Evaluation of the Geology and Stratabound Base Metal Potential of the Middle and Upper Purcell Supergroup, Southeastern British Columbia (NTS 082G/03, 04, 05, 06)

by R.P. Hartlaub[1] and S. Paradis[2]

KEYWORDS: Middle Proterozoic, Purcell Supergroup, Nicol Creek Formation, Creston Formation, sediment-hosted copper, mineral exploration

INTRODUCTION

The Middle Proterozoic Purcell Supergroup of southeastern British Columbia hosts the Sullivan deposit, one of the world's largest SEDEX Zn-Pb deposits. The Sullivan is hosted in the Aldridge Formation of the lower Purcell Supergroup, near Kimberly, BC. The discovery of this deposit led to extensive exploration of the Aldridge Formation, and these exploration activities continue to this day. Younger rocks of the middle and upper Purcell Supergroup, those rocks lying above the Aldridge/Prichard formation, have received much less attention in BC, even though they host numerous sediment-hosted Cu (±Ag±Co) deposits and polymetallic veins (Fig 1, 2).

Sediment-hosted Cu deposits are the second most important global source of Cu, following only porphyry Cu deposits in total resource. The majority of sediment-hosted Cu deposits are formed within continental rift basins (Brown, 1992) due to fluid mixing within permeable, shallow-water sedimentary and, more rarely, volcanic rocks (Cox et al., 2003). Major deposits lie within the Kupferschiefer belt of Europe and the Zambian Copperbelt of Africa. Proterozoic sedimentary rocks of the middle Belt Supergroup in Montana also contain important sediment-hosted Cu-Ag deposits, including Troy, Rock Creek and Montanore (Fig 1; Hayes and Einaudi, 1986; Boleneus et al., 2005).

This paper reviews the stratabound base metal potential of the middle and upper Purcell Supergroup in the area south and east of Cranbrook, BC in NTS sheets 082G/03, 04, 05 and 06. This area was previously mapped by Höy and Carter (1988), with detailed unit descriptions reported in Höy (1993). Five weeks of reconnaissance mapping were conducted across the area and some detailed work was carried out within areas of known mineral occurrences (Fig 2). Important contributions from this work include the discovery of a new sediment-hosted Cu occurrence and recognition of volcanic-hosted massive sulphide (VHMS) potential.

[1] *Department of Mining and Mineral Exploration, British Columbia Institute of Technology, Burnaby, BC*

[2] *Geological Survey of Canada – Pacific, Sidney, BC*

This publication is also available, free of charge, as colour digital files in Adobe Acrobat® PDF format from the BC Ministry of Energy, Mines and Petroleum Resources website at http://www.em.gov.bc.ca/Mining/Geolsurv/Publications/catalog/cat_fldwk.htm

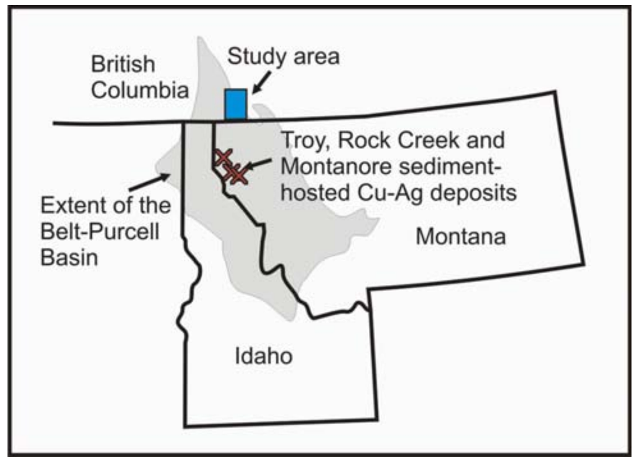

Figure 1. Approximate extent of the exposed Belt-Purcell Basin in British Columbia, Montana, Idaho and Washington. The location of the study area is shown in relation to known sediment-hosted Cu deposits.

REGIONAL GEOLOGY

The Mesoproterozoic Belt-Purcell Basin is believed to represent an intracontinental rift system that has been filled by both marine and fluviatile sediments (Lydon, 2007). The basin, which is termed the 'Belt Basin' or the 'Belt Supergroup' in the United States and the Purcell Supergroup in Canada, extends from southeastern British Columbia into Idaho, western Montana and eastern Washington. The basin developed as a branching system of sub-basins along basement structures that were later shortened and folded (Price and Sears, 2000). In southeastern BC, the oldest rocks of the Purcell Supergroup are exposed along the core and western margin of a large-scale anticlinorium. Mesoproterozoic rocks of the Purcell Basin in Canada have been stratigraphically subdivided in different ways by different authors working in different locations. Readers are directed to Höy (1993), Lydon (2007) and Gardner and Johnston (2007) for a complete discussion of stratigraphic changes within the basin.

