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Fluid–melt partitioning in experiments and nature

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The exsolution of aqueous fluids from crystallizing magmas and related re-distribution of ore metals between coexisting phases is probably one of the most drastic steps in the evolution of magmatic-hydrothermal ore deposits. Accordingly high is the chance that some of the fundamental differences between barren and mineralized systems are generated at this stage. In order to understand the effect of fluid–melt partitioning on the mineralization potential we need to be able to answer the following questions: (i) how do fluid–melt partition coefficients vary as a function of p, T, f_{O2}, fluid and melt chemistry?, (ii) what values are realized in nature, and (iii) what are the main causes for variations in nature?

The effect of individual parameters on fluid–melt partition coefficients is best explored experimentally. However, despite the apparent simplicity of the approach it can be very difficult in practice to change only one parameter with all other parameters being held constant. For example, at the relatively large fluid/melt ratios commonly used in experimental studies an increase in fluid salinity likely will be accompanied by a change in melt aluminosity and, therefore, in fluid pH, such that it may be difficult to say what caused the observed change in partition coefficient. Furthermore, for some elements relatively large uncertainties in calculated fluid–melt partition coefficients can arise due to slow equilibration rates and/or problems of alloying.

Studying fluid–melt partition coefficients on natural samples is challenging for several reasons. First, it is difficult to find samples containing fluid and melt inclusions that were not only trapped unambiguously at the same time, but also are well preserved and large enough for analysis. So far, only about a dozen samples (mostly from barren intrusions) are known that meet this criteria. Second, to be able to interpret variations in the measured partition coefficients among different samples correctly it is necessary to reconstruct a large number of parameters (p, T, f_{O2}, fluid salinity, melt aluminosity, pH, presence of other ligands such as sulfur, fluorine or carbon-bearing species). Many complementary studies including the analysis of volatiles in re-homogenized melt inclusions are thus necessary to fully characterize the conditions of fluid–melt partitioning in natural settings.

Another important point to consider in natural systems is that many of them (in particular the ore-forming ones?) cannot be viewed as closed systems. There is growing evidence from porphyry-Cu/Au/Mo deposits that a close interaction between mafic and felsic magmas occurred, and that volatiles and metals were transferred from mafic magmas to overlying felsic magmas. Fluid–melt partitioning should thus not be viewed as a unidirectional transfer of matter from the magma to the exsolving fluid phase(s), but as a process that also may act into the opposite direction. The presence of anhydrite phenocrysts in felsic magmas associated with porphyry systems testifies to such a process.

Fluid–melt partition coefficients of selected ore-forming elements measured in natural samples and in experiments will be discussed against this background, and the implications for the mineralization process be elucidated.