfaces (pyrite ?).	3.0	9.0
2	lava, dark green, massive or quartz amygdules, disseminated pyrite, includes angular reddish brown siltstone xenoliths to 40 cm across.	6.0	6.0
Van Creek Formation			
1	siltstone, light green, rusty weathering, thin to medium thick laminations; grades upward into green and mauve siltstone; ripple marks, desiccation cracks; locally, contact between Van Creek and Nicol Creek formations marked by coarse conglomerate with clear rounded quartz, elongate green siltstone, and lava clasts in a purple volcaniclastic sandstone matrix.	1.1	-

Nicol Creek Formation; Echoes Lake

Location: 3 km west-southwest of Skookumchuck, elev. 884 m (2900 ft); NTS Skookumchuck 82G/13; UTM grid 586000E-5527900N

Measured by L. Diakow and T. Höy (1982), field section D82S3

Unit	Description	Thickness (metres)	Height above base (metres)
Gateway Formation (incomplete)			
6	*siltstone, quartzite, dark green; interbedded with light green siltstone.*		
5	gap.	1.5	13.5
Nicol Creek Formation (12.0 m - incomplete)			
4	siltstone, argillaceous, commonly graded with silty bases, thinly laminated; intercalated with thin-bedded dolomitic argillite; grades upward to interbedded thin to medium-bedded, green volcaniclastic sandstone and tuff.	3.0	12.0
3	basaltic lava, green to purple tinged, vesicular, amygdaloidal (quartz and minor secondary calcite); flows up to approximately 45 cm thick are graded from massive at base to vesicular at top.	4.0	9.0
2	*siltstone, mauve to green, thinly laminated, hornfelsed.*	2.75	5.0
1	siltstone, green, medium to thick bedded, thinly laminated, with micaceous parting planes; gradational contact with unit 2 above.	2.25	2.25

Nicol Creek Formation; Skookumchuck Creek

Location: Along Skookumchuck Creek, 4 km west of Skookumchuck, elev. 1040 m (3400 ft); NTS Skookumchuck 82G/13; UTM grid 585000E-5528000N

Measured by T. Höy (1983), field section H83S4

Unit	Description	Thickness (metres)	Height above base (metres)
Nicol Creek Formation (133.5 m - incomplete)			
8	partially covered, lava outcrops occur along strike to south.	28.5	133.5
7	siltstone, green, minor mauve, thin bedded.	12.0	105.0
6	covered; mixed green siltstone and lava scree.	10.5	93.0
5	generally covered, lava outcrops occur along strike to south.	12.0	82.5
4	lava, thick flows, generally green, minor purple, amygdaloidal to massive.	30.0	70.5
3	covered.	9.0	40.5
2	lava, green, generally thick massive flows, some amygdaloidal flows.	15.0	81.5
1	lava, green, minor purple, massive, porphyritic with large hornblende crystals; amygdaloidal flows with quartz and calcite-filled amygdules, pillows common.	16.5	16.5

Phillips Formation; Echoes Lake

Location: 5 kilometres south of Skookumchuck, elev. 853 m (2900 ft); NTS Skookumchuck 82G/13; UTM 587550E-5524000N

Measured by L. Diakow (1982), field section D82Y6

Unit	Description	Thickness (metres)	Height above base (metres)
Phillips Formation (complete ?)			
3	quartzite, maroon, thin to thick bedded, commonly graded; interbedded with siltstone and intercalated silty argillite, maroon; graded siltstone-argillite, thin to medium laminations, mud-chip breccias, symmetrical ripple marks, cross-laminations, white micas on planar surfaces in silty argillite.	66.0	224.0
2	gap; (steep slope with Phillips Formation debris)	155.0	158.0
Gateway Formation (incomplete)			
1	siltstone, olive green, thin bedded.	3.0	3.0

Cranbrook and Gateway Formations; Perry Creek

Location: 4 km due south of Marysville, elev. 1220 m (approximately 4000 ft); NTS Cranbrook 82G/13; UTM grid 575100E-5494500N (base) to 575400E-5494550N

