

Biotite chemistry of the Casino porphyry Cu-Mo-Au occurrence, Dawson Range, Yukon

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Selby, David and Nesbitt, Bruce E., 1998. Biotite Chemistry of the Casino Porphyry Cu-Mo-Au Occurrence, Dawson Range, Yukon. *In: Yukon Exploration and Geology 1997; Exploration and Geological Services Division, Yukon, Indian and Northern Affairs Canada, p. 83-88.*

ABSTRACT

Biotites from hydrothermal alteration zones of the Casino porphyry Cu-Mo-Au deposit have a chemical composition that is distinct from biotites of the unaltered Dawson Range Batholith and Casino Plutonic Suite. Biotites from potassic, phyllic, and propylitic alteration zones contain distinctly higher XMg ($XMg = Mg/(Mg+Fe)$) values than biotites from the unaltered country rocks. The XMg values are positively correlated with Ti, F, Cl, Si, and negatively correlated with Al, Fe, Mn, Ba contents. The XF/XOH (X = mole fraction) values are positively correlated with XMg/XFe values and describe a positive linear trend from propylitic, to potassic, to phyllic zones. The distinct XMg, Ti, F, Cl, Al, Fe, Mn, and XF/XOH and XMg/XFe compositions of biotites from alteration zones may prove to be useful in understanding the evolution of fluid chemistry, and the identification of alteration zones in porphyry copper systems in the Dawson Range.

RÉSUMÉ

Les biotites des zones d'altération hydrothermale du gisement de Cu-Mo-Au du porphyre de Casino ont des compositions chimiques distinctes de celles des biotites du batholite non altéré du chaînon Dawson et de la suite plutonique de Casino. Les biotites des zones d'altération potassique, phylliteuse et propylitique se caractérisent par des valeurs nettement plus élevées du rapport XMg ($XMg = Mg/(Mg+Fe)$) que les biotites des roches encaissantes non altérées. Les valeurs de XMg présentent une corrélation positive avec les teneurs en Ti, F, Cl et Si et une corrélation négative avec les teneurs en Al, Fe, Mn et Ba. Les valeurs de XF/XOH (X = fraction molaire) présentent en outre une corrélation positive avec les valeurs de XMg/XFe et une tendance linéaire positive caractérisant respectivement les zones propylitique, potassique et phylliteuse. Les valeurs particulières des teneurs et rapports XMg, Ti, F, Cl, Al, Fe, Mn, XF/XOH et XMg/XFe des biotites des zones d'altération s'avéreront peut-être utiles à la compréhension de l'évolution de la chimie des fluides et à l'identification des zones d'altération dans les systèmes de cuivre porphyrique du chaînon Dawson.

INTRODUCTION

There are numerous porphyry copper-molybdenum±gold occurrences in the Dawson Range, central Yukon. The largest occurrence is the Casino mineralization with a geological resource of 675 million tonnes of 0.25% Cu, 0.48 g/t Au and 0.024% Mo (Bower et al., 1995; Yukon Minfile 115J 028). Documentation of the geology and alteration at many of the porphyry deposits in the Yukon is largely based on research in academic programs (e.g. Casino: Godwin, 1976; Mt. Nansen: Sawyer and Dickinson, 1976, Cash: Sinclair et al., 1981), while regional geology is derived from reconnaissance mapping by Tempelman-Kluit (1974, 1984), Payne et al. (1987) and Carlson (1987).

This paper presents results from a study of biotite chemistry from the Casino deposit, the Dawson Range Batholith and the Casino Plutonic Suite. This study shows that biotite compositions may prove useful in identifying alteration zones of porphyry systems. Criteria to differentiate biotite from altered and from unaltered rocks are proposed.

