Geologic Setting of the Devonian-Mississippian, Rea and Samatosum VMS Deposits of the Eagle Bay Assemblage, Adams Lake Area, South Central British Columbia

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ABSTRACT

Highly deformed, low-grade metasedimentary and metavolcanic rocks of the Eagle Bay Assemblage host the volcanogenic (?) massive sulphide Twin Mountain and Rea deposits, and the Samatosum vein deposit. The Twin Mountain deposit consists of sulphide-bearing quartz-carbonate-barite lenses hosted by sericitized and silicified schists of volcanic origin. The Rea deposit consists of at least two massive sulphide lenses. The Samatosum deposit is a stratabound sulphide-rich quartz vein system that could be interpreted as a stockwork zone. The Rea and Samatosum deposits occur within an overturned metasedimentary sequence of sericitized and silicified argillites structurally overlain by mafic volcaniclastic rocks and flows. The stratigraphic sequences at Rea and Samatosum are very similar and we suggest that structural repetition by faulting occurred, and that the sedimentary and volcanic succession is of Devonian-Mississippian age.

INTRODUCTION

Highly deformed Cambrian to Mississippian metasedimentary and metavolcanic rocks of the Eagle Bay Assemblage in the Adams Lake area host numerous polymetallic sulphide deposits. The region has long been recognized as favorable for various types of sulphide deposits, and is still today a prospective "ground" for mineral exploration. The Homestake barite-sulphide deposit was discovered in 1893. Since then numerous sulphide occurrences have been found in the district. Some of these, including Samatosum, Rea and Homestake, have had limited production, and others, such as Twin Mountain, have had extensive exploration work over the years.

This paper briefly describes the Samatosum, Rea, and Twin Mountain sulphide deposits located in the Adams Lake area of south central British Columbia, approximately 80 kilometers northeast of Kamloops (Figure 1). It defines their geological settings, and addresses some fundamental structural and stratigraphic problems in the region. This study was initiated during the summer of 1999 as the M.Sc. project of the first author (Sean L. Bailey) and included 1: 5000 scale regional mapping of an approximately 30 km^2 area conducted over a 7 week period. It is part of the Ancient Pacific Margin NATMAP metallogenic study of syngenetic sulphide deposits of the Kootenay Terrane and the correlative Yukon-Tanana Terrane in northern British Columbia and Yukon.

The area is dominated by dense vegetation, thick till coverage, and steep mountainous terrane. A series of logging and drill roads allow good access to the plateau of Samatosum mountain, with the best exposures found along roadcuts, clearcuts, trenches remaining from past exploration, and creeks.

EXPLORATION HISTORY

The first documented discovery of sulphide occurrence in the Adams Lake area dates back to 1893 with the discovery of the Homestake barite-sulphide deposit. The Homestake mine was worked intermittently between 1893 and 1984. In the 1920s, numerous sulphide occurrences were found in the Birk Creek and Harper Creek areas. In 1978, the Chu Chua massive cupriferous pyrite deposit was discovered in basalts of the Fennell Formation. However, none of these discoveries resulted in significant production.

In 1983, A. Hilton and R. Nicholls discovered the Rea massive sulphide deposit. They optioned it to Rea Gold Corporation who in turn optioned it to Corporation Falconbridge Copper (presently Inmet Mining Corporation). Drilling carried out by Corporation Falconbridge Copper in the 1980s outlined two small but fairly high-grade massive sulphide lenses (known as the "Discovery zone" or the "Rea horizon"). The most recent published estimate of the mineralization was 376,000 tonnes grading 0.33 percent copper, 2.2 percent lead, 2.3 percent zinc, 6.1 grams per tonne gold, and 69.4 grams per tonne silver (Northern Miner – November 30, 1987).

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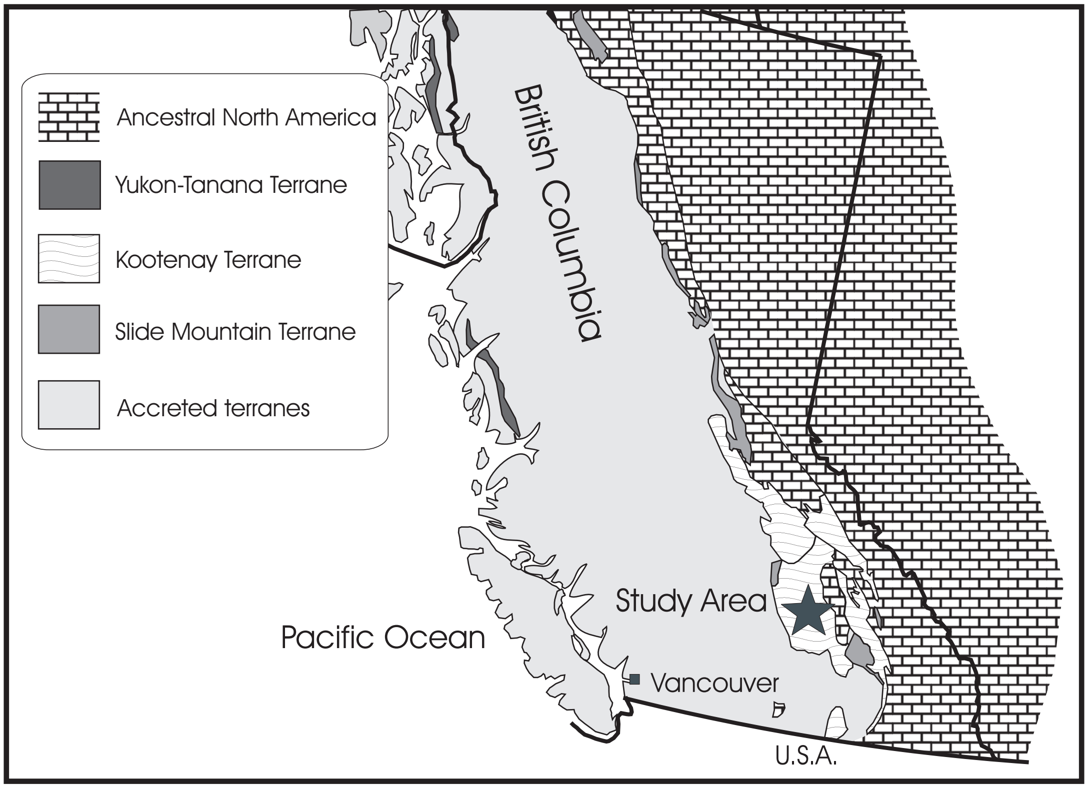

