GEOLOGICAL MAPPING OF THE YAHK MAP AREA, SOUTHEASTERN BRITISH COLUMBIA: AN UPDATE (82F/1)

By D.A. Brown and P. Stinson

(Contribution No. 18, Sullivan-Aldridge Project)

KEYWORDS: Proterozoic, lower Purcell Supergroup, tourmalinite, ultrabasic breccia dikes.

INTRODUCTION

This article summarizes new findings of the East Kootenay project after completion of 2 months of fieldwork in the Yahk map area (82F/1) in 1994. The project was initiated in 1993 to provide 1:50 000-scale geological maps with improved stratigraphic correlations, and to stimulate base metal exploration southwest of the Sullivan mine. Work in 1994 focused on fill-in traverses and measured sections to complete mapping of the Yahk sheet, and the Iron Range Mountain study (Stinson and Brown, 1995, this volume). The regional geological setting and 1993 preliminary results were summarized by Brown *et al.* (1994); two 1:50 000-scale maps are now available (Brown, 1995a, b).

Mapping in the 1994 field season was extended to the west into metamorphosed, polydeformed Purcell Supergroup strata underlying the Creston map area (82F/2; see Brown *et al.*, this volume), and collectively, the two map areas provide an excellent opportunity to study the transition from hinterland (parautochthonous strata of the Purcell anticlinorium) to orogen (deformed North American miogeocline strata of the Kootenay Arc). This project contributes to the Sullivan-Aldridge project, a multidisciplinary research effort involving the Geological Survey of Canada, Geological Survey Branch, United States Geological Survey, four universities, Cominco Ltd. and Consolidated Ramrod Gold Corporation.

PREVIOUS WORK

Geological mapping in the Nelson East Half map area was completed in 1938 by the Geological Survey of Canada (Rice, 1941). Farther east, the Fernie West Half map area was initially mapped by Daly (1912a), Schofield (1915) and Rice (1937), and later, Leech (1960) completed a 1:126 720-scale map (1"=2 mile). Recent 1:250 000 and 1:100 000-scale mapping has been published to the east and north by Höy (1993) and Reesor (1993), and south of the international boundary by Harrison *et al.* (1992), Aadland and Bennett (1979) and Stoffel *et al.* (1991; Figure 1a). A new 1:250 000-scale coloured compilation map of the entire British Columbian Purcell anticlinorium is now available (Höy *et al.*, 1995a). More detailed mapping adjoining the Yahk map area includes work by Burmester (1985), Miller (1983) and Reesor (1981; Figure 1b).

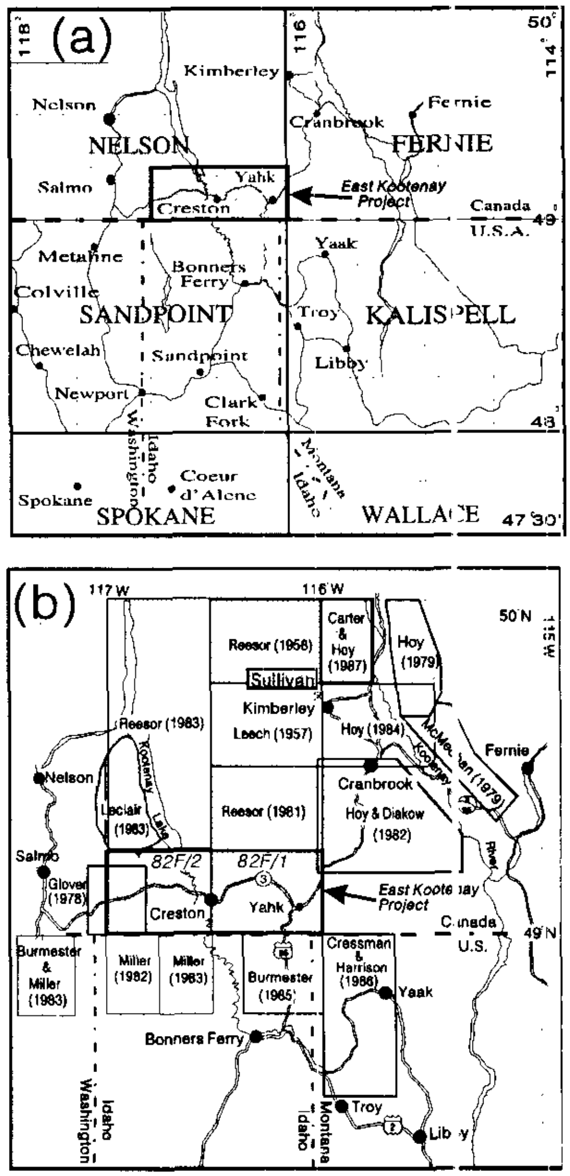
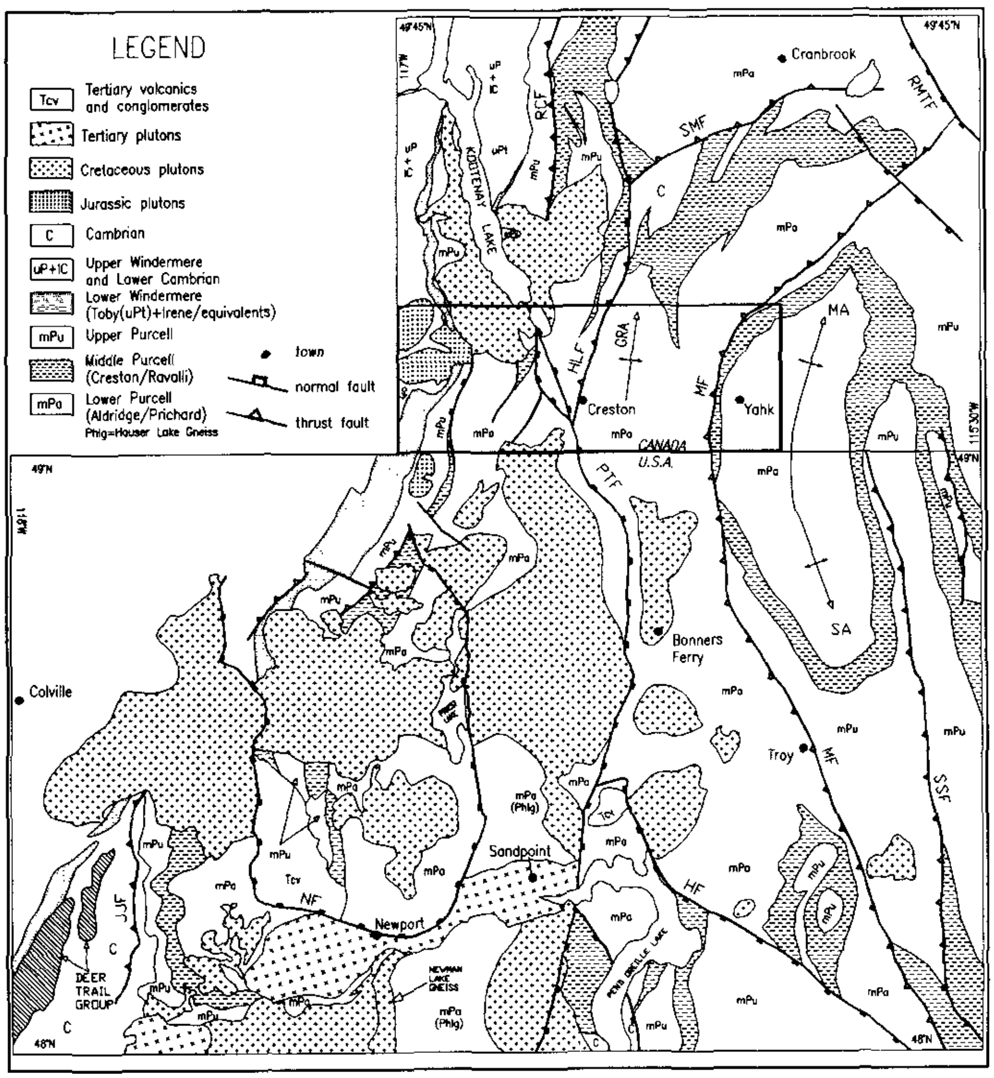


Figure 1. Location of the Yahk and Creston map areas (dark hatched rectangle) relative to areas of previously published geologic maps. (a) The 1:250 000, 1:126 720 or 1:100 000-scale map coverage includes: Fernie West-half (82G/West) -- Leech (1958, 1960), Höy and Carter (1988), Höy (1993); Nelson East-half (82F/east) -- Rice (1941), Reesor (1993). Sandpoint -- Aadland and Bennett (1979); Kalispell -- Harrison *et al.* (1992); Spokane -- Griggs (1973), Stoffel *et al.* (1991) · Wallace -- Harrison *et al.* (1986). (b) The 1:50 000, 1:48 000 and 1:25 000-scale maps in the immediate vicinity of the Yahk and Creston map areas include: Burmester (1985), Burmester and Miller (1983), Cressman and Harrison (1986), Glover (1978), Höy and Diakow (1982), Miller (1982, 1983), Reesor (1981, 1983).

