885755 → Mt. Milligan

geographic reconstruction of t.. depositional setting in which the Alaskan deposits formed.

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4. APPLICATION OF LITHOGEOCHEMISTRY OF BOULDER COMPOSITES TO EXPLORATION FOR PORPHYRY DEPOSITS IN BRITISH COLUMBIA

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Introduction

Lithogeochemistry of boulder composites provides a means of assessing bedrock geochemistry in glaciated areas. The technique is particularly applicable to exploration for mineral deposits that have relatively large and geochemically distinct primary alteration halos in areas of limited bedrock exposure. Boulder lithogeochemistry has been used extensively in exploration for unconformity-type uranium deposits in the Athabasca Basin of Saskatchewan (Earle *et al.* 1990). Two orientation case histories presented here show that the technique is equally applicable to exploration for porphyry-type deposits in the glaciated Interior Plateau of British Columbia.

Study Areas

Boulder lithogeochemical orientation studies have been completed at the Mt. Milligan and NAK Cu-Au porphyry deposits in central British Columbia (Fig. 1). The Mt. Milligan deposits are hosted by Late Triassic – Early Jurassic Takla Group volcanic rocks and coeval monzonitic feldspar porphyry stocks. The deposits contain approximately 299 Mt grading 0.45 g/t Au and 0.22% Cu (Sketchley *et al.* 1995). In the vicinity of the stocks, rocks are affected by potassic (biotitic) and propylitic alteration. Gold-Cu mineralization is closely associated with the potassic alteration, whereas Au-only mineralization occurs with propylitic alteration.

Figure 1. Location of the Mt. Milligan and NAK study areas.

The NAK deposit is hosted by volcanic and sedimentary rocks of the Early-Middle Jurassic Hazelton Group and by Eocene biotite-feldspar porphyries of the Babine igneous suite (Carter 1994). The deposit contains approximately 200 Mt grading 0.2% Cu and an additional 50 Mt grading 0.7% Cu equivalent. There is locally abundant biotite alteration at NAK, especially within the intrusive rocks. Pyritization is largely restricted to the area outside a 1500-m-diameter halo surrounding the mineralized zone.

Both the Mt. Milligan and NAK deposits are covered with glacial drift. At Mt. Milligan, morainal materials predominate to the south and north of the deposit, and there is an extensive area of glaciofluvial drift – with eskers – directly over the deposit (Sibbick & Kerr 1995). The ice-advance direction in the area of the deposit was from west to east.

At NAK, the drift thickness varies up to 50 m, and both morainal and glaciofluvial materials were observed. The regional ice-advance direction was from northwest to southeast. Geochemical analysis of tills shows Cu concentrations elevated to 1.5 times the regional background level (44 ppm), with values of several hundred ppm Cu at two sites (Levson *et al.* 1997).