Figure 1. Location of the study area, within the Kootenay Terrane of central British Columbia (modified after Wheeler and Mcfeely, 1991).

Mapping in 1984 and 1985 by Corporation Falconbridge Copper produced a general understanding of the stratigraphy and structure in the area. In addition, horizontal-loop electromagnetic (HEM) surveys defined several long stratiform conductors. By early 1986, a new mineralized horizon (the "Silver zone") was found, and this was immediately followed by the discovery of the Samatosum deposit.

Regional Geology

Metavolcanic and metasedimentary rocks of the Eagle Bay Assemblage of the Kootenay Terrane host the Rea and Twin Mountain sulphide deposits and the Samatosum vein deposit. The Kootenay Terrane and correlative rocks of the Yukon-Tanana Terrane farther north comprise dominantly Paleozoic sedimentary and volcanic rocks that are inferred to have been deposited on the distal western edge of ancestral North America. The successions of the Kootenay Terrane include the Lardeau Group, the Eagle Bay Assemblage, eastern assemblages of the Late Paleozoic Milford Group, and equivalent rocks within the Shuswap metamorphic complex (Höy, 1999).

The Eagle Bay Assemblage, described by Schiarizza and Preto (1987), comprises Lower Cambrian to Mississippian rocks that are intruded by Late Devonian orthogneiss and Jurassic-Cretaceous granodiorite and quartz monzonite of the Raft and Baldy batholiths. Within the study area, the Eagle Bay Assemblage is contained within four west-directed thrust slices. The assemblage consists of clastic metasedimentary rocks (units EBH and EBQ Schiarizza and Preto 1987), mafic metavolcanic rocks and limestone (unit EBG), and structurally overlying clastic metasedimentary rocks, with minor carbonate and volcanic rocks (unit EBS), all of which are interpreted as Cambrian in age. These are in turn overlain by Devonian-Mississippian mafic to intermediate metavolcanic and metasedimentary rocks (units EBA and EBF, respectively), which are overlain by metaclastic rocks (unit EBP).

Numerous volcanogenic sulphide occurrences of the Eagle Bay Assemblage, including Rea, Homestake, Samatosum and Twin Mountain are within mafic to intermediate metavolcanic and metasedimentary rocks of units EBA, EBF, and EBG (Figure 2). Regional mapping by Schiarizzia and Preto (1987) and this study indicate that units EBA, EBF, and EBP between the Samatosum and Homestake deposits are apparently right-way-up regionally but locally overturned (Figure 2). These are structurally overlain by mafic metavolcanic rocks of EBG and the Tshinakin Limestone Member which is assigned a Lower Cambrian age (Schiarizza and Preto, 1987). These stratigraphic and structural relationships led to the inference by Schiarizza and Preto (1987) of the Haggard Creek Thrust Fault, which places Cambrian rocks on Devonian–Mississippian rocks. The Samatosum and Rea deposits are located near the inferred trace of this fault, and controversy exists over which package(s) of rocks hosts