GEOLOGICAL SETTING

The Proterozoic Purcell Supergroup (Belt Supergroup in the United States), a siliciclastic and carbonate sediment sequence at least 12 kilometres thick, accumulated in a pericratonic basin between about 1500 and 1350 Ma ago. It is preserved in an area 750 kilometres long and 550 kilometres wide, extending from southeastern British Columbia to eastern Washington, Idaho and western Montana. In British Columbia, the Purcell Supergroup is exposed in the Purcell anticlinorium, a broad, gently north-plunging structural culmination (Figure 2). The stratigraphic nomenclature for the Purcell Supergroup varies across the basin; this article adopts divisions used in the east-half of the Nelson map area (Reesor, 1983; Höy, 1993).

Purcell sedimentation may have ended with the onset of the **East Kootenay orogeny**, a metamorphic and structural event between 1350 and 1300 Ma (McMechan and Price, 1982). Within the basin, syn-Aldridge tectonism is evidenced by early faults and emplacement of the Moyie intrusions. A Late Proterozoic extensional event, the **Goat River orogeny** (800-900 Ma), resulted in rifting (block faulting), erosion of up to 4 kilometres of Purcell strata, and initiation of the Cordilleran miogeocline with deposition of the Windermere Supergroup (Lis and Price, 1976; Price, 1984). By the Middle Jurassic, collision of allochthonous terranes from the west (**Columbian orogeny**; Terrane I; Monger *et al.*, 1982) onto the western margin of North America produced deformation, metamorphism and plutonism that affected the western edge of the Purcell Supergroup. Docking of Terrane II to North America resulted in another compressional event in the Cretaceous to early Tertiary (**Laramide orogeny**, *circa* 100-70 Ma) that produced the dominant folds and thrust faults in the map area. Strata were transported to the east on west-dipping thrust faults that extended into the cratonic basement (Cook and Van der Velden, in press) producing the Purcell anticlinorium with Proterozoic strata in its core. Emplacement of several large, syntectonic and post-tectonic Cretaceous plutons accompanied this event. Some of the plutons plugged folds and thrusts; for example, the St. Mary fault zone is plugged by the Reade Lake stock and the Hall Lake fault is occupied by the White Creek batholith (Price, 1981; Archibald *et al.*, 1983; Höy, 1993). Reactivation of some of the Cretaceous thrust faults during Eocene extension is locally important, notably west of the Yahk map area (see Brown *et al.*, 1995, this volume).



STRATIGRAPHY

The Yahk map area is underlain largely by the Aldridge Formation, the lowermost division of the Purcell Supergroup (Figure 3). The Creston Formation (about 2300 m thick; Reesor, 1983) gradationally overlies the Aldridge Formation. The overlying Kitchener Formation includes the lowermost significant carbonate accumulations in the Purcell succession. The Aldridge, Creston and Kitchener formations are the equivalents to the Prichard and Ravalli groups, and Wallace and Helena formations in the United States, respectively.

LOWER ALDRIDGE – RAMPARTS FACIES

Strata equivalent to the lower Aldridge Formation occur in the map area, based on stratigraphic distance below the lowest middle Aldridge marker laminite, lack of any markers in over 700 metres of stratigraphy, and presence of numerous Moyie sills. However, the outcrops are unlike the typical rusty weathering, thin-bedded siltstone and argillite of the lower Aldridge Formation farther east in the basin. They are generally thick-bedded, grey-weathering (non-rusty), quartzitic wackes, and called "Ramparts facies" for their type locality east of Creston, along the Ramparts below Mount Thompson (D. Anderson, personal communication, 1994; Photo 1).

The Ramparts facies consists primarily of distinct, light grey to buff, medium to fine-grained quartzitic wackes with lesser green-grey argillites. The thick to medium-bedded wacke forms prominent cliffs or ribs along hillsides. Unlike the type locality, the rocks carry no pyrrhotite, except for the extreme base of the Ramparts exposure southeast of Creston. Locally, the quartzitic units are crossbedded, graded and/or laminated. Some beds are lenticular in outcrop and show cut-and-fill features suggestive of channel deposits and shallow water deposition. Beds tend to form amalgamated sets that fine upward. Between the sets are sequences of more thinly bedded quartz wacke and argillite. Bedding is wavy and lenticular, showing features of current activity (ripple crosslamination; Photo 2) and loading (load ripples and flames). This wavy bedform indicates more current activity than has been suggested for typical lower Aldridge in the Kimberley area to the northeast. Euhedral to subhedral pits on the weathered surfaces of argillite beds contain remnants of a soft white mineral that may be pseudomorphs after gypsum(?), near Mount Thompson. The presence of gypsum would signify saline conditions, at least locally. In the same area, probable mud-chip breccia may indicate desiccation. Quartz wacke interbeds grade upward into more quartzofeldspathic and locally calcareous beds of the middle Aldridge Formation. The transition is subtle and difficult to map at 1:50 000 scale, partly due to the lack of exposure.

At Creston the Ramparts facies is estimated to be 700 metres thick, exposed as a flat-lying succession in the core of the Goat River anticline. To the east, Ramparts facies can be recognized at America Creek and at Hawkins Creek, where only about 150 metres are exposed at surface (the estimated total thickness is 400 metres; D. Anderson, personal communication, 1994). The Ramparts facies thickens toward the U.S. border then thins farther to the south (D. Anderson, personal communication, 1994). It also thins to the east and northeast. The Ramparts facies may be a proximal part of a turbidite fan that correlates in part with the lower Aldridge footwall quartzite exposed in the Sullivan area. This implies that the upper siltstone (distal turbidites) of the Sullivan area are replaced to the southwest by proximal to middle fan turbidites of the Ramparts facies.

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

Photo 1. View east to subhorizontal beds of quartzitic wacke of the Ramparts facies intruded by several gabbro sills exposed in cliff faces along the Ramparts, southeast of Creston. This is the type area for the facies, a proximal equivalent to the lower Aldridge Formation in the Sullivan area.

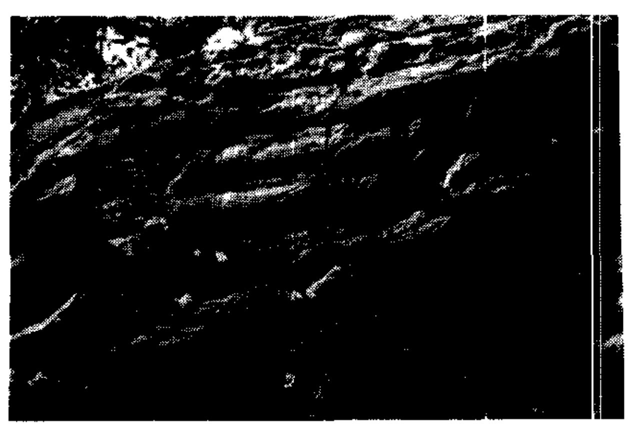


Photo 2. Brown-weathering bed bottom with asymmetric ripple marks, Ramparts facies about 5 kilometres south of Mount Thompson (5-centimetre diameter lens cap on top of block; PST94-200).

Figure 3. Simplified geology of the Yahk map area (82F/1), updated from Brown *et al.* (1994). Note Moyie sills south of Little Moyie River and south of Hawkins Creek appear anomalously thick because they are exposed along dip slopes.

MIDDLE ALDRIDGE

The middle Aldridge underlies most of the map area and comprises a thick sequence of fine siliciclastic rocks, dominantly planar-bedded, fine-grained quartzofeldspathic wacke to quartz wacke, with lesser argillite. It differs from the overlying Purcell Supergroup strata in that it was deposited in deeper water as turbidites, is intruded by numerous gabbro sills, contains extensive and distinctive marker units and has disseminated pyrrhotite throughout (Cressman, 1989; Höy, 1993). Medium-grained wacke is uncommon, and coarse-grained wacke is rare. Total thickness is at least 3000 metres, and may be as much as 4000 metres, based on estimates from map distribution. In contrast, the middle Aldridge in the Cranbrook area is about 2500 metres thick and farther north in the Sullivan mine area, only 2100 metres thick (Höy, 1993).

Isolated outcrops of sedimentary breccias and conglomerates ("fragmentals") are interpreted by Cominco geologists and others to be derived from fluidizing (dewatering) of consolidated to semi-consolidated sediments into crosscutting tabular bodies, sheet-like mounds and debris flows (Cominco staff geologists.; Turner *et al.*, 1992; Brown *et al.*, 1994; Höy, 1993; Cressman, 1989). A newly discovered fragmental locality, south of Yahk in King Creek, contains oblong wacke clasts up to 9 centimetres long. Clasts are concentrated along two horizons parallel to bedding.

