# THE MOYIE INDUSTRIAL PARTNERSHIP PROJECT: GEOLOGY AND MINERALIZATION OF THE YAHK-MOYIE LAKE AREA, SOUTHEASTERN BRITISH COLUMBIA (82F/01E, 82G/04W, 82F/08E, 82G/05W)

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*KEYWORDS: R*egional geology, Proterozoic, Purcell Supergroup, Aldridge Formation, Moyie sills, peperites, SEDEX deposits, tourmalinite, fragmentals, mineralization, aeromagnetic data.

## INTRODUCTION

This article summarizes results of the Moyie Industrial Partnership Project after completion of two months of fieldwork in the Yahk, Grassy Mountain, Yahk River, and Moyie Lake map areas (82F/1, 8; 82G4, 5) in 1997. The primary focus of this project is to provide updated compilation maps for the Aldridge Formation. The project will provide new 1:50 000-scale Open File geologic maps based on compilation at 1:20 000-scale. These maps draw extensively from Cominco Ltd.'s geological maps, recent work by Abitibi Mining Corp. in the Yahk area; and Kennecott Canada Exploration Inc., SEDEX Mining Corp., Höy and Diakow (1982), and Höy (1993) in the Moyie Lake area. Generous financial, technical and logistical support by these companies allowed for the success of this project. New drill hole, tourmalinite and fragmental databases are another contribution of the Moyie Project.

Access to the map area is provided from Cranbrook via Highway 3 and by a network of logging roads that range from well maintained to overgrown. Mapping focused on two areas that are dominated by the Aldridge Formation, the core of the Moyie anticline, and the structural panel between the Moyie and Old Baldy faults (Figure 1). Geological features pertaining to each area

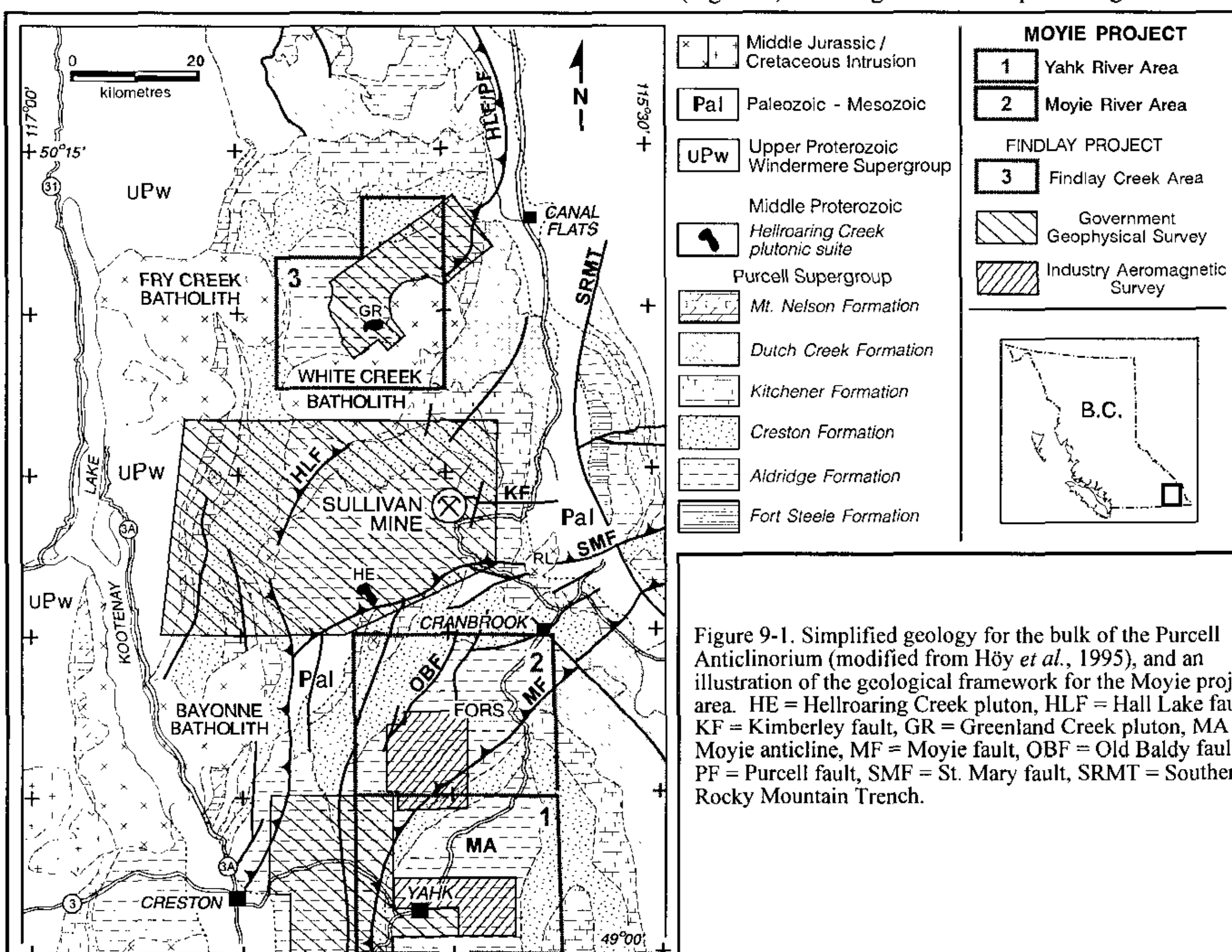


Figure 9-1. Simplified geology for the bulk of the Purcell Anticlinorium (modified from Höy *et al.*, 1995), and an illustration of the geological framework for the Moyie project area. HE = Hellroaring Creek pluton, HLF = Hall Lake fault, KF = Kimberley fault, GR = Greenland Creek pluton, MA = Moyie anticline, MF = Moyie fault, OBF = Old Baldy fault, PF = Purcell fault, SMF = St. Mary fault, SRMT = Southern Rocky Mountain Trench.

are discussed after a brief review of the regional stratigraphy, intrusive rocks, structure and metamorphism.

Physiographically, most of the map area consists of broad valleys and rounded mountains. The highest and lowest features in the Yahk area correspond to an unnamed peak 6 km south of Yahk (2057 m elevation) and Kingsgate (823 m); and in the Moyie area, Grassy Mountain (2491 m) and Elizabeth Lake (930 m). Relief is subdued with extensive glacial, alluvial and colluvial cover southwest of Mt. Olsen throughout the broad Hawkins Creek/Meadow Lake valley. The area northwest of Moyie Lake is dominated by two major northeast-trending, structurally-controlled valleys, occupied by the Moyie River and Lamb Creek. Moyie Lake lies in a north-trending, U-shaped valley but has no known structural control. The region is blanketed by locally dissected glacial and glaciofluvial deposits of variable thickness. An example of this is the drainage system from Kiakho Lakes to Palmer Bar Creek and Moyie River where a series of prominent incised valleys, visible on airphotographs and Landsat images, are interpreted to represent meltwater channels.

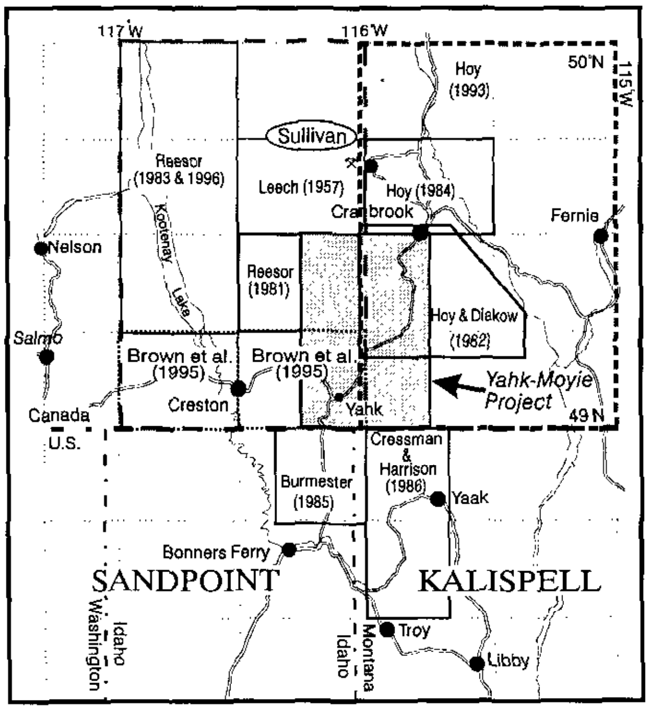


Figure 9-2. Location of Moyie project area (shaded rectangle) relative to areas of previously published geologic maps. The 1:250 000 to 1:100 000-scale map coverage includes: Fernie West-half (82G/west) -- Leech (1958, 1960), Höy (1993); Nelson East-half (82F/east) -- Rice (1941), Reesor (1996); Sandpoint -- Aadland and Bennett (1979); Kalispell -- *Harrison et al. (1992). The 1:50 000, and 1:48 000-scale* maps in the immediate vicinity of the Yahk-Moyie Lake map area include: Brown *et al.* (1995c), Burmester (1985), Cressman and Harrison (1986), Höy and Diakow (1982), and Reesor (1981).

## Previous Geological Mapping

Geological mapping in the Nelson East Half map area was completed by Rice (1941), and in the Fernie West Half by Daly (1912a), Schofield (1915) and Rice (1937), and later, Leech (1960; Figure 2). Recent 1:100 000-scale mapping has been published by Höy (1993) and Reesor (1996). South of the international boundary, 1:250 000 scale maps were produced by Harrison *et al.* (1992), and Aadland and Bennett (1979; Figure 2). Höy *et al.* (1995a) produced a 1:250 000-scale coloured compilation map of the entire British Columbian Purcell anticlinorium. More detailed mapping adjoining and including part of the project area includes work by Brown *et al.* (1995a and c), Doughty *et al.* (1997), Burmester (1985), Höy and Diakow (1981, 1982), and Reesor (1981; Figure 2).

## Geological Setting

The project area lies in the center of the Purcell anticlinorium, a broad, gently north-plunging structural culmination cored by the Proterozoic Purcell Supergroup (Figure 1). The supergroup comprises a siliciclastic and lesser carbonate sequence at least 12 kilometres thick, that initially accumulated in an intracratonic rift basin. The strata are preserved in an area 750 kilometres long and 550 kilometres wide, that extends from southeastern British Columbia to eastern Washington, Idaho and western Montana. The original extent and geometry of the basin is poorly known, partly because the western and northwestern limits are poorly exposed, and partly due to Laramide contractional deformation.

The project area is underlain primarily by the lower strata of the Purcell Supergroup; the conformable succession of Aldridge, Creston and Kitchener formations. These units have been discussed by Höy (1993) for the Fernie west half, and by Brown *et al.* (1994) and Brown and Stinson (1995) for the Yahk map area. Therefore, synoptic lithological descriptions are presented here, followed by key geological features, mineral occurrences and exploration activity highlights.

# PROJECT AREA STRATIGRAPHY

## Aldridge Formation (Pa)

*The Aldridge Formation is over 3000 m thick in the* project area and was the focus of the mapping (Figures 1 and 3). It is divided into lower, middle and upper members in the Sullivan Mine area (Höy, 1993). However, distinction of lower and middle members becomes ambiguous to the southwest of the mine (i.e. in *the Moyie project area).* This is due to the absence of the distinctive, thin-bedded rusty weathering quartz wacke of the lower Aldridge that is evident in the Sullivan area.