The Canadian portion of the basin, south and east of Cranbrook, contains up to 12 km thicknesses of rift-fill turbidite rocks at the base. These 'rift-fill' rocks, termed the 'Aldridge Formation', host the world-class Sullivan SEDEX Zn-Pb deposit (Lydon, 2007). Above the Aldridge Formation, the Creston, Kitchener and Van Creek formations, taken together, can be considered the middle succession of the Purcell Supergroup (Fig 3). They represent the beginning of the 'rift-cover' sequence (Lydon, 2007), but they predate the eruption of a thick package of flood basalts termed the 'Purcell lavas', also known as the Nicol Creek Formation. The upper Purcell Supergroup consists of shallow-water, fine-grained clastic rocks of the Van Creek, Gateway, Phillips and Roosville formations (Höy, 1993), which are overlain by flood basalts and volcaniclastic rocks of the Nicol Creek Formation. Directly overlying the Nicol Creek Formation are coarse clastic and stromatolitic carbonate rocks of the Sheppard Formation.

An extremely thick overburden blanket covers much of the Purcell Mountains south of Cranbrook. This glacial overburden has placed a severe limitation on mapping and prospecting activities in the region. Outcrops are limited to steep cliff faces, roadcuts and local ridges. Although this lack of outcrop may have limited the success of prospecting and soil sampling, other methods can now be applied to the region in order to 'see through' this cover. In addition, forestry roads provide excellent access to most parts of the region.

UNIT DESCRIPTIONS

The following descriptions of stratigraphic units are based on five weeks of reconnaissance mapping in the southern Purcell Mountains, within NTS sheets 082G/03, 04 and 05. As such, the following unit descriptions and stratigraphy (Fig 3) are specific to this area and do not account for regional differences within the basin. Höy (1993) and Gardner and Johnston (2007) can be consulted for additional information on unit thicknesses and regional variations. The middle and upper Purcell Supergroup was examined both regionally and in detail around known mineral occurrences.

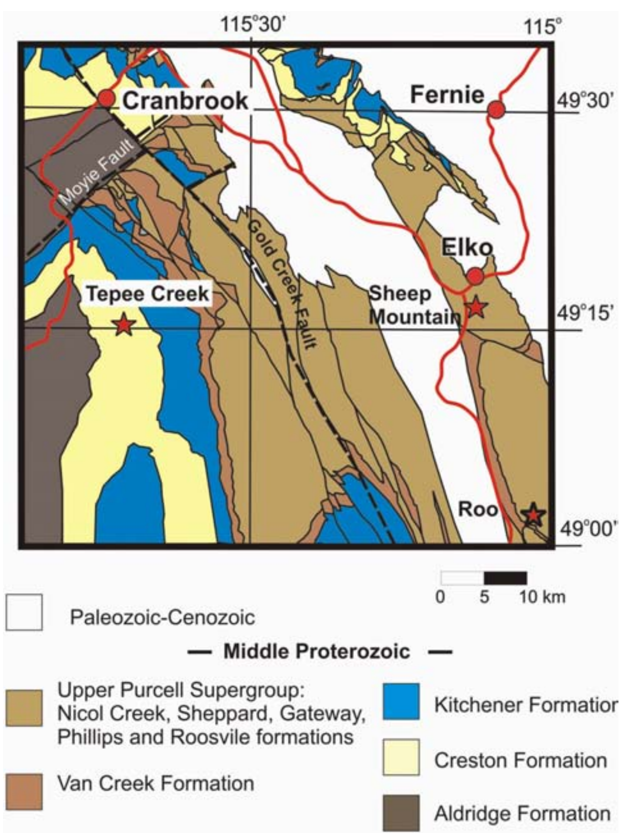

Figure 2. Simplified geology of the study area (*modified from* Höy et al., 1995). Mineral occurrences discussed in the text are indicated with red stars.

Creston Formation

The Creston Formation has been divided into three units based on lithology and environment of deposition (Höy, 1993). The lowermost unit is dominated by siltstone and argillite, the middle unit is dominated by quartz arenite with lesser siltstone, and the upper unit is predominantly siltstone. It is the middle sandstone-dominated unit, termed the 'Revett Formation' in Montana, that hosts the Troy, Rock Creek and Montanore Cu-Ag deposits. The Creston Formation was examined east of Moyie Lake along several forestry roads that parallel Tepee Creek. The lower Creston (i.e., Burke Formation) in this area contains a distinctive dark grey to black fissile siltstone. Above this unit, mauve and green siltstone and argillite predominate, becoming interlayered with quartz arenite of the middle Creston. Crossbedding and ripple marks are common within the quartz-rich sandstone, consistent with deposition in a relatively shallow, high-energy environment (Fig 4). Both siltstone and sandstone are variably bleached and contain epigenetic euhedral crystals of either pyrite or magnetite.

