# New Models for Mineral Exploration in British Columbia: Is there a Continuum between Porphyry Molybdenum Deposits and Intrusion-Hosted Gold Deposits?[1]

by G.B. Arehart[2], J.L. Smith[2] and R. Pinsent[3]

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## INTRODUCTION

There has been very little research into, or exploration for, molybdenum deposits in Canada or elsewhere since the early 1980s, but that is likely to change, particularly if the price of molybdenum and tungsten stay at or anything near current levels. There are numerous poorly understood, relatively underexplored molybdenum deposits and occurrences in the Canadian Cordillera that are likely to be explored over the next several years, and it would be of great benefit to the exploration community if more was known about high and low-fluorine type molybdenum deposits in the province.

In addition, there are geochemical similarities (*e.g.*, redox state of the associated pluton; trace and major element chemistry of associated plutons; mineral and elemental assemblages such as high Bi, Te, W and low and peripheral Cu, Pb, Zn) between porphyry molybdenum deposits and 'intrusion-hosted' gold deposits (*e.g.*, Tombstone Belt; Fig 1), suggesting a possible genetic link. The Adanac molybdenum deposit belongs to an important class of occurrences within the Atlin gold camp. The Adanac deposit contains no gold itself, but placer gold is still being mined on the lower reaches of Ruby Creek below the deposit. Historically, it has always been assumed that the molybdenum deposit postdates gold mineralization, which occurs in quartz-carbonate-bearing shears in Cache Creek Group volcanic strata and as placers. However, isotopic work by Mihalynuk *et al.* (1992) suggests that this may not be the case. Mihalynuk's work on Feather Creek (pers comm, 2005) suggests that at least some of the placer gold in the Atlin area may have been derived from the Surprise Lake batholith. This is consistent with the presence of gold and tungsten-bearing quartz veins in the Boulder Creek drainage immediately south of the Adanac molybdenum deposit, because wolframite is commonly associated with porphyry molybdenum deposits, peripheral to the molybdenite zone (Wallace *et al.*, 1967). Thus, the presence of gold in those wolframite veins raises the question of a potential linkage between gold-depleted molybdenum and gold-bearing tungsten 'intrusion-related' deposits. Understanding the association (or lack thereof) is an important step toward focusing further exploration in the province for both of these deposit types.

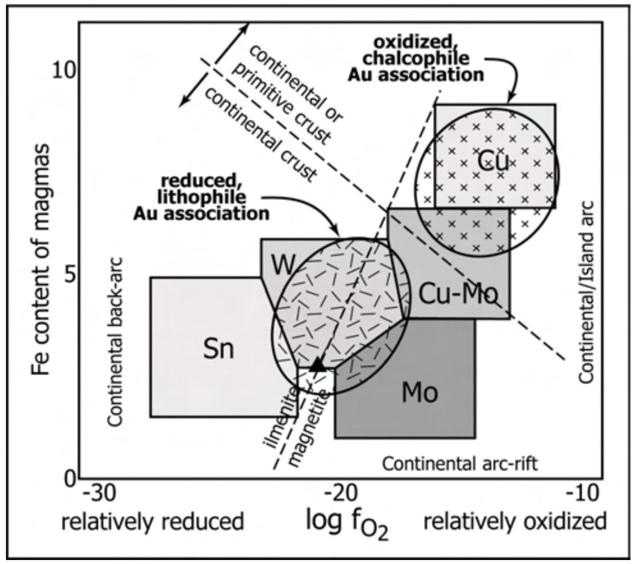


Figure 1. Plot of Fe content versus oxidation state for plutons and associated 'porphyry' mineral deposits (fields *from* Thompson *et al.*, 1999); note that Au is found in both oxidized (porphyry Cu) and reduced (porphyry Sn-W-Mo) environments; Surprise Lake batholith plots approximately at the solid triangle.