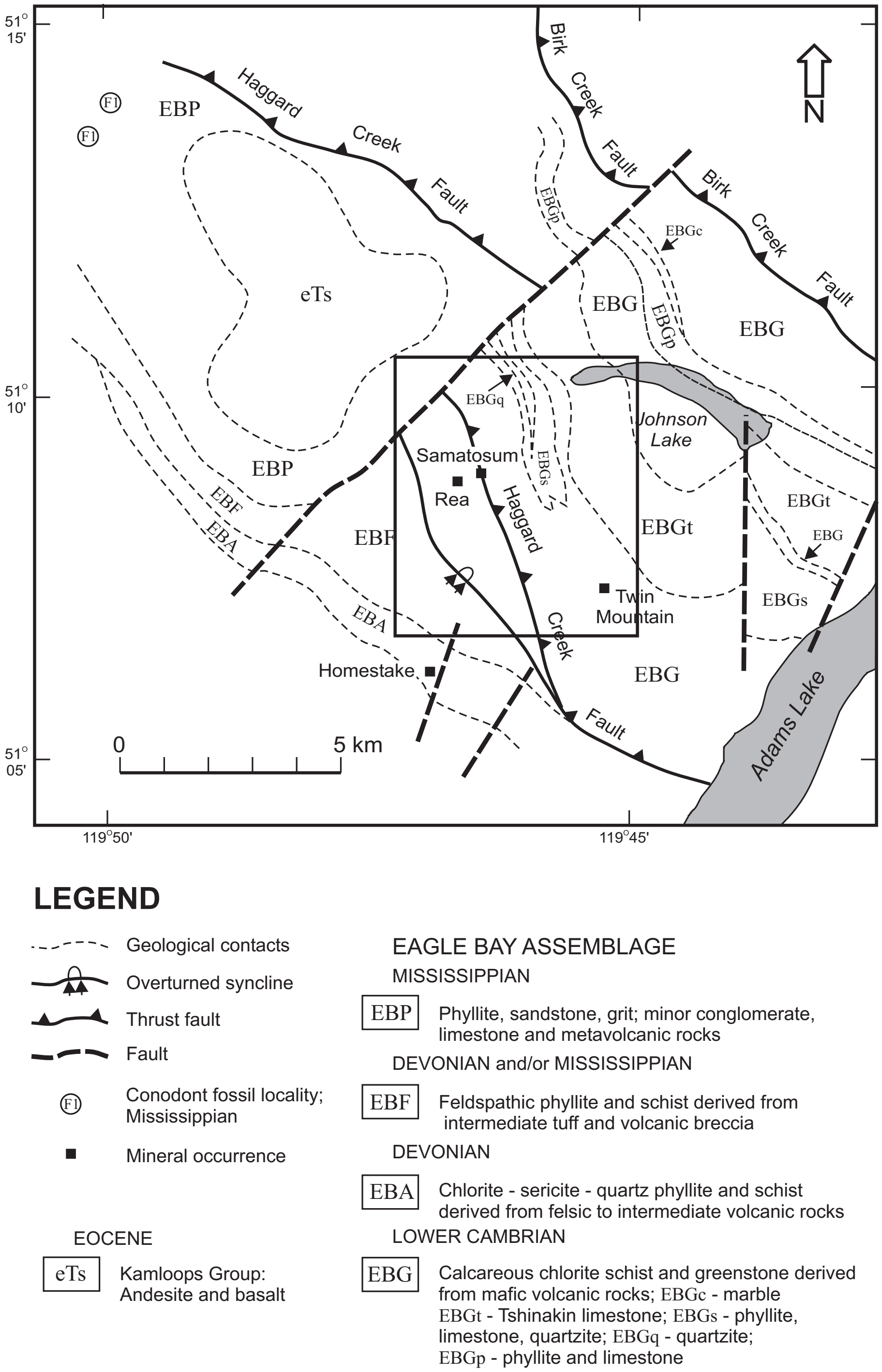

Figure 2. Geological map of the Johnson Lake area, modified after Schiarizza and Preto (1987)

the deposits and whether or not a major thrust fault exists. This study will attempt to resolve these matters.

Local Stratigraphy

The main stratigraphic units encountered in the area of the deposits are described below and their distribution illustrated in Figure 3. An interpreted SW-NE cross-section through the Rea and Samatosum zones is shown in Figure 4. Lack of age control makes our interpretation somewhat preliminary and hence other scenarios are possible.

Fossil archaeocyathids were found within limestone at a single locality 50 kilometers north of the study area in a different fault panel. Correlation of this limestone with the Tshinakin limestone member at Johnson Lake sug-