Measured by T. Höy (1982), field section H82K4

Unit	Description	Thickness (metres)	Height above base (metres)
Cranbrook Formation (260.5 m - incomplete)			
33	quartz wacke, quartzite, tan weathering, thin bedded; argillite, dark grey, laminated, lenticular bedded with thin quartzite lenses.	9.0	326.5
32	siltstone, light grey-green, very thin bedded, commonly graded with dark grey to black argillite tops.	4.5	317.5
31	dolomite (?), granular, with quartz grains scattered throughout, and concentrated in thin discontinuous lenses.	8.25	313.0
30	magnesite, granular, with 15-20% very thin quartzite and green siltstone lenses throughout; these weather in relief producing a characteristic irregular weathered surface.	4.5	304.75
29	granular, tan-weathering magnesite at base; grading upward to green siltstone, thin bedded, interlayered with green phyllite, tan magnesite.	3.75	300.25
28	magnesite, tan weathering, coarse grained.	6.75	296.5
27	quartzite, pink tinged, with irregular discontinuous lenses of brown-weathering magnesite; at base magnesite lenses and layers increase to 20-30%; minor green siltstone layers.	5.25	289.75
26	siltstone, quartzite, thin bedded, mauve to grey, with discontinuous purple-tinged argillaceous siltstone lenses throughout; grading up to granular sandstone, mauve to grey with carbonate cement.	6.0	284.5
25	calcareous siltstone, silty limestone, brown weathering, thin bedded, gradational basal contact.	6.0	278.5
24	quartz wacke, grey to purple, tan weathering, thin bedded, irregular, wavy beds, calcareous cement at top; minor dark grey argillite partings.	12.0	272.5
23	quartzite, with limestone lenses throughout.	1.5	260.5
22	similar to unit 24, with minor calcareous siltstone lenses at top.	4.5	259.0
21	quartzite, quartz wacke, mauve to light tan, with irregular discontinuous dark patches throughout; quartzite, granular, with calcite cement; some large low-angle crossbeds.	12.0	254.5
20	magnesite, brown weathering, medium to coarse grained, with 5-10% irregular streaks of granular quartzite throughout; grades down section through intermixed granular quartzite and magnesite to predominantly brown to mauve quartzite and quartz wacke.	18.0	242.5
19	quartz wacke, grey, thin bedded, with irregular, purple to dark grey streaking.	6.0	224.5
18	quartz-feldspar arenite, grey to tan coloured, thick bedded, with prominent low-angle tangential crossbeds.	3.0	218.5
17	quartzite, white, coarse grained, impure, generally poorly sorted.	2.5	215.5
16	fining-upward sequence; at base (196.5-204.5 m), quartz arenite, grey to purple, relatively pure, medium, irregular bedded, with tangential crossbeds; grading up (204.5-212.0 m) through fine-grained, thin-bedded to medium-bedded grey quartz arenite; to green siltstone at top.	16.5	213.0
15	fining-upward sequence; thin-bedded grey quartzite with minor green siltstone interbeds at base, grading up to thin to very thin bedded green siltstone.	5.25	196.5
14	quartzite, white, coarse grained, thick bedded; minor interbeds of thin-bedded, impure grey quartzite near top.	3.75	191.25
13	quartz arenite, white, pure, medium to thick bedded, massive, rare dark grey argillite partings.	60.0	187.5
12	units 11 to 12 are a fining-upward sequence; interbedded grey siltstone and orthoquartzite at base, thin bedded, grading up to fissile green siltstone near top; gradational contact with unit 11 below.	3.0	127.5
11	quartz arenite, white, thick bedded.	4.5	124.5

10	quartz arenite, grey, thin bedded, interlayered with phyllite, green, with irregular discontinuous pods of quartzite throughout; at base is thin-bedded quartz wacke and quartz arenite.	3.75	120.0
9	quartz arenite, quartz wacke, thick bedded, with thinner bedded, finer grained quartz wacke near top.	9.75	116.25
8	fining-upward sequence; quartz arenite, pure to feldspathic, thick bedded, sharp basal contact; grading up to interlayered siltstone and phyllite, green, at top.	9.0	106.5
7	quartz arenite, feldspathic, buff weathering, thin bedded, graded, with green siltstone tops, crossbeds common.	4.5	97.5
6	quartz arenite, pure, white, thick bedded, with minor siltstone 'partings'.	14.25	93.0
5	fining-upward sequence; quartz arenite, white, thick bedded, massive at base; grading up to thin-bedded feldspathic arenite, interbedded with green siltstone at top.	12.75	78.75
Gateway Formation (?) (58.5 m - incomplete)			
4	siltstone, purple, thin bedded, mud cracks; interbedded with phyllitic green siltstone; minor thin white quartzite layers at top; fissile grey to purple interbedded argillaceous siltstone and silty quartzite at base.	13.5	66.0
3	siltstone, purple to red, thin bedded; green siltstone layers interbedded near base.	81.5	52.5
2	siltstone, purple, with thin light green siltstone 'partings'.	13.5	21.0
Nicol Creek Formation (7.5 m - incomplete)			
1	volcaniclastic sandstone, green; minor green volcaniclastic siltstone; lava flow at base.	7.5	7.5