## Lower Aldridge Formation *(Pa1)*

Lower Aldridge Formation exposures occur in two parts of the project area; along Rabbit Foot Creek (Höy and Diakow, 1982); and along Hawkins Creek, where the strata are included in the Rampart Facies, a siliceous, thicker-bedded western facies of the Lower Aldridge proper (see Brown *et al.*, 1995). The former is more typical of the lower Aldridge as seen in the Sullivan area, 45 km to the north. Outcrops along the Rabbit Foot road are uniformly rusty brown weathering fine-grained quartz wacke. This thin bedded to laminated unit contains a thick bedded quartzite over 15 m thick that could be equivalent to the Footwall Quartzite at Sullivan. The facies change from typical lower Aldridge to the Ramparts Facies remains poorly defined but must lie between Marysville and the South Moyie River area.

## Middle Aldridge Formation *(Pa2)*

The middle Aldridge underlies most of the map area and comprises a medium- to thick-bedded sequence of fine siliciclastic turbidites, dominantly planar-bedded, fine-grained quartzofeldspathic wacke to quartz wacke, with lesser argillite. It contains less pyrrhotite and hence is not as rusty brown weathering as the lower Aldridge Formation. Uncommon medium-grained units occur, and rare coarse-grained quartz arenite; for example, as exposed near Sundown Creek. Based on estimates from map distribution, the total thickness of the middle Aldridge is at least 3000-4000 metres. In the Cranbrook area it is about 2500 metres thick and farther north near the Sullivan mine area, only 2100 metres thick (Höy, 1993). This apparent thinning of the section is compatible with north to northeast-directed paleocurrents and the interpretation of a southwest source feeding northeast-prograding, submarine turbidite fans.

An atypical middle Aldridge argillaceous facies is poorly exposed along a new logging road 10.5 km southeast of Cold Creek - South Hawkins Creek junction (Figure 3b). It comprises thin bedded to laminated siltstone and argillaceous siltstone with rusty fractures. Extensive trough cross-bedding (medium scale, 2-7 cm) is unique to this local facies, and suggests a higher energy, perhaps shallower-water environment.

### *Marker laminates*

Over twenty distinct laminated siltstone marker units that occur in the middle Aldridge Formation provide stratigraphic control across the Purcell (Belt) basin (Edmunds, 1977; Huebschman, 1973). Each marker unit comprises a unique sequence of alternating light and dark grey, parallel siltite laminae that can be correlated over distances up to several hundred kilometres. They are analogous to merchandise bar codes. Individual laminae consist of quartz and feldspar grains with disseminated biotite, muscovite and pyrrhotite. The marker units range from a few centimetres to over 9 metres thick and they can be expanded by turbiditic wacke or sill intrusion. The rusty weathering markers contain anomalous amounts of Pb and Zn relative to the background turbidites. A number of new marker laminate occurrences were located and identified during the project. This information is critical for detailed correlations and accurate map projections.

The origin of the marker units is a subject of debate as reviewed in Brown *et al.* (1994). Episodic sedimentation of terrigenous material from dust storms as recorded in the Gulf of California (Turner *et al.*, 1992) appears to be one of the better potential modern analogues. The duration required to deposit these units is unknown.

## Upper Aldridge Formation *(Pa3)*

Good exposures of the upper Aldridge Formation occur along the trace of the Moyie anticline, east of St. Eugene Mine, and west of Moyie Lake along Etna Road (Figure 3a). The upper Aldridge is a distinctly dark rusty brown weathering, thinly bedded to laminated argillaceous siltstone unit. It is planar bedded with a platy to fissile cleavage. The absence or rare occurrence (<5%) of thicker bedded (>10 cm) quartzofeldspathic wacke turbidite beds distinguish upper from middle Aldridge.

## Creston Formation (Pc)

The Creston Formation underlies about 20% of the map area within the Moyie anticline; exposures north of the Old Baldy Fault were not examined (Figures 1 and 3a). The 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). It represents shallow-water, reworked sediments accumulated on northward prograding deltas or fans (Hrabar, 1973). To the south, the Revett Formation, the middle Creston Formation equivalent, hosts several stratabound copper-silver deposits including Spar Lake, Montanore and Rock Creek in the western Montana copper belt.

Excellent exposures of the middle Creston Formation occur along Highway 3 east of Moyie Lake, along the shore of Moyie Lake, and along West Yahk River near the U.S. border. In the southeast, trough cross-bedded, light green fine-grained quartz arenite is interbedded with mudcracked mauve argillite. Mudchip breccia beds occur within apple green laminated to thin bedded quartz arenite. Wavy to lensoidal bedding is common. A measured section of most of the Creston Formation west of Moyie Lake was completed by Höy (1993, Section 10; location shown on Figure 3a).

The lower and middle Creston Formation produces prominent aeromagnetic anomalies in numerous areas, for example in much of the Moyie anticline (see Figure 6). This is due to fine disseminated magnetite, and quartz-magnetite veinlets and stringers. For example,

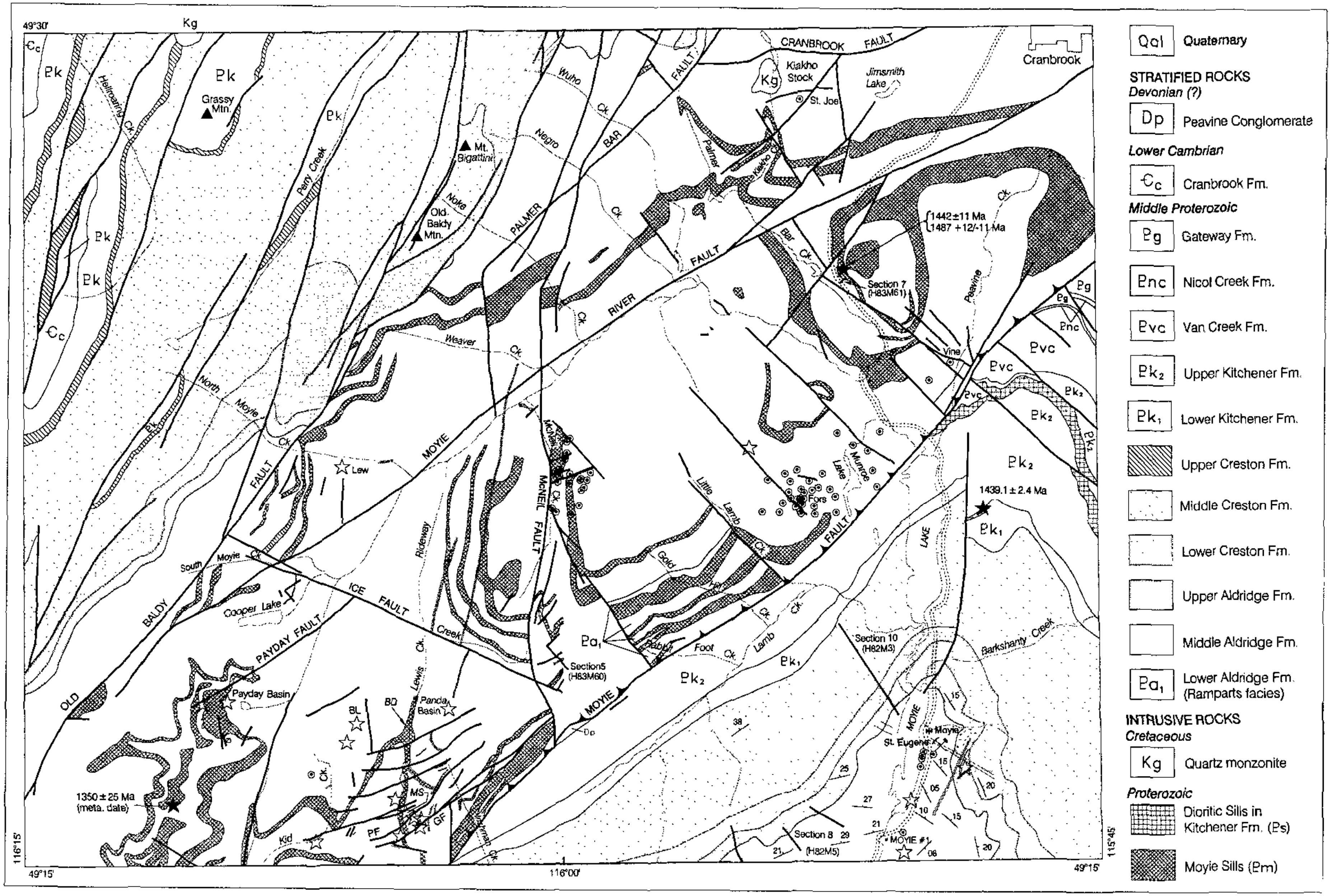


Figure 9-3(a). Simplified geology of the northern half of the Yahk-Moyie Project map area. The Moyie panel (82F/8E, 82G/05W) includes compilation from Höy (1993) and Reesor (1981, 1996) for the area northwest of the Old Baldy fault. BL = Big Lewis, BD = Bear Dike, MS = Miss Pickle, GF = Goodie fault, PF = Panda fault. Four U-Pb dates shown are from; Anderson and Davis (1995; 1487+12-11 Ma), Höy (1993; 1442 ± 11 Ma), Ross *et al.* (1992; 1350 ± 25 Ma), and this report (1439 Ma).


Figure 9-3(b). Simplified geology of the southern half of the Yahk-Moyie Project map area which corresponds to the core of the Moyie anticline (82F/1E, 82G/04W). The western half is taken from Brown *et al.* (1994) with minor revisions southeast of Yahk.

thin irregular fractures (< 2 mm wide) filled with black magnetite in pale green phyllitic argillite crop out in the lower Creston along Highway 95, 5.5 kilometres south of Curzon. Disseminated magnetite euhedra (<2%) occur in pale green, cross-bedded siltstone of the middle Creston at the north end of Etna Road, west of Moyie Lake.

## Kitchener Formation (Pk)

The Kitchener Formation overlies the Creston Formation and comprises green dolomitic siltite, argillite, carbonaceous dolomite, dolomite and limestone. It forms a succession 1600 to 1800 metres thick that is divisible into two members, a lower pale green dolomitic siltstone unit, and an upper dark grey, carbonaceous, silty dolomite and limestone unit. Typical lithologies and deposition in a shallow-water shoal environment are discussed in Höy (1993). Kitchener Formation is exposed in the footwall of the Moyie fault around Moyie Lake. Prominent but thin, brown-weathering dolomitic siltstone beds distinguish basal Kitchener Formation from uppermost Creston Formation.

Molar-tooth structures are a common feature of the formation, and are well exposed along Highway 3, 8.5 km north of Moyie. They were also noted in the southeast corner of the map area. The irregular, calcite-filled features occur in argillaceous dolomite. Their presence within small argillaceous rip-up fragments in dolomitic breccia, and as folded wedges perpendicular to bedding, indicate that they formed during diagenesis. This has led to the interpretation that they formed by gas bubble migration and expansion crack development perhaps from $CO_2$, $H_2S$ and $CH_4$ gas generation (Furniss *et al.*, 1994). These structures are illustrated in Plate 28 of Höy (1993, p. 29).