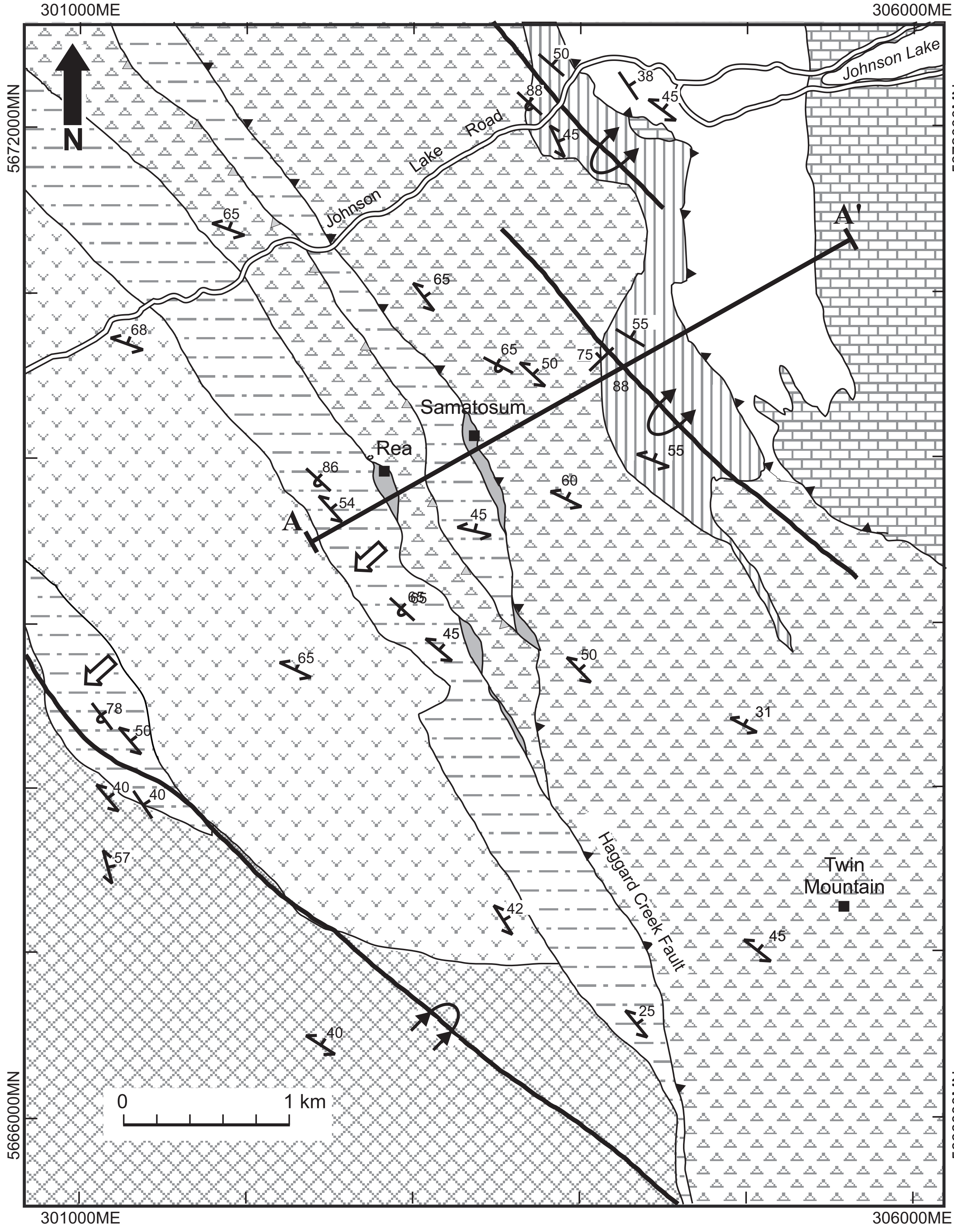

Figure 3. Preliminary geological map of the Johnson Lake area.