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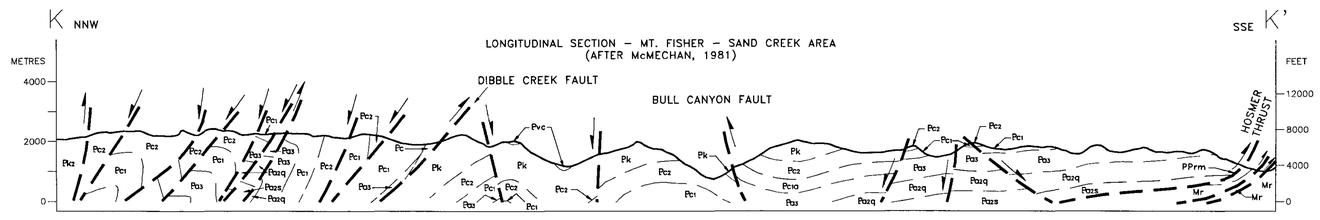
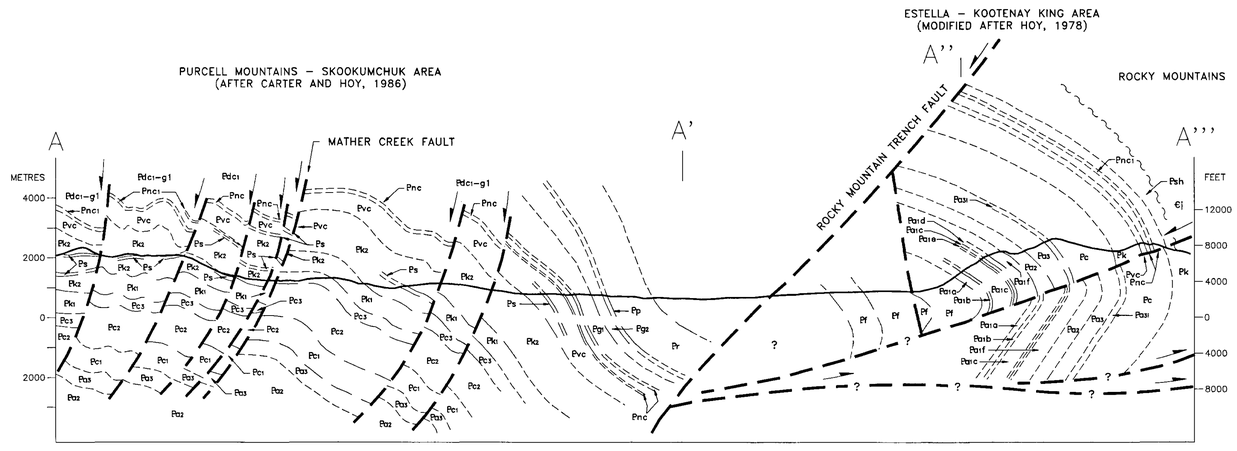