The Wallace and Helena Formations in the United States are correlative with the Kitchener Formation. Shallowing-upward cycles, consisting of siliciclastics overlain by tan-weathering dolomite have been studied in detail by Eby (1977), Grotzinger (1986), Winston (1993) and others. Their work suggests the cycles represent repeated changes in water level such that the deeper water siliciclastics are overlain by shallower water dolomitic sediments. Whether these cycles represent lacustrine or marine transgressions and regressions continues to spark debate.

The age of the Kitchener Formation is presumed to be roughly equivalent to that determined for a bentonite horizon in the uppermost Middle Belt Carbonate, 1449 ± 10 Ma (Aleinikoff *et al.*, 1996).

## Van Creek and younger strata (Pvc, Pnc, Pg, Cc, Dp)

Van Creek, Nicol Creek and Gateway formations underlie a small part of the northeastern margin of the project area. Lower Cambrian Cranbrook Formation white quartzite to pebble conglomerate occurs in the northwest corner of the map area (Reesor, 1981), and isolated, fault-bounded slivers of Devonian (?) Peavine polymictic conglomerate/breccia and carbonate lie along the hangingwall of the Moyie fault (Leech, 1962; Höy, 1993; Reesor, 1996). None of these units were examined during the course of this project.

# INTRUSIVE ROCKS

## Moyie intrusions (Pm)

Moyie intrusions, sills and rarely dikes, occur within the lower and middle Aldridge formations. The sills were first discussed by Daly (1905, 1912a) and more recently described by Höy (1989, 1993) and dated by Anderson and Davis (1995). They are commonly 50 to 100 m thick but can reach over 500 m thick, and extend laterally over tens of kilometres. The fine- to medium-grained sills range in composition from hornblende (± pyroxene) gabbro to hornblende quartz diorite and hornblendite. Mafic phenocryst contents vary up to 70%. Pyroxene is rare and due to pervasive alteration only found as relict cores surrounded by amphibole. Some of the thicker sills (>20 m) contain irregular patches of coarse pegmatitic hornblende and feldspar.

Moyie sills (meta-gabbro) are distributed throughout the project area, they reach a maximum cumulative thickness of about 800 m east of Cold Creek. In the subsurface, a 900 m thick sill within the lower Aldridge Formation was intersected south of Moyie Lake in a drill hole by Duncan Energy (Anderson, 1987; Schultze, 1988).

A model for emplacement of Moyie sills into wet, unconsolidated sediments was first proposed by Höy (1989). The zones of thickest accumulation of Moyie sills are currently considered to be closest to the feeder zones or rift axis. However, the opposite scenario is demonstrated for mafic sills in a late Carboniferous basin in northern Britain (Francis, 1982). The saucer-shaped bodies are thickest in the central part of the basin and the feeder dikes occur on the flanks, where the sills are thinnest. Therefore, more detailed observations are required to determine whether this model holds true for the Purcell Basin.

Granophyre is the term used for zones of intensely altered, biotite-rich metasediment and rare gabbro associated with the margins of meta-gabbro sills. In thin section, the rock displays a characteristic micrographic intergrowth of quartz and plagioclase (Craig Leitch, pers. comm., 1997). These granoblastic-textured rocks contain more quartz and less K-feldspar than Cretaceous intrusive rocks. Several exposures previously interpreted to be underlain by granitoid rocks, for example the small plug along America Creek (see Höy and Diakow, 1982) are currently interpreted to be zones of granophyre. For some unknown reason granophyres are restricted stratigraphically to the lower Aldridge Formation (Peter Klewchuk, per. comm., 1997). Locally they contain disseminated base metals and fine tourmaline needles (Craig Kennedy, per. comm., 1997).

Similar granophyre textures have been documented where mafic sills intruded wet arenaceous sediments of mid-Proterozoic age in Antarctica. Krynauw *et al.* (1988) used the field term "granosediment" for partially fused and homogenized sediments along sill margins. The features they describe and illustrate in these "reconstituted sediments" are identical to macro- and microscopic textures found in the Aldridge Formation; in particular are ovoid structures and intergrowths of quartz with albite and K-feldspar. They speculate that boron or fluorine from trapped seawater may have acted as a flux to cause incipient melting in the quartz-albite-orthoclase system.

### *Sundown Creek sill-sediment contact*

Supportive evidence of the interpretation that sills were emplaced into wet, unconsolidated sediments is well exposed along Stone Creek road at Sundown Creek. The medium to thin bedded quartz wacke beds are contorted/disharmonically folded along the upper contact of the sill on the east side of Sundown Creek. The sharp, undeformed basal contact of the sill is exposed on the west side of the creek. Peperite textures described later (see Sedimentary fragmental units) also suggest synsedimentary emplacement of the sills.

### *U-Pb dates*

The most accurate date for the Moyie sills, yielding a 1467.2 ± 1.1 Ma age, has been obtained from two concordant single zircon grain analyses (Don Davis, written comm., 1997). The amphibolite-grade meta-gabbro sample is correlated with the Moyie sills, and was collected 10.5 km west-northwest of Creston along Highway 3 near the Summit Creek bridge (see Brown *et al.*, 1995a). Four other Moyie sill samples from the lower and middle Aldridge Formation have yielded an upper intercept U-Pb date of 1468 +3-2 Ma (Anderson and Davis, 1995). A younger 1445 ± 11 Ma zircon U-Pb age of emplacement was reported by Höy (1993) for the Lumberton sill hosted in the middle Aldridge Formation (Figure 3a). In addition, a sill collected 6.5 km southwest of Cooper Lake yielded a slightly younger titanite U-Pb date of circa 1350 Ma (Ross *et al.*, 1992; Figure 3a). This result was re-interpreted as reflecting the East Kootenay event by Anderson and Davis (1995). Previous K-Ar dates ranged from 845 ± 50 to 1585 ± 95 Ma (Hunt, 1962) and reflect partial resetting by younger thermal events and, less commonly, excess argon.

## "Upper" Mafic sills and dikes

Gabbroic to dioritic sills and rare dikes also occur in the Creston and Kitchener formations, however, they are fewer and less voluminous than the Moyie sills. A 200-300 m thick sill in the Upper Kitchener Formation underlies the hinge zone of the Moyie anticline northeast of Moyie Lake (Höy and Diakow, 1982; Figure 3a). Another narrower (at least 75 m thick), medium-grained, massive sill with prominent joints is well exposed along new logging roads to the southwest, near the Lower-Upper Kitchener contact.

A similar 30-40 m thick, dioritic sill within the Kitchener Formation occurs in the southeast corner of the map area (Figure 3b). The dull brown weathering, pale olive green sill is fine to medium-grained, massive meta-diorite. Unlike the sills northeast of Moyie Lake, this unit has equant, white K-feldspar megacrysts (up to 2 cm) that form about 5% of the rock, in a dark green, chloritic groundmass.

Contact relationships have not been studied during this project, however, unlike the Moyie sills there have been no soft-sediment features observed (Trygve Höy, pers. comm., 1997). These sills and dikes are interpreted to be subvolcanic equivalents to the Nicol Creek lava that lies 6 km farther to the northeast.

In an effort to help constrain the age of the upper Purcell Supergroup the 75 m thick sill was sampled northeast of Moyie Lake for U-Pb dating (Figure 3a). It has yielded a 1439.1 ± 2.4 Ma zircon U-Pb date (Don Davis, written comm., 1997; Figure 4). This date is interpreted to represent the age of sill emplacement and probably the age of the Nicol Creek lavas. The new 1439 Ma age is concordant with the age of 1443 ± 10 Ma obtained by Aleinikoff *et al.* (1996) for the correlative Purcell Lava in Montana.

# STRUCTURE

The project area is naturally divided into two structural domains that comprise the footwall and hangingwall of the Moyie fault (Figure 5). The **Moyie fault** is an important transverse thrust fault that trends obliquely across the Purcell anticlinorium. It extends from the east side of the Rocky Mountain Trench, where it is called the Dibble Creek fault, southwestward through the project area and southward into northern Idaho. It is one of a family of transverse contractional faults that include the St. Mary, Hall Lake and Purcell faults (Figure 1; Benvenuto and Price, 1979). Its arcuate trace in the map area is mimicked by the Moyie-Sylvanite anticline in the footwall domain. The fault records a complex history of normal displacement that began in the Proterozoic and continued with younger reverse motion (Benvenuto and Price, 1979; Höy, 1993; McMechan, 1981). Leech (1962) believed that the fault followed a Devonian gypsum horizon that overlies the Peavine conglomerate. A portion of the fault zone in the Yahk area was examined and described by Brown and Stinson (1995).

## Footwall Domain

The footwall domain (equivalent to part of the "Moyie Block" of Benvenuto and Price, 1979) is represented by the **Moyie anticline**, an open, gently northeast-plunging upright parallel fold (orthogonal thickness is constant). Its southern extension, the

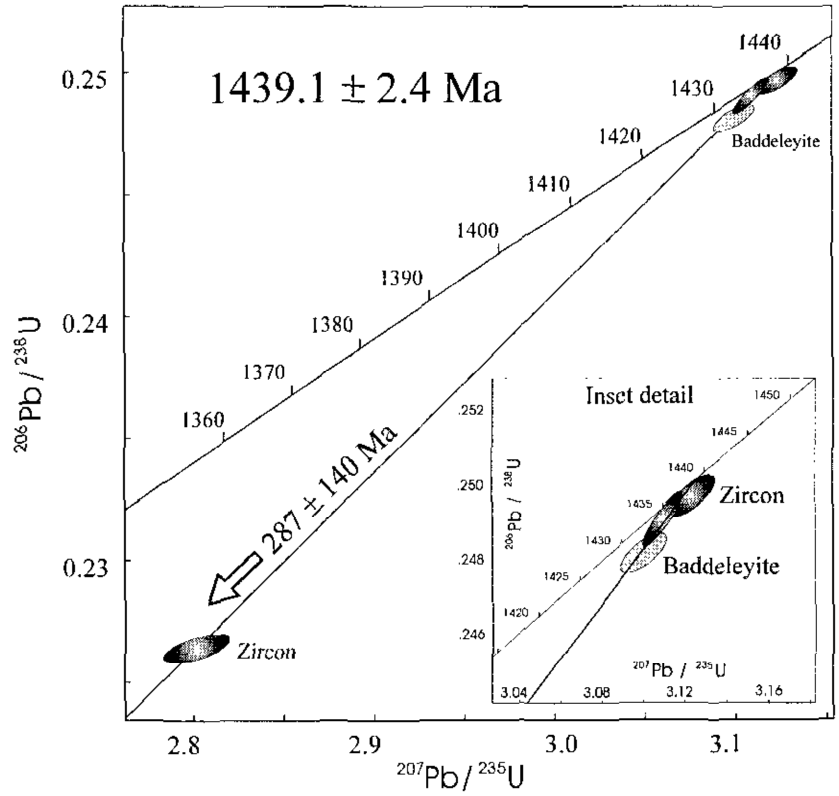


Figure 9-4. Concordia diagram showing U-Pb data points from analyses of zircon (dark shaded ellipses) and baddeleyite (light grey ellipse) in the mafic sill hosted in Kitchener Formation provided by Don Davis (Royal Ontario Museum, Nov., 1997). The regression line to all the data points is also shown.