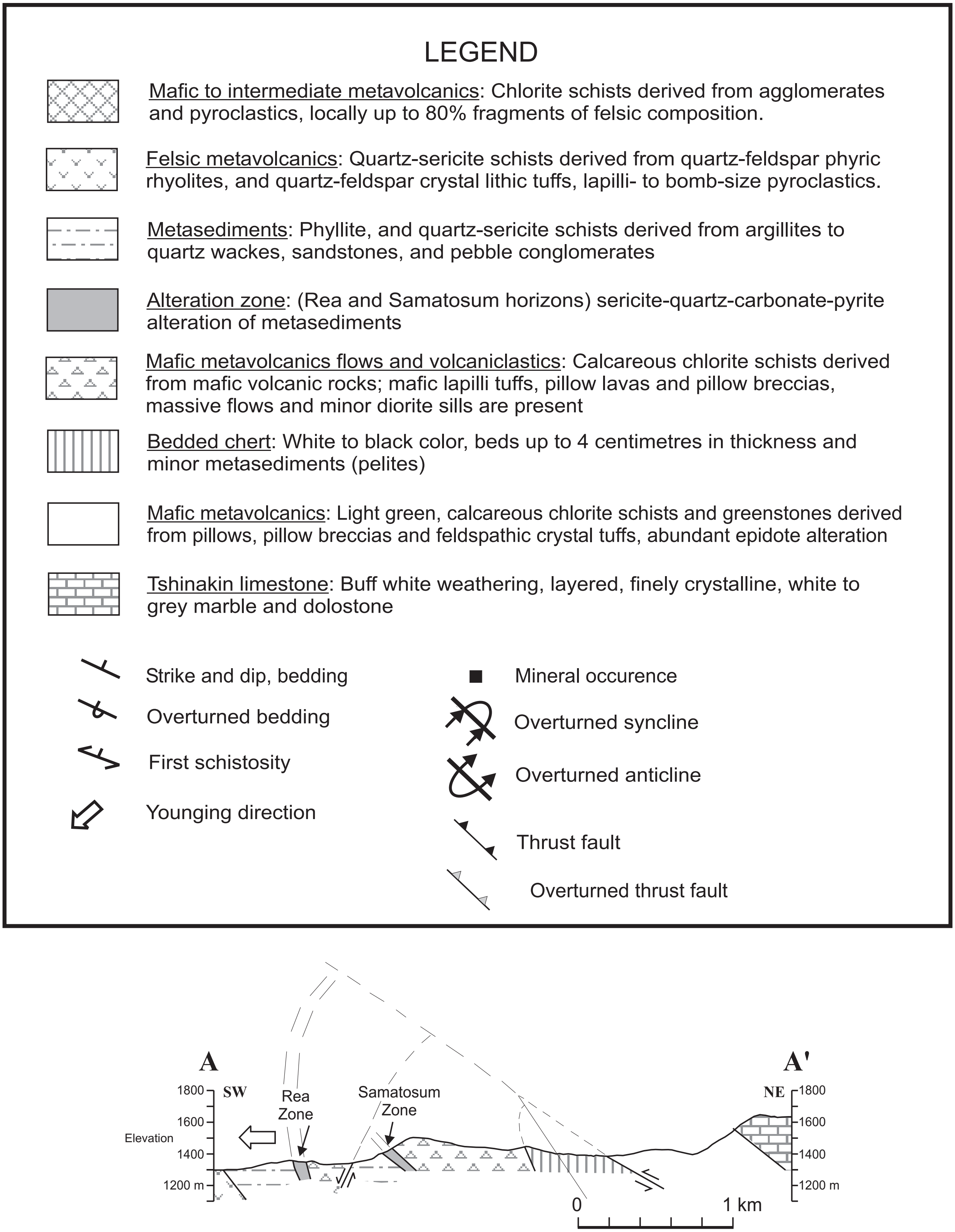

Figure 4. SW-NE cross section through the Rea and Samatosum zones, no vertical exaggeration.

gests an Early Cambrian age for this unit (Schiarizza and Preto, 1987). Mafic volcanic rocks are locally interbedded with the limestone and consequently are interpreted to be Early Cambrian (Schiarizza and Preto, 1987). U-Pb zircon age dates of 387 Ma (*i.e.*, Middle Devonian) have been obtained from felsic metavolcanics of unit EBA on the east shore of Adams Lake (Preto, 1981; Preto and Schiarizza, 1985). Felsic to intermediate rocks of unit EBF are interpreted to be younger (*i.e.*, Devonian and/or Mississippian), as they are stratigraphically above rocks of unit EBA and below rocks of unit EBP, which contains Mississippian conodonts (Schiarizza and Preto, 1987).

The deposit area is underlain by northeast-dipping metasedimentary and metavolcanic rocks that, based on well developed graded beds (Höy and Goutier, 1986; and this study), display an overall younging direction structurally down-section and toward the west (Figure 4). Hence, much of the stratigraphy within this region is overturned. From oldest to youngest, the stratigraphy includes the Tshinakin limestone, mafic metavolcanic rocks, bedded cherts, mafic metavolcanic flows and volcaniclastic rocks, metasediments, and mafic to intermediate metavolcanic rocks.

Tshinakin Limestone

The Tshinakin limestone outcrops in the eastern portion of the map area (Figure 3) and is best exposed in the cliffs above Johnson Lake. It consists dominantly of finely crystalline white to grey marble with minor dolostone, which display a buff white to grey weathered surface. It is usually massive; however, laminations defined by light and dark bands are locally observed (Figure 5A). It is interbedded with calcareous chlorite schist at other locations, such as nearby Adams Lake (Schiarizza and Preto, 1987).

Mafic Metavolcanics

This unit is composed of greenstones and chlorite schists derived from pillows, pillow breccias and feldspathic crystal tuffs. Pillows locally exceed one meter or more in length. The metavolcanics have a light green color due to abundant epidote, and commonly have a white or grey weathered surface. Tuffs contain crystals of feldspar less than 1 mm in diameter.

Bedded Chert

A bedded chert unit occurs between two distinct mafic volcanic packages (Figure 3). The chert is light grey-white to black in color, locally graphitic, and has well defined bedding (Figure 5B). Minor amounts of pelites occur, which locally contain particles up to sand size and display a c-s fabric along the contact with the structurally overlying pillow breccias.

Mafic Metavolcanic Flows and Volcaniclastics

The mafic metavolcanic rocks in the central portion of the map area are dominated by calcareous chlorite-sericite-quartz schists and chlorite schists derived from mafic volcanic rocks. Abundant volcaniclastic rocks and rare mafic massive flows and pillow basalts and breccias are also present. The most common rock type is a lapilli-tuff with average fragment size of approximately 4-5 centimeters. The lapilli are commonly bleached and are thought to be of similar composition to the matrix. Locally, the fragments are up to bomb size (Figure 5C) as exposed at the Samatosum mine site. Fine-grained chlorite schists are abundant throughout the unit. The massive flows contain calcite and quartz amygdules. Pillows are approximately 1 meter in size, are amygdaloidal, and have been flattened in the penetrative foliation plane. These display an outer non-vesicular 2 to 3 centimeters rim. The entire unit is calcareous, and locally contains disseminated pyrite.

Major and trace element analysis of these mafic units, indicate that they are dominantly alkali, within-plate basalts (Höy, 1987). As most of the Devonian-Mississippian volcanic rocks of the Eagle Bay Assemblage are calc-alkaline it was suggested that the Rea and Samatosum stratigraphy represented deposition in a rifted volcanic arc (Höy 1987).

Diorite sills or dikes were observed within this unit and may have played a role in sulphide mineralization. The Twin Mountain sulphide deposit occurs within pyritic, calcareous chlorite-sericite-quartz schists and chlorite schists derived from mafic volcanic rocks.