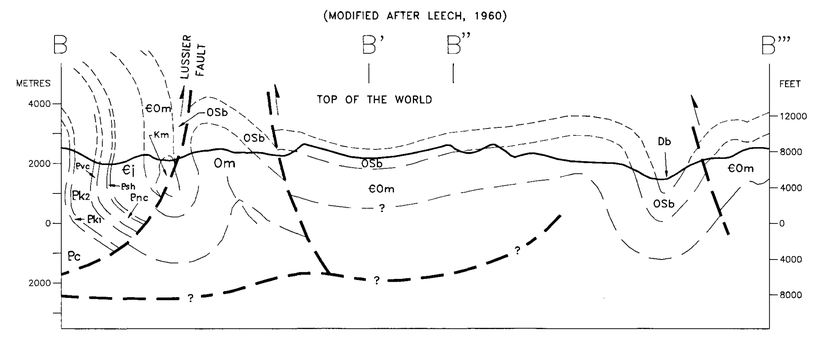
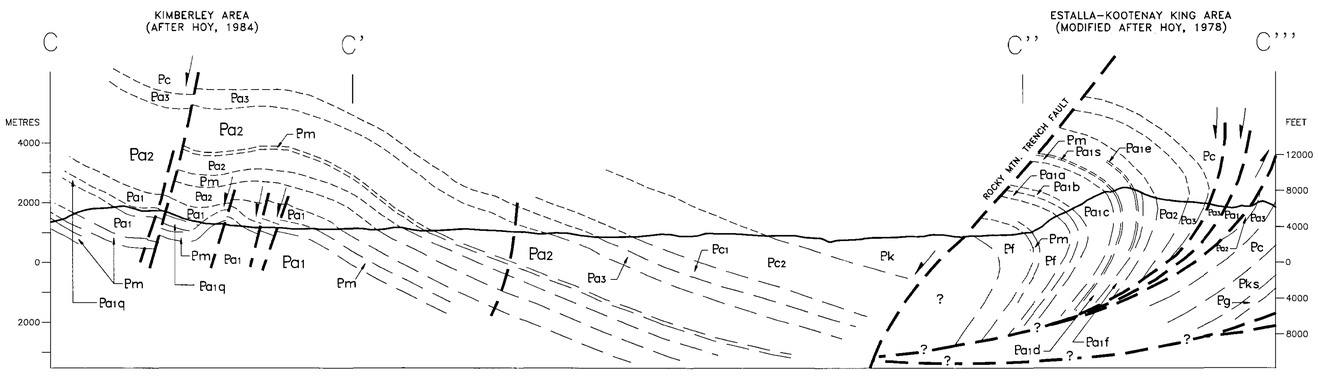
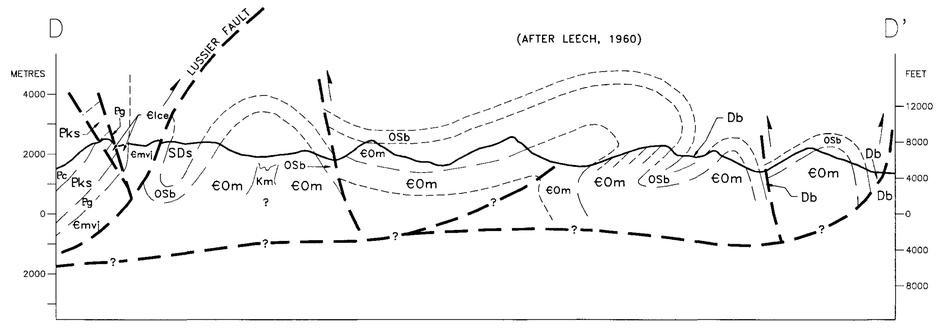
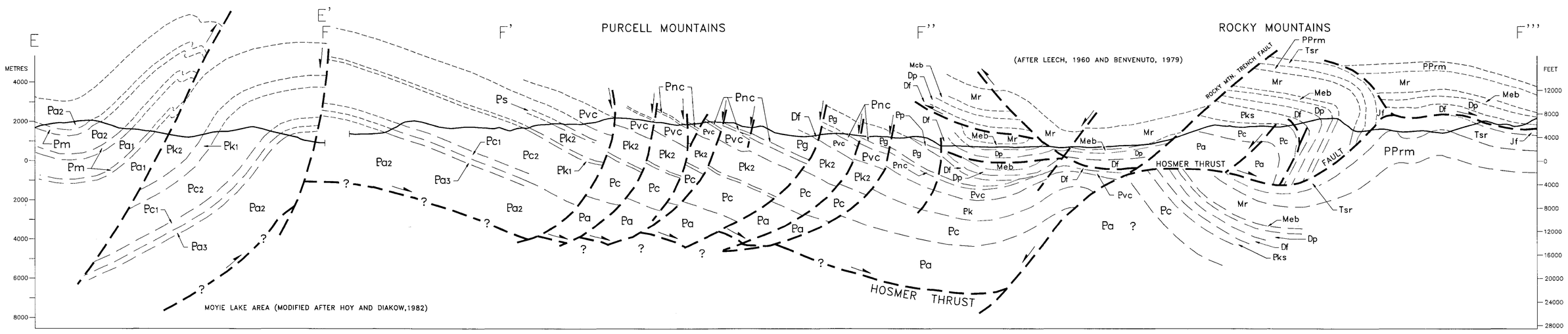


