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Special Paper:

The Composition of Magmatic-Hydrothermal Fluids in Barren and Mineralized Intrusions

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Abstract

This paper addresses the question of whether or not there are fundamental differences in the composition of magmatic-hydrothermal fluids in barren versus variably mineralized systems, and if so, at which stage of magmatic-hydrothermal evolution the differences were generated. Combining microthermometry and laser ablation ICP-MS, we studied high-temperature, premineralization fluid inclusions in three barren granites, one Sn-W-mineralized granite, one porphyry Cu-mineralized intrusion, one porphyry Mo-mineralized intrusion, and one Th-U-REE-mineralized granite, and compared the results with published data from 10 other intrusive systems. Many of the fluid inclusions are paragenetically associated with melt inclusions, providing direct insights into the stage at which metals were transferred from the crystallizing magma into the exsolving aqueous fluids.

In 10 out of 14 magma systems in which the physical and compositional properties of the magmatic fluid(s) could be determined, the exsolved aqueous fluid was a single phase of relatively low salinity (2–13 wt % NaCl equiv; avg 5 wt % NaCl equiv), confirming predictions based on indirect evidence and observations made in earlier studies. Furthermore, in magmas that crystallized at low pressure (<1.3 kbars), the salinity of the magmatic fluid increased with increasing degree of crystallization, whereas in magmas that crystallized at higher pressure (>1.3 kbars) the opposite behavior occurred, as predicted by published numerical models of aqueous fluid-saturated magma crystallization. During the transition from magmatic to subsolidus conditions, both pressure and temperature within and adjacent to intrusions decreased, leading to widespread vapor-brine immiscibility. Due to the low salinity of the single-phase parent fluid the two-phase field generally was entered from the vapor side, resulting in condensation of subordinate amounts of brine from the low-density bulk fluid. If the transition from single- to two-phase aqueous fluid occurred in locally closed systems one can use the compositions of vapor and brine in subsolidus boiling assemblages to calculate the composition of the bulk fluid. This method was applied to those occurrences in which no single-phase parent fluid was found (i.e., where the earliest aqueous fluid found was already in the two-phase field).

The metal content of the least fractionated low-salinity fluids at each location correlates positively with the type and amount of mineralization in the associated intrusions, with high Cu concentrations being observed in

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fluid related to porphyry Cu deposits, high Sn and W concentrations in fluids related to Sn-W mineralization and high Ce concentrations in fluids related to REE mineralization. The earliest fluids in barren intrusions are comparatively metal poor, except for two cases in which certain metal concentrations are as high as in mineralized systems. A significant portion of the geochemical signature of barren versus mineralized intrusions was thus inherited from earlier stages in the development of these magma systems. In the case of Mo, Sn, W, and Ce, the correlation between fluid composition and type and amount of mineralization is more distinct in high-temperature brines than in the least fractionated low-salinity fluids. This, together with other lines of evidence, suggests that brine condensates play a central role in the formation of Sn, W, Mo, and REE deposits. In the case of porphyry Cu (-Au) systems it appears more likely that the greater proportion of metal precipitated from the vapor phase, although brines may have played a significant role as well.