Metasediments

The metasediments are phyllites and quartz-sericite schists thought to have originally been fine-grained argillites and quartz wackes. A quartz-lithic pebble conglomerate at the stratigraphic top of this sequence is composed of clasts (commonly 2-3 centimeters in diameter) of chert, chlorite schist, and vein quartz. This conglomerate has been traced to the northwest, extending beyond the map area where it appears to thicken.

Near the Samatosum and Rea deposits, the metasediments are part of a structurally complex sequence called the "Mine Series". The Samatosum and Rea deposits are located within the metasediments near the contact with the structurally overlying mafic volcanic rocks. Here, the metasediments are highly strained and altered (*i.e.*, sericitized ± clay, silicified, and carbonatized). They consist of carbonaceous black argillites, sericitized yellowish argillites containing chert lenses, and pyrite-rich silicified greyish argillites. Some of the beds show graded bedding and rip-up clasts. Locally distributed massive to brecciated chert within the metasediments appears to be spatially associated with base-metal sulphides.

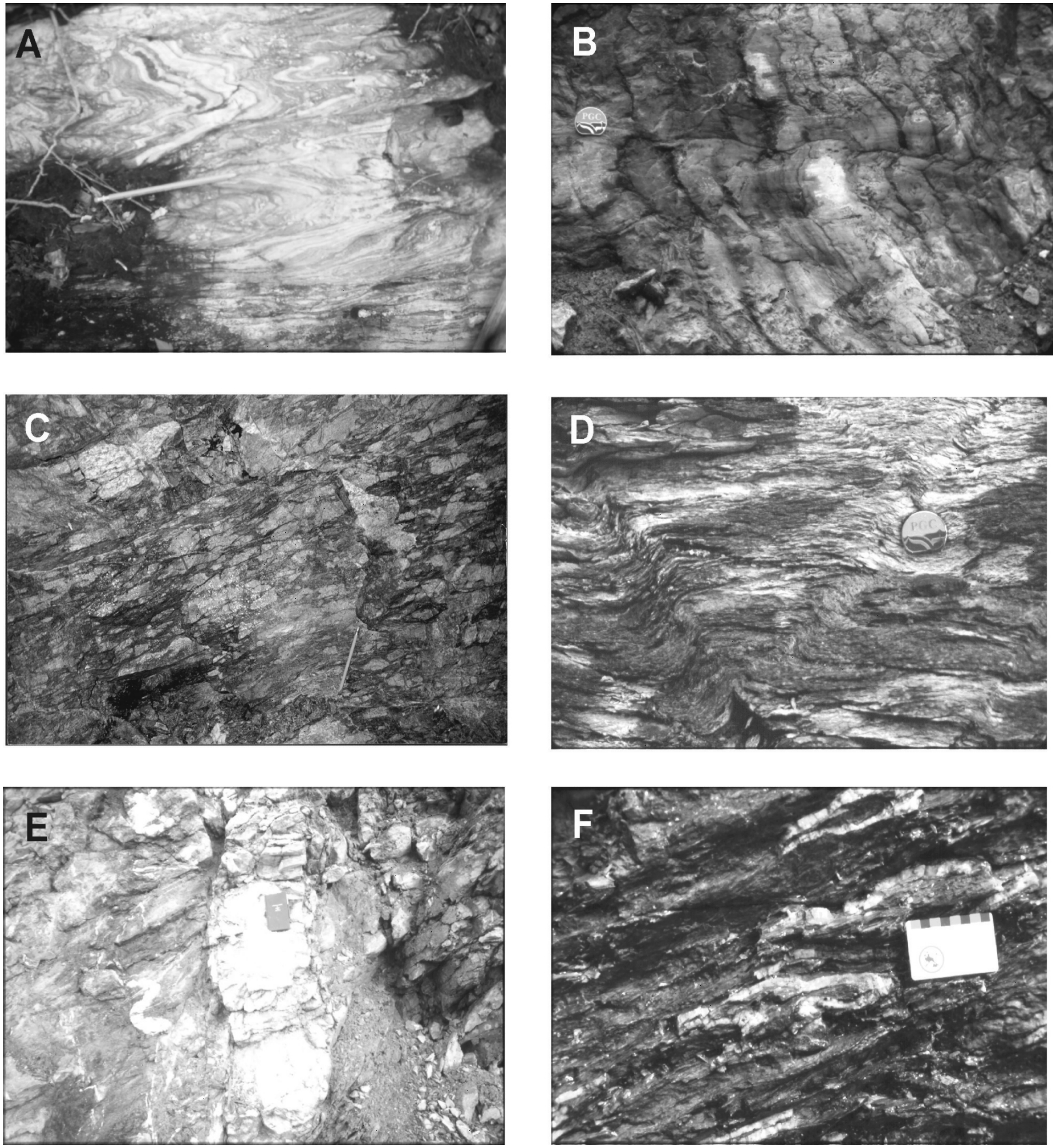

Figure 5. A.) Parasitic folding of layers in Tschinikan Limestone. B.) Bedded chert, (Pin for scale is 3 centimeters in diameter). C.)Mafic flow breccia, fragments are bleached, and range from bomb to lapilli size. D.) Kink bands and reverse kink bands in mafic tuff. E.) Mineralized quartz veins at the Samatosum deposit. F.) Quartz veins,(2 centimeters thickness) which have been folded by, and transposed into the penetrative foliation, hosted within sericitized-silicified sediments, Samatosum deposit.