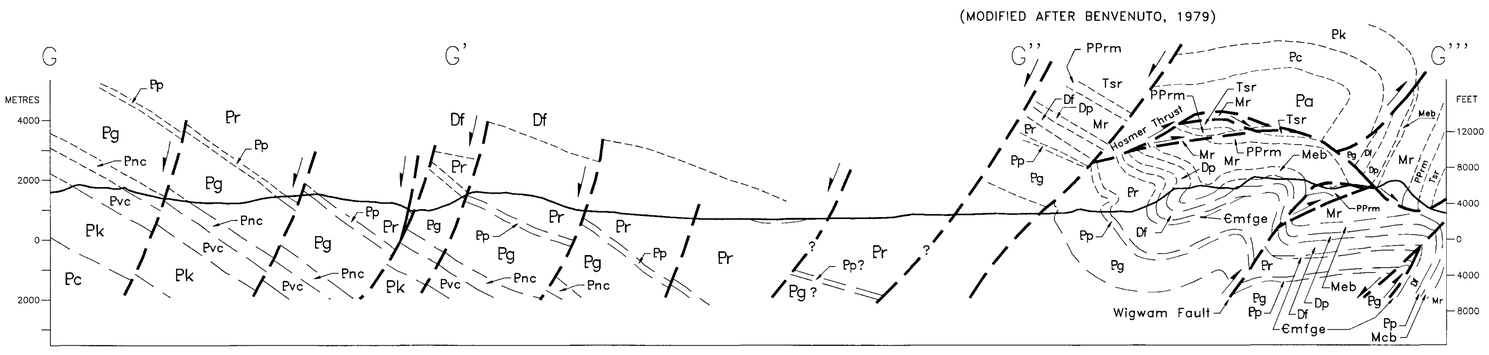


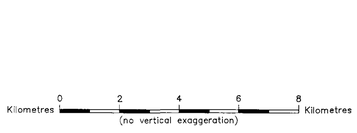


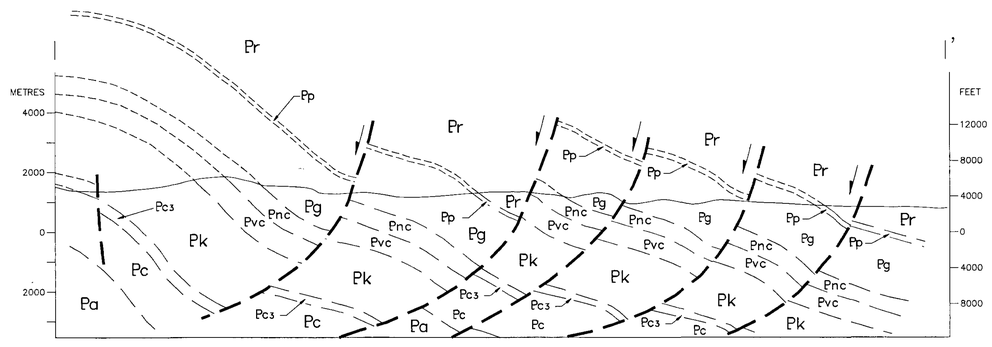


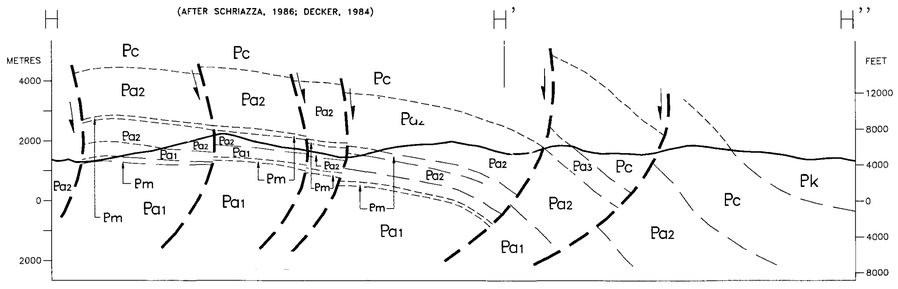


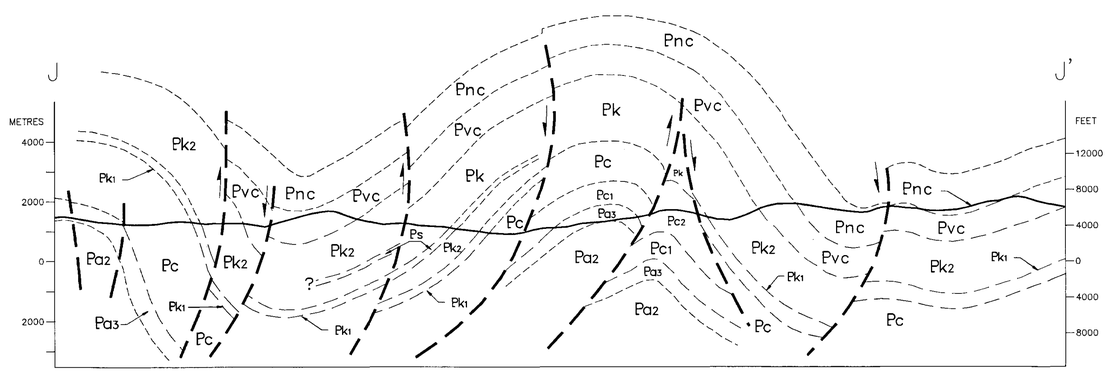






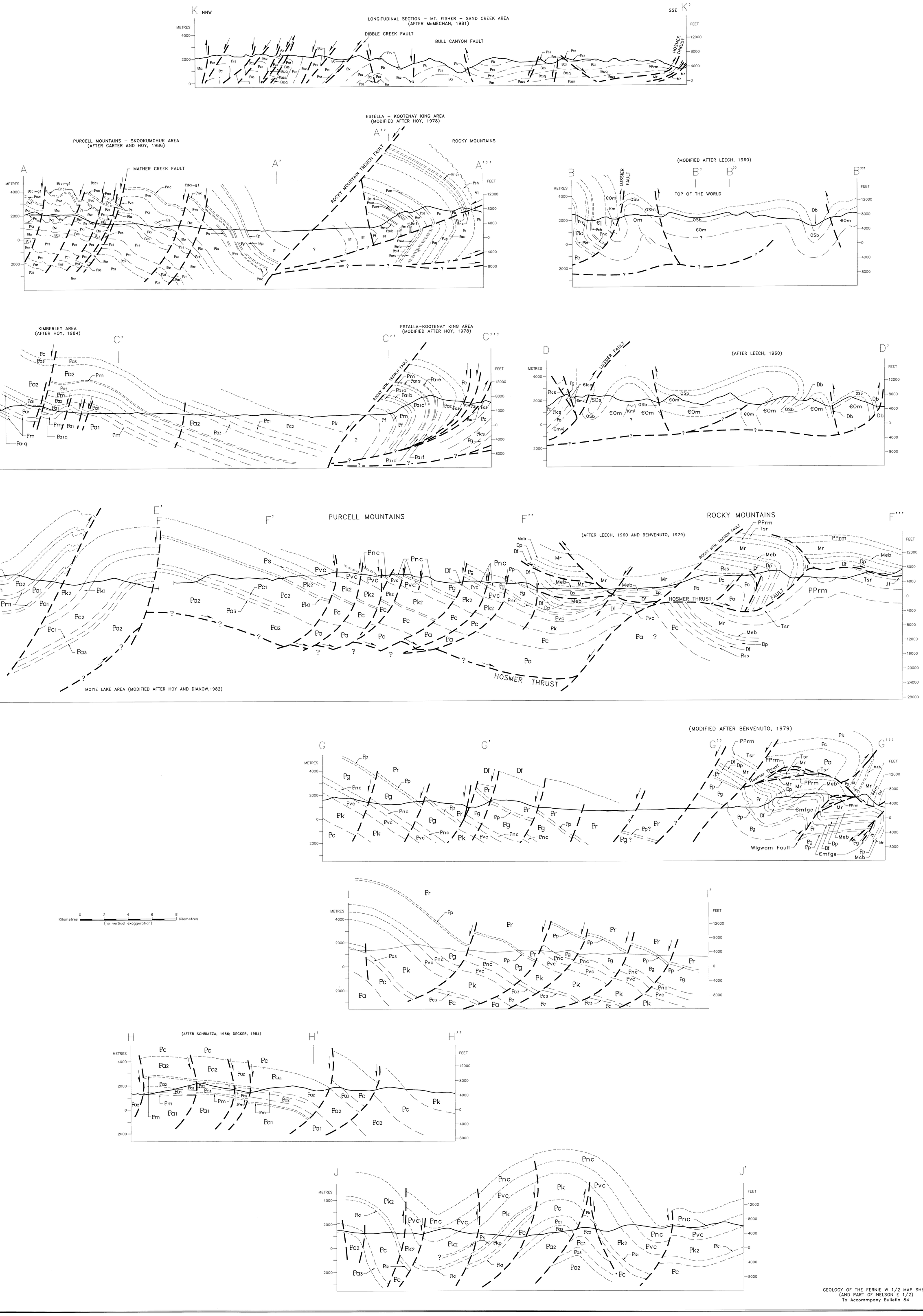






GEOLOGY OF THE FERNIE W 1/2 MAP SHEET
(AND PART OF NELSON E 1/2)
To Accommpany Bulletin 84

570 000 m 116°00'
640 000 m 115°00'
50°00'
49°00'
5530 000 m
5430 000 m
WHITE CREEK BATHOLITH
Kimberley
Sullivan deposit
Reade Lake Stock
Kootenay King
Estella
Magnesite
Kikokho Stock
St. Joe
Fernie Coal
Fernie
Cranbrook
Moyie Lake
Aurora
Gunsden
St. Eugene
Society Girl
Midway
Moyie fault
Cranbrook fault
Rocky Mtn Trench fault
Hosmer thrust
Gold Creek fault
Dibble Creek fault
Boulder Creek fault
Lussier Creek fault
Mount Stephens
Mount Fisher
Mount Broadwood
Mount Hosmer
Mount Proctor
Mount Thompson
Mount Ward
Mount Selkirk
Mount Nicol
Mount Ashley
Mount Cornwall
Mount Gerrard
Mount Hunter
Mount Ryan
Mount Wilson
Mount Fernie