Sylvanite anticline, plunges gently southeast and results in the overall arcuate-shaped anticline, with a hinge zone over 100 km long and about 60 km across (at surface), in the footwall of the Moyie fault. The Moyie anticline is clearly defined by the distribution of lithologic units. The oldest exposed stratigraphy within the core comprises gently-dipping lower Aldridge strata, locally called the Rampart Facies in the Hawkins Creek area. The northwest and southeast limbs of middle Aldridge strata dip moderately. However, strata steepen abruptly and bend into a north trend adjacent to the Kingsgate fault, which bounds Creston Formation in the Kingsgate graben (Brown and Stinson, 1995). The anticline is cut by numerous north-northeast, north, and northwest-trending known and inferred faults.

The Moyie anticline was investigated in 1979 by Duncan Energy Inc. as a potential hydrocarbon trap. They were searching for Paleozoic carbonates in the core of the fold, and conducted seismic and gravity surveys before drilling a 3477 m deep vertical hole south of Moyie Lake (Figure 3a; Anderson, 1987; Schultze, 1988). Cook and van der Velden (1995) combined this data with Lithoprobe seismic studies to suggest that the lower Aldridge Formation, including a series of mafic sills, was at least 8 km thick and the anticline was cored by crystalline basement.

## Hangingwall Domain

The Hangingwall domain (equivalent to a portion of the "St. Mary Block" of Benvenuto and Price, 1979) extends northwest from the trace of the Moyie fault to the Old Baldy fault, the limit of this project's mapping. The domain is dominated by gently-dipping middle Aldridge Formation (Figure 5), which form the northwest limb of a moderately northeast-plunging half anticline (*Ibid.*). In a few specific areas bedding is tightly folded and overturned, for example near the Palmer Bar fault (Höy and Diakow, 1982). The area is cut by a series of faults, at least some of which appear to have been active in the Proterozoic, an important consideration for SEDEX mineral deposit exploration.

### *Northeast-trending faults*

There are a series of northeast-trending faults in this domain. The Old Baldy, and Palmer Bar faults are the two most prominent after the Moyie fault. The **Old Baldy fault** is a northwest-side-down, normal fault that is well exposed on the David property south of the North Moyie River (Figure 6). It comprises a zone 8 metres wide of sheared, intensely silicified and/or albitized meta-wacke with fine disseminated pyrite and minor galena (Peter Klewchuk, written comm., 1997). Extensive quartz veins occur within the cataclastic to mylonitic shear zone. A steeply, northwest-dipping sericitic foliation (195/75 NW) developed in bleached quartz-sericite altered wacke delineates the fault. Local tight, steeply north northeast-plunging minor folds and chlorite schist zones (sheared Moyie sill gabbro) occur along the fault zone. Dip-slip slickensides suggest nomal movement late in the fault history. The **Palmer Bar fault** is a northwest-dipping fault with overturned beds in the hangingwall that suggest reverse displacement (Benvenuto and Price, 1979), however, stratigraphic offset implies normal movement. Discrete chlorite-sericite-pyrrhotite-bearing shear zones lie parallel to the northeast-trending Moyie fault in the Panda Basin area, which is at the headwaters of Lewis Creek (Figure 3a). Narrow, fine-grained, magnetic mafic dikes (ex. near Goodie fault; see below) in these zones are correlated with the Moyie intrusions and therefore suggest a Proterozoic age for some of the structures. This implies that the early and probable extensional movement on the Moyie fault could have occurred in the middle Proterozoic.

### *North-trending faults*

The north-trending McNeil fault is the most apparent fault of this orientation in the hangingwall domain. It corresponds to a linear airborne magnetic anomaly that extends north of the Moyie River fault without any lateral offset (Figure 7). The fault zone is poorly exposed, but includes albite-altered, iron-oxide breccia along a northeast-trending shear zone adjacent to the McNeil fault at the head of McNeil Creek (Steven Coombes, pers. comm., 1997). The breccia resembles Iron Range mineralization near Creston as described by Stinson and Brown (1995).

### *Northwest-trending faults*

A series of northwest-trending faults were mapped by Höy and Diakow (1982) and Cominco Ltd. east of the McNeil fault. These faults terminate at the Moyie fault but may continue on the north side of the Moyie River fault. They commonly contain gabbro dikes, for example at the Vine vein (Peter Klewchuk, per. comm., 1997), which implies some Proterozoic movement. This is supported by extensive drilling on the Fors property which indicates that the northwest faults controlled sub-basin deposition during Aldridge time, localized fragmental units and caused arching of a gabbro sill. The thick sill (up to 500 m) lies close to the lower-middle Aldridge contact and may correlate with the Mine Sill at Sullivan.

## METAMORPHISM

Much of the middle Aldridge Formation in the project area comprises meta-wacke with biotite (± muscovite) porphyroblasts in the bedding planes. In addition, several areas have prominent, biotite flakes aligned semi-randomly perpendicular to bedding. Locally the biotite is partially to completely retrograded to chlorite. Coarse hornblende porphyroblasts (up to 8 mm long) concentrated along calcareous layers within thin bedded to laminated meta-siltstone and wacke of the upper part of the middle Aldridge crop out near Mt. Olsen.

These biotite and hornblende porphyroblasts are being dated using the $^{40}Ar$-$^{39}Ar$ method in an attempt to refine age constraints on the Proterozoic burial metamorphic event. Previous dating in this region produced a biotite K-Ar date of 720 ± 3 Ma (from Wanless *et al.*, 1967 but recalculated using the Steiger and Jäger (1977) decay constants). This result is interpreted to reflect partial resetting of older metamorphic minerals by younger thermal events.

It is speculated that these metamorphic minerals developed during the East Kootenay Orogeny. If correct, the Ar-Ar dates should approach the circa 1370 Ma ages obtained from metamorphic monazite in the Matthew Creek area near Sullivan (R. Parrish, unpub. data, 1996), and titanite from a Moyie sill near Cooper Lake (Figure 3a; Ross *et al.*, 1992). The East Kootenay Orogeny has recently been interpreted to involve bimodal magmatism, basin rifting, and subsidence and sedimentation (Doughty and Chamberlain, 1996).

## SULLIVAN GEOLOGICAL INDICATORS

Sullivan indicators are features associated with the Sullivan orebody. They include the obvious stratiform

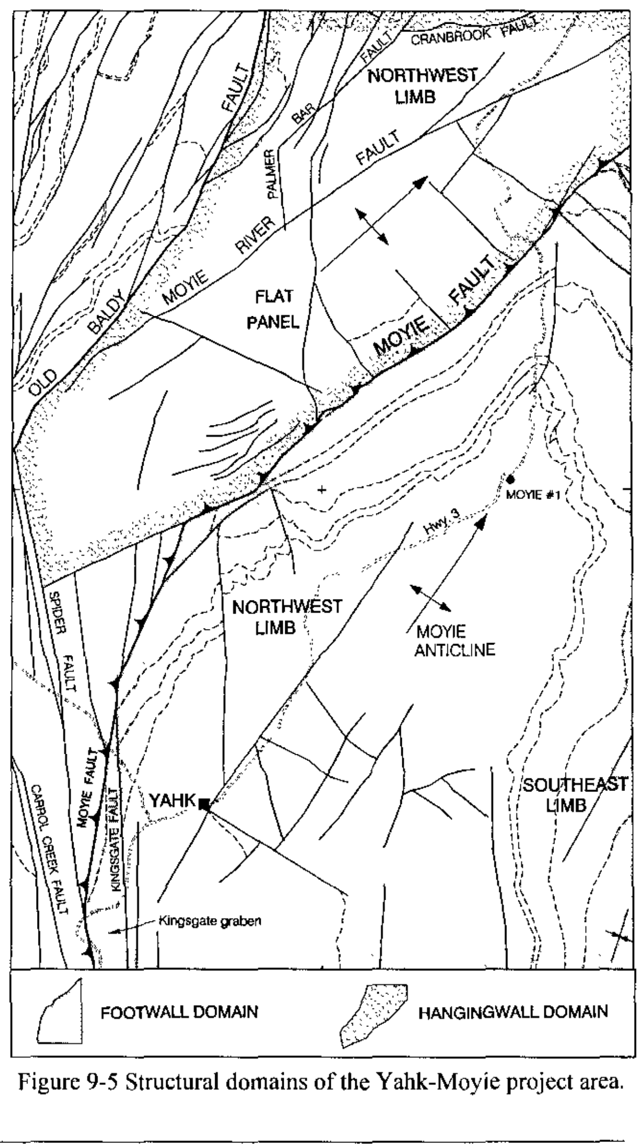

Figure 9-5 Structural domains of the Yahk-Moyie project area.

massive sulfide mineralization and less directly linked features such as structural control, sedimentary fragmental units (referred to as "conglomerates" by Höy, 1993), tourmalinite (tourmaline replaced rock), sericite, albite, and other alteration types, manganese-rich garnet horizons, syndepositional faults, and gabbro arches. Individuals have placed different values on any particular feature. When these indicators occur in combination, or are closely related in a regional context, a higher exploration significance is assigned. The goal of the Aldridge mineral explorationist is to sift through those features mentioned above to identify those related to a mineralizing system; rather than those related to background in the basin succession which are barren.

## Structural control

Structural control plays a vital role and most if not all Sullivan indicators are related to structure. Basic geologic mapping and geophysics are commonly the most valuable tools for defining favourable structures. Structural intersections, cross-structures, transfer zones and graben trends maybe identified from regional studies. The best example is the intersection of the Sullivan-North Star corridor and the Kimberley fault which are interpreted to be important Proterozoic faults. This intersection controlled the locus of the Sullivan hydrothermal system (Turner *et al.*, 1992). The Vine property area is another example of a sub-basin controlled by intersecting structures (Höy *et al.*, in prep.).

## Sedimentary fragmental units

Sedimentary fragmental units, referred to as "fragmentals" (or "conglomerates" in Höy, 1993, p. 19-20), occur sporadically in the otherwise well bedded, fine- to medium-grained, homogeneous quartz wacke Aldridge Formation. Fragments consist of sedimentary clasts that range in size up to 2 m, and in degree of roundness, from completely angular to rounded. Fragmental units fall into three basic descriptive types: (1) stratabound, (2) discordant, and (3) massive. The stratabound units are further divided into disrupted beds and biotite-rich breccia. At the Sullivan Mine there are also sulfide-matrix fragmental units. This classification scheme is modified from detailed studies around the Sullivan Mine as summarized in Turner *et al.* (in press), and in a regional synthesis by Höy *et al.* (in prep.). Some fragmental occurrences also include tourmalinite and albite alteration (flooding), albite porphyroblasts, actinolite, sericite, and manganese-rich garnet. Locally, where fragmental occurrences contain sulfide-rich clasts, clasts are interpreted to be derived from a massive sulfide horizon (ex. Vine Vein area, Dave Pighin, per. comm., 1997). Other fragmental terms include "Choatic breccia" as found under the Sullivan orebody (Jardine, 1966), and bedded pebble fragmental. A model relating fragmental development to dewatering and sill intrusion, and demonstrating the continuum from discordant to stratabound units is presented in Höy *et al.* (in prep.).