IRISHMAN CREEK MEASURED SECTIONS

Two sections through parts of the middle Aldridge Formation were measured along Highway 3 on either side of Irishman Creek, in the northeast corner of the Yahk map area (Figures 3 and 4). Both sections are dominated by turbidites, with thin to thick planar, massive sand beds (Photo 3). Sediments associated with turbidity current processes are described by Walker (1979), and a regional discussion of the middle Aldridge Formation is given in Höy (1993).

In the eastern section (section 1), the bedding has a consistent dip to the west-northwest, and in the western section (section 2) the rocks have a variable, moderate dip to the west; the sections are on either side of a broad, gently north-plunging anticline, bisected by Irishman Creek (Figures 3 and 5). The base of section 2 is 200 to 300 metres stratigraphically above the top of section 1. Each section is broken by two to five normal faults; in every case offset across the faults is less than 2 metres based on bed-to-bed matches on either side of the faults.

The medium to fine-grained quartz wacke and wacke contains 10 to 20% fine-grained biotite, based on hand specimen examination, which is the metamorphic product of the original clay constituents. Lesser arenite and quartz arenite are interbedded with the wacke. The lithological consistency, particularly in section 1, is remarkable.

Individual sand beds range in thickness from several centimetres to over a metre. Internally, most of the beds are massive with faint parallel stratification towards their tops. These beds rhythmically alternate with sections of laminated siltstone 1 to 20 centimetres thick. The packages of thickest beds, mainly towards the top of section 1, are usually amalgamated; the fines of the previous turbidity current are completely eroded by the next turbidite. The amalgamated sand beds are up to 2 metres thick, with internal contacts only faintly visible. Thicker packages of laminated argillite and siltstone, deposited during quiescent periods in the basin, occur sporadically.

Sedimentary structures reflecting the turbidity current processes were observed; these include flute casts, and less common groove casts and bounce marks. Flame structures are present locally. Paleocurrent directions, bedforms, and lithologic variations are presented on the graphic sections (Figure 4). Most of the measured paleocurrent indicators trend northwest, after rotation to paleohorizontal. Where their asymmetry could be determined, they indicated currents to the north to northwest.

A thick sequence of siltstone and argillite towards the base of section 2 exhibits small-scale, well developed trough crossbedding and local flaser bedding. Foresets are composed of alternating light brown silt and black argillite. This section is near the top of the middle Aldridge and may indicate a regression, similar to the shallowing which resulted in the transition to upper Aldridge argillite. There are more turbidites above this unit, so it only represents a temporary change in depositional environment.

Each section has two Moyie sills. Section 1 was measured to the base of a sill 30 metres thick; it forms a steep cliff which marks the end of the exposure. The other, thinner sills have narrow chilled margins. The contacts of the two sills in section 2 are well exposed, and are concordant with bedding. The contacts are slightly sheared, as this part of the section is gently warped. The sills appear to have a zone of hornfels above their top contacts.

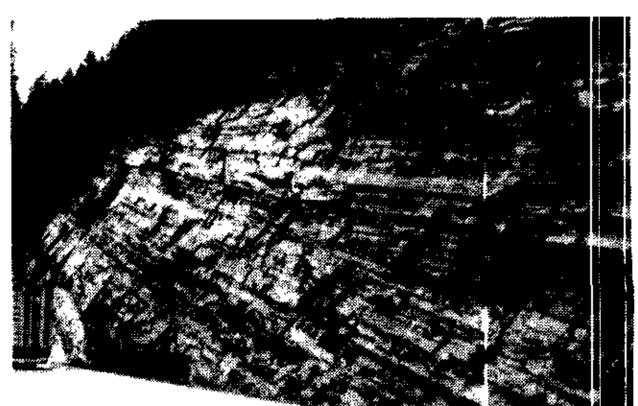


Photo 3. Part of the west Irishman Creek section illustrating planar bedforms and typical middle Aldridge formation exposure. Most of the photo corresponds to unit 28 on Figure 4. Rear of cattle truck for scale.

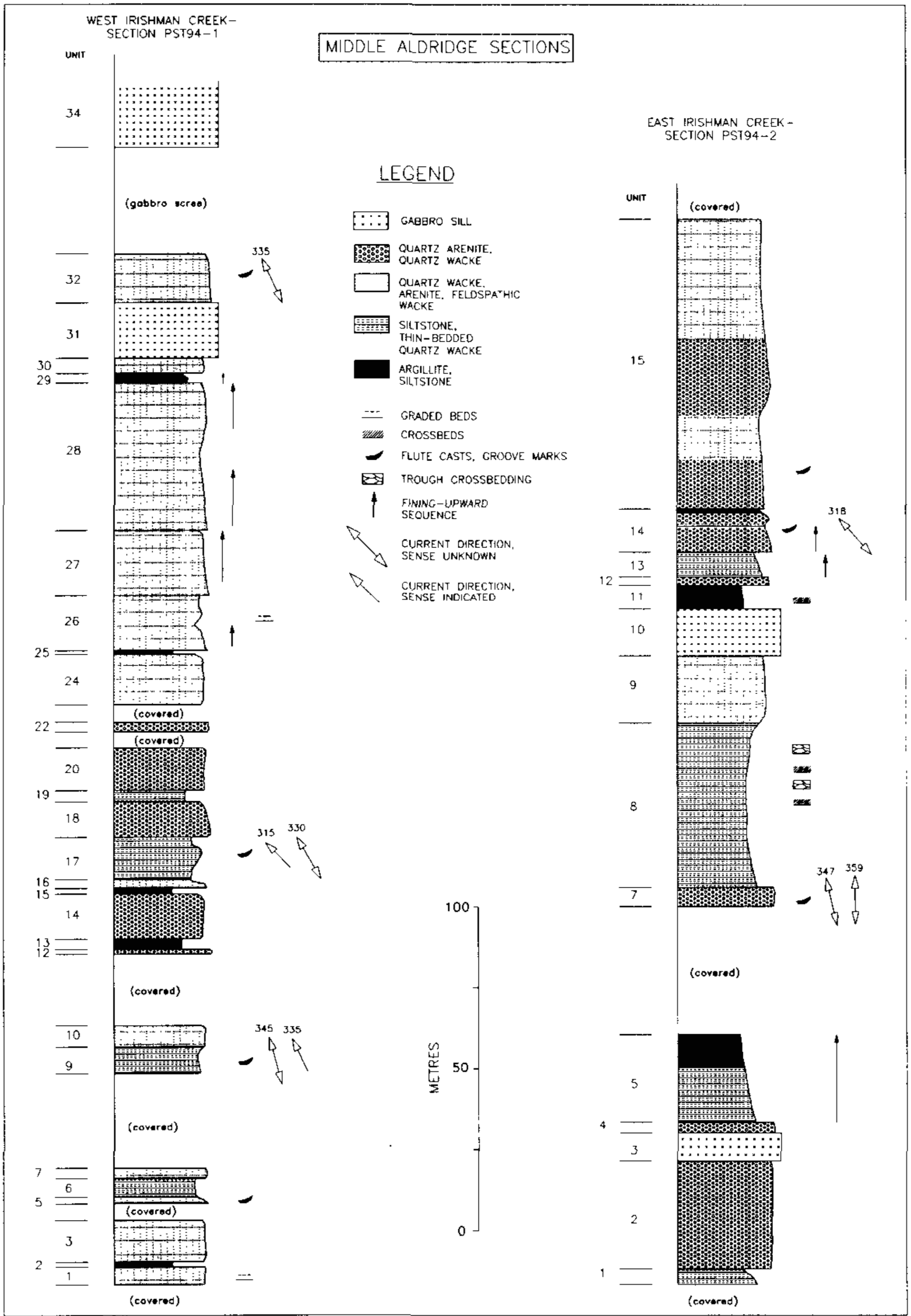


Figure 4. Measured sections of the middle Aldridge Formation at Irishman Creek, Highway 3. Locations of sections are shown on Figure 3. Unit numbers correspond to detailed divisions.

SHORTY CREEK AREA -- UNUSUAL FEATURES WITHIN THE ALDRIDGE FORMATION

Some unusual sedimentary and intrusive rocks crop out on a ridge above Shorty Creek, about 7 kilometres west of Kingsgate (Figure 3). The Shorty Creek succession consists of medium to fine-grained wacke, siltstone, minor argillite, rare limestone, and small, xenolithic, intermediate to mafic plugs and dikes. Beds dip gently to the northeast, parallel to bedding in the enclosing middle Aldridge Formation.