GEOLOGY

The Casino porphyry Cu-Mo-Au mineralization occurs in the Dawson Range, which is part of the Yukon-Tanana Terrane of the central Yukon. In the Casino area the Yukon-Tanana Terrane is represented by the Devono-Mississippian Wolverine Creek Metamorphic Suite (Johnston, 1995; Fig. 1). This suite is divided into two units, meta-igneous rocks and metasedimentary rocks (Payne et al., 1987). The metasedimentary unit is dominated by quartz-feldspar-mica schist and gneiss, quartzite and micaceous quartzite. The meta-igneous unit is comprised of hornblende amphibolite, biotite-hornblende-feldspar gneiss and orthogneiss. The Wolverine Creek Metamorphic Suite was intruded by the Dawson Range Batholith and Casino Plutonic Suite during mid-Cretaceous time (Payne et al., 1987). The Dawson Range Batholith (104.0±5.0 Ma U-Pb zircon date by J.K. Mortensen pers. comm., 1997) is dominated by hornblende>biotite and biotite>hornblende-bearing granodiorite. Field relationships indicate that the Dawson Range Batholith was intruded by the Casino Plutonic Suite although the date is contemporaneous (104.2±0.5 Ma; J.K. Mortensen, pers. comm., 1997). Casino Plutonic Suite contains fine- to medium-grained, locally porphyritic, leucocratic granodiorite, quartz monzonite and aplite phases.