Commonly, fragmental occurrences are poorly defined and difficult to recognize due to lack of exposure, therefore, they can not be accurately classified geometrically or genetically. However, careful mapping allows some of the fragmentals to be divided into genetic classes. For example, they can represent sedimentary fill along active, fault-bounded sub-basins as determined along the North Star corridor (Turner *et al.*, 1992). Other discordant fragmentals include dewatering structures as interpreted at the Highway 3A exposure at Moyie Lake (Figure 3a; Höy, 1993). Fluidized sediments along or near Moyie sill contacts (some examples best defined by the term peperite, see below) form another variety. An excellent example of a peperite lies near the upper contact of a sill in the Payday Basin (Figure 3a; Photo 9-1c, d, e). Irregular-shaped pods of gabbro occur in a coarse, sediment-clast dominated fragmental sheet that parallels the sill contact. The most laterally extensive fragmentals include a group of the coarsest fragmentals known that are concordant with the lower-middle Aldridge contact, for example in the Doctor Creek area (see Brown and Termuende, this volume).

Emplacement of hot mafic sills into water-saturated, unconsolidated sediments results in boiling of superheated pore water and fluidizing of the host sediment. The fragmented rock produced is known as peperite. These peperites suggest that the Aldridge basin water column was less than 3150 metres deep, assuming the basin was filled with salt water (or 2160 m if there was fresh water); the hydrostatic pressure of the water column would prevent boiling below these depths (Cas and Wright, 1987, p. 45).

### *Stratabound fragmentals*

Stratabound fragmentals are massive to bedded units that are parallel to the regional bedding attitudes. Turner et al (in prep.) also use the term "conglomeratic siltstone" for these units. Lithic clasts dominate; commonly argillite fragments are sericite-rich.

#### *Disrupted beds*

Disrupted beds, a variety of the stratabound fragmentals, are discontinuous zones of laminated to bedded material broken into centimetre to millimetre-scale tabular blocks. Beds above and below remain intact and undeformed. Soft-sediment deformation of argillaceous layers and slump folds occur rarely within these beds. These fragments are contorted which suggests they were ductile (unlithified) during fragmentation. Hagen (1985) used the terms "collapse" and "slump" fragments for similar units.

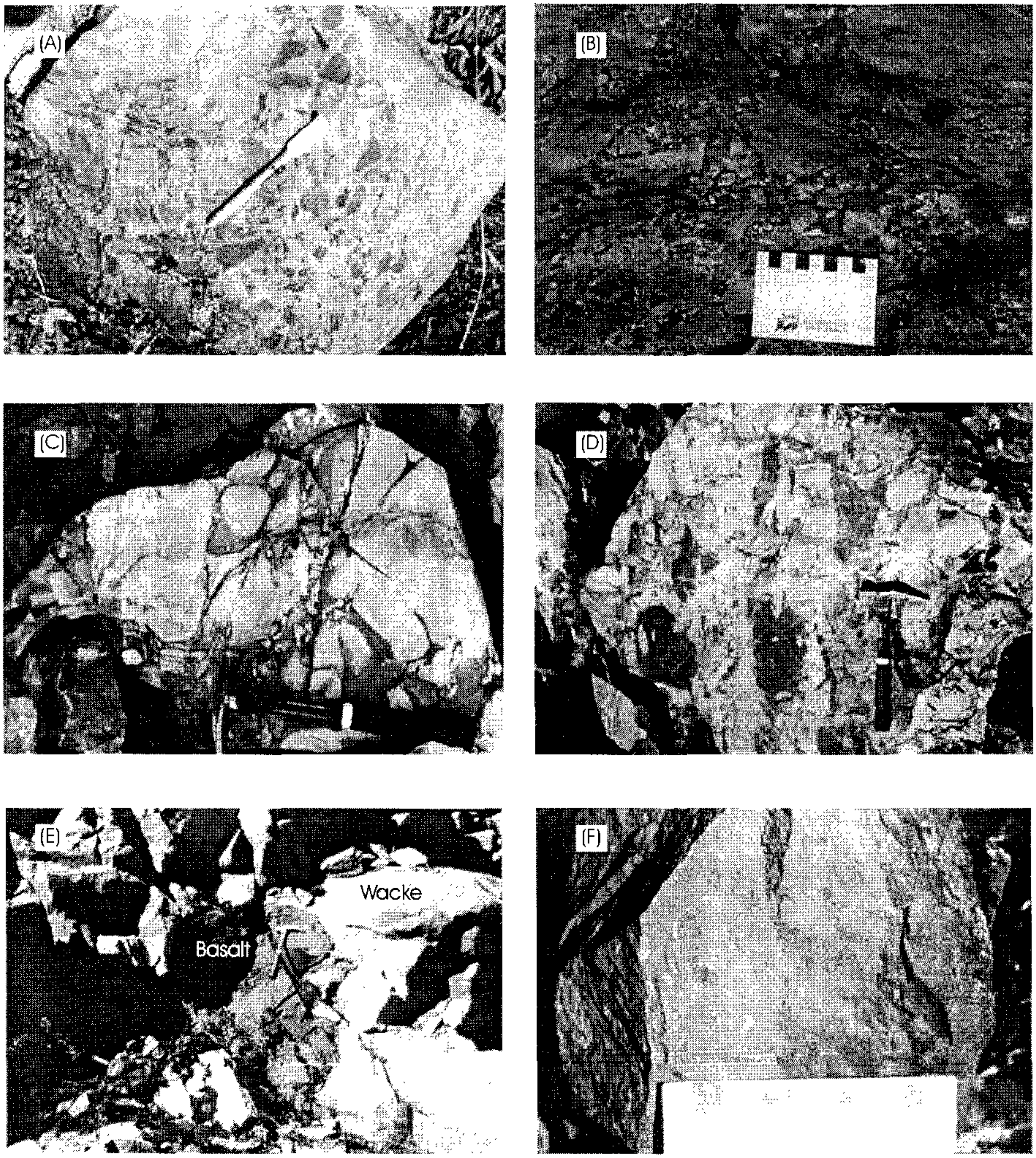


Photo 9-1. Selected examples of fragmental units in the Moyie project area: (a) Miss Pickle fragmental with matrix-supported siltstone clasts in a siltstone matrix, Panda Basin; (b) poorly size-sorted Miss Pickle fragmental; (c) sericite-altered and fragmented wacke, Payday Basin; (d) biotite-rich, large angular clasts of a stratabound fragmental in Payday Basin; (e) Bulbous amygdaloidal basalt fragment in wacke, Payday Basin; (f) massive fragmental hosted in Upper Aldridge Formation, between St. Eugene and Society Girl mines.

### *Biotite-rich breccia/fragmental*

Clast-supported, biotite-rich, fine-grained, angular to rounded wacke clasts form a variety of fragmental that is common in the Payday Basin area, 2.75 km south of Cooper Lake (Figure 9-3a; Photos 9-1c, d, e; 9-2). They are stratabound, contain albite-altered clasts and are spatially associated with Moyie sills. It is speculated that they formed during sill emplacement.

### *Discordant fragmentals*

Discordant fragmental occurrences cross-cut bedding at high angles. They are equivalent to clastic dikes/sandstone dikes found in shale basins except they include centimetre and smaller-scale siltstone fragments. Hagen (1985) used the term "cross-cutting" fragmentals for this type.

A well exposed discordant fragmental outcrops along Highway 3A at Moyie Lake (Figure 3a). The 10 m wide clastic dike cuts bedding at a high angle. It is massive weathering in contrast to the well bedded host strata. Diffuse, subangular siltstone and mudstone fragments (up to about 2 cm) are supported in a fine sandstone matrix. The subvertical contacts are irregular and suggest emplacement before complete lithification (see Stop 1-6 in Turner *et al.*, 1992, p. 20). This unit probably resulted from dewatering, either caused by a seismic event or by fluidization related to sill emplacement at a lower stratigraphic level.

The discordant Goodie fragmental in the Panda Basin area lies sub-parallel to the Moyie fault and is similar to the Moyie Lake unit discussed above.

### *Massive fragmentals*

Massive fragmentals are structureless with no internal stratification, and commonly form knobs or knolls because they lack bedding planes and therefore resist erosion. Commonly, their geometry relative to host strata is unknown due to lack of exposure. Two of the largest massive fragmental units known in the district are the Clair conglomerate in the St. Mary Lake area and the Cold Creek conglomerate exposed on the east flank on the Moyie anticline. The Clair is over 70 m thick and is exposed over 7.5 km, along a north-trending fault. The zone contains stratabound fragmentals, disrupted beds, discordant fragmentals and low-grade Pb-Zn mineralization with abundant pyrrhotite clasts. The Cold Creek fragmental is over 150 m thick and has been traced northward over 5.5 km along strike.

Massive fragmentals also occur along the St. Eugene vein system. They form at least three fragmental units, two within the St. Eugene Mine workings, and the third lies stratigraphically above the St. Eugene Mine and below the Society Girl Mine

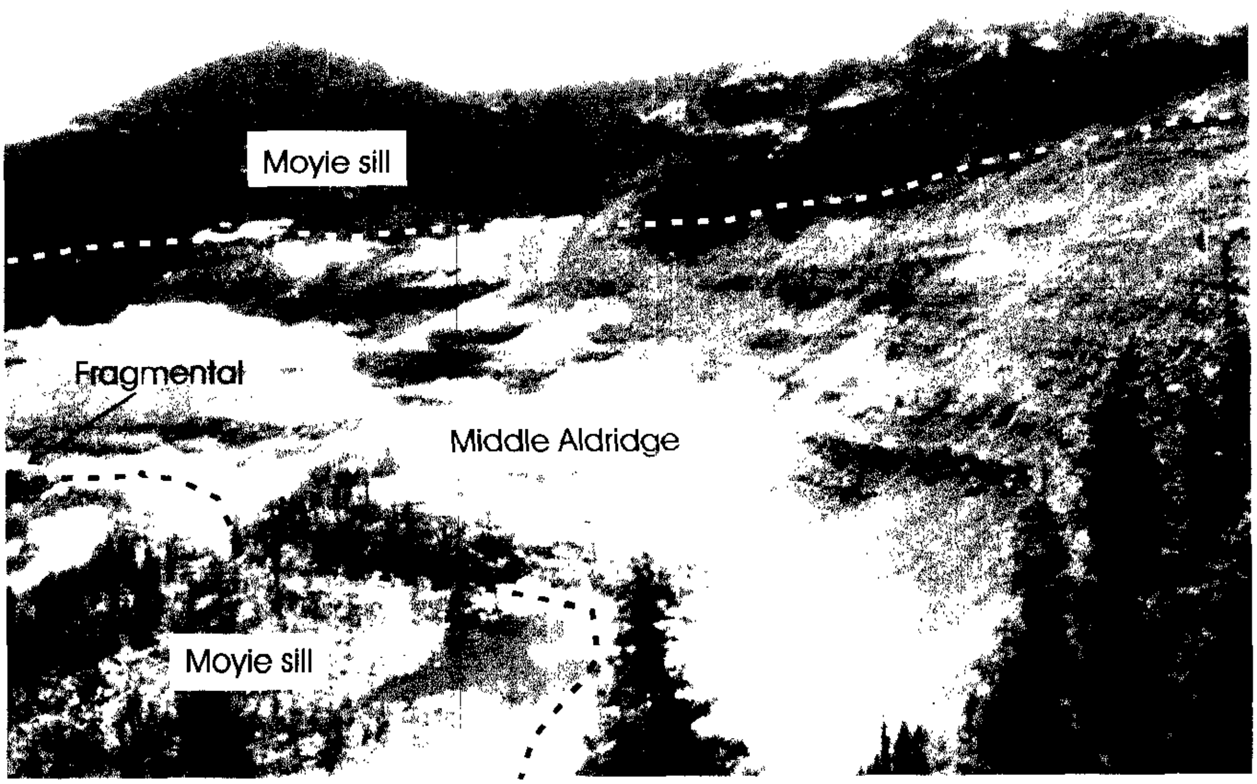


Photo 9-2. Payday Basin area displaying flat-lying middle Aldridge strata where it is intruded by two prominent Moyie sills. View to south.