Kitchener and Van Creek Formations

The Kitchener Formation is a distinctive horizon of carbonate rocks that include oolitic limestone and dolomitic siltstone (Höy, 1993). This unit is commonly pyritic, but no stratabound mineral occurrences have been recorded within it. The overlying Van Creek Formation consists of maroon or green interlayered siltstone and argillite. The unit is thinly bedded to laminated and locally fissile. Mud-chip breccias, ripple marks and desiccation cracks indicate that this unit was deposited in shallow water. Gabbro

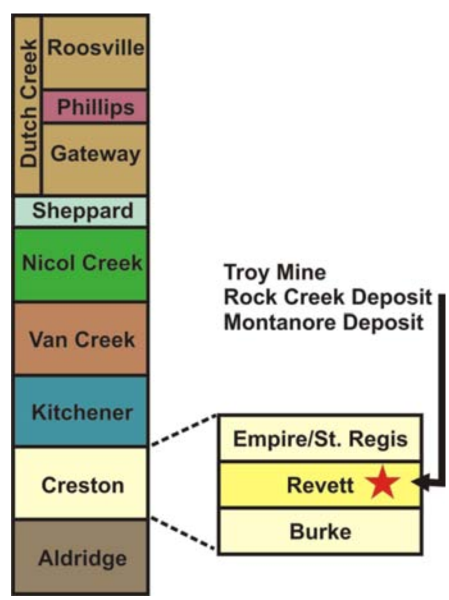

Figure 3: Simplified stratigraphy of the Purcell Supergroup, southeast of Cranbrook, British Columbia.

dikes and sills are relatively common near the top of the Van Creek Formation.

Nicol Creek Formation

The Nicol Creek Formation consists of a distinctive flood basalt unit within the dominantly siliciclastic Belt-Purcell Supergroup. In the United States, the Nicol Creek Formation is termed the 'Purcell lavas' and is best exposed in Glacier National Park, Montana. The Purcell lavas are commonly used as a marker horizon within the basin due to their distinctive nature and relatively widespread occurrence. The Nicol Creek basalts have not been dated, in large part due to a general lack of zircon in mafic extrusive rocks. However, a regionally restricted rhyolite to quartz latite flow yielded a 1443 ±7 Ma age from the Purcell lavas in Montana (Evans et al., 2000). Within the study area, the Nicol Creek Formation is dominated by vesicular and amygdaloidal flows. Vesicles and gas chambers locally provide well-defined top indicators to the flows (Fig 5a, b). Plagioclase-porphyritic flows are also relatively common and are typically interlayered with the vesicular lavas (Fig 6). No sign of pillow structures was noted, consistent with subaerial lava eruption. Höy (1993) produced several measured sections of the Nicol Creek Formation and reported that thin pillowed horizons do exist. Volcaniclastic rocks and layered tuffs occur, but are relatively thin horizons compared to the massive basalts (Fig 7). McGimsey (1985) provided a detailed account of volcanic flow and vent facies from the Purcell lavas within Glacier National Park in Montana. The Nicol Creek basalts are reported to have a subalkaline to alkaline, within-plate geochemical signature (Höy, 1993). A full suite of volcanic samples was collected in 2007 for detailed petrographic, geochemical and geochronological analysis.

Sheppard Formation

The Sheppard Formation directly overlies volcanic rocks of the Nicol Creek Formation, but is thin and rarely exposed within the mapping area. Where exposed, the formation is extremely distinctive due to the presence of well-developed stromatolitic rocks at the top of the section. The growth of stromatolites within the Sheppard Formation may have been aided by hydrothermal activity within the basin (e.g., Canet et al., 2005), initiated by the emplacement of Nicol Creek magmas. Interlayered siltstone, quartz arenite and oolitic carbonate rocks were all identified in the Gold Creek area south of Cranbrook. An unconformable relationship between the Sheppard and Nicol Creek formations has been suggested due to locally missing (eroded?) Nicol Creek strata and the local presence of conglomerate at the base of the Sheppard (Höy, 1993). An angular unconformity appears to be present locally at the contact between these two formations at the Roo mineral occurrence (Fig 2).

Figure 4. Fine crossbedding, quartz veining and bleaching in a quartz arenite from the middle Creston Formation (07RH-222, UTM Zone 11, 5451375N, 593089E, NAD 83).

Gateway, Phillips and Roosville Formations (Dutch Creek)

The Gateway Formation is a relatively thick unit that is well exposed south of Cranbrook, especially on the slopes of Mount Baker and along the Gold Creek forestry road. The unit comprises maroon or green siltstone and argillite. The shallow-water nature of this unit is clearly indicated by an abundance of ripple marks, desiccation cracks and salt casts (Fig 8). The presence of salt casts has been considered distinctive of the stratigraphically equivalent unit in