The lowest rocks, which overlie middle Aldridge wacke, are massive, faintly laminated black siltstone. Rarely exposed limestone occurs toward the top of the siltstone. It is massive, crystalline, but locally contains trains of round, 2 to 5-centimetre clasts of the same lithology. The origin of this limestone unit, its extent, and its relationship to the other rocks in this package are unknown. The black siltstone is overlain by greenish grey wacke and siltstone beds. The wacke is characterized by wavy, nonparallel beds from 3 to 25 centimetres thick. Internally, the beds are massive, or have a faint parallel stratification. Scours are common at the base of the beds. The sand grains are mainly angular, and consist of lithic grains and feldspar, although some beds are quartz rich. These rocks are interpreted to be epiclastic sandstones based on their green colour, crystal content and composition of lithic fragments. Rare, thick, massive beds of similar composition strongly resemble trachytic to andesitic lavas, but are more likely well indurated volcanic wacke.

Siltstone is exposed toward the top of the succession, and laminated siltstone is locally interbedded with wacke. The upper siltstone consists of alternating dark green and red-brown discontinuous beds. Greenish layers have up to 15% hornblende porphyroblasts, giving beds a spotty appearance. This is probably a contact metamorphic effect.

Several intrusions cut the Shorty Creek facies. A stock of medium-grained diorite, 30 metres wide, cuts the uppermost part of the section and is exposed in a large clearing which extends across the International Boundary. The intrusion contains numerous rounded inclusions of gabbro (autoliths?) and subrounded to angular xenoliths of wacke and siltstone. The inclusions are 1 to 20 centimetres wide, and most of the igneous ones have well developed reaction rims consisting mainly of feldspar. Notably, some of the igneous inclusions are sulphide and/or magnetite rich, forming rusty holes in the weathered outcrop surface. Two aphanitic, black, mafic dikes, 20 to 30 centimetres wide, were noted elsewhere in this package.

The Shorty Creek facies is anomalous for the Yahk map area, and appears to have a volcanic component. Several occurrences of volcanic rocks and associated mineralization in the middle Aldridge Formation are described by Höy *et al.* (1995, this volume). A tourmalinite occurrence crops out several kilometres southwest of the exposures described above. The Shorty Creek area deserves further study based on the anomalous, possibly volcaniclastic facies of the middle Aldridge Formation, possible relationships of such rocks to mineralization, and the possible association with tourmalinite alteration.

UPPER ALDRIDGE

The upper Aldridge Formation underlies about 10% of the Yahk map area in three areas, on the northwest limb of the Moyie anticline and the east and west limbs of the Goat River anticline (Figure 3). It is rusty, dark brown weathering, fissile argillaceous siltstone. It is grey to dark grey, thin-bedded to laminated, commonly containing distinctive white siltstone laminae (Reesor, 1981). Ripple marks are rare. Quartzofeldspathic wacke beds are very rare and thin (<10 cm). Talus derived from the fissile upper Aldridge forms chip-size fragments. Moyie sills are absent. The upper Aldridge reflects waning input of turbidites and final pelagic sedimentation prior to the shallowing of the Purcell (Belt) Basin, as represented by the Creston Formation.

Strata correlative with the upper Aldridge in the United States are informally called "lined rock" (Cressman, 1989). South of the Yahk map area, Burmester (1985) identifies a "lined argillite" unit, an equivalent to the upper Aldridge, that is conformably overlain by a "transition zone" unit, which correlates with the lower Creston Formation.

CRESTON FORMATION

The Creston Formation underlies about 15% of the Yahk map area: on the northwest limb of the Moyie anticline, along the north-trending Kingsgate graben that extends southward into Idaho and Montana (Figure 2), and on the eastern and western limbs of the Goat River anticline (Figure 3).

The Creston Formation, is divided into a lower argillaceous member (~1000 m thick), a middle quartzitic member (~1000 m thick) and an upper siltite and argillite (< 300 m thick). They correlate with the Burke, Revett and St. Regis formations of the Ravalli Group in the United States. The Creston Formation represents shallow-water, reworked deposits accumulated on northward prograding deltas or fans (Hrabar, 1973). The Revett Formation hosts stratabound copper-silver deposits (including Spar Lake, Montanore and Rock Creek) in the western Montana copper belt (Wells *et al.*, 1981; Balla, 1982, 1993) and in the Sage Creek area in the Lewis thrust sheet in southeast British Columbia.

The lower and middle Creston Formation produce a prominent areomagnetic signature, most notably within the Moyie anticline. This is due to fine disseminated magnetite, and quartz-magnetite veinlets and stringers throughout. Thin irregular fractures (< 2 mm wide) are filled with black magnetite forming prominent veinlets in pale green phyllitic argillite in an outcrop of lower Creston along Highway 95, 5.5 kilometres south of Curzon. Speckled argillite with small euhedral magnetite crystals is common in the upper Burke Formation in the Montanore deposit area (Adkins, 1993).

KITCHENER FORMATION

The Kitchener Formation, defined by Daly (1905) and Schofield (1915), overlies the Creston Formation and comprises green dolomitic siltite, argillite and carbonaceous dolomite and limestone. It forms a succession 1800 metres thick (in the Nelson East Half area where mapped by Reesor, 1983) of shallow-water deposits that correlate with the middle Belt carbonate, the Wallace Formation to the south and the Helena Formation to the southeast. Molar tooth structures are common and stromatolites are locally important (Winston, 1986).

The formation is poorly exposed and fault bounded in the northeast corner of the Yahk map area, within the Moyie fault zone. Prominent but thin, brown-weathering dolomitic siltstone beds distinguish Kitchener Formation from Creston Formation here. Discontinuous dolomitic siltstones layers pit-out and produce rough and irregular, tan to brown weathered surfaces. Otherwise, the wavy bedded, pale green siltstone and argillaceous siltstone are similar to the Creston Formation.

MOYIE INTRUSIONS

Moyie intrusions, dominantly sills and rarely dikes, occur mainly within two stratigraphic intervals; the lower, and middle of the middle Aldridge formations. Therefore two main episodes of sill emplacement are proposed (Rice, 1941; Leech, 1957). Both sill packages occur in the Yahk map area, but aside from stratigraphic position, no distinct mineralogy or visible features were recognized to differentiate them in the field. The sills were discussed by Daly (1905, 1912a), Schofield (1915) and Rice (1937, 1941). Geochronometric and geochemical studies are ongoing by Gorton *et al.* (in preparation) and E. Anderson (Geological Survey of Canada) as part of the Sullivan-Aldridge project.

The fine to medium-grained sills range in composition from hornblende(±pyroxene) gabbro to hornblende quartz diorite and hornblendite, and they extend laterally over tens of kilometres. Mafic phenocryst contents vary up to 70%. Pyroxene is only found rarely as relict cores surrounded by amphibole, due to widespread deuteric alteration. Some of the thicker sills (>20 m) contain irregular patches of coarse pegmatitic hornblende and feldspar. Zones of granophyre are rare in the Yahk map area.

LOWER SILL PACKAGE

The lower sill package underlies three areas, Ramparts east of Creston, west of Kingsgate, and Hawkins Creek near Yahk (Figure 3). The sills in the Ramparts area are exposed along the prominent escarpment that rises about 1400 metres above the Creston valley (Photo 1). There are at least four sills here, comprising a cumulative thickness of at least 600 metres in a section about 1370 metres thick (43% sills). The thickness and number of sills decreases southward toward the U.S. border to about 250 metres (27% as two sills; D. Anderson, personal communication, 1994).

Moyie sills in the Hawkins Creek area appear to be thickest (albeit not well exposed) adjacent to an inferred northwest-trending fault, and to terminate abruptly to the northeast (Figure 3). The inferred fault may have formed in the Proterozoic and partially controlled the emplacement and distribution of the sill sequence. In this area, albite alteration with associated sedimentary fragmental units (south of Hawkins Creek), and several tourmalinite localities, including Mount Mahon, immediately east of the map area, indicate hydrothermal activity.

Five sills on Moyie Mountain west of Kingsgate intrude Ramparts facies. They were mapped and described as the "Moyie sills", now a widely used term, by Daly (1912a, p. 221-255). The sills correlate with the Crossport sill sequence studied by Bishop (1973). The Kingsgate sills are exposed along the International Boundary cut above 1220 metres elevation (Figures 13 and 14 and Photo 25 of Daly, 1912a). They can be traced northward for about 12 kilometres, where they are truncated by the Carroll fault (Figure 3).

The lower sill package comprises thicker individual sills that are less extensive or continuous compared to the upper sill package in the Yahk map area.

UPPER SILL PACKAGE

A conspicuous section in the middle of the middle Aldridge contains two to four prominent sills. This upper sill succession is well exposed south of Kid Creek, where a sequence of four sills is repeated by faulting. They have a cumulative thickness of about 240 metres in a section 1200 metres thick (960 m of sedimentary rocks and 5% sills). To the west, on Mount Kitchener, the same stratigraphic section contains two sills (Figure 3).