(Figure 3a; Höy *et al.*, 1995c, p. 30). This highest fragmental is unusual because it occurs near the upper Aldridge - Creston formation contact. It is not known to the authors whether these are stacked sheets or discordant bodies. The uppermost St. Eugene fragmental is massive with angular fragments up to 3 cm long supported in a fine wacke matrix (Photo 9-1f).

## Tourmalinite alteration occurrences

Tourmalinite alteration is significant because it is spatially and genetically associated with the Sullivan deposit (see Hamilton *et al.*, 1982, 1983; Slack, 1993), therefore, it may provide a regional exploration vector. Tourmaline occurrences are divided into two basic types: stratabound and discordant. They vary from aphanitic tourmaline to zones of tourmaline needles. Stratabound occurrences include alternating beds or laminations of aphanitic tourmalinized mudstone and fragmented zones where clasts are variably replaced by tourmaline. Black tourmaline is more common than brown but co-existing brown and black tourmalinite, considered an indication of high fluid to rock ratios (Slack, 1993), may discriminate potentially mineralized from barren tourmalinite showings. The size of tourmaline alteration zones varies.

## Other alteration types

Several alteration types occurring in the Sullivan Mine area are found elsewhere in the Aldridge Formation. They include sericite-chlorite alteration, albitization, biotite-chlorite alteration, actinolite/tremolite alteration, and silicification. Readers may refer to Leitch *et al.* (1991; 1995) for additional information.

## Manganiferous garnet-rich beds

A narrow concentration (up to 6 cm thick) of pink, manganiferous euhedral garnets in sericitic quartz wacke on the south flank of Mount Mahon and farther south across Hawkins Creek (for locations, see Brown, 1995a) may have an exhalative origin. No sulfide mineralization has yet been identified with these garnets, despite their occurrence near the stratiform Mt. Mahon tourmalinite and the presence of faults that may have been active in the Proterozoic.

## Gabbro arch

Moyie sills locally cut up or down section to produce arches; the best example is at the Sullivan Mine (Hamilton *et al.*, 1982). These changes in attitude indicate Proterozoic structural controls that are important in SEDEX models and mineral exploration.

# MINERAL OCCURRENCES AND EXPLORATION

The following discussion reviews producers, past producers, placer operations and mineral occurrences of the project area, and summarizes exploration history and activity for several properties. Sullivan-type SEDEX deposits (Hamilton, 1982; Hamilton *et al.*, 1983; Höy, 1993; Leitch *et al.*, 1991; Turner and Leitch, 1992; Leitch and Turner, 1992) are the prime exploration target throughout the Purcell Basin. Several new alteration and fragmental zones have been discovered recently and warrant further mapping and prospecting. In addition, gold-bearing shear zones and placer deposits have attracted exploration attention in this area.

The 1997 exploration programs included geological mapping, soil and lithogeochemistry, detailed gravity surveys and diamond drilling. Selective results from this work are incorporated in this report. In addition, an extensive drilling program was completed by Citation Resources Inc. on the Fors Property.

## Producers

### *Swansea Ridge Ballast Quarry (Minfile 082GSW065)*

The Canadian Pacific Railway operates a ballast quarry at Swansea, about 15 km southwest of Cranbrook. The quarry extracts and crushes an estimated 400,000 tonnes of railway ballast annually to supply the CP Rail System in eastern British Columbia, southern Alberta and parts of Saskatchewan. At the facility, the moderately, northeast-dipping succession of middle Aldridge Formation rocks includes a 60 m thick Moyie diabase/gabbro (Sill D of Höy and Diakow, 1982) that is mined, crushed, stockpiled and loaded into railway cars.

## Past producers

### *St. Eugene vein system (Minfile 082GSW023, 025,027, 030 )*

The St. Eugene vein system lies in the core of the Moyie anticline and its southeast-trending structure (about 110°) hosts four past producers, St. Eugene, Aurora, Society Girl and Guindon (Figure 6; Table 1). St. Eugene is the largest vein deposit to be mined in the Purcell Supergroup (excluding the Coeur d'Alène deposits in Idaho); its regional setting, the vein characteristics and mineralogy are reviewed by Höy (1993). A M. Sc. thesis study of alteration mineralogy and geochemistry, including local garnet-chlorite metamorphosed alteration assemblage, and isotope geochemistry of the vein materials is in progress by Isabelle Jonas (Département de géologie et de génie géologique, Université Laval, Québec).

The vein system extends 3.3 km laterally and 1.3 km vertically. Locally, subrounded quartz clasts (broken quartz vein material) supported in a flow foliated sulfide matrix (*durchbewegung texture*) illustrate that there has been movement along parts of the vein system. A mafic dike exposed at surface above 1475 m elevation trends northerly, it is correlated with the Kitchener sill unit discussed above. If this dike cuts the vein then it provides strong support for Proterozoic mineralization (St. Eugene Mine plans may illustrate this).

Galena Pb isotopic signatures from ore samples at St. Eugene fall along the linear array of Proterozoic epigenetic vein deposits defined by the Coeur d'Alène deposits. Galena cores surrounded by metamorphic garnet rims along the St. Eugene vein margins yield similar Pb isotopic compositions. This suggests that the St. Eugene mineralization and alteration are pre-metamorphic, and older than the East Kootenay orogeny (circa 1370 Ma; Beaudoin, 1997).

### *Midway Mine (Minfile 082GSW021)*

The Midway Mine is a former gold producer that was mined in the early 1930's. An east-dipping (30-50°) quartz vein cuts middle Aldridge Formation turbiditic wacke beds. The vein was developed by upper and lower adits, 381 m and 320 m long, respectively. The vein ranges up to about 2.4 m wide and contains pyrite, arsenopyrite, chalcopyrite and minor galena and sphalerite (Jim Fyles, 1974, Property File). The vein extends at least 200 m upslope from the adits but lower gold values are reported at this level (H. Sargent, 1938, Property File).

The mine produced ore for seven years in the period 1933 to 1962; yielding 1,168 tonnes averaging 7.7 gm/T Au, 73.2 gm/T Ag (Table 1). It is also the only tin producer, other than the Sullivan Mine. More information is available in the Minister of Mines Annual Reports from 1929 to 1962. Exploration and drifting were reported on the property in 1986 by Consolidated Sea Gold (George Cross Newsletter, Oct. 24, 1986).

## Placer Operations

### *Moyie River (Minfile 082FSE102)*

Fiorentino Bros. Contracting operate a placer deposit along the Moyie River valley. Placer gold occurs in competent gravels. The auriferous channel is about 1.8 m thick by 80 m wide as defined by drilling and seismic data. It is covered by 10 to 15 m of glacial till, gravel and clay (Leitch, 1996). Eight years of sporadic production between 1880 and 1945 yielded a reported 148 844 grams Au (Leitch, 1996). In 1988 and 1989 a total of 53,901 cubic metres were mined that produced 137 051 grams of Au (*Ibid.*). Large nuggets (sold to jewellers) and finer-grained gold are recovered; the gold is about 92% pure.

### *Weaver Creek (Minfile 082FSE084)*

The Weaver Creek placer deposit produced gold between 1874 and 1930 (Table 1). Exploration programs in 1992 and 1994 included reverse circulation drilling that outlined a glaciofluvial channel, additional drilling was recommended to define a minable resource (Clarkson, 1994).

## Mineral Occurrences

### *Vine Vein (Minfile 082GSW050)*

The Vine Vein occurrence lies in the hangingwall of the Moyie fault and it has been described in Höy (1993) and Höy and Pighin (1995). The vein is hosted in a 120° trending fault zone that dips 65°-75° southwest. Most of the ore is hosted in quartzite correlated with the Footwall Quartzite, and has been explored in detail in recent years. Drill indicated reserves are about 240 000 tonnes proven grading 5.20 % Pb, 2.24 % Zn, 67.23 g/t Ag and 1.92 g/t Au, and 307 000 tonnes probable grading 4.22 % Pb, 2.51 % Zn, 39.77 g/t Ag and 1.75 g/t Au (Pighin, 1991; in Höy and Pighin, 1995).

Table 9-1. Production data for mineral occurrences in the project area.

| MINFILE NO. | NAME | MINED (T) | Pb (kg) | Zn (kg) | Cu (kg) | Ag (gm) | Au (gm) | Year |
|---|---|---|---|---|---|---|---|---|
| 082FSE084 | Weaver Creek * | unknown | 0 | 0 | 0 | 0 | 23,605 | 1880-1930 |
| 082FSE102 | Moyie River * | 53,901 | | 0 | 0 | 0 | 285,895 | 1880-1989 |
| 082GSW021 | Midway | 1,168 | 2,549 | 1,701 | 108 | 85,534 | 9,082 | 1933-62 |
| 082GSW023 | Aurora | 3,763 | 274,307 | 512,674 | 0 | 411,463 | 0 | 1900-27 |
| 082GSW025 | St. Eugene | 1,475,266 | 113,034,479 | 14,482,913 | 0 | 182,690,658 | 78,846 | 1899-1929 |
| 082GSW027 | Guindon | 28 | 3,312 | 3,494 | 0 | 3,328 | 0 | 1919-27 |
| 082GSW030 | Society Girl | 2,984 | 499,655 | 23,914 | 0 | 432,052 | 0 | 1900-52 |
| 082GSW037 | Payroll | 16 | 0 | 0 | 0 | 715 | 187 | 1907 |
| **Total** | | **1,537,126** | **113,814,302** | **15,024,696** | **108** | **183,623,750** | **397,615** | |

Note: All production is from vein deposits except those placers marked by "*".