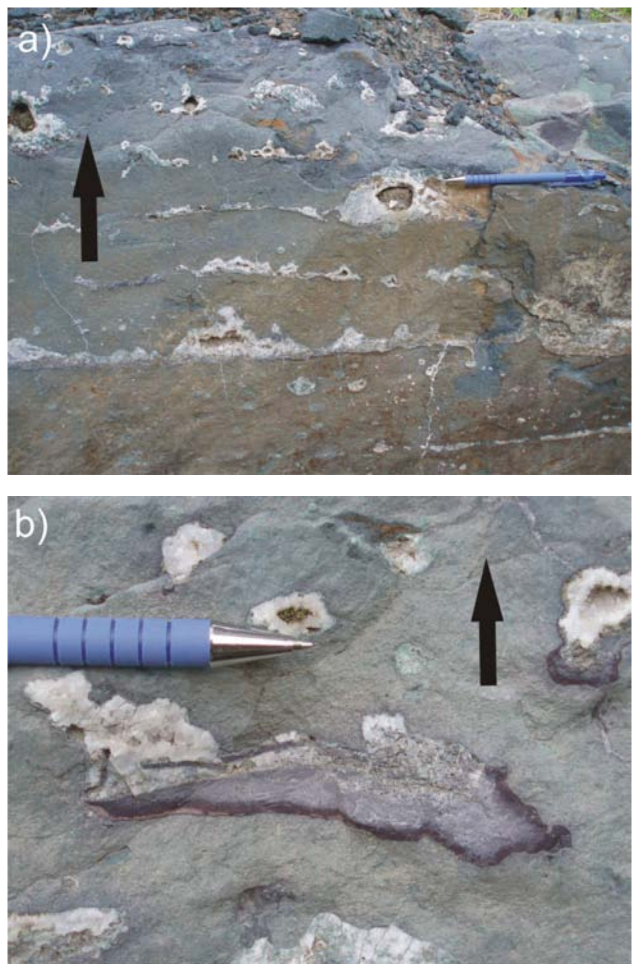

Figure 5. a) and b) Quartz and chalcedony (agate)-filled vesicles and gas chambers indicating way-up direction in Nicol Creek basalts, with arrow indicating top direction (07RH-022; UTM Zone 11, 5471929N, 600783E, NAD 83).

Figure 6. Plagioclase-porphyritic basalt flow (bottom), overlain by aphyric basalt (top; 07RH-246; UTM Zone 11, 5431970N, 646320E, NAD 83).

Figure 7. Volcanic breccia interpreted to be pyroclastic in nature. Clast types are heterogeneous, including those interpreted to be basalt (top right) and aphanitic tan ones that may be tuffaceous (07RH-237; UTM Zone 11, 5492107N, 593798E, NAD 83).

Figure 8. Well-developed salt casts in siltstone from the Gateway Formation (07RH-055; UTM Zone 11, 5471044N, 602185E, NAD 83).

Montana (O'Brien, 1968). The Gateway ranges from thin to thick bedded, and a strong cleavage is locally developed. The Gateway is separated from the overlying Roosville Formation by a distinctive maroon sandstone rich in muscovite, termed the 'Phillips Formation'. Without this marker formation, it is impossible to identify the contact between the upper Gateway and the lower Roosville (Gardner and Johnston, 2007).

INTRUSIVE ROCKS

Intrusive rocks are extremely rare within the study area. A coarse-grained gabbro dike, exposed near Eager hill north of Cranbrook, cuts the Kitchener Formation and includes numerous thin veins containing chalcopyrite (Fig 9). This gabbro may represent a feeder dike to the overlying Nicol Creek basalts. A geochemical comparison will be undertaken to explore this possibility. The presence of Cu in this dike is also consistent with local Cu mineralization in the Nicol Creek Formation. Additional gabbro dikes were identified within the Van Creek Formation, west of the satellite towers near the top of Mount Baker. The margins of these dikes locally display contact metamorphism and quartz veining.

Several K-feldspar porphyritic syenite sills are exposed on the steep east slope of Sheep Mountain (Fig 2). At this location, they cut siltstone and dolomitic rocks of the Dutch Creek Formation. The matrix of the sills is extremely fine grained, suggesting a very shallow level of emplacement. Sheep Mountain also hosts a large zone of alteration and sporadic Cu mineralization that could be related to the emplacement of the syenite magmas. A suite of poorly exposed lamprophyre, minette dikes is also found on the northwest side of Sheep Mountain.

EXPLORATION HISTORY AND ECONOMIC GEOLOGY

Within BC, the Purcell Supergroup has a relatively limited mineral exploration history south and east of Cranbrook. This is especially apparent when compared to the portion of the basin north and west of Cranbrook. Despite this, a couple exploration programs have focused on sporadic Cu (Gold Creek, MINFILE 082GSW022; MIN-

Figure 9. Gabbro dike containing numerous chalcopyrite-bearing veins (07RH-225; UTM Zone 11, 5492533N, 592837E, NAD 83).