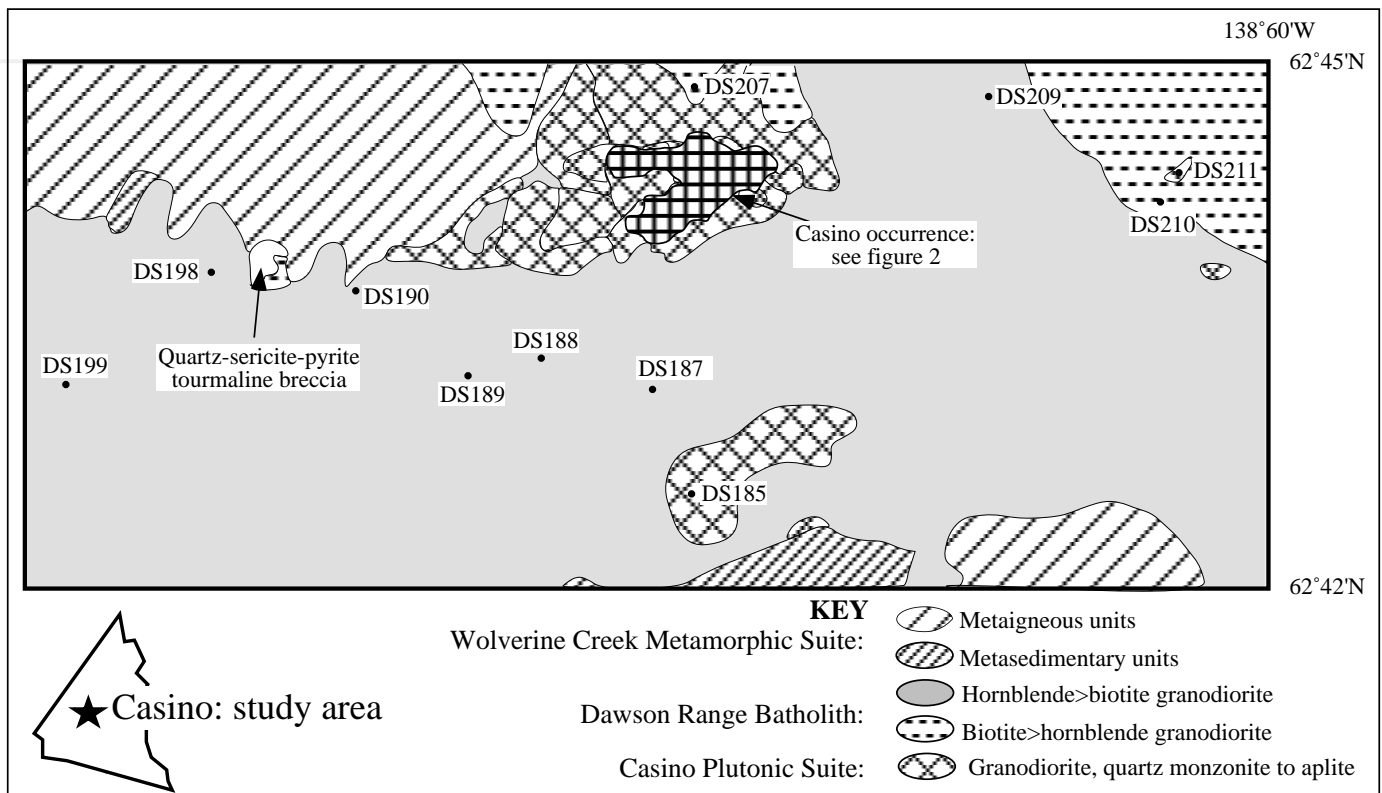


Figure 1. Geology of the Casino area (modified after Payne et al., 1987 and Johnston, 1997). Bold cross-hatched area is the limit of mineralization and alteration surrounding the Casino occurrence (Fig. 2). Dots indicate the location of rocks from which biotite was extracted.

The copper-molybdenum-gold mineralization of the Casino porphyry occurrence is genetically related to the Patton Porphyry, a small (500 by 700 m) late Cretaceous (72.4 ± 0.5 Ma U-Pb zircon date by J.K. Mortensen, pers. comm., 1997) porphyritic plagioclase-biotite dacite. Mineralization and hydrothermal alteration at the Casino occurrence are hosted by the Patton Porphyry and surrounding country rock, which is dominantly the Dawson Range Batholith. Ore mineralization consists of chalcopyrite, molybdenite and gold, with minor bornite and tetrahedrite, and supergene minerals of native copper, chalcantite, malachite, brochantite (Bower et al., 1995). Mineralization occurs in veins, disseminations, irregular patches, boxworks, and as coatings on pyrite grains (Bower et al., 1995). Hydrothermal alteration of the Casino occurrence is centered upon a potassic-altered breccia pipe, which is bordered by strongly developed, fracture-controlled phyllic alteration. A weakly formed propylitic assemblage lies at the northern edge of the Casino occurrence (Bower et al., 1995). The potassic alteration assemblage typically comprises K-feldspar, biotite, magnetite, and quartz. Quartz, pyrite, sericite, and tourmaline characterize the phyllic alteration assemblage. The propylitic alteration assemblage consists of epidote, chlorite, and minor calcite. Probably genetically related to mineralization and alteration at Casino is a small (200 by 500 m) breccia pipe located 4 km west of the Casino occurrence (Fig. 1). The breccia pipe is strongly altered to quartz-sericite, and contains tourmaline and pyrite, an assemblage that is typical of the phyllic alteration zone of the Casino occurrence.

BIOTITE CLASSIFICATION

Biotites of this study are classified as either magmatic, or secondary origin. The term magmatic denotes biotites that crystallized from a magma. Magmatic biotites are further divided into unaltered and hydrothermal biotites. The term 'unaltered' is used for biotites from unaltered rock types, and 'hydrothermal' is used for biotites present in hydrothermal alteration assemblages (e.g. potassic, phyllic and propylitic). Secondary biotites are those that formed from a hydrothermal fluid, and their distinguishing characteristics are described below. Samples collected from the potassic zone of the Patton Porphyry contain both hydrothermal and secondary biotites, while the potassic zone of the Dawson Range Batholith contains only secondary biotites. Only hydrothermal biotite is observed in the phyllic- and propylitic-altered Dawson Range Batholith, and the phyllic-altered Patton Porphyry.

PETROGRAPHY

Unaltered biotites of the Dawson Range Batholith and Casino Plutonic typically occur as euhedral to subhedral phenocrysts and microphenocrysts, and as subhedral to anhedral flakes.