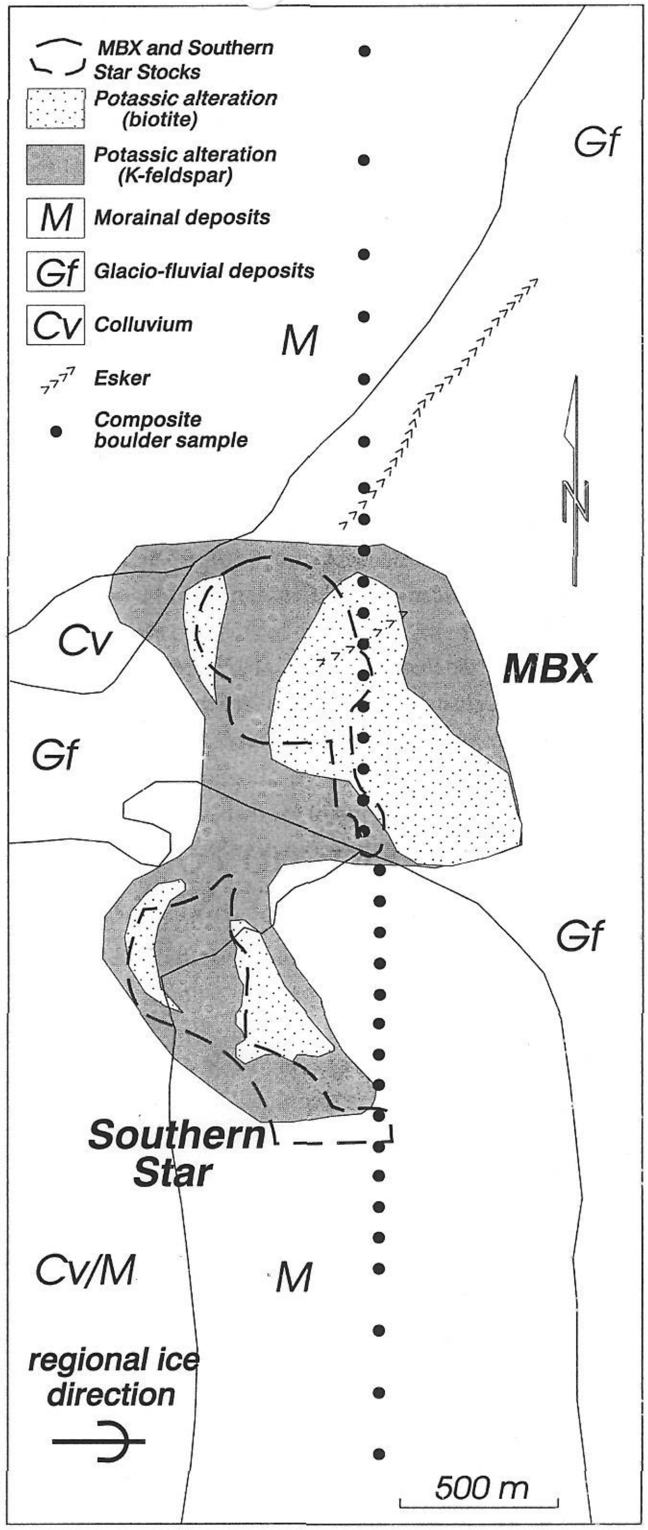

Figure 2. Geology and sample locations at Mt. Milligan.

Sample Collection and Analysis

Samples of boulder composites were collected at 36 sites along a north-south line through the MBX deposit at Mt. Milligan (Fig. 2), and at 39 sites along a southwest-northeast line through the NAK deposit (Fig. 3).

Sample spacings were 100 m in the mineralized areas, and 200 m elsewhere.

Composite chip samples were collected from approximately ten of the largest and most angular boulders present at each site. Lithology, alteration, and mineralization were not considered in selection of boulders to sample, except that boulders of obvious exotic origin – such as granites or gneisses – were avoided.