FILE, 2007) and mercury showings (Frankie, MINFILE 082GSW034) within the upper Purcell Supergroup along Gold Creek south of Cranbrook. Drilling was concentrated on the Nicol Creek volcanic rocks and the Gateway sedimentary rocks that had geophysical (IP, VLF-EM) anomalies. High Cu values (up to 0.65% over 0.3 m) were noted in several quartz veins near the upper contact of the Nicol Creek basalts (Klewchuk et al., 1990, DH#90-1). Although the first author was unable to locate any surface occurrences associated with this work, a new Cu occurrence was discovered in older strata of the middle Creston Formation. Two other areas with significant exploration histories were also examined. The first is the Sheep Mountain region, near Elko. This area contains a large group of vein and sediment-hosted Cu occurrences (Silver King, Ramshorn, Leah, Jennie, and Sweet May). Secondly, a group of mineral occurrences is located in the Galton Range just north of the Canada – United States border (Roo, Wilda, Green, Wolf and Cabin).

Sediment-Hosted Copper Potential of the Middle Creston Formation

As noted above, a new Cu occurrence was discovered within the Creston Formation along the Tepee Creek forestry road (UTM 593577E, 5454607N). The new showing, termed here 'Tepee Creek', consists of green argillite containing fine bornite and chalcopyrite along the bedding planes (Fig 10). Minor amounts of green Cu oxidation mark the discovery outcrop. Two grab samples returned assay results with elevated Cu (564 and 2086 ppm) and Ag (2 and 6 ppm). The showing is about 1.5 km southeast of the Silver Pipe occurrence, a gossanous vein system with elevated Pb, Ag and Cu values (MINFILE 82GSW058). The Silver Pipe occurrence is also hosted in interbedded siltstone and quartzite of the middle Creston Formation. Grab samples from the gossan yielded high Pb, Ag and Cu values (Yeager and Ikona, 1982). It is interesting to note that the Troy mine in Montana contains significant Ag (i.e., 32.3 g/t; Revett Minerals Inc., 2007), has an outer mineralization zone of galena-calcite and contains veins that crosscut stratigraphy (Mauk and White, 2004).

Figure 10: Finely disseminated chalcopyrite-bornite±chalcocite in a green argillite layer within the middle Creston Formation (07RH-142; UTM Zone 11, 5454607N, 593577E, NAD 83).

A significant alteration zone is exposed about 1 km south of the Tepee Creek Cu occurrence. In this area, spectacular purple and red hematite mottling is indicative of oxidized fluid movement along bedding planes and fractures (Fig 11a, b). A similar style of alteration occurs at the Kupferschiefer sediment-hosted Cu deposit in Poland (Cox et al., 2003). The alteration may mark the location of a localized redox front. Identifying such redox fronts is important for tracing the movement of ore-bearing fluids. The presence of magnetite or pyrite may be helpful in identifying reduced units that are prospective for Cu deposition.

Intrusions, Copper Mineralization and Alteration Zones of the Sheep Mountain Area

Numerous small mineral showings occur on and adjacent to Sheep Mountain, directly south of Elko near the intersection of the Wigwam and Elk rivers (Fig 2). Showings in this area include the Ramshorn, Jennie, Sweet May, Silver King, and Leah (MINFILE 82GSW010, 011, 012, 028 and 029). Although the recorded locations of these showings are vague, there can be no doubt that numerous miner-

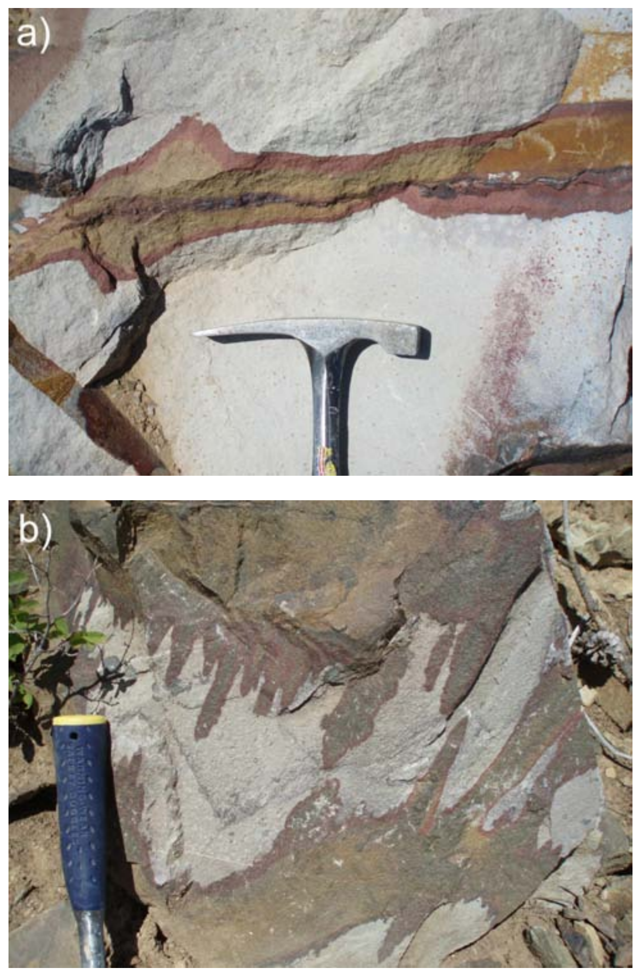

Figure 11. a) and b) Red and purple iron-oxide alteration patterns within sandstone from the middle Creston Formation. This alteration is especially striking due to the white bleaching (argillic alteration) of the rock. The alteration is exposed approximately 1 km south of the newly discovered Tepee Creek Cu occurrence (07RH-220; UTM Zone 11, 5453395N, 594044E, NAD 83).