Felsic Metavolcanics

The felsic metavolcanic unit is composed of white weathering, beige quartz-sericite schists derived from quartz-feldspar porphyritic rhyolite, quartz-feldpar-crystal-lithic tuffs and pyroclastics. The feldspar component of this unit is mainly albite. The volcanics are bounded to the east by quartz-lithic pebble conglomerate and appear to be interlayered with phyllite and quartz wackes, which commonly contain several percent euhedral pyrite.

Mafic to Intermediate Metavolcanics

Chlorite schists derived from mafic volcaniclastic rocks are located in the western part of the map area. The most common rock type is mafic volcanic breccia containing 30-centimetre fragments. However, in the eastern most section of this unit, the metavolcanics include fragments of felsic volcanic rocks that locally account for 65 to 80 percent of the rock.

STRUCTURE AND METAMORPHISM

The structure of the area is dominated by a series of northwest trending, shallow dipping, tight overturned folds, with penetrative axial planar cleavage defined by lower to middle greenschist metamorphic minerals. These folds are west-verging, have parallel axial traces to, and are likely related to a series of southwest-directed thrust faults (Schiarizza and Preto, 1987). Bedding-cleavage relationships and stratigraphic top determinations indicate that the western limbs of these folds are overturned. Parasitic folds plunge at shallow to moderate angles to the northwest.

The penetrative cleavage is crenulated by a second cleavage. The crenulation lineation trends northeast, and appears to have formed in conjunction with northeastward trending low amplitude folds (Schiarizza and Preto, 1987).

Graded beds are the most commonly observed indicators of stratigraphic tops. They are a series of fine sandy layers, which abruptly overlie muddy layers, and grade up into mud. In the coarser units, this gradation proceeds from pebble conglomerate to coarse sand. Rare sedimentary features such as rip up clasts, and scour-and-fill structures were also observed. Höy (1987) interpreted this as a turbidite sequence developed on the distal continental margin in deep marine conditions during rifting.

MINERALIZATION

Prospectors and geologists have long recognized the Johnson-Adams Lake area as a favourable region for base-metal sulphide deposits. Several significant mineral occurrences including Samatosum, Rea, and Twin Mountain are located within the map area (Figure 3). These deposits have been suggested to be volcanogenic sulphide deposits (Höy and Goutier, 1986). The Twin Mountain deposit consists of sulphide-bearing quartz-carbonate-barite lenses hosted by sericitized and silicified schists derived from mafic volcanic rocks (unit EBG of Schiarizza and Preto, 1987). The Rea deposit consists of volcanogenic massive to semi-massive sulphide lenses, whereas the Samatosum deposit may be a stockwork system related to stratabound volcanogenic sulphide lenses.

The Samatosum and Rea deposits are within a similar overturned sequence of greenschist metamorphic grade sericitized, silicified and carbonaceous argillites that are structurally overlain by mafic volcaniclastics and flows. We suggest that the sulphide mineralization at Samatosum and Rea occur within a fault repetition of the same stratigraphic sequence. Alternatively, two distinct but similar stratigraphic sequences may host the deposits. Lead isotopes from the Rea deposit suggest a Late Devonian age (Goutier, 1986), supporting the speculation that rocks hosting the Rea and Samatosum deposits belong to the Devonian-Mississippian succession of the Eagle Bay Assemblage.

Rea

The Rea deposit was discovered in 1984 by local prospectors, Alex Hilton and R. Nicholl, who optioned it to Corporation Falconbridge Copper. Subsequent exploration revealed two massive sulphide lenses, named RG8 lens and L100 lens. The RG8 lens is the southernmost and has a surface strike of 75 metres with a downdip extension of 80 metres. The northern lens (L100) or discovery zone has a surface strike of 50 meters and a down dip extension of at least 120 meters.

Combined reserves for the two massive sulphide lenses totaled 376,000 tonnes grading 0.33 percent copper, 2.2 percent lead, 2.3 percent zinc, 6.1 grams per tonne gold, and 69.4 grams per tonne silver (Northern Miner – November 30, 1987). Sulphides are pyrite, sphalerite, galena, arsenopyrite, chalcopyrite, and tetrahedrite. These are fine to medium grained with banded to breccia texture in the massive sulphide lenses. Gold and silver are associated with massive sulphide and barite.

Rea has been examined in considerable detail by Höy and Goutier (1986) and Höy (1987; 1991. The deposit occurs on the overturned eastern limb of a northwest-trending syncline. The stratigraphic footwall of the deposit consists of metamorphosed mafic tuffs and chert, which show sericite-quartz-carbonate alteration, likely representing footwall alteration of a mafic volcanic precursor. The two massive sulphide lenses, one of which contains a barite cap (RG8), are stratigraphically above this horizon and overlain by a thin mafic tuff. These are then stratigraphically overlain by a several hundred meter-thick sequence of argillites and minor tuffs, which grades into a quartz pebble conglomerate at the top.

