

Br-Cl fractionation in mid-crustal fluid-rock systems

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Coupled Proton-induced X-ray Emission and electron probe element mapping shows that co-existing scapolite and ferromagnesian minerals exhibit radically different Br:Cl ratios. The samples examined in this pilot study formed in mid-crustal environments and represent a biotite-scapolite (Me%: 72-91) calc-silicate rock metamorphosed to amphibolite facies, and an edenitic hornblende-scapolite (Me%: 40-47) hydrothermally altered amphibolite. In the calc-silicate rock, scapolite (Br: 32-56 ppm) and biotite have average Br:Cl ratios of 0.02230 and <0.00067 respectively, whereas in the altered amphibolite, scapolite (Br: 522-741 ppm) and amphibole have average Br:Cl ratios of 0.00191 and <0.00039 respectively. These data show that in each case scapolite preferentially partitions proportionately greater Br than the co-existing ferromagnesian silicates, indicating high K values where $K_{Br/Cl\ Sep-Bt} [(Br/Cl_{Sep}) / (Br/Cl_{Bt})]$ is >33.5 and $K_{Br/Cl\ Sep-Hbl}$ is >4.9. Br⁻ in scapolite, biotite and amphibole is most likely accommodated in the same sites as Cl⁻ (cf. Pan and Dong, 2003). However, higher Br/Cl in scapolite compared to co-existing biotite or amphibole probably relates to size-dependent fractionation, where larger anion sites in scapolite more readily accommodate Br than those in the ferromagnesian silicates (cf. Teertstra and Sherriff, 1997). This probably also holds for partitioning of iodine. The high K_D values reported here indicate that halogens are readily fractionated in at least some mid-crustal environments, and that hydrodynamic models need to consider fluid-rock interaction (in systems devoid of halite) as a viable process to fractionate halogens in large-scale hydrothermal systems. Br:Cl ratios of common ferromagnesian silicates cannot be used to estimate this ratio in coexisting fluid phases in the absence of a proper understanding of this fractionation.

References

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Hydrothermal processes in a breccia-hosted Au deposit

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Intrusion-related Au deposits often occur in brecciated country rocks, where steep gradients in pressure, temperature, and fluid chemistry provide an effective environment for ore mineral precipitation. In this study, we present microtextural, isotopic, and LA-ICP-MS fluid inclusion data from the breccia-hosted Mt. Leyshon Au Deposit (392-381 Ma). Based on these results we interpret the controls on ore formation in a shallow hydrothermal system that implicates dilute fluids in ore metal transport.

Mineralisation at Mt. Leyshon can be divided broadly into pre-ore, high temperature quartz-molybdenite veins, and ore-stage quartz-K-feldspar-carbonate-sulphide ± Au breccia cements. Pre-ore fluids underwent phase separation into saline Na-K-Fe-Mn brines and CO₂-rich vapour at ca. 600°C and 0.5 kbar, although LA-ICP-MS microanalyses suggest that metal partitioning into the vapour phase was insignificant in this Cl-dominated system.

SEM-CL imaging of ore-stage quartz cements demonstrates an episodic history of fracturing, fluid flow, and mineralisation in the breccia environment. Ion microprobe analyses of quartz across CL zones reveal δ¹⁸O values ranging from 14‰ to 0‰ (vs. VSMOW). These zones represent distinct episodes of fluid input from ¹⁸O-enriched magmatic and ¹⁸O-depleted meteoric sources. The titration of meteoric fluids into the hydrothermal system confirms surface connectivity and explains cooling-dilution trends observed by microthermometry. The fluids attending ore deposition have Fe, Zn, Cu, and Pb concentrations that strongly match modal proportions of sulphides in the bulk ore. These results are in contrast to previous LA-ICP-MS studies of deeper-seated porphyry Cu-Mo-Au deposits, where Zn and Pb are enriched in exsolved fluids relative to the bulk ore [1]. Despite the high probability that these dilute fluids were magmatic-meteoric mixtures, they are interpreted as pregnant ore-fluids, *i.e.* physical gradients at the magma-breccia interface were the major controls on sulphide and Au precipitation, rather than fluid mixing *per se*.

Reference

- [1] Ulrich, T., Günther, D., and Heinrich, C.A. (1999) *Nature* **399**, 676-679.