alized exploration trenches and adits exist on Sheep Mountain. A thick apron (>50 m) of glacial till covers much of the area, and the west side of Sheep Mountain has minimal bedrock exposure. The steep east side of the mountain has numerous small exposures, as well as at least one adit. Steep cliffs along west shore of the Elk River also have exposed outcrop, but they were not investigated due to the difficulty of access. The Roosville Formation is the main unit exposed on Sheep Mountain, but the limited outcrop prevents a complete stratigraphic description. A 10 m thick syenite sill with large, well-developed K-feldspar phenocrysts intrudes siltstone and dolostone of the Roosville Formation along the eastern face of the mountain. Quartz arenite, which may be part of the Mount Nelson Formation, is exposed along the top of the slope as well as in several exploration pits.

A huge zone of alteration is coincident with the exposed syenite sill, but it is unclear whether the alteration zone is related to the sill or other intrusions. Intense argillic and sericitic alteration occurs for several kilometres along the Elk River (Fig 12). Although sedimentary layering is still identifiable, most original minerals have been replaced by clay, sericite, quartz and pyrite. Quartz stockwork (Fig 13) and thick quartz-carbonate veins occur throughout the area. Copper mineralization is typically found within these veins and coating fractures in sedimentary rocks (Fig 14). One major Cu-bearing vein trends approximately 060° and dips steeply southeast. Copper minerals include chalcopyrite, bornite, malachite and azurite. A significant amount of iron-oxide alteration also occurs in angular float on the west side of mountain.

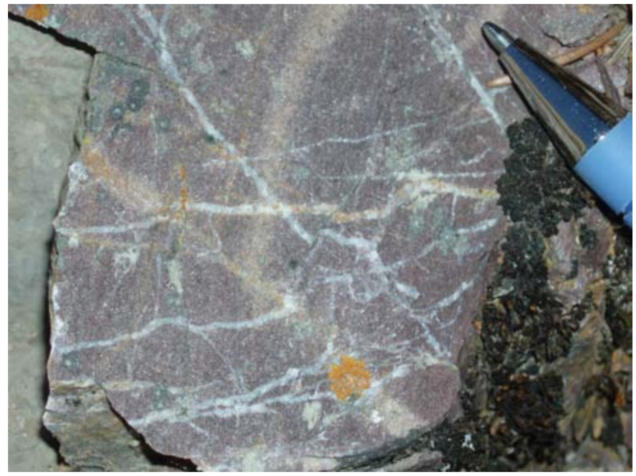

Figure 13. Fine quartz stockwork cutting the Philips Formation on the east shore of the Elk River near Sheep Mountain (07RH-076; UTM Zone 11, 5457834N, 638848E, NAD 83).

VHMS Potential of the Nicol Creek Volcanic Rocks (Roo Property)

The Roo property (Fig 2) is located within the Galton Range east of Roosville, north of the border with the United States and within the Phillips Creek drainage basin. The Nicol Creek Formation is well exposed on the property and is directly overlain by sandstone, conglomerate, and stromatolitic carbonate rocks of the Sheppard Formation. The volcanic rocks of the Nicol Creek include a series of amygdaloidal and porphyritic basalt flows, as well as pyroclastic rocks. Thin-section analysis of the pyroclastic rock indicates that the angular to slightly flattened clasts are porphyritic and/or amygdaloidal, and range in composition from felsic to mafic. A trachyte sill has also been reported in the area (Thomson, 1990a). Initial discoveries of mineralization were reported from 1902, but more recent work was completed by Cominco Ltd. in 1967, Teck Corporation in 1989 and Noranda Inc. in 1993. Previous work included prospecting, trenching, geological mapping, drilling and geochemistry. Drilling by Teck Exploration Ltd. recorded numerous 1 to 5 m thick mineralized intersections with Cu grades up to 1.8% (Thomson, 1990a). The majority of Cu mineralization was hosted in coarse clastic rocks of the Sheppard Formation (Thomson, 1990a, b), possibly related to a synsedimentary growth fault (Kemp, 1992). Recent discoveries, however, indicate that mineralization occurs in both the sedimentary and underlying volcanic rocks (C.

Figure 12. Well-developed argillic and sericitic alteration exposed on the east side of the Elk River near Sheep Mountain. An anastomosing array of near-vertical faults cut through the outcrop and were probable pathways for hydrothermal fluid (07RH-075; UTM Zone 11, 5458239N, 638624E, NAD 83).