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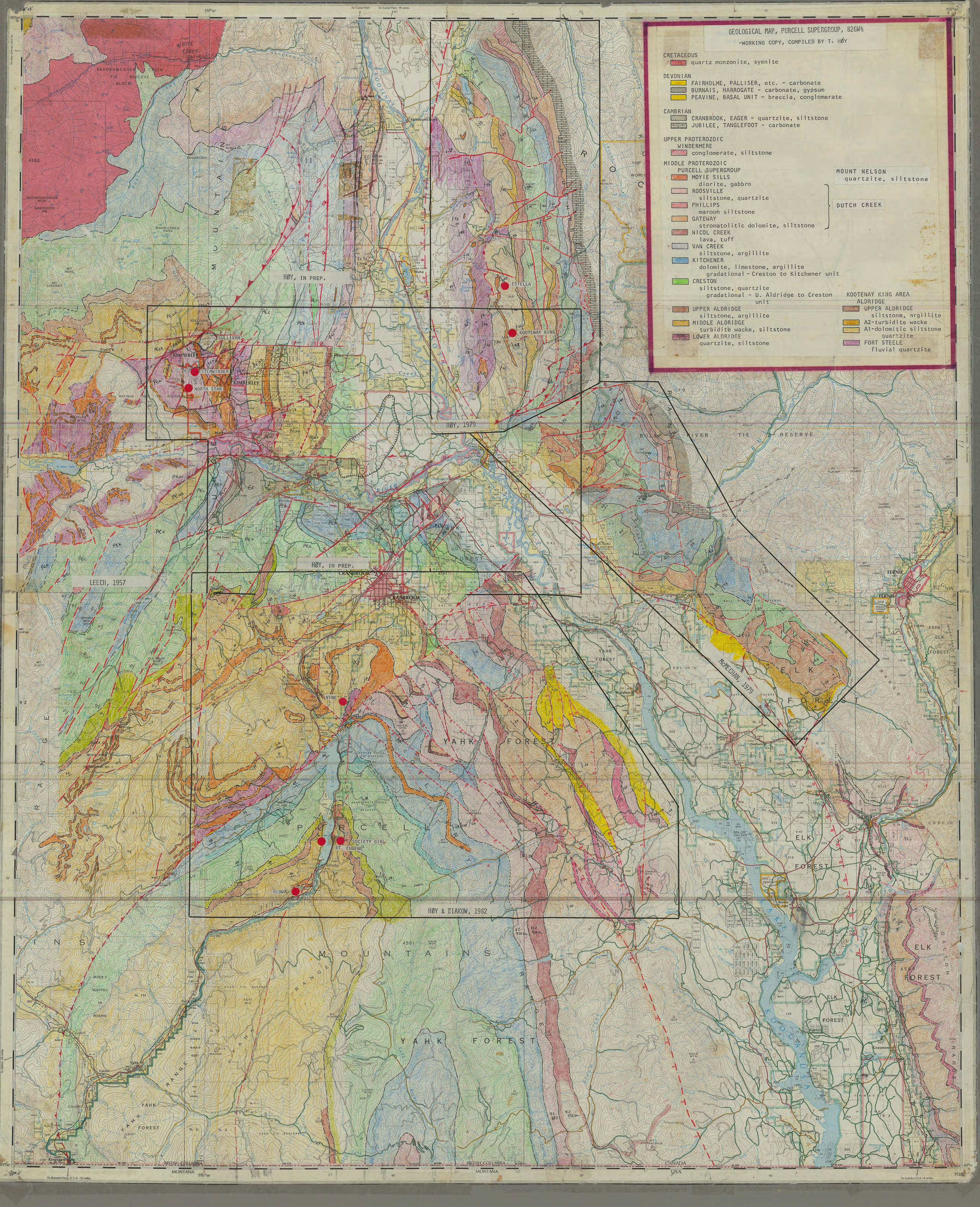
GEOLOGICAL MAP, PURCELL SUPERGROUP, 82GW½
-WORKING COPY, COMPILED BY T. HØY
CRETACEOUS
quartz monzonite, syenite
DEVONIAN
FAIRHOLME, PALLISER, etc. - carbonate
BURNAIS, HARROGATE - carbonate, gypsum
PEAVINE, BASAL UNIT - breccia, conglomerate
CAMBRIAN
CRANBROOK, EAGER - quartzite, siltstone
JUBILEE, TANGLEFOOT - carbonate
UPPER PROTEROZOIC
WINDERMERE
conglomerate, siltstone
MIDDLE PROTEROZOIC
PURCELL SUPERGROUP
MOYIE SILLS
diorite, gabbro
ROOSVILLE
siltstone, quartzite
PHILLIPS
maroon siltstone
GATEWAY
stromatolitic dolomite, siltstone
DUTCH CREEK
NICOL CREEK
lava, tuff
VAN CREEK
siltstone, argillite
KITCHENER
dolomite, limestone, argillite
gradational - Creston to Kitchener unit