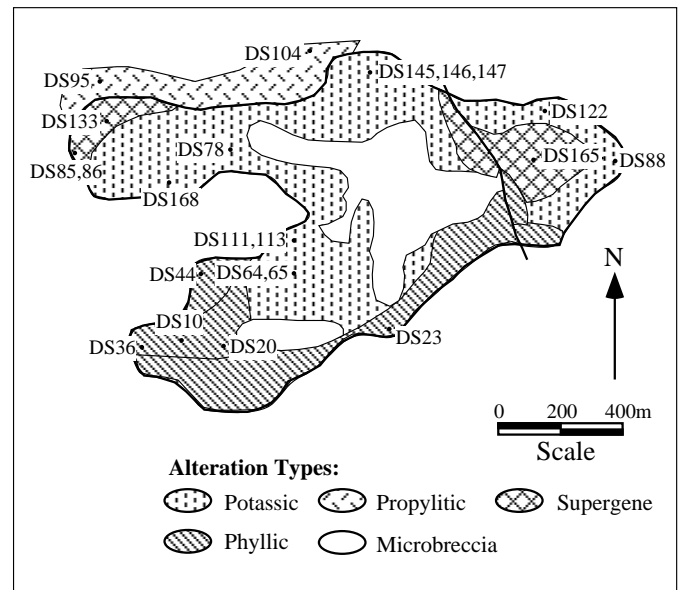


Figure 2. Geology and alteration of the Casino occurrence (modified after Bower et al., 1995) and the location of rock samples for biotite chemistry determinations.

Some unaltered biotites exhibit frayed and ragged grain edges. Hydrothermal biotites of the Patton Porphyry are commonly euhedral phenocrysts, while those of the Dawson Range Batholith are ragged, splintery, frayed, kinked, and partially chloritized. Altered rock types of the Casino Plutonic suite contain highly chloritized biotites that were not suitable for analysis. Secondary biotites are a major constituent of the potassic alteration assemblage. Texturally, secondary biotites are distinct from unaltered and hydrothermal biotites, being small (typically 10 to 100 μm), occurring as aggregate clusters, which exhibit a random orientation of grains, with shapes that may define pseudomorphs after hornblende and biotite.

ANALYTICAL PROCEDURES

Biotites from thin section slides were analyzed to determine Mg, Fe, Ti, Al, Mn, Si, Ba, F, and Cl contents. Figures 1 and 2 show the location of samples analyzed. A suite of natural standards were used for calibration, biotite was used for F, Si, Al, and Fe; kaersuittic amphibole for Mg, and Ti; tugtupite for Cl; sanidine for Ba, and willemite for Mn. Analyses were conducted using a beam width of 3 μm and current of 15kv (accelerating potential), and a probe current measured on the faraday cup at 15 nA. The counting time used for each element analysis was 20 seconds. Matrix effects were corrected using ZAF based on 22 oxygens. The full procedure is described in Selby (In prep.). A microprobe analysis in this study is defined as the arithmetic mean of five spot analyses of a biotite.