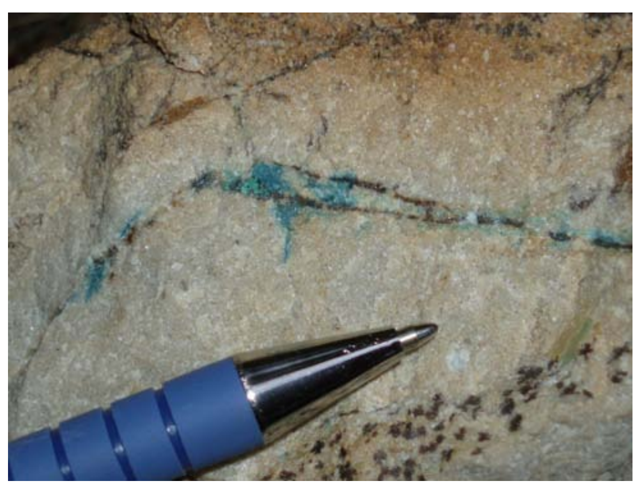

Figure 14. Fine Cu mineralization (chalcopyrite-bornite) and alteration coating fractures within a quartz arenite. This mineralization is exposed within exploration pits on Sheep Mountain (07RH-111; UTM Zone 11, 5457246N 637820E, NAD 83).

Kennedy, Ruby Red Resources Inc., pers comm, 2007). It has been suggested that Cu from Nicol Creek magmas was remobilized into the sedimentary rocks (Thomson, 1990b), but it is possible that all mineralization on the property is directly associated with volcanic activity (VHMS-type). Propylitic and sericitic alteration of the volcanic rocks was locally noted, and barite veins occur throughout the area. A vein up to 1.5 m wide at the Phillips Creek occurrence (MINFILE 082GSE001) was mined for barite in 1940. Barite veining, alteration and elevated cobalt values are all consistent with the presence of a volcanic vent in the area. An angular unconformity locally exists between the Nicol Creek and Sheppard formations; however, this contact may represent the rapid build-up, tilting and erosion of a volcanic pile surrounding a vent complex. Wave-washed sandstone and conglomerate could have been deposited along the flanks of the volcanic pile, while stromatolites developed as the pile stabilized.

Figure 15: Exposure on the west side of the Elk River, south of Elko. The thick layer of glacial drift that is exposed at the top of the cliff is typical of much of the study area. The underlying Purcell Supergroup rocks have undergone significant argillic alteration. Height of the cliff face is approximately 100 m (photo taken from 07RH-075; UTM Zone 11, 5458239N, 638624E, NAD 83).

FUTURE DIRECTIONS FOR MINERAL EXPLORATION

A fairly thick blanket of glacial drift covers much of the bedrock south of Cranbrook and southwest of Fernie (Fig 15). Despite the limited bedrock exposure, a large network of forestry roads provides excellent access and several Cu occurrences have been noted. The high potential of the region is reinforced by the existence of large Cu-Ag deposits in Montana. To capitalize on this potential, targeted exploration methods are required. The following list includes some methods that may prove successful:

- Focus exploration on strata of the middle Creston and Nicol Creek formations.
- Acquire high-resolution geophysics to trace prospective horizons and redox fronts.
- Determine mineral alteration assemblages in order to target drill programs.
- Develop a geochemical database of units to better track geochemical anomalies.
- Utilize remote (spectral?) imaging to determine outcrop locations.
- Obtain basal till samples for geochemical and heavy mineral studies.
- utilize new methods, such as Mobile Metal Ion (MMI)SM geochemistry.

A final consideration for exploration activities is the prospective size of target mineralization. The Troy orebody in Montana is approximately 2300 m (7500 ft.) long, 550 m (1800 ft.) wide and 25 m (80 ft.) thick (Revett Minerals Inc., 2007). Therefore, the surface expression of a similar sediment-hosted Cu deposit is likely to be relatively thin, but should be traceable for a reasonable distance along strike.

ACKNOWLEDGMENTS

Research funding for this project was provided to the first author by the Targeted Geoscience Initiative III (TGI-3) of Natural Resources Canada. Craig and Sean Kennedy are deeply thanked for their informative discussions and for providing access to some of the properties discussed in this text. Dave Grieve and David Gardner are thanked for their continued interest and for insightful discussions. Dave Pigkin provided interesting background information and access to his core-logging facilities. Finally, Tanweer Razi is thanked for his cheerful and reliable assistance in the field.

REFERENCES

Boleneus, D.E., Appelgate, L.M., Stewart, J.H. and Zientek, M.L. (2005): Stratabound copper-silver deposits of the Mesoproterozoic Revett Formation, Montana and Idaho; *United States Geological Survey*, Scientific Investigations Report 2005-5231, 66 pages.

Brown, A.C. (1992): Sediment-hosted stratiform copper deposits; *Geoscience Canada*, Volume 19, Number 3, pages 125–141.

Canet, C., Prol-Ledesma, R.M., Torres-Alvarado, I., Gilg, H.A., Villanueva, R.E. and Cruz, R. (2005): Silica-carbonate stromatolites related to coastal hydrothermal venting in Bahia Concepcion, Baja California Sur, Mexico; *Sedimentary Geology*, Volume 174, pages 97–113.