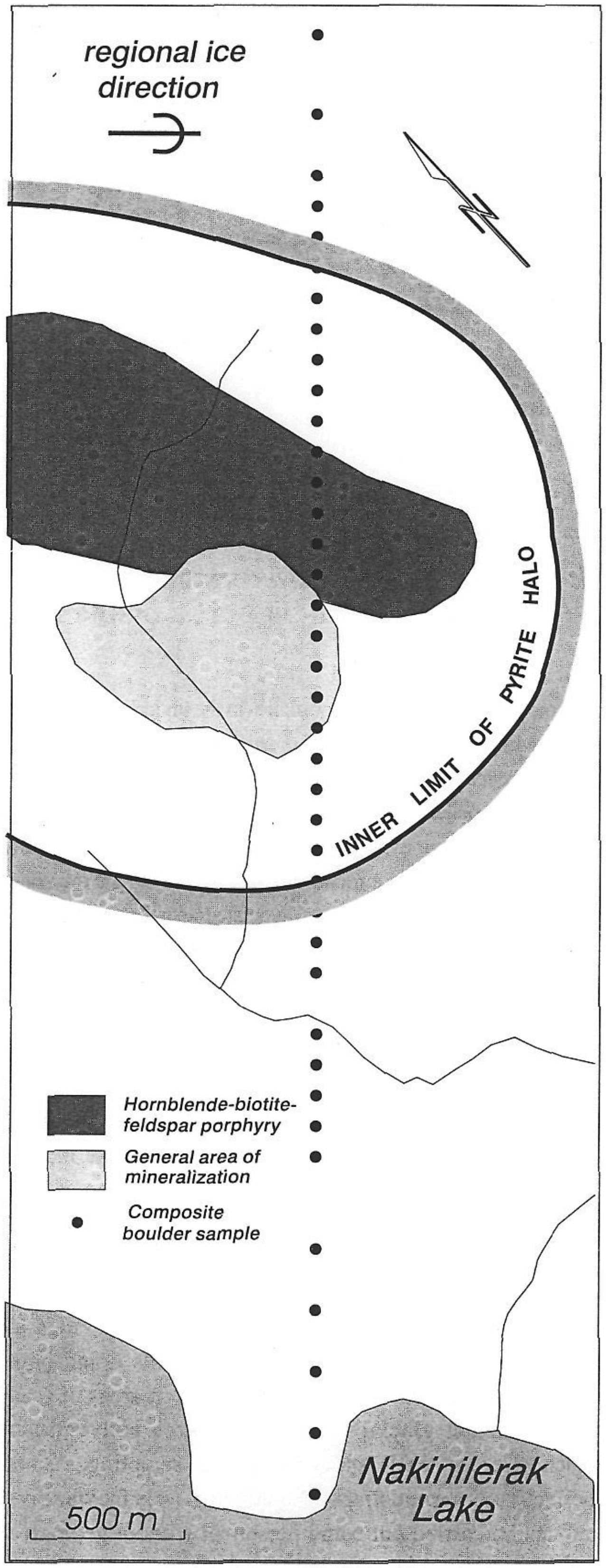

Figure 3. Geology and sample locations at NAK.

The chip samples were crushed and ground prior to fire-assaying for Au using 30-g sub-samples. Sulfur was determined by LECO induction furnace, and various trace and major elements were determined by ICP–ES following digestion in HF, HNO_3, and $HClO_4$ acids. Samples from the two study areas were analyzed at different laboratories.

RESULTS

The strongest and most consistent anomalies in boulder samples at Mt. Milligan are in Au, S, and Cu (Fig. 4). The background Au level is <5 ppb, but most samples from near the mineralized area contain at least 10 ppb Au and three contain >100 ppb to a maximum of 655 ppb. Three samples collected from within a few hundred meters of the orebody contain 10 ppb to 15 ppb Au.

The sulfur background in rock in the Mt. Milligan area is ~0.1%. Most of the samples from the deposit area have at least 0.5% S although there is some evidence that S abundances are higher near the periphery of the deposit than in the center. The Cu background in the area is ~100 ppm. Several samples from within the mineralized area have >200 ppm Cu, and the maximum value is 7060 ppm. Molybdenum and K also show significant enrichment in boulder samples at Mt. Milligan, whereas Zn and Mn are consistently depleted in samples from the mineralized area.

At NAK, Cu and Au are strongly enriched in boulder samples from the mineralized area, and S and As are enriched in samples collected in the vicinity of the pyrite halo (Fig. 5). Several boulder samples from within the limits of the mineralization contain >75 ppm Cu, and two contain >300 ppm Cu. Background in the area is ~30 ppm Cu. Gold background at NAK is around 1 ppb, and several samples from within the mineralized area contain >10 ppb Au, to a maximum of 154 ppb Au. Molybdenum is also enriched in samples from the deposit area, whereas Mn is inconsistently depleted.

Background values of S at NAK are ~0.05%. Sulfur levels are relatively low in samples collected directly over the mineralized zone, but strong enrichment in S is associated with the pyrite halo. Sulfur exceeds 0.2% in several samples, to a maximum of ~0.6%. Tungsten, As, and Sb are also significantly enriched within the area of the pyrite halo. The lithogeochemical response of Au, Cu, and Mo in boulders directly over the NAK mineralized zone, and of S, As, Sb, and W in the area of the pyrite halo, are clearly evident on the smoothed compilation profiles shown in Figure 6.

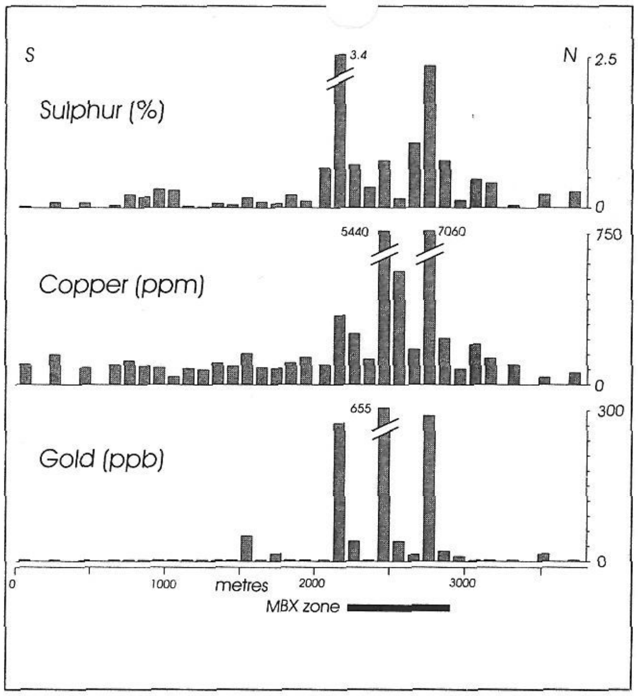

Figure 4. Boulder-sample lithogeochemical profiles at Mt. Milligan.

