

Experimental Constraints on Hypogene Alteration: Acidic Gases and Magmatic Brines

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Formation of porphyry copper deposits (PCD), and other magmatic-hydrothermal ore deposits relies on the scavenging of metals from intrusive magmas via exsolution of volatile fluids during decompression and crystallization at shallow levels. However, the nature of volatile fluids which exsolve from arc magmas varies greatly (e.g., $\sum\text{Cl}$, $f\text{HCl}$, Na/K/Fe) depending on the melt composition, pressure, temperature, and timing of exsolution. In addition, PCDs are characterized by patterns of hydrothermal alteration. Commonly, the most mineralized zone within the hypogene ore shell is at the contact between the high-temperature potassic and sericitic alteration zones.

Existing models aimed at explaining the mechanisms for producing PCD alteration sequences are backed by limited experimentation. Few criteria discriminate between the effect of magmatic volatile phases in producing the characteristic high-temperature alteration sequences common to PCD. Models ignore a potentially useful discrimination tool for separating mineralized systems from barren systems altered by nonmineralizing fluid fluxes.

We present experiments to characterize the reaction of porphyritic suites of rocks with a variety of high-temperature magmatic volatile phases, which are analogous to those present in PCDs. Samples of diorite and gabbro from the Val Fredda Complex, Adamello, Italy and dacite from Mount St Helens, USA, were crushed to a coarse powder and used as analogues for the varied porphyritic host rocks in PCDs. The rocks are reacted with a variety of synthetic high-temperature fluids in gold capsules for 3 weeks. The compositions of the magmatic-hydrothermal fluids have been tailored by using complementary experiments that characterize the fluids that are produced during shallow intrusive events. This allows us to set realistic concentrations of $\sum\text{Cl}$ and $\sum\text{S}$ in the fluids as well as appropriate ratios of key elements in hypogene alteration (e.g., Na/K/Fe/H). The fluids include primary exsolved volatile phases such as supercritical gasses (10 wt % NaCl_{eq}) as well as high-salinity magmatic brines (>50 wt % NaCl_{eq}) and their associated low-salinity vapors (0–5 wt% NaCl_{eq}). In addition, we will explore the role of HCl-rich vapors similar to those proposed as products of reactions between shallow exsolved/unmixed brines (Cu-Fe-Cl rich) and mafic-derived sulfurous gasses ($\text{SO}_2/\text{H}_2\text{S}$ -rich).

Two trial experiments were conducted, reacting dacite with magmatic brine (50% NaCl_{eq}) and pure water to examine the range of alteration expected throughout the experiments. No alteration was discernable in either the feldspar or amphibole in run HAW21 after 3 weeks at 700°C. In contrast, the results of HAW21 demonstrated the pervasive breakdown of iron-magnesian minerals and transformation of plagioclase to alkali feldspar and mica in the presence of highly saline magmatic fluids; this is in contrast to the very limited potential for alteration by pure water. Experiments are underway to examine the alteration characteristics of lower-K brines and supercritical fluid analogous to those exsolved from intrusive suites in Chile, in addition to experiments reacting mineralization exhaust gas in a similar fashion. These experiments will place tighter constraints on the alteration styles of the varied magmatic volatile phases present in shallow arc systems, and their relative roles in generating the complex ore zones of PCDs.