## *Fors (Minfile 082GSW035)*

Mineralization and alteration on the Fors Property is described by Britton and Pighin (1994, 1995). An extensive drilling program in 1996 and 1997 included 16 diamond drill holes, totaling over 12,000 metres. Citation Resources Inc. conducted the work and report that hole #2 intersected 42 m of disseminated Pb-Zn mineralization including 7 m of pyrrhotite that resembles the Concentrator Hill horizon in the Sullivan area (distal Sullivan Mine stratigraphy; Mike Leask, pers. comm., June, 1997). The property is part of a 1 by 4 km northwest-trending corridor with several different sedimentary fragmental units, disseminated and massive sulfides, and a gabbro arch. One of the fragmental units, which is over 125 m thick and occurs at the lower-middle Aldridge contact, is restricted to a sub-basin bounded by northwest-trending faults (Gordon Leask, pers. comm., Nov., 1997). Tourmalinite replacement occurs sporadically throughout 200 metres of drill core and there is an important change from brown to black tourmalinite near the lower-middle Aldridge contact ("Sullivan time"). The Fors, located 400 m above the

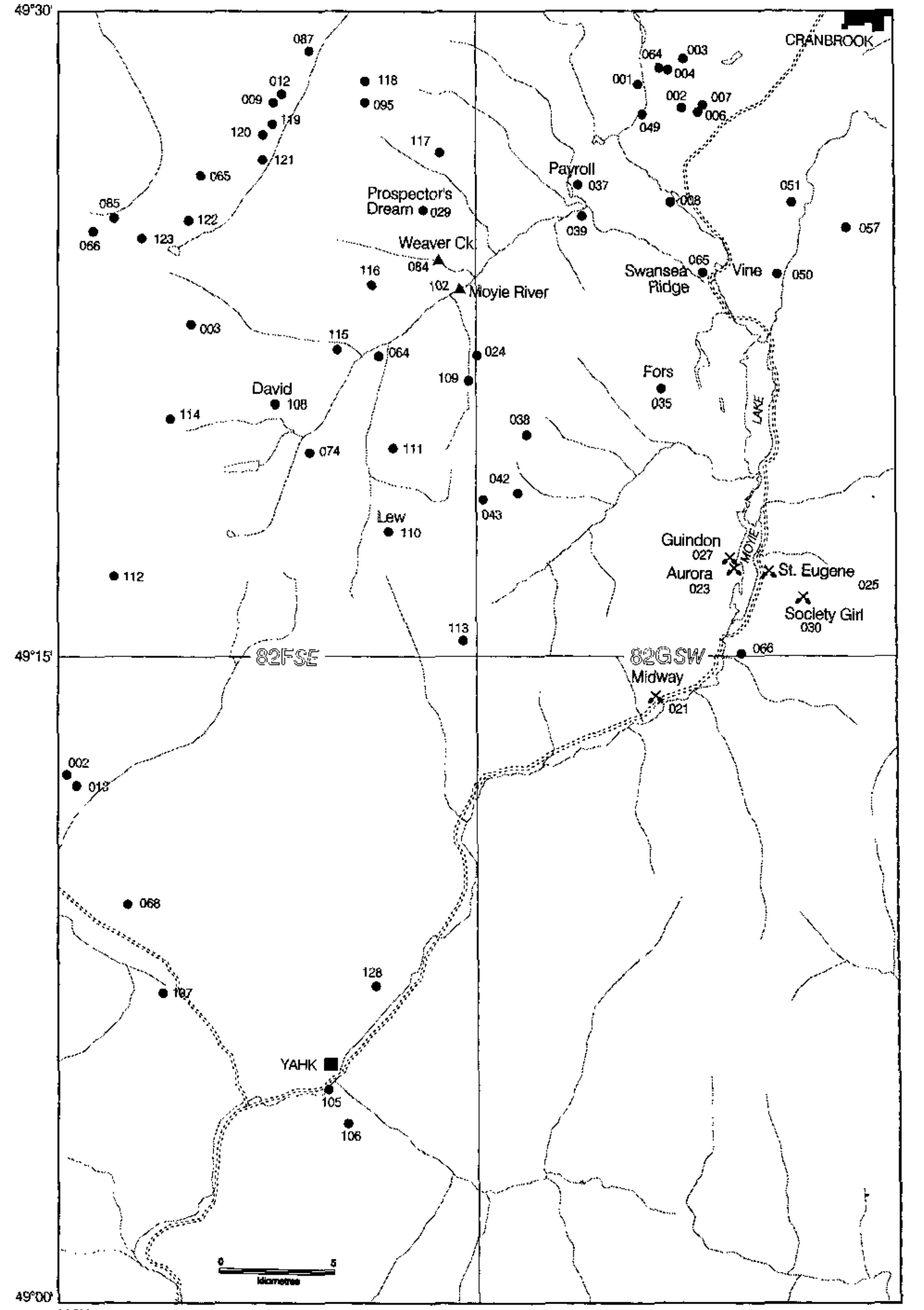


Figure 9-6 Minfile mineral occurrences of the Moyie project area. Those named on the figure are discussed in the text.

lower-middle Aldridge contact, comprises a zone of intense and varied alteration (c.f. Britton and Pighin, 1995) within a horst block. Half-grabens on the flanks of the intense alteration zone contain over 100 m of Sullivan-like black mudstone, underlain by 60 m of zinc-bearing fragmental near the lower-middle Aldridge contact (Mike Leask, pers. comm., Nov., 1997).

### *David (Minfile 082FSE108)*

Northeast-trending, steeply northwest-dipping shears that are parallel to the Old Baldy fault host auriferous quartz-sericite alteration zones. The David property occurs 4.5 km north of Cooper Lake and was explored by Dragoon Resources Ltd. as summarized by Höy (1993; after Klewchuk, 1991) and by Leitch (1996). The alteration zones are hosted in middle Aldridge Formation and Moyie sills. Mineralization comprises pyrite, galena, chalcopyrite and sphalerite with rare visible gold. The shear zone averages about 2 m wide; mineralization has been traced for a strike length of 150 m and to a depth of more than 120 m. Drill-indicated reserves stand at 91 000 tonnes of 10 g/T Au (Mike Bapty, per. comm., 1996).

### *Prospectors Dream (Minfile 082FSE029)*

Prospector's Dream was discovered in 1898 and at that time two declines, two shafts and numerous hand trenches were completed (Minister of Mines, Annual Report, 1898; Appendix 2, p. 1013). The workings lie between 1675 and 1800 m elevation and are hosted in both middle Aldridge arenite and Moyie sills. Mineralization comprises pyritic quartz veins containing minor visible gold in limonitic vugs, and minor chalcopyrite and hematite. Grab samples run up to 72.99 g/T gold (O'Grady, 1991) and trench sampling results from 1991 are summarized in O'Grady (1992). The property is important because it demonstrates the potential of gold-bearing veins in the region.

### *Pay Roll (Minfile 082GSW037)*

The Pay Roll occurrence consists of a series of narrow (< 5 cm), steeply, southwest-dipping quartz veins. They crop out on the northeast side of Negro Lake and are easily accessed via an old wagon trail at the Moyie River logging road Negro Creek junction. The veins contain pyrite, chalcopyrite, altaite (a lead telluride), and rare visible gold.

## Exploration activity and results

### *Panda Basin area*

The Panda Basin is located 7 km southeast of Cooper Lake; where several fragmental and tourmalinite occurrences were identified by prospectors Mike and Tom Kennedy. A series of fragmentals trend northwesterly and include the Miss Pickle. The Miss Pickle stratabound fragmental sheet and discordant zone lies east of the Bear Dike along the southern flank of a ridge (Photos 9-1a, b; 9-3). It weathers light grey and is

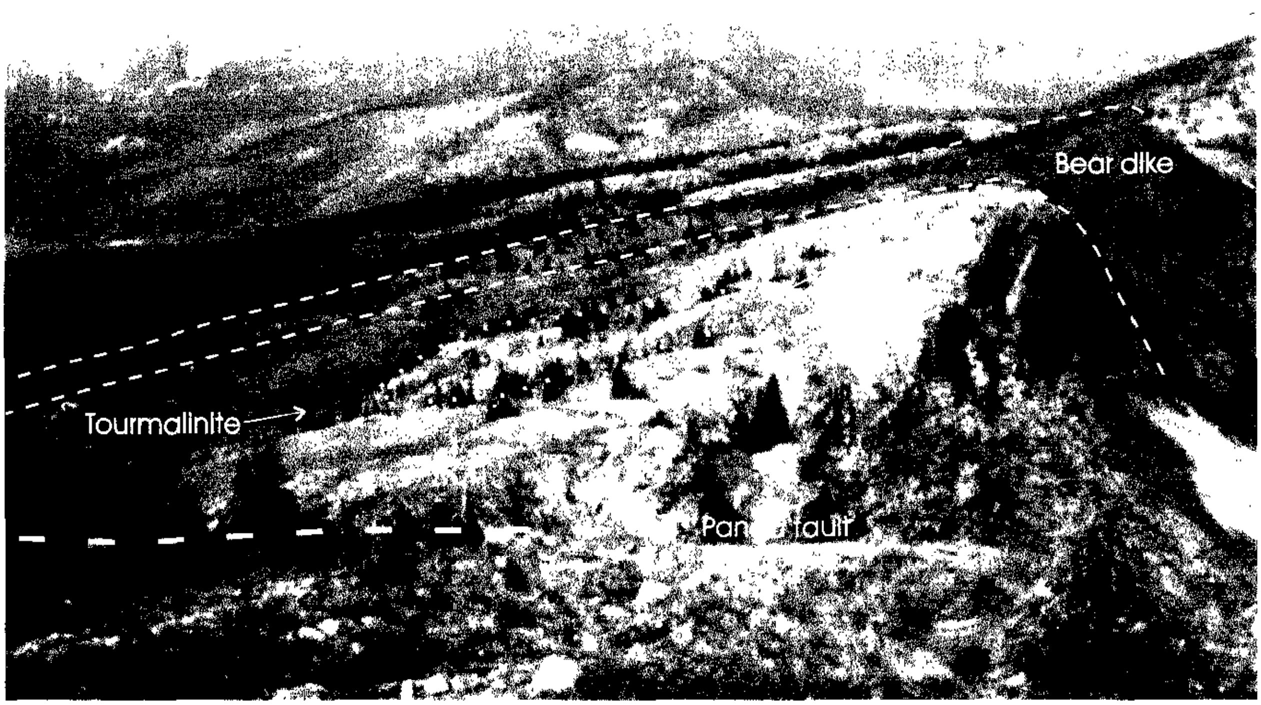


Photo 9-3. The Miss Pickle fragmental area adjacent to the Bear Dike, Panda Basin (view toward 290°).

massive at outcrop scale (i.e. no bedding evident). In this area, fine white spots (up to 2 mm across) developed in grey quartz arenite and argillite beds are believed to be albite porphyroblasts. A black, aphanitic tourmalinite occurrence lies on the southern end of the Miss Pickle fragmental sheet. It is an isolated exposure, about 2 metres across. The relationship to the fragmental is unknown.

The Bear Dike, part of a gabbro arch, comprises a medium to coarse-grained gabbro that produces a moderate to strong magnetic anomaly. Locally it hosts quartz veins with rare arsenopyrite. Another magnetic feature that lies within the Moyie fault zone comprises albite-chlorite-magnetite breccia and stringers. Between the fault zone and Bear dike the middle Aldridge wacke/arenite contains fine disseminated tourmaline needles over at least 70 m of stratigraphic thickness. Narrow (up to 2 cm) white quartz veins here contain abundant tourmaline needles with minor arsenopyrite.

Drilling in this area has intersected a sequence of bedding parallel and discordant bands of massive, coarsely crystalline sulfides consisting almost entirely of sphalerite and galena with very minor chalcopyrite and pyrrhotite (diamond drill hole K-97-03; Peter Klewchuk, per. comm., 1997). The mineralization contains no quartz which is atypical for most vein-type mineralization in the region. This intersection consists of 2.55 m of 15.47 % combined lead and zinc, including 0.65 m of massive sphalerite with minor pyrrhotite and fracture-filled chalcopyrite. The area has numerous fragmental bodies and extensive zones of albite-tourmaline-chlorite-sericite alteration with associated Zn-Pb-As anomalies.