CRESTON
siltstone, quartzite
gradational - U. Aldridge to Creston unit
UPPER ALDRIDGE
siltstone, argillite
MIDDLE ALDRIDGE
turbidite wacke, siltstone
LOWER ALDRIDGE
quartzite, siltstone
MOUNT NELSON
quartzite, siltstone
KOOTENAY KING AREA
ALDRIDGE
UPPER ALDRIDGE
siltstone, argillite
A2-turbidite wacke
A1-dolomitic siltstone
quartzite
FORT STEELE
fluvial quartzite
HØY, IN PREP.
HØY, 1979
HØY, IN PREP.
LEECH, 1957
McMECHAN, 1979
HØY & DIAKOW, 1982
ESTELLA
KOOTENAY KING
STEMWINDER
NORTH STAR
SOCIETY GIRL
ST. EUGENE
MIDWA
VINE
SULLIVAN
KIMBERLEY
CRANBROOK
FERNIE
Fort Steele
Skookumchuck
Wasa
Marysville
Jaffray
Elko
Newgate
Kingsgate
Yahk
Curzon
Moyie
Roosville
Grasmere
Baynes Lake
Wardner
Cranbrook
YAHK FOREST
ELK FOREST
PURCELL MOUNTAINS
BRITISH COLUMBIA
MONTANA
USA
CANADA