Most of the Moyie sills have no aeromagnetic signature; however, one sill does produce a strong anomaly, most prominent on Arrow Mountain near Creston. The anomalous response can be traced from south of Creston northward across the entire map area. It extends southward across the International Boundary at least 50 kilometres (D. Anderson, personal communication, 1994) and it is clear that the magnetic property of this sill is useful for regional correlation.

SILL EMPLACEMENT EFFECTS

Bleached, albitized metasedimentary rocks occur locally, such as on the Goat River road near Highway 93 (Figure 3; Turner *et al.*, 1992; Stop 1-8), and may be due to sill emplacement. A granophyre exposure related to "Purcell intrusive" was noted by Rice (1941, p. 26) along a trail up to Iron Range Mountain, but was not examined during this study. Another occurrence of albite alteration is exposed on a knob along the basal contact of a lower package Moyie sill, south of Yahk. Here a fragmental horizon occurs within the albitite zone (D. Anderson, personal communication, 1994).

ULTRABASIC DIKES

Several ultrabasic breccia dikes crop out on Iron Range Mountain. One dike, located 6 kilometres northwest of the town of Kitchener, is 12 to 15 centimetres wide, strikes north and has sharp, planar contacts. Dikes farther north on Iron Range Mountain have irregular outcrop patterns and are 0.3 to 1 metre wide. All the dikes have abundant, rounded inclusions of carbonate, possible ultramafic lithologies, and xenoliths of Aldridge Formation (Photo 4). The southernmost dike has 0.5 to 1-centimetre feldspar and biotite phenocrysts, while the other dikes have phlogopite megacrysts, some up to 8 centimetres across. Thin sections reveal that in every sample the groundmass and all non-carbonate inclusions are completely altered to fine-grained calcite and chlorite.

These rocks are difficult to classify. The southern dike may be a lamprophyre, based on the phenocryst types. The other dikes have petrographic similarities to diatreme breccias in the Golden area, which are ultramafic lamprophyre and alnoite (Pell, 1994, p. 77-89). The dikes on Iron Range Mountain may represent the root zones of eroded diatreme systems, as the variety and nature of inclusions in them indicate rapid emplacement. One of the dikes on the northern part of Iron Range Mountain yielded a Late Carboniferous K-Ar date of 301±10 Ma (D. Anderson, personal communication, 1994). Diatreme breccia and related rocks are known from several areas in the province (Pell, 1994). The Iron Range breccia dikes and similar rocks to the north in the Horsethief Creek area (Pope, 1989, p. 198-214) lie farther west than known diatreme breccias occurrences (Pell, 1994).

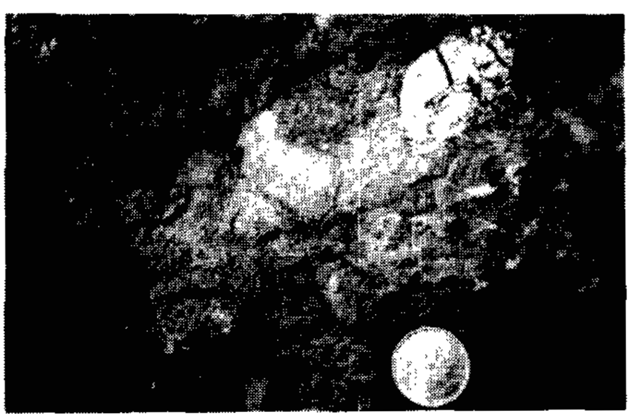


Photo 4. Green-weathering, ultrabasic breccia dike with phlogopite megacrysts and dull brown weathering, rounded, recessive carbonate inclusions, Iron Range Mountain, X-ray claim (PST94-I.R.5).

REGIONAL STRUCTURAL SETTING

The Yahk map area includes two regional anticlines, the Moyie and Goat River anticlines, in the western half of the Purcell anticlinorium. The anticlines are separated by a disrupted zone that is bounded on the east by the Moyie fault, a regionally important transverse thrust fault. The fault trends obliquely across the anticlinorium and records a complex history beginning in the Proterozoic (Höy, 1979, 1993; McMechan, 1979, 1981). The structure may reflect the geometry of a structural weakness in the underlying continental basement along which the fault propagated and ramped up higher in the section. The basement anisotropy may correspond to northeast-trending boundaries of the cratonic blocks of different ages, in particular the Rimbey and Medicine Hat domains (cf. Figure 7 in Ross *et al.*, 1992).

YAHK MAP AREA STRUCTURES

The Yahk map area has been divided into three structural domains, separated by high-angle faults (Brown *et al.*, 1994). The eastern and western domains are dominated by broad, north-trending and gently north-plunging folds, the Moyie and the Goat River anticlines (Figure 5). Structural style is characterized by broad open folds and steep faults. Brittle fractures and weak, spaced cleavage are present throughout the map area, but penetrative fabrics occur adjacent to faults, especially the Moyie fault, and west of the Arrow fault The following section provides additional detail and some modification of previous ideas.

EASTERN DOMAIN

The eastern domain consists of a segment of the northwest limb and core of the Moyie-Sylvanite anticline, a doubly plunging, banana-shaped culmination that terminates 30 kilometres to the northeast (Höy, 1993) and 25 kilometres to the southeast (Harrison *et al.*, 1992; Figure 2). The northwest limb of the fold lies in the footwall of the Moyie fault, the thrust that carries the next imbricate sheet to the west including the Goat River anticline. The limb is disrupted locally by north-trending vertical faults with apparent sinistral offset, and a minor, open north-plunging fold near Irishman Creek. The core of the Moyie anticline is exposed east of the northeast-trending, down-to-the-northwest Yahk fault. The core comprises gently dipping strata with local open folds. However, strata in the core and on the northwest limb steepen abruptly and bend into a north trend approaching the Kingsgate fault, which bounds Creston Formation in the Kingsgate graben.

KINGSGATE GRABEN

The Kingsgate graben preserves Creston Formation in a north-trending belt that extends southward along the western flank of the Moyie anticline. It is bounded on the west by the Moyie fault; the zone of convergence with the

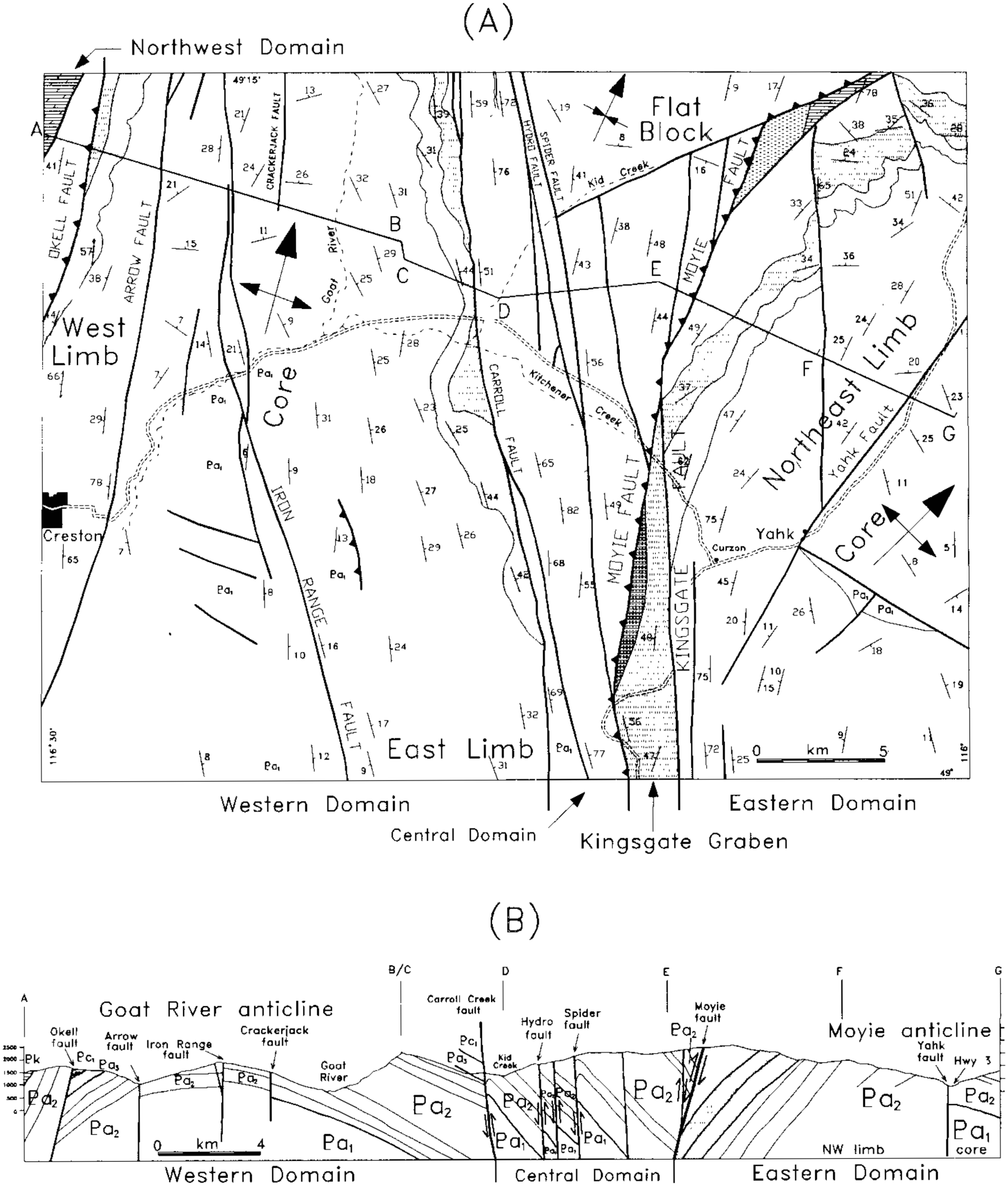


Figure 5. (a) Structural features of the Yahk map area, and (b) Schematic cross-section, modified from Brown *et al.* (1994)