## GEOLOGICAL BACKGROUND

The Adanac molybdenum deposit is located in the northwestern corner of British Columbia, near the town of Atlin (Fig 2). The geology of the Atlin area was mapped by Aitken (1959), and the regional setting of the deposit was discussed by Christopher and Pinsent (1982). The Atlin area (Fig 3) is underlain by deformed and weakly metamorphosed ophiolitic rocks of the Pennsylvanian and/or Permian Cache Creek Group (Monger, 1975). These rocks, which include serpentinite and basalt, as well as limestone, chert and shale, have long been thought to be the source of much of the placer gold found in the Atlin area. The sedimentary and volcanic rocks are cut by two younger batholiths: a Jurassic granodiorite to diorite intrusion

[1] *Geoscience BC contribution GBC024*

[2] *Department of Geology, University of Nevada–Reno, MS-172, Reno, Nevada 89557*

[3] *Adanac Molybdenum Corporation, 15782 Marine Drive, Suite 2A, Whiterock, BC V4B 1E6*

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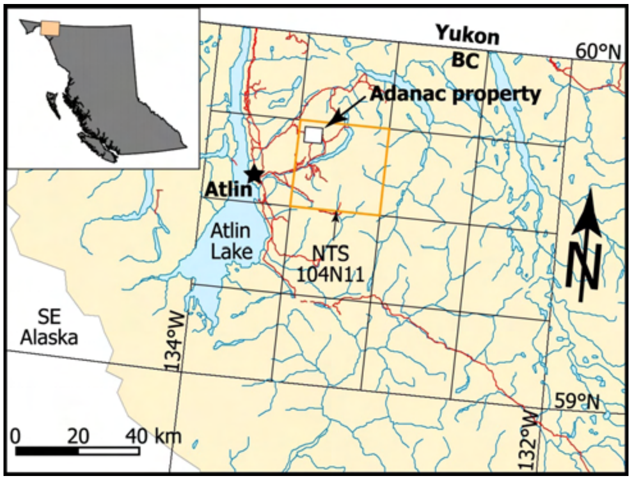


Figure 2. Location of the Adanac molybdenum deposit; white box is approximate location of Figure 3.

(Fourth of July batholith) north of Pine Creek and a Cretaceous granitic to quartz monzonitic intrusion (Surprise Lake batholith) north and south of Surprise Lake. The rocks are locally strongly faulted and the Adanac deposit is located near the intersection of two major syn to postmineral fault systems.

The deposit area was described by Sutherland Brown (1970), White *et al.* (1976), Christopher and Pinsent (1982), and Pinsent and Christopher (1995). The Adanac molybdenum deposit underlies the valley floor near the head of Ruby Creek. It is largely buried and has very little surface expression. There is little outcrop in the lower part of the valley and molybdenite is only rarely found in float and/or veins in outcrop in the bed of the creek. The geology underlying the valley floor is largely derived from drill data (Fig 4). Although the geology of the Adanac deposit is moderately well understood, it has had almost no detailed research. It appears to be a Climax-type high-fluorine alkalic stockwork deposit (Westra and Keith, 1982) with a single flat-lying to steeply dipping 'shell' of mineralization, as described by White *et al.* (1976) and Pinsent and Christopher (1995).

The deposit is near the western margin of the Surprise Lake batholith, a composite, highly evolved, uranium-rich granite. It is entirely within plutonic rock. There are three stages of intrusion: an early, generally coarse-grained stage that was deformed prior to intrusion of second-stage 'porphyry' domes, and a late, fine-grained phase that was injected through the previous two stages at about the same time as mineralization. The deposit itself is a disrupted, blanket-shaped deposit that formed late in the development of the plutonic suite. The deposit is partially controlled and offset by the Adera fault system, which trends approximately northeast and defines much of the southern boundary of the pre-ore Fourth of July batholith. The approximately north-trending Boulder Creek fault system appears to have localized emplacement of the late, third-stage porphyritic and aplitic plutonic rocks that are thought to have generated the majority of mineralization.

## 2006 SUMMER FIELD PROGRAM

The first phase of the study, comprising the development of a genetic and exploration model for the deposit type, including chemical, mineralogical and alteration zoning, was launched in the summer of 2006. Time was spent becoming familiar with deposit geology: background reading, field checking of old core logs and logging of new core from the drill program currently being carried out by Adanac Molybdenum Corporation. However, most of the summer focused on sampling. A total of 182 samples from core was collected along a series of cross-sections of the deposit shown in Figure 4. Thirty of these samples have been selected for petrographic analysis, the purpose of which is to shed light on major rock types (listed in Fig 4) and provide preliminary mineralogical and hydrothermal alteration data. Additional optical microscopy will be done as the project progresses.