### *Mount Mahon Property*

In 1979, St. Eugene Mining Corporation Ltd. first mapped tourmalinite occurrences on Mt. Mahon. In 1980-81 they conducted a drill program of thirteen holes (YA-1 through Y-13-81) totaling 1767 metres of core drilling. Diamond drill hole YA-6 intersected a massive sulfide zone and was the target of follow-up drilling. In 1984 Chevron Canada Resources Ltd. optioned the property and drilled two holes (MM-84-1 and MM-87-1) totaling 1084 metres to test the lower-middle Aldridge contact on Mt. Mahon for sulfide mineralization. In 1991 Minova Inc. optioned the property and drilled six holes (MM-91-1 through MM-92-06; Burge, 1991) totaling 1819 metres in search of extensions of the massive sulfide horizon intersected in YA-6.

Pink garnet-rich beds on the south flank of Mount Mahon, correlated with similar beds farther south across Hawkins Creek, were traced for over 2000 metres by prospector, Craig Kennedy. This garnet-rich horizon lies stratigraphically below stratiform tourmalinite on Mt. Mahon and is near the projected trace of the lower-middle Aldridge contact. The horizon could be a distal exhalite comprised of mixed wacke and exhalative material.

### *Cold Creek fragmentals and tourmalinite*

In 1996, Abitibi Mining Corp initiated prospecting in the Cold Creek area based on company and government airborne magnetic surveys. New tourmaline and fragmental occurrences were located and followed up by a soil survey. In 1997, Abitibi completed prospecting and mapping the area in conjunction with a regional gravity survey.

Three tourmalinite occurrences and several fragmental exposures occur in a 2 km northeast-trending belt east of Cold Creek (Van Angeren, 1997; Figure 3b). The pale brown and black aphanitic tourmalinite replaces a fragmental unit (Leitch, 1997) and locally contains disseminated galena and sphalerite. In contrast, in another part of the system, sericite alters a fragmental to produce a waxy green, soft altered rock. Another interesting feature in this area is that marker laminite occurs as clasts within the one of the fragmental units.

## AEROMAGNETIC IMAGE

The aeromagnetic image for the project area (Figure 9-7), provided by Carmel Lowe of the Geological Survey of Canada, includes regional 1:250 000 scale and recently acquired 1:50 000 scale data as indicated. The latter data set, part of the East Kootenay Geophysical Survey, extends 13.5 km to the west toward Creston and is reviewed in Lowe *et al.* (1998). In addition, a detailed airborne magnetic survey at 200 m line spacing was completed in 1996 by the Abitibi/SEDEX joint venture. Part of their data was provided in Woodfill (1997). The main features of this image as labeled on Figure 7, and those in the industry data, are summarized below. The data allows more accurate extrapolation of contacts into covered areas and has led to modifications of previous surface mapping.

**Feature 1**: The Creston Formation in the Moyie anticline is strongly magnetic and is delineated on Figure 7. Oddly the magnetism varies from the lower to middle Creston as currently mapped. North-trending faults, for example along Irishman Creek, offset units and displace the magnetic feature. **Feature 2**: A broad magnetic anomaly is centered in the core of the Moyie anticline in an area that exposes the deepest stratigraphic levels of the Aldridge Formation, south of Yahk in the Hawkins Creek area. This area also corresponds to a thick accumulation of Moyie sills but they have no elevated magnetism at surface suggesting a buried source for the anomaly (Lowe *et al.*, 1998). **Feature 3**: An isolated magnetic high in the Panda Basin area corresponds to the Bear Dike (Figure 3a). **Feature 4**: Another isolated high 4 km north of feature 3 is a clearly defined U-shaped anomaly on the SEDEX Mining Corp. images. The feature occurs at the intersection of the Ice and Kid faults and corresponds to a buried gabbro body. Drilling in 1997 intersected a series of albite-magnetite-rich veins hosted in Moyie gabbro and overlying Aldridge wackes. **Feature 5**: A linear, north-trending anomaly corresponds to the surface trace of the McNeil fault (Figure 3a). The anomaly terminates at the Palmer Bar fault to the north and at the Moyie fault to the south **Feature 6**: This northeast-trending, elongate anomaly lies along the Old Baldy fault zone. Much of the exposure in this area is unaltered middle Aldridge Formation with rare to no Moyie sills, however, locally there are magnetic sills on the David property and quartz-epidote veins and fractures along the upper contact of a Moyie sill within the middle Aldridge Formation meta-wacke. A

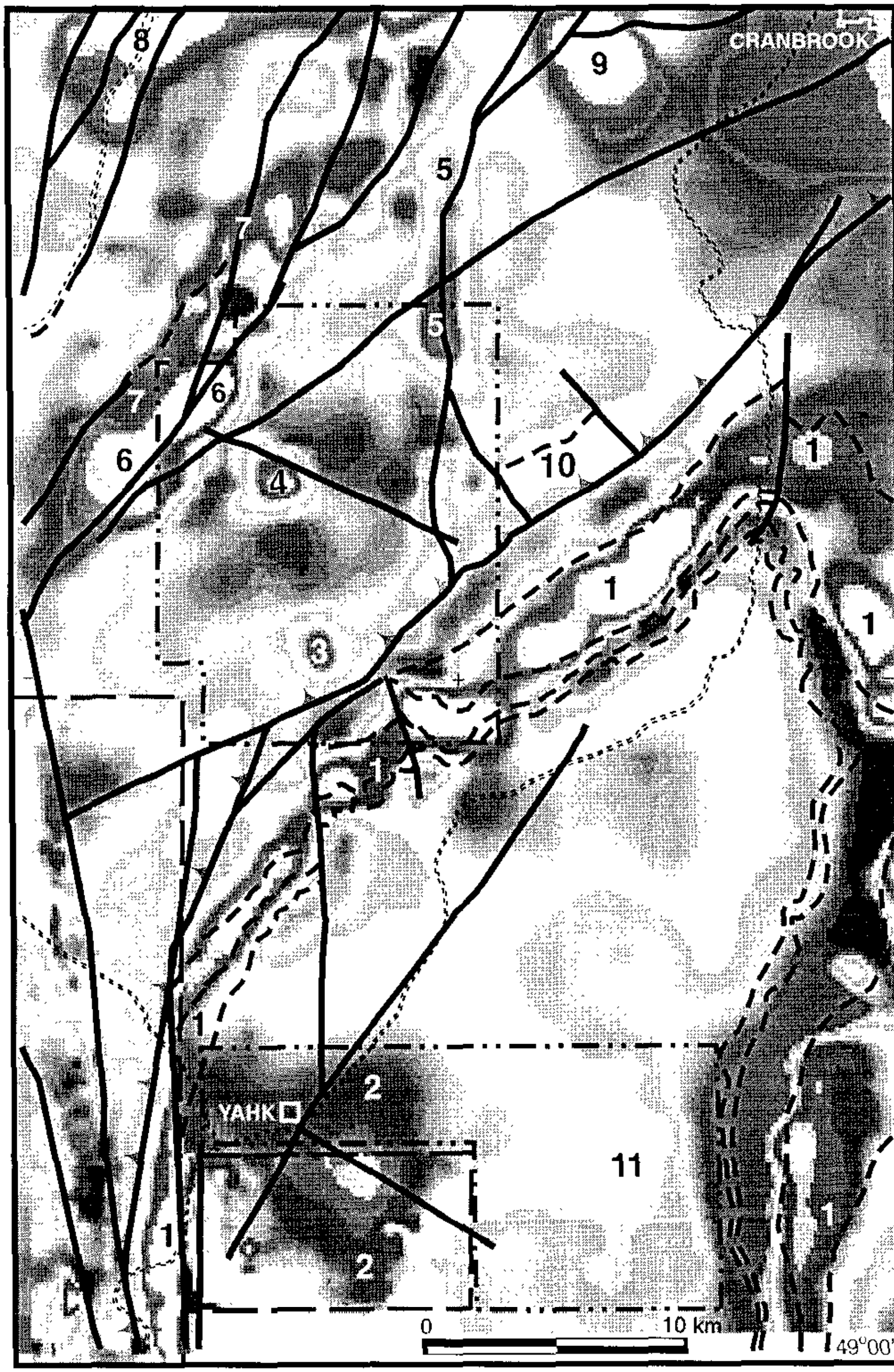


Figure 9-7 Generalized total field magnetic anomaly image for the Moyie project area incorporating regional 1:250 00 scale and recently acquired 1:50 000 scale data (available from the Geological Survey of Canada). Outline of areas where new 200 m line spaced aeromagnetic survey was acquired by industry is shown by dotted rectangles. The southern block was released in Woodfill (1997).

Cretaceous intrusion could lie at shallow depths below the present erosional surface to produce the large and intense magnetic feature. **Feature 7**: Most of the anomaly corresponds to the Creston Formation north of the Old Baldy fault and as in the Moyie anticline anomaly, it varies in intensity along strike. **Feature 8**: This feature in the northwest corner of the Figure 6 is underlain by a small Cretaceous stock that intrudes the Creston and Kitchener formations (Reesor, 1981). The magnetic anomaly extends across lithologic contacts at surface which suggest there is a magnetic halo related to the pluton. **Feature 9**: The Kiakho Pluton and surrounding host-rocks form this anomaly. The pluton is a member of the middle Cretaceous suite of plutons with magnetic phases, the most prominent magnetic anomaly on a regional scale is related to the Reade Lake pluton (Lowe *et al.*, 1997; Höy, 1993) located 15 km to the northeast. **Feature 10**: The lower Aldridge around Rabbit Foot Creek produces a weak anomaly that is believed to be related to the disseminated pyrrhotite occurring in the rusty weathering exposures of that area. **Feature 11**: The weak oval anomaly acquires a linear, north-trending geometry on the more detailed industry survey data and it correlates with the uppermost sill in the middle Aldridge Formation. The columnar jointed sill has highly magnetic parts in outcrops along Branch 17 of the Freeman Creek road.

### Other Features

A series of narrow (<10m wide) meta-gabbroic dikes produce distinct linear magnetic anomalies that are evident on the more detailed surveys of Abitibi/SEDEX but not on the regional data. One of these dikes extends northward and is exposed on the Upper Mahon road. Here, the steeply-dipping, north-trending dike cuts gently, southwest-dipping middle Aldridge quartz wacke beds. The fine-grained massive gabbro ranges from extremely to weakly magnetic. The dike in thin section comprises fine-grained unaltered plagioclase and clinopyroxene with interstitial magnetite grains. Secondary amphibole occurs in the groundmass. This dike was sampled for U-Pb dating which is in progress.

## GRAVITY DATA

A broad regional gravity anomaly encompasses the Moyie anticline and extends north to the Sullivan Mine area (Cook and Van der Velden, 1995) where it terminates against the westward projection of the northern border of the Vulcan Low (Woodfill, this volume). The source of this anomaly has been interpreted to be a basement sliver (Cook and Van der Velden, 1995) or mafic Moyie sills accumulated along the ancient Purcell rift axis (Sears, 1995; Woodfill, this volume). A secondary anomaly, part of this broad anomaly, lies along the east flank of the Moyie anticline within the study area. It is interpreted to be related to gently, east-dipping gabbro sills in the lower and middle Aldridge Formation.

## CONCLUSIONS

The Sullivan deposit projected to surface covers a 1.5 by 1.7 km area but only the old open pit area was visible mineralization at surface. Discovery of a blind deposit of similar or smaller size will require determination and utilization of all the available data for the Purcell Basin. The Moyie Project provides new map data and Sullivan indicator databases that will be utilized in continued mineral exploration in the region. Additional studies on fragmental types, their genesis and classification would be useful.

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