Kingsgate fault to the north is poorly understood. A splay of the Kingsgate fault system is exposed along the Canadian Pacific railway tracks, 1 kilometre southwest of Curzon. Motion appears to be dip-slip based on rare, steeply plunging mineral-fibre slickensides. Bedding-cleavage intersections across the graben indicate that most of the Creston Formation within it comprises an east limb of a broad, faulted syncline, probably a truncated footwall syncline to the Moyie fault.

TRANSVERSE CONTRACTIONAL FAULTS – MOYIE FAULT

The Moyie fault extends from the east side of the Rocky Mountain Trench (Dibble Creek fault) southwestward through to the Yahk map area and into northern Idaho (Figure 2; Benvenuto and Price, 1979; Harrison *et al.*, 1992; Höy, 1993; Höy and Diakow, 1982; Leech, 1958; Reesor, 1981). Its arcuate trace is mimicked by the surface trend of the Moyie-Sylvanite anticline in the footwall at about 116° longitude.

The trace of the fault is defined by juxtaposition of middle Aldridge Formation against Creston or Kitchener formations, steepening of bedding attitudes, local tight folding and zones of intense cleavage. The best evidence of the fault in the Yahk map area comprises tight, upright moderately north plunging folds in middle Aldridge Formation, and a Moyie sill adjacent to openly folded middle Creston Formation, exposed along a ridge 10 kilometres north of Curzon. Here a series of parallel gullies is presumed to represent eroded zones of cataclasite and gouge. The fault, a zone of folded and faulted strata, at least 500 metres wide, bends to the north-northeast at this location. Farther northeast, at the headwaters of Kid Creek, lack of exposure precludes accurate delineation of the fault zone, but there appears to be a series of fault-bounded blocks of Kitchener Formation in the footwall of the main fault.

In the Yahk map area, the apparent west-side-up vertical throw is on the order of 1.0 to 1.5 kilometres. Sense and magnitude of displacement along the trace of the fault are predictably variable. Four kilometres of reverse dip-slip motion was estimated in the Cabinet Mountains (Fillipone and Yin, 1994) and about 12 kilometres of right-lateral movement was documented by Benvenuto and Price (1979) in the Fernie area. Timing of fault motion remains poorly constrained; pre-Devonian north-side-down and younger oblique reverse movement are suggested for the Dibble Creek fault (Leech, 1958). The latest movement on the Moyie fault is interpreted to be between 71 and 69 Ma, based on the age of muscovite neoblasts in the mylonitized western margin of the Dry Creek stock (Fillipone and Yin, 1994). The Moyie fault therefore has a complex and episodic history with variable character along its length.

CENTRAL DOMAIN

The central domain, bounded by the Moyie and Carroll faults, is an internally faulted horst-like block, underlain by lower and middle Aldridge Formation. It comprises a series of narrow, north-trending panels separated by steep faults, the most important being the Carroll, Spider and Hydro faults. The latter two are east-dipping reverse faults which repeat a sequence of sills and marker laminates. Dips within the block are moderate to steep, except for a flat-lying panel east of the Spider fault on the north side of Kid Creek. Minor folds are absent and cleavage is poorly developed, except adjacent to the bounding faults where tight and intense folding, with steeply plunging fold axes, is common, for example adjacent to major faults like the Moyie and Carroll. Most of the faults are steeply dipping but it is difficult to determine dip direction; they are either east-dipping reverse faults or west-dipping normal faults. A tentative interpretation is that they are subsidiary antithetic reverse faults related to the Moyie fault (Figure 5a).

An inferred fault in the Kid Creek valley separates the flat-lying block to the north from moderate-dipping strata in the central domain. Distribution of Moyie sills around an unnamed mountain and several gently dipping bedding attitudes characterize this block. It probably represents the core of a broad syncline that may extend to the north-northeast toward Cooper Lake (Grassy Mountain map area (82F/8); Reesor, 1981)

The Carroll fault down-drops lower Creston against middle Aldridge Formation. It consists of a bleached, clay-altered mylonitic rock that was exposed across a zone 2 metres wide by road building on the Star property (P. Ransom, personal communication, 1994). The Carroll and Iron Range faults are steeply dipping to vertical; Brown *et al.* (1994) inferred an east dip for the Carroll fault, but recently Cook and Van der Velden (in preparation) suggest it is a west-dipping normal fault. Although the dip direction is uncertain, there is agreement on the relative displacement across the fault.

WESTERN DOMAIN

The western domain comprises much of the Goat River anticline, plunging gently to the north, and where its eastern limb is truncated by the Carroll Kid fault. It is slightly asymmetric with a steeper and more foliated, west-dipping limb cut by the Okell fault. Like the Moyie anticline, lower Aldridge strata are exposed in the core of this fold. A contractional fault cuts the eastern limb of the anticline, 3 kilometres east of Mount Kitchener (Figure 3). Decimetre-scale, open to tight, southeast-verging folds developed in medium-bedded quartz wacke have moderate northwest-dipping axial planes, 2.5 kilometres southeast of Mount Thompson. A similar style of folding occurs in the hangingwall of the Moyie fault along the ridge 10.5 kilometres due north of Curzon. The core of the Goat River anticline is cut by two main north-trending faults, the Iron Range and Arrow faults. The Arrow fault is poorly exposed, but separates gently west-dipping strata from moderate to steeply west-dipping variably foliated rocks. It parallels Arrow Creek and is exposed near Creston as a zone of folded phyllitic wacke. The Iron Range fault is discussed in Stinson and Brown (1995, this volume).

NORTHWEST DOMAIN-- WEST OF ARROW FAULT

An intense penetrative cleavage developed in quartz wacke occurs on the west limb of the Goat River anticline. It is well exposed along the Lakeview - Arrow Creek road, west of the Arrow fault. Gabbro sills are foliated and cut by discrete shear zones (chlorite schist) and abundant quartz-carbonate veins. The intense fabric may be related to the Okell fault, an east-directed contractional fault that places middle Aldridge on Creston and upper Aldridge formations (Figure 3). It is not well exposed but is marked by zones of tight folding and pervasive cleavage in its hangingwall in the Creston map area (Brown *et al.*, 1995, this volume). The fault extends northward into the Goat River valley where it may join with the St. Mary fault system (Reesor, 1981). Southward, it disappears under the thick Quaternary cover in the Creston Valley.

MINERAL OCCURRENCES AND ALTERATION

Sullivan-type sedex deposits are the prime exploration target throughout the Purcell Basin. The Sullivan deposit has been described by Hamilton *et al.* (1983), Höy (1984) and others. Recent studies by Leitch *et al.* (1991), Turner and Leitch (1992) and Leitch and Turner (1992) have refined the Sullivan model. Massive sulphide mineralization, tourmalinite, albite and muscovite alteration, manganese-rich garnet, sedimentary fragmental units and syndepositional sedimentary structures (slumps) and faults are characteristic features. Co-existing brown and black tourmalinite may discriminate potentially mineralized from barren tourmalinite showings (Slack, 1993). The Fors and Vine deposits, south of the Sullivan mine, near Moyie Lake, are exploration targets described elsewhere in this volume (Britton and Pighin, 1994, 1995, this volume; Höy and Pighin, 1995, this volume).

Several new alteration zones were discovered during the course of mapping and may warrant further prospecting. A knob of well exposed albite-flooded wacke and sedimentary fragmental within Ramparts facies crops out on the west side of Hawkins Creek in a logging clearing. Pervasive biotite flooding (with prominent biotite flakes weakly aligned perpendicular to bedding planes) of quartzofeldspathic wacke of the middle Aldridge below a sill 100 metres thick, is exposed along a new logging road directly south of the Highway 3 and 95 junction (Curzon). Some layers are so biotite rich they resemble a biotite lamprophyre (minette), however, relict bedding is still visible. The zone of biotite alteration extends southwest at least 300 metres. In another fragmental locality in King Creek, south of Yahk, clasts up to 20 centimetres long are supported in a wacke matrix. Pink garnet-rich beds on the south flank of Mount Mahon may correlate with similar beds farther south across Hawkins Creek. This garnet-rich horizon may be useful for detailed stratigraphic correlation (for locations, see Brown, 1995a).