Cox, D.P., Lindsey, D.A., Singer, D.A. and Diggles, M.F. (2003): Sediment-hosted copper deposits of the world: deposit models and database; *United States Geological Survey*, Open-File Report 03-107.

Evans, K.V., Aleinikoff, J.N., Obradovich, J.D. and Fanning, C.M. (2000): SHRIMP U-Pb geochronology of volcanic rocks, Belt Supergroup, western Montana: evidence for rapid deposition of sedimentary strata; *Canadian Journal of Earth Sciences*, Volume 37, pages 1287–1300.

Gardner, D.W. and Johnston, S.T. (2007): Sedimentology, correlation, and depositional environment of the upper Purcell Supergroup, northern Purcell Basin, southeastern British Columbia; *Geological Survey of Canada*, Current Research 2007-A6, 13 pages.

Hayes, T.S. and Einaudi, M.T. (1986): Genesis of the Spar Lake strata-bound copper-silver deposit, Montana: part I, controls inherited from sedimentation and pre-ore diagenesis; *Economic Geology*; Volume 81, pages 1899–1931.

Höy, T. (1993): Geology of the Purcell Supergroup in the Fernie west-half map area, southeastern British Columbia; *BC Ministry of Energy, Mines and Petroleum Resources*, Bulletin 84, 157 pages.

Höy, T., Price, R.A, Legun, A., Grant, B., and Brown, D. (1995): Purcell Supergroup, geological compilation map; *BC Ministry of Energy, Mines and Petroleum Resources*, Geoscience Map 1995-1, scale 1:250 000.

Höy, T. and Carter, G. (1988): Geology of the Fernie west half map sheet (and part of Nelson east half) (082G/W half, 082F/E half); *BC Ministry of Energy, Mines, and Petroleum Resources,* Open File 1988-14, scale 1:100 000.

Kemp, R. (1992): Geological and geochemical report on the Roo 1–7 claim group; *BC Ministry of Energy, Mines and Petroleum Resources*, Assessment Report 22644, 33 pages.

Klewchuk, P., Bapty, M. and Ryley, J.K. (1990): Geochemical, geophysical and diamond drill report on the Gold Creek Project; *BC Ministry of Energy, Mines and Petroleum Resources*, Assessment Report 19965, 349 pages.

Lydon, J.W. (2007): Geology and metallogeny of the Belt-Purcell Basin; *in* Mineral Deposits of Canada: A Synthesis of Major Deposit Types, District Metallogeny, the Evolution of Geological Provinces, and Exploration Methods, Goodfellow, W.D., editor, *Geological Association of Canada*, Mineral Deposits Division, Special Publication 5, pages 581–607.

Mauk, J.L. and White, B.G. (2004): Stratigraphy of the Proterozoic Revett Formation and its control on Ag-Pb-Zn vein mineralization in the Coeur d'Alene district, Idaho; *Economic Geology*, Volume 99, pages 295–312.

McGimsey, R.G. (1985): The Purcell lava, Glacial National Park, Montana; *United States Geological Survey,* Open File Report 85-0543, 191 pages.

MINFILE (2007): MINFILE BC mineral deposits database; *BC Ministry of Energy, Mines and Petroleum Resources*, URL <http://www.em.gov.bc.ca/Mining/Geolsurv/Minfile/> [November 2007].

O'Brien, D.C. (1968): Cubic casts as indicators of 'top and bottom' in the Shields Formation (Precambrian Belt Supergroup); *Journal of Sedimentary Petrology*, Volume 38, pages 685–687.

Price, R.A. and Sears, J.W. (2000): A preliminary palinspastic map of the Mesoproterozoic Belt-Purcell Supergroup, Canada and USA: implications for the tectonic setting and structural evolution of the Purcell anticlinorium and the Sullivan deposit; *in* The Geological Environment of the Sullivan Deposit, British Columbia, Lydon, J.W., Höy, T., Slack, J.F., and Knapp, M.E., editors, *Geological Association of Canada*, Mineral Deposits Division, Special Publication 1, pages 61–81.

Revett Minerals Inc. (2007): Troy mine project; *Revett Minerals Inc.*, URL <http://www.revettminerals.com/revOp Troy.php> [November 30, 2007].

Thomson, G.R. (1990a): Diamond drilling report on the Roo 1–3 claims; *BC Ministry of Energy, Mines and Petroleum Resources*, Assessment Report 20700, 71 pages.

Thomson, G.R. (1990b): Geological and trenching report on the Roo claims; *BC Ministry of Energy, Mines and Petroleum Resources*, Assessment Report 19898, 45 pages.

Yeager, D.A. and Ikona C.K. (1982): Geological and geochemical report on the Silver Pipe 1–16 mineral claims; *BC Ministry of Energy, Mines and Petroleum Resources*, Assessment Report 10907.