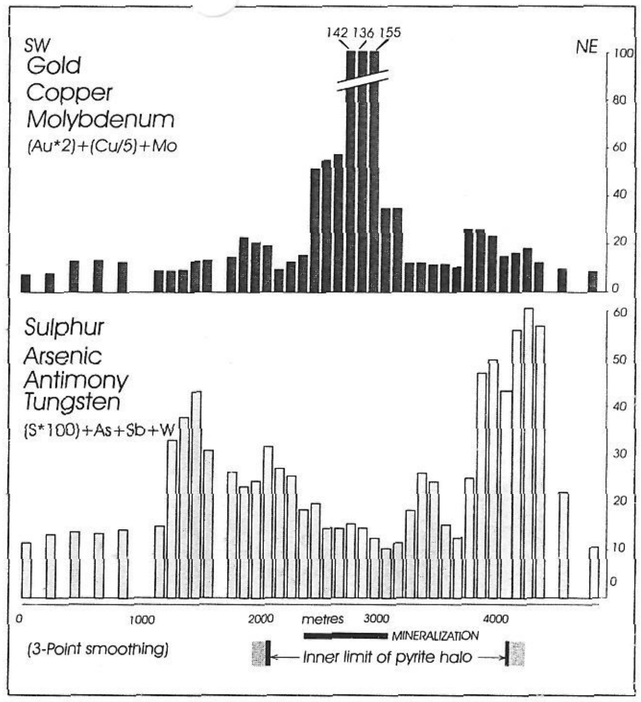

Figure 5. Boulder-sample lithogeochemical profiles at NAK.

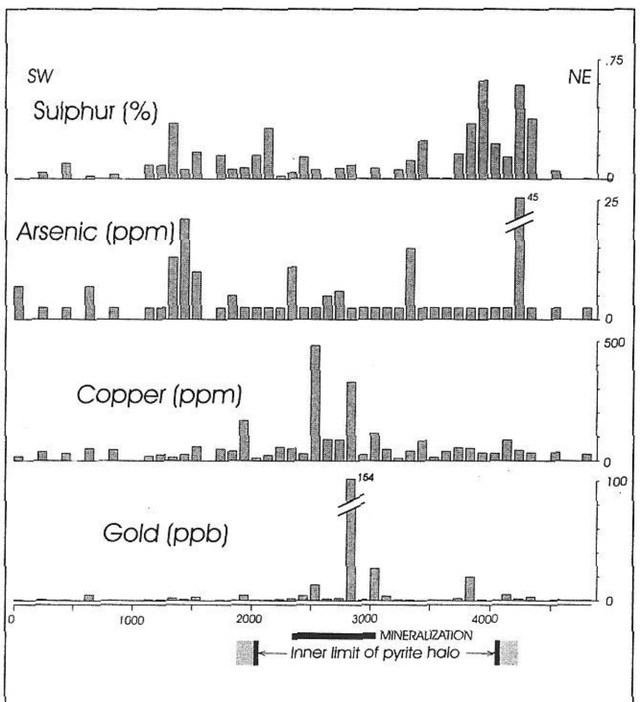

Figure 6. Smoothed compilation of boulder lithogeochemistry at NAK.

Conclusions

Data from the Mt. Milligan and NAK deposits show that the geochemistry of samples of boulder composites provides a clear picture of geochemical anomalies in the underlying bedrock. At Mt. Milligan, the anomalies are strong and consistent in spite of the presence of glaciofluvial deposits over much of the deposit area. At the smaller NAK deposit, anomalies are less pronounced, though there is clear evidence of zonation in the boulder patterns – with Au, Cu, and Mo enrichment associated with the ore zone, and S, W, As, and Sb enrichment associated with the pyrite halo.

The key principle underpinning the effectiveness of boulder lithogeochemistry is the use of composite samples. Although it is rarely possible to know the transport history of any individual boulder, it is likely that some of the boulders present at a location will have been transported only a few hundred meters or less. Unpublished orientation studies, based on bedrock lithogeochemical data from Mt. Milligan and elsewhere, indicate that as long as the geochemical contrast between background and altered rock is sufficiently high, boulder-geochemistry anomalies should be evident even where only a minority of sub-samples in a composite sample is derived from altered rocks.

Composite-boulder lithogeochemistry provides an opportunity to explore for porphyry deposits – and other deposits with extensive alteration halos – in areas of thick and consistent glacial overburden where conventional geochemical methods, such as soil or till sampling, may be ineffective. Sample collection is fast, relatively inexpensive, and can be carried out using personnel without geological training. The technique is applicable both on a property scale – as demonstrated here – and also on a regional scale.

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