TOURMALINITES

Tourmalinite occurrences are important because some are associated with lead-zinc mineralization, notably the Sullivan orebody. There are at least five stratiform or discordant tourmalinite occurrences in the Yahk map area (Figure 3). The stratiform occurrences are interpreted to have formed either by early diagenetic sub-seafloor replacement or by reaction between exhalative boron and aluminous sediments in a brine pool (Slack, 1993). Occurrences in the region have been studied by Ethier and Campbell (1977; Kingsgate and Mount Mahon), and divided into stratiform and discordant types by Slack (1993).

The Goatfell tourmalinite occurrence is the best known in the map area because it forms a pipe-like body exposed along part of a prominent knob visible from Highway 3, 6.25 kilometres northwest of Curzon. Argillite layers and rip-up fragments (2 to 10 mm long) within medium-grained quartzitic wacke are selectively replaced by tourmaline. The aphanitic, hard black tourmalinite forms concoidal fractures and looks like chert. In thin section, fine olive-brown tourmaline crystals are interstitial to quartz (Ethier and Campbell, 1977). Another tourmaline occurrence with associated arsenopyrite, pyrrhotite, pyrite and chalcopyrite was discovered 4 kilometres northwest of Goatfell in 1989 by Chevron Minerals Ltd. (Rebic, 1989).

Tourmaline fracture fillings in fine-grained quartzofeldspathic wacke, and replacement of mudstone layers and fragments are well exposed between Canuck and America creeks, southeast of Yahk at Monument 222 on the U.S. border (this is probably the Kingsgate site of Ethier and Campbell, 1977). The irregular fractures, up to 2 centimetres wide, are perpendicular to bedding. The angular tourmaline-rich mudstone fragments are interpreted to be rip-ups of local derivation and resemble those at Mount Mahon immediately east of the Yahk map area, as discussed by Ethier and Campbell (1977). A Moyie (gabbro) sill, 40 metres thick, crops out immediately below a gently southwest-dipping succession of middle Aldridge Formation at Monument 222.

Tourmalinite float, probably derived from Mount Mahon, was found southwest of Hawkins Creek. It is characterized by well bedded, aphanitic black tourmalinite dotted with small (<3 mm) brown, euhedral garnet crystals. The garnet is assumed to be a manganese-rich variety, perhaps formed in a brine pool by exhalative processes (Slack, 1993).

EXPLORATION ACTIVITY AND POTENTIAL

Drilling programs were completed on the Sun and Indigo claims in the Yahk map area, and a third conducted immediately to the east on the Canam property. The Sun claims, owned by David Wiklund of Creston and optioned to Hastings Management Ltd., cover a lead-zinc soil anomaly that was the target of a 300-metre drill hole. East-striking, steeply south-dipping galena-bearing quartz veins, up to 30 centimetres wide, are hosted by the middle Aldridge Formation. Cominco Ltd. completed soil geochemistry and an EM survey on the property in 1984. Later trenching exposed the quartz veins. Black argillites with some thin slump sheets are present.

The Indigo claim group lies north of the Moyie fault in the headwaters of Kid Creek. A vertical drill hole, started in 1993 (275 m), was extended to a depth of about 1020 metres in 1994. The hole, collared in the middle of the middle Aldridge, was drilled to the predicted lower-middle Aldridge contact. One narrow (2 cm), galena-bearing quartz vein was intersected at 960 metres. Bleached core with albite alteration occurs in numerous intercepts. A second drill hole was collared at the same site and directed 45° to the west for about 100 metres but encountered no visible mineralization or intense alteration.

The Hawkins Creek area remains attractive for exploration; the creek bisects the lower-middle Aldridge contact, there are numerous sills that change thickness rapidly across an inferred fault, and there are exposures of albitite alteration and fragmental rocks. In addition, drilling of coincident geochemical and geophysical anomalies encountered a zone of gouge, 15 centimetres wide, containing native silver and copper (34 100 g/t Ag and 10.3% Cu) in a drill hole on the ENG property (Stephenson, 1990). This supergene mineralization may be an indicator of a disseminated target. The Canam prospect comprises weakly disseminated sphalerite and galena and quartz-sulphide veinlets. Stratabound tourmalinites, local pervasive biotite alteration with patchy garnets are all within the middle Aldridge Formation (Anderson, 1991 and personal communication, 1994). The property lying immediately east of the Yahk map area, remains under exploration.

CONCLUSIONS

A summary of the results of fieldwork in the Yahk map area includes recognition of atypical lower Aldridge Formation, defined as the Ramparts facies. Two Moyie sill packages are indistinguishable except for stratigraphic position in Ramparts facies and in the middle of the Middle Aldridge. The Iron Range fault and an inferred northwest-trending fault in Hawkins Creek may define conduits for the emplacement of Moyie sills in the Ramparts and Hawkins Creek areas. Deformation and metamorphism in the Yahk map area increases abruptly west of Arrow fault. A north-trending array of Early Carboniferous(?) ultrabasic breccia dikes occurs near the Goat River valley. Sullivan-style mineralization indicators, including the lower-middle Aldridge contact (Sullivan horizon) at depth below much of the area, sulphide occurrences, albitite zones, fragmentals, and tourmalinites occur in the map area. The nearby Fors occurrence suggests targets in the middle Aldridge Formation also warrant exploration attention.

ACKNOWLEDGMENTS

John Bradford, James Britton, Dean Barron, Gavin Manson and Dave Melville were all valuable members of the East Kootenay project in 1993 and 1994; their mapping and many ideas are incorporated in this paper. Trygve Höy and Cominco Ltd. geologists Doug Anderson and Paul Ransom provided guidance in the field and shared their knowledge of regional stratigraphy and metallogeny. Discussions in the field with Peter Klewchuk, David Pighin, Richard Walker and Dave Wiklund were of considerable help. Reviews by Doug Anderson, Trygve Höy, John Newell and David Lefebure improved the manuscript; we thank them for their comments.

REFERENCES

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

Adkins, A.R. (1993): Geology of the Montanore Stratabound Cu-Ag Deposit, Lincoln and Sanders Counties, Montana; Programs and Abstracts, Belt Symposium III, *Belt Association*, Spokane, Washington.

Anderson, D. (1991): Diamond Drilling Report, Canam Property (NTS 82F/1, 82G/4); *B.C. Ministry of Energy, Mines and Petroleum Resources*, Assessment Report 21786.

Archibald, D.A., Glover, J.K., Price, R.A., Carmichael, D.M. and Farrar, E. (1983): Geochronology and Tectonic Implications of Magmatism and Metamorphism, Southern Kootenay Arc and Neighbouring Regions, Southeastern British Columbia, Part I: Jurassic to Mid-Cretaceous; *Canadian Journal of Earth Sciences*, Volume 20, pages 1891-1913.

Balla, J.C. (1982): Geology of the Troy Deposit, Northwestern Montana; Abstracts, Genesis of Rocky Mountain Ore Deposits, *Denver Regional Exploration Geological Society.*

Balla, J.C. (1993): Geology of the Rock Creek Deposit, Sanders County, Montana; Programs and Abstracts Belt, Symposium III, *Belt Association*, Spokane, Washington.

Benvenuto, G.L. and Price, R.A. (1979): Structural Evolution of the Hosmer Thrust Sheet, Southeastern British Columbia; *Bulletin of Canadian Petroleum Geologists*, Volume 27, pages 360-194.

Bishop, D.T. (1973): Petrology and Geochemistry of the Purcell Sills in Boundary County, Idaho; *in* Belt Symposium, 1973, Volume II: *University of Idaho* and *Idaho Bureau of Mines and Geology*, Special Publication, pages 15-66.

Britton, J.M. and Pighin, D.L. (1994): The Fors Prospect, a Proterozoic Sedimentary Exhalative Base Metal Deposit in Middle Aldridge Formation, Southeastern British Columbia (82G/5W); *Northwest Geology*, Volume 23, pages 33-39.

Britton, J.M. and Pighin, D.L. (1995): Fors - A Proterozoic Sedimentary Exhalative Base Metal Deposit in Middle Aldridge Formation, Southeastern British Columbia (82G/5W); *in* Geological Fieldwork 1994, Grant, B. and Newell, J.M., Editors, *B.C. Ministry of Energy, Mines, and Petroleum Resources*, Paper 1995-1 this volume.

Brown, D.A. (1995a): Geology and Mineral Occurrences of the Yahk Map Area (82F/1); *B.C. Ministry of Energy, Mines and Petroleum Resources*, Open File 1995-14.