Subsequent exploration of the Rea zone has shown that it can be traced along strike for seven kilometers and hosts at least five volcanogenic massive sulphide lenses (Carmichael, 1991).

Samatosum

The Samatosum Ag-Pb-Zn-Cu deposit originally contained 634,984 tonnes of ore containing 1.9 grams/tonne Au 1,035 grams/tonne Ag, 1.2 percent Cu, 1.7 percent Pb and 3.6 percent Zn (Pirie, 1989). It was mined by Inmet Mining Corporation between 1989 and 1992.

The deposit consists of a highly deformed quartz vein system containing massive to disseminated tetrahedrite, sphalerite, galena, and chalcopyrite. It lies within altered and deformed metasediments close to the contact with structurally overlying mafic volcaniclastic rocks. According to Pirie (1989), structural evidence indicates that the sequence is inverted and that the deposit is on the overturned limb of a recumbent syncline.

The sequence is called the "Mine Series" by the mining companies. Metasediments consist of carbonaceous black argillites, sericitized yellowish argillites containing chert lenses, and pyrite-rich silicified greyish argillites. Some of the beds show grading and rip-up clasts. The metasediments are heavily strained and highly altered; they display pervasive quartz-pyrite-sericite-fuchsite-carbonate alteration, which is most intense along the metasediment-metavolcanic contact. The protolith of these rocks is difficult to recognize because of intense alteration, deformation, and mineralization. Future geochemical and petrographic studies will try to resolve this issue.

Mafic volcaniclastic rocks structurally overlying the sediments are most commonly tuffaceous to lapilli in texture. Some pillowed flows are present. Folded and brecciated mineralized quartz veins crosscut the metasediments and the metavolcanics in the vicinity of the deposit (Figures 5E and F).

Twin Mountain

The Twin Mountain occurrence consists of galena, sphalerite, chalcopyrite, and pyrite mineralization within carbonate-quartz veins, and sulphide barite lenses. The host rock consists of sericitized and silicified schists derived from mafic volcanic flows and volcaniclastic rocks. The property was explored by Camoose Mines Ltd. during the 1950's, and was reexamined during the 1980's by Corporation Falconbridge Copper. A drill hole intersected 2.37 meters assaying 10.6 grams per tonne gold, 335.3 grams per tonne silver, 3.13 percent zinc, 2.74 percent lead and 0.55 percent copper (George Cross Newsletter #237, 1987).

DISCUSSION

The stratigraphic and structural setting of the metasedimentary and metavolcanic rocks of the Eagle Bay Assemblage in the Johnson Lake-Adams Lake region has important implications for understanding the genesis of the sulphide mineralization.

Schiarizza and Preto (1987) inferred a major thrust fault, the Haggard Creek Fault, between the structurally overlying Cambrian mafic volcanic rocks (unit EBG of Schiarizza and Preto, 1987) and the underlying Devonian-Mississippian metasedimentary rocks (units EBF, EBA and EBS). This thrust fault trends roughly along the Samatosum and Rea horizons, *i.e.*, along a package of overturned metasedimentary-metavolcanic rocks referred to as the "Mine Series". The Rea deposit was interpreted to be within the Devonian-Mississippian volcano-sedimentary sequence, whereas the Samatosum deposit was interpreted as hosted in Devonian-Mississippian strata with Cambrian volcanics in thrust contact.

The stratigraphic sequences at Rea and Samatosum are very similar. Moreover, the deposits have similar alteration and mineralogy. At Rea, the contact between the mafic volcaniclastic rocks and the underlying metasediments is a stratigraphic one (Höy and Goutier, 1986). These factors suggest that the stratigraphic sequence is the same for both deposits and is repeated by faulting. It also suggests that the sedimentary and volcanic succession hosting Rea, Samatosum, and possibly Twin Mountain, is Devonian-Mississippian in age.

At Samatosum, the presence of quartz and carbonate veins in the structural hanging wall (*i.e.*, mafic volcanic rocks) and the presence of stratiform mineralization within the metasediments, along with pervasive sericite-quartz-carbonate-pyrite alteration of both metasediments and metavolcanics, seems to indicate a stratigraphic rather than structural contact between these two units. This may be verified by geochemical studies, now in progress. At the present, we have inferred the presence of an overturned thrust fault (Figure 4.) to repeat this stratigraphy. In the cross section (Figure 4) this appears to be a normal fault. However the surface trace of the fault appears to strike parallel to the penetrative cleavage (Figure 3) and cleavage does not appear to vary across the fault, which indicates that the fault predates folding and subsequent overturning of the units. Thus, the fault would have been formed during early compression, and rotated into its current orientation as the units were overturned.

Schiarizza and Preto (1987) have noted that Devonian-Mississippian strata unconformably overlie Lower Cambrian rocks at other localities within the Eagle Bay Assemblage. It is possible that this relationship may apply here, although based on the overall regional stratigraphy (Figure 2), a thrust fault seems most likely. Further work will attempt to date stratigraphic units and determine their tectonic settings and geochemical signatures.

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