Adanac Molybdenum Corporation had previously completed Mo percentage analysis in 10-foot (3 m) intervals on all drillholes and trace element analysis (excluding fluorine) on 5 of the 55 drill holes. Since the pulps from these analyses were still available, pulps from the drillholes on the cross-section in Figure 4 were composited according to similar lithology on intervals ranging from 30 to 50 feet (9–15 m). These composites are being analyzed for 41 trace elements plus fluorine by inductively coupled plasma mass spectrometry (ICP-MS). When the results become available, they will be used to generate the model of trace element zoning and alteration halos that is the ultimate goal of the first phase of this project.

Samples of a tungsten (huebnerite-wolframite) deposit that is located on the Adanac property and possibly related to the Adanac deposit (MINFILE 104N 053; MINFILE, 2006) were collected for comparison of fluid inclusions with those of the molybdenum deposit. Fluid inclusion measurements on these samples will provide clues as to whether the tungsten mineralization is directly related to the same hydrothermal system that deposited the molybdenum.

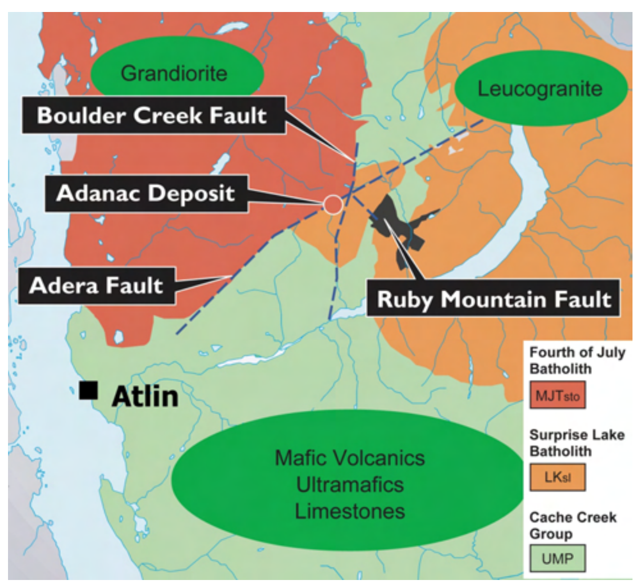


Figure 3. General geology of the Adanac deposit area (*modified from* Aitken, 1959).