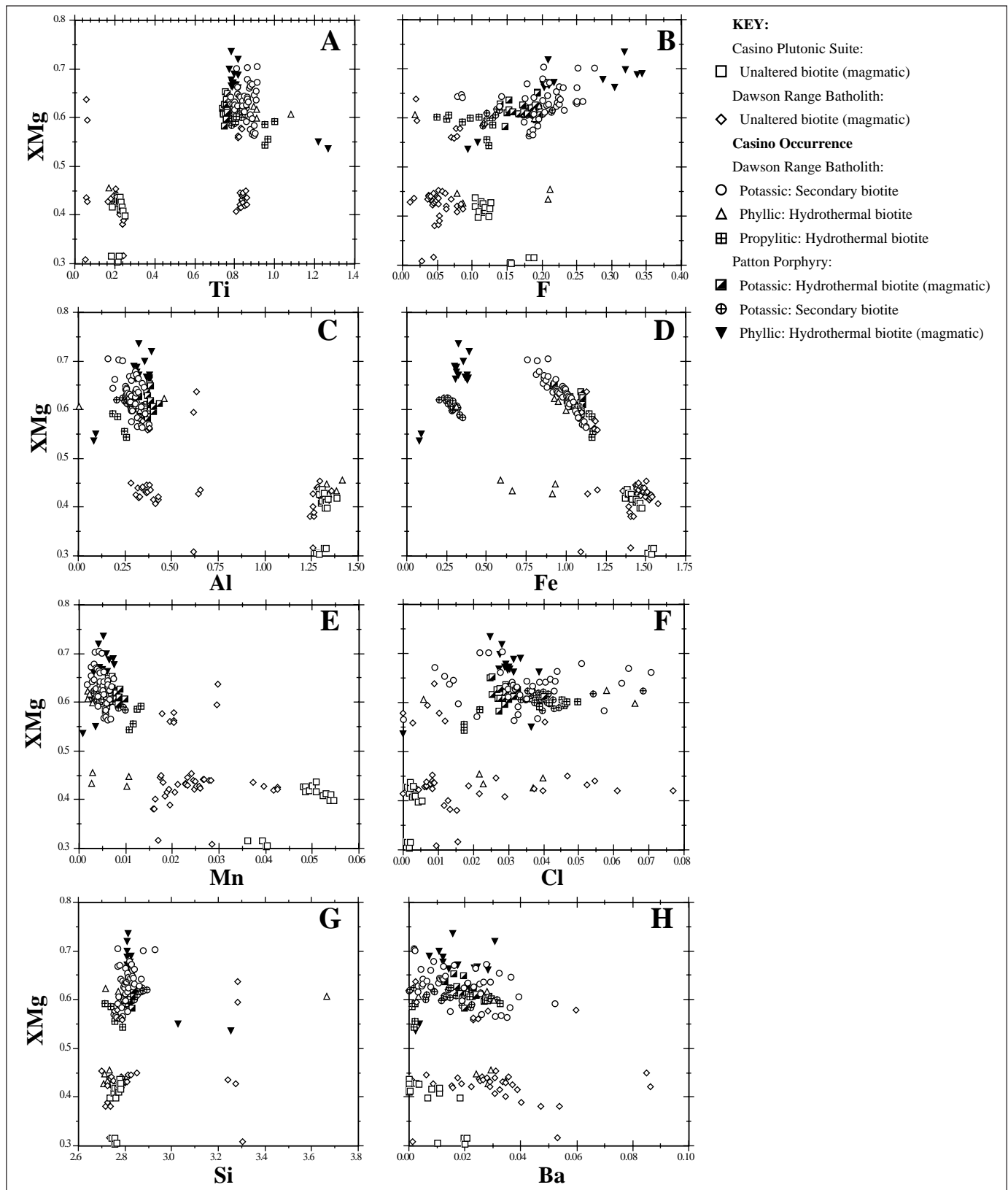


Figure 3. Chemical compositions of biotites from alteration zones of the Casino porphyry mineralization, the Dawson Range Batholith and the Casino Plutonic Suite. The composition of the biotites are plotted as XMg vs. Ti, F, Al, Mn, Ba, Si, and Cl. The XMg value is defined as Mg/(Mg+Fe) on a cation basis, and Ti, F, Al, Fe, Mn, Ba, Si, Cl contents are in an atomic basis, calculated using 22 oxygens/formula units.

BIOTITE COMPOSITIONS

The compositions of biotite types are shown in Figures 3A-H, plotting XMg (defined as $Mg/(Mg+Fe)$ in moles) against Ti, F, Si, Cl, Ba, Mn, Al, and Fe contents. For all these elements except Fe, the concentrations are calculated from oxide values determined from electron microprobe analyses. The biotite data from the Casino area show that the XMg value is the most significant factor in the chemical distinction between unaltered, hydrothermal and secondary biotites. Biotites (hydrothermal and secondary) present in the alteration zones of the Casino occurrence have higher XMg values than unaltered biotites. Unaltered biotites from the Dawson Range Batholith and Casino Plutonic Suite are fairly homogeneous with respect to XMg value, except for the unaltered biotites in samples DS198 and DS207. Sample DS198 is proximal to the breccia pipe west of the Casino occurrence (Fig. 1), and contains minor epidote, chlorite and sericite. Sample DS207 is located north of the northern limit of the Casino occurrence (Fig. 1), and contains minor chlorite. The biotites from these samples have XMg values similar to biotites from the propylitic alteration zone.