Brown, D.A. (1995b): Geology and Mineral Occurrences of the Creston Map Area (82F/2); *B.C. Ministry of Energy, Mines and Petroleum Resources*, Open File 1995-15.

Brown, D.A., Bradford, J.A., Melville, D.M., Legun, A.S. and Anderson, D. (1994): Geology and Mineral Deposits of Purcell Supergroup in Yahk Map Area, Southeastern British Columbia (82F/1); *in* Geological Fieldwork 1993, Grant, B. and Newell, J.M., Editors, *B.C. Ministry of Energy, Mines, and Petroleum Resources*, Paper 1994-1, pages 129-151.

Brown, D.A., Stinson, P. and Doughty, T. (1995): Preliminary Geology of the Creston Map Area, Southeastern British Columbia (82F/2); *in* Geological Fieldwork 1994, Grant, B. and Newell, J.M., Editors, *B.C. Ministry of Energy, Mines and Petroleum Resources*, Paper 1995-1, this volume.

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

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

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

Cook, F.A. and Van der Velden, A.J. (in press): Three-dimensional Crustal Structure of the Purcell Anticlinorium in the Cordillera of Southwestern Canada, *Geological Society of America*, Bulletin.

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

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

Daly, R.A. (1905): Summary Report 1904, Part A; *Geological Survey of Canada*, pages 91-100.

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

Daly, R.A. (1912b): Geology of the Forty-ninth Parallel; *Geological Survey of Canada*, Map 78A.

Ethier, V.G. and Campbell, F.A. (1977): Tourmaline Concentrations in Proterozoic Sediments of the Southern Cordillera of Canada and their Economic Significance; *Canadian Journal of Earth Sciences*, Volume 14, pages 2348-2363.

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

Gorton, M.P., Schandl, E.S. and Höy, T. (in preparation): The Igneous and Metamorphic Evolution of the Moyie Sills in Southeastern British Columbia.

Griggs, A.B. (1973): Geologic Map of the Spokane Quadrangle, Washington, Idaho, and Montana; *U.S. Geological Survey*, Miscellaneous Geologic Investigations Series, Map I-768.

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

Hamilton, J.M., Delaney, G.D., Hauser, R.L. and Ransom, P.W. (1983): Geology of the Sullivan Deposit, Kimberley, B.C.; *in* Sedimentary-hosted Lead-Zinc Deposits, Sangster, D.F, Editor, *Mineralogical Association of Canada*, Short Course Notes, Chapter 2, pages 31-83.

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

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

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

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

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

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

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

Höy, T. and Pighin, D. (1995): Vine - A Middle Proterozoic Massive Sulphide Vein, Purcell Supergroup, Southeastern British Columbia; *in* Geological Fieldwork 1994, Grant, B. and Newell, J.M., Editors, *B.C. Ministry of Energy, Mines and Petroleum Resources*, Paper 1995-1, this volume.

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

Höy, T., Pighin, D., Ransom, P.W., (1995): Volcanism in the Middle Aldridge Formation, Purcell Supergroup, Southeastern British Columbia; *in* Geological Fieldwork 1994, Grant, B. and Newell, J.M., Editors, *B.C. Ministry of Energy, Mines and Petroleum Resources*, Paper 1995-1, this volume.

Hrabar, S.V. (1973): Deep-water Sedimentation in the Ravalli Group (Late Precambrian Belt Megagroup), Northwestern Montana; *in* Belt Symposium, 1973, *University of Idaho* and *Idaho Bureau of Mines and Geology*, Volume 2, pages 67-82.

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

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

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

Leitch, C.H.B. and Turner, R.J.W. (1992): Preliminary Field and Petrographic Studies of the Sulphide-bearing Network Underlying the Western Orebody, Sullivan Stratiform Sediment-hosted Zn-Pb Deposit, British Columbia; *in* Current Research, Part E, *Geological Survey of Canada*, Paper 92-1E, pages 71-82.

Leitch, C.H.B., Turner, R.J.W. and Höy, T. (1991): The District-scale Sullivan - North Star Alteration Zone, Sullivan Mine Area, British Columbia; *in* Current Research, Part E, *Geological Survey of Canada*, Paper 91-1E, pages 45-57.

Lis, M.G. and Price, R.A. (1976): Large-scale Block Faulting During Deposition of the Windermere Supergroup (Hadrynian) in Southeastern British Columbia; *Geological Survey of Canada*, Paper 76-1A, pages 135-136.

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

McMechan, M.E. (1981): The Middle Proterozoic Purcell Supergroup in the Southwestern Purcell Mountains, British Columbia, and the Initiation of the Cordilleran Miogeocline, Southern Canada and adjacent United States; *Bulletin of Canadian Petroleum Geology*, Volume 29, pages 583-641.

McMechan, M.E. and Price, R.A. (1982): Superimposed Low-grade Metamorphism in the Mount Fisher Area, Southeastern British Columbia -- Implications for the East Kootenay Orogeny; *Canadian Journal of Earth Sciences*, Volume 19, pages 476-489.

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

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

Monger, J.W.H., Price, R.A. and Tempelman-Kluit, D.J. (1982): Tectonic Accretion and the Origin of the Two Major Metamorphic and Plutonic Welts in the Canadian Cordillera; *Geology*, Volume 10, pages 70-75.

Pell, J. (1994): Carbonatites, Nepheline Syenites, Kimberlites and Related Rocks in British Columbia; *B.C. Ministry of Energy, Mines, and Petroleum Resources*, Bulletin 88.

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

Price, R.A. (1981): The Cordilleran Foreland Thrust and Fold Belt in the Southern Canadian Rocky Mountains; *in* Thrust and Nappe Tectonics, McClay, K.R. and Price, R.A., Editors, *The Geological Society of London*, pages 427-448.

Price, R.A. (1984): Tectonic Evolution of the Purcell (Belt) Rocks of the Southeastern Canadian Cordillera and adjacent parts of the United States; Abstracts and Summaries, Belt Symposium II, 1983, *Montana Bureau of Mines and Geology* Special Publication 90, pages 47-48.

Rebic, Z. (1989): Diamond Drilling, Geology and Geochemistry Report on the Goatfell Property (NTS 82F/1); *B.C. Ministry of Energy, Mines and Petroleum Resources*, Assessment Report 19304.

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

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

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

Rice, H.M.A. (1937): Cranbrook Map-area; British Columbia, *Geological Survey of Canada*, Memoir 207.

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

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

Schofield, S.J. (1915): Geology of the Cranbrook Map-area; *Geological Survey of Canada*, Memoir 76.

Slack, J.F. (1993): Models for Tourmalinite Formation in the Middle Proterozoic Belt and Purcell Supergroups (Rocky Mountains) and their Exploration Significance; *in* Current Research, Part E, *Geological Survey of Canada*, Paper 93-1E, pages 33-40.

Stephenson, L. (1990): Report on Diamond Drill Hole E90-4 and 5, Eng Property, Fort Steele Mining Division, *B.C. Ministry of Energy, Mines and Petroleum Resources*, Assessment Report 20828.

Stinson and Brown (1995): Iron Range Deposits, Southeastern British Columbia; *in* Geological Fieldwork 1994, Grant, B. and Newell, J.M., Editors, *B.C. Ministry of Energy, Mines and Petroleum Resources*, Paper 1995-1, this volume.

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

Turner, R.J.W. and Leitch, C.H.B. (1992): Relationship of Albitic and Chloritic Alteration to Gabbro Dikes and Sills at the Sullivan Deposit and nearby area, Southeastern British Columbia; *in* Current Research, Part E, *Geological Survey of Canada* Paper 92-1E, pages 95-106.

Turner, R.J.W., Höy, T., Leitch, C.H.B. and Anderson, D. (1992): Guide to the Tectonic, Stratigraphic and Magmatic Setting of the Middle Proterozoic Stratiform Sediment-hosted Sullivan Zn-Pb Deposit, Southeastern British Columbia; *B.C. Ministry of Energy, Mines and Petroleum Resources*, Information Circular 1992-23.

Walker, R.G., (1979): Facies Models 8. Turbidites and Associated Coarse Clastic Deposits; *in* Facies Models; Geoscience Canada Reprint Series 1; *Geological Association of Canada*.

Wells, J.D., Lindsey, D.A. and Van Loenen, R.E. (1981): Geology of the Cabinet Mountains Wilderness, Lincoln and Sanders Counties, Montana; *U.S. Geological Survey*, Bulletin 1501-A, pages 9-21.

Winston, D. (1986): Sedimentology of the Ravalli Group, Middle Belt Carbonate and Missoula Group, Middle Proterozoic Belt Supergroup, Montana, Idaho and Washington; *in* A Guide to the Proterozoic Rocks of Western Montana and Adjacent Areas, Roberts, S.M., Editor, *Montana Bureau of Mines and Geology*, Special Publication 94, pages 85-124.

NOTES