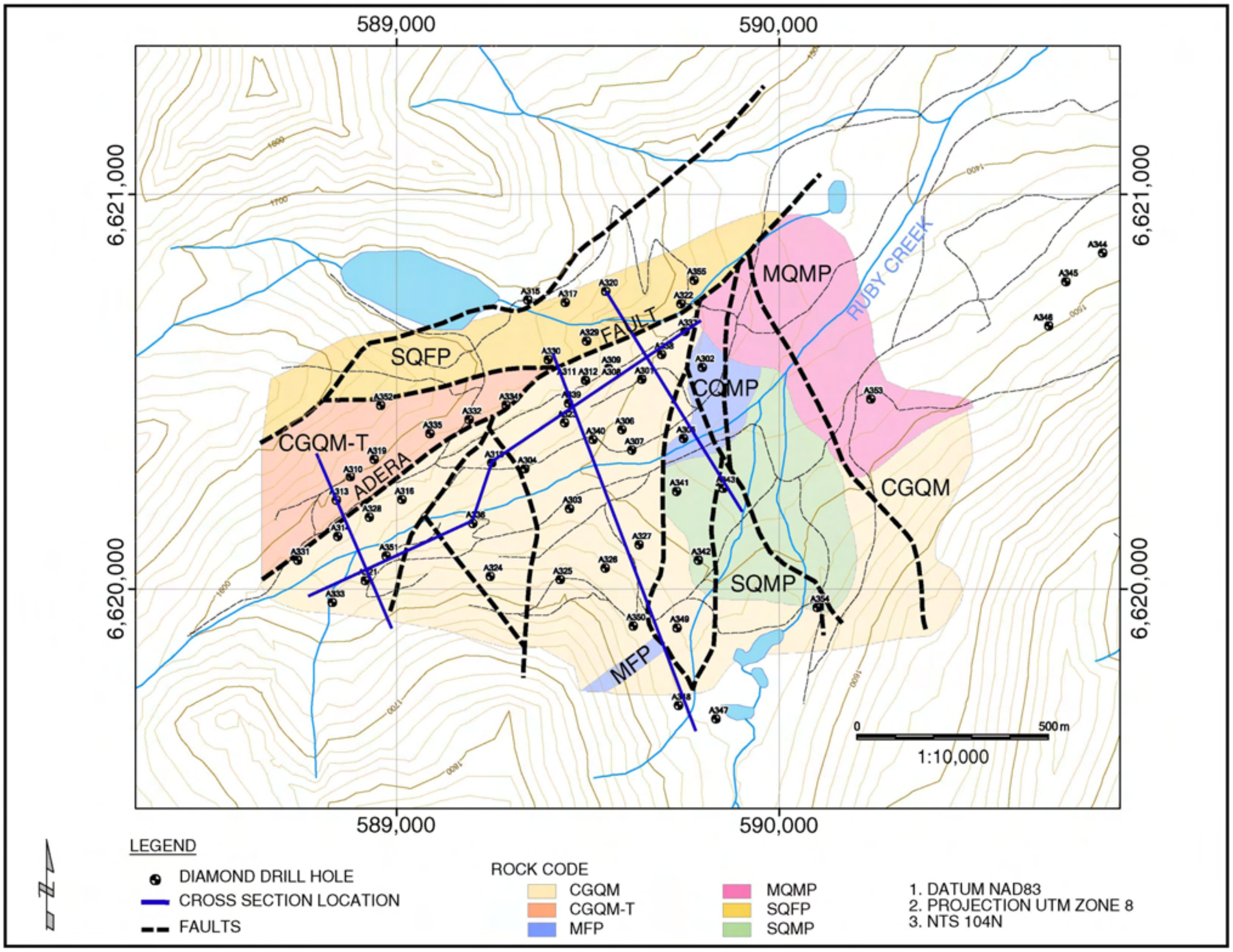


Figure 4. Surface geology of the Adanac molybdenum deposit (*modified from* unpublished company reports), showing a cross-section of diamond-drill holes from which samples were collected for geochemical analysis.

The second phase of the project is to compare this deposit with other molybdenum deposits in western North America, as well as with nontraditional molybdenum deposits, specifically intrusion-hosted gold deposits of the Tombstone Belt. To this end, fresh rock samples from the Surprise Lake pluton were collected in order to compare the chemistry of this pluton with that of other plutons in productive mineral belts. Oxidation state of these plutons will be investigated using magnetite/ilmenite by reflected-light microscopy and $Fe^{2+}/Fe^{3+}$ geochemical analyses. This will help to place the pluton more clearly in the context of the geochemistry of porphyry intrusions (Fig 1). Isotope geochemistry (O and S isotope composition) will also be used to further constrain the origin of the plutons. At the deposit scale, stable isotopes can be used to constrain the origins of fluid components and for developing a model for fluid flow and water-rock interaction.

In addition, several samples of molybdenite were collected for Re-Os isotope geochronology. This will place a more precise date on the mineralization event. More important to the exploration community, however, is using that age in conjunction with Re-poor phases like pyrite to obtain an initial Re isotope composition for the molybdenite event. Comparison of the initial Re isotope composition of the placer gold in Ruby Creek with that of the Mo system will allow a determination of whether there is a geochemical link between the gold and molybdenite. Proving or disproving this link will have very important ramifications for exploration strategies at a regional scale.

## CONCLUSIONS

The first phase of fieldwork has been completed and a more complete model of mineralization at Adanac is being developed, including geological, geochemical and mineralogical patterns. These data will more clearly elucidate the similarities and differences between Adanac and other molybdenum and gold deposits in western North America.

## ACKNOWLEDGMENTS

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