The XMg values are positively correlated with Ti, F, Cl, Si, and negatively correlated with Al, Mn, Fe, and Ba contents (Figs. 3A-H). With respect to Ti, F, Cl, Al, Fe, and Mn contents, biotites of the Dawson Range Batholith from the zone of hydrothermal

alteration of the Casino occurrence have significantly different compositions relative to unaltered biotites (Fig. 3A-F). The Si content of unaltered and hydrothermal biotites from all alteration zones is essentially the same, with secondary and hydrothermal biotites from the potassic and phyllic zones having slightly higher Si values (Fig. 3G). The Ba content of secondary and hydrothermal biotites is slightly lower than unaltered biotites of the Dawson Range Batholith (Fig. 3H). The Fe contents of hydrothermal biotites of the potassic zone from the Patton Porphyry and Dawson Range Batholith are similar (Fig. 3D); however, secondary biotites of the Patton porphyry have distinctly lower Fe contents. Hydrothermal biotites from the phyllic alteration zone of the Patton Porphyry have slightly higher Fe values than secondary biotites from the same rock type (Fig. 3D).

The compositions of biotites from the phyllic zone from the Dawson Range Batholith and Patton Porphyry are variable (Figs. 3A-H), although the hydrothermal biotite from the potassic zone of the Patton Porphyry shows more homogeneous chemistry. The Ti, F, Al, Mn, and Fe content of hydrothermal biotite from the propylitic zone is diagnostically distinct from that of unaltered biotites and biotites of the potassic and phyllic zones (Fig. 3A-E).

The Ti and Al contents of unaltered biotites of the Dawson Range Batholith describe two distinct biotite populations (Fig. 3A and C). The population with higher Ti contents contain lower Al contents, but have similar XMg values to the population with lower Ti and higher Al contents. Those with higher Ti and lower Al contents correlate with the Ti and Al contents of biotites from all alteration zones. Because there no increase in the XMg value between the populations suggests that the Ti and Al contents reflect those incorporated at the time of crystallizing.

Figure 4 shows a distinction between the XMg/XFe and XF/XOH values of unaltered biotites, and those of all the altered samples. Secondary and hydrothermal biotites have XMg/XFe and XF/XOH values that increase progressively from unaltered, to propylitic, to potassic, to phyllic alteration types (Fig. 4). The XMg/XFe and XF/XOH values for secondary and hydrothermal biotites from the potassic and phyllic alteration zones define a linear trend (Fig. 4), indicating that a systematic F and Mg enrichment is occurring simultaneously during potassic, phyllic and propylitic alteration. Biotites from the unaltered Dawson Range Batholith that reveal Mg or F enrichment similar to biotites from the propylitic alteration zone, are found in samples DS207 and DS198. These data suggest that hydrothermal fluids, which were probably related to mineralization and alteration of the Casino occurrence, have altered the chemistry of biotites in rock types proximal to the occurrence.

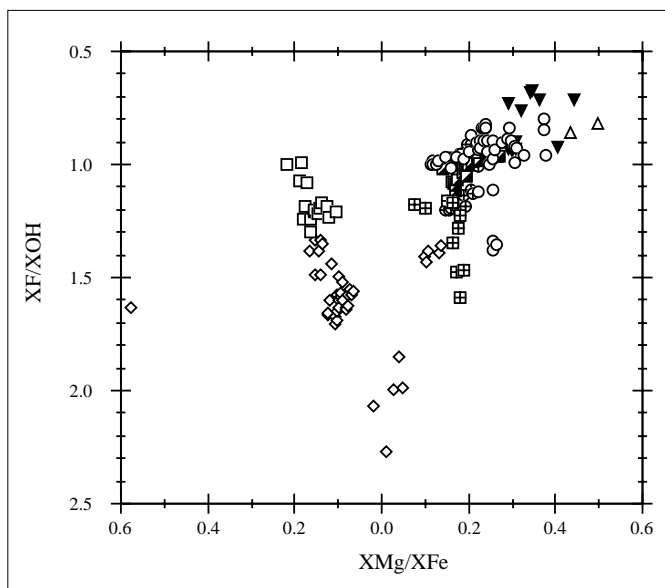


Figure 4. A plot of XMg/XFe vs. XF/XOH of biotites from alteration zones of the Casino porphyry mineralization, the Dawson Range Batholith and the Casino Plutonic Suite. Symbols are the same as in Figure 3.

