Geophysical Research Abstracts,
Vol. 10, EGU2008-A-06185, 2008
SRef-ID: 1607-7962/gra/EGU2008-A-06185
EGU General Assembly 2008

The use of porphyry-stage fluid compositional data obtained by LA-ICP-MS to constraining source magma chemistry and processes

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At the magmatic-hydrothermal transition variably salty, aqueous ($\pm$ CO_2) fluids exsolve from evolving magma in subvolcanic chambers, rise and may form porphyry to epithermal Cu-Mo-Au and vein-type Sn-W deposits. Early, hot magmatic-hydrothermal fluid stages as preserved in quartz-hosted fluid inclusion assemblages (FIA) are investigated here by LA-ICP-MS to shed light on fluid generation, magma evolution and source contributions.

The Climax-type porphyry-Mo deposit at Questa, USA, consists of stockwork veining superimposed on a magmatic-hydrothermal breccia. Earliest FIA in both stages are of intermediate density and ca. 7 wt% $NaCl_{equiv}$, which then boiled off a vapor (ca. 420 ˚C / 300 bar) to leave behind a Mo-enriched ($<$ 1100 μg/g) brine. Ratios of (Cs)/(Na+K+Mn+Fe) and (Rb)/(Na+K+Mn+Fe) define two clusters, the later stockwork veins being conspicuously enriched in hydrothermally non-reactive Cs and Rb. It reveals fluid exsolution in two distinct pulses from a progressively more fractionated magma. Mass balance calculations using the fluid chemical data return a high water content of the source melt, ca. 10 wt%, allowing for the hypothesis that fluid exsolution may have occurred at confining pressures exceeding 500 MPa. Deep fluid exsolution from a large mass of magma might thus be beneficial for the formation of large Climax-type Mo deposits.

The multiple stage El Teniente porphyry Cu-Mo deposit, Chile, provides intermediate

density FIA petrographically immediately predating early brine - vapor FIA indicative of brine condensation upon fluid phase separation, formed at ca. 400 ˚C / 300 bar. Ratios of Cs/(Na+K+Mn+Fe) are constant from pre-ore to all syn-ore fluid stages, suggesting protracted fluid generation in a large