SUMMARY

The XMg value is a useful criterion for the distinction between unaltered biotites and biotites. Further, trends in XMg vs. Ti, F, Fe, Al, Mn, Si, Ba and Cl contents discriminate between unaltered biotites and biotites from alteration zones. Unaltered biotites are further distinguished from biotites from alteration zones based on XMg/XFe and XF/XOH values, which describe an increasing enrichment in Mg and F from unaltered, to propylitic, to potassic, to phyllic zones. The composition of biotites from the propylitic zone show distinct chemistries from those of the potassic and phyllic zones. The composition of biotites from samples DS198 and DS207 from outside the alteration zone of the Casino occurrence indicate the interaction of hydrothermal fluids to alter the primary chemistry. Therefore biotite chemistry could be used to understand the fluid chemistry in porphyry copper systems. Further, biotite chemistry may be a useful technique to detect the presence of ancient hydrothermal fluids which may have led to porphyry copper mineralization.

ACKNOWLEDGMENTS

The results summarized here will form part of a Ph.D thesis at the University of Alberta. This research was funded with the aid of a NSERC Strategic Grant to Bruce Nesbitt, and financial support from the Society of Economic Geologists, Geological Society of America, and Circumpolar Institute. Craig Hart and Fred Flykt-Rosén are thanked for field work assistance and their pre-eminent company. Alkan Air and Trans North Helicopters provided prompt and efficient transportation, and a critical review by Charlie Roots improved the manuscript.

REFERENCES

- Bower, B., Payne, J., Delong, C., and Rebagliati, C.M., 1995. The oxide-gold supergene and hypogene zones at the Casino gold-copper-molybdenite deposit, west-central Yukon. *In: Porphyry Deposits of the Northwestern Cordillera of North America*, T.G. Schroeter (ed.), Canadian Institute of Mining, Metallurgy and Petroleum, Special Volume 46, p. 352-366.
- Carlson, G. G., 1987. Geology of Mt. Nansen (115-I/3) and Stoddart Creek (115-I/6) map areas, Dawson Range, Central Yukon. Indian and Northern Affairs Canada, Northern Affairs: Yukon Region Open File 1987-2.
- Godwin, C. I., 1976. Casino. *In: Porphyry Deposits of the Canadian Cordillera*, A. S. Brown (ed.), Canadian Institute of Mining and Metallurgy, Special Volume 15, p. 344-354.
- Johnston, S. T., 1995. Geological complication with interpretation from geophysical surveys of the northern Dawson Range, central Yukon (115-J/9 and 115-J/10, 115 I/12, 1:100 000 scale map). Exploration and Geological Services Division, Yukon, Indian and Northern Affairs Canada, Open File 1995-2(G).
- Payne, J.G., Gonzalez, R. A., Akhurst, K. and Sisson, W.G., 1987. Geology of the Colorado Creek (115-J/10), Selwyn River (115-J/9), and Prospector Mountain (115-I/5) Map areas, Western Dawson Range, west-central Yukon. Exploration and Geological Services Division, Yukon, Indian and Northern Affairs Canada, Open File 1987-3.
- Selby, D., *In prep.* Fluid characteristics and evolution in porphyry Cu and Mo systems, Yukon and British Columbia, Canada. Ph.D. thesis, University of Alberta.
- Sinclair, W.D., Cathro, R. J., and Jensen, E.M., 1981. The Cash porphyry copper-molybdenum deposit, Dawson Range, Yukon Territory. *Canadian Institute of Mining and Metallurgy Bulletin*, v. 74, p. 67-75.
- Templeman-Kluit, D. J., 1974. Reconnaissance geology of Aishihik Lake, Snag and part of the Stewart River map areas, west-central Yukon Territory. Geological Survey of Canada, Paper 73-14, 93p.
- Templeman-Kluit, D. J., 1984. Geology of the Lebarge and Carmacks map sheets, Geological Survey of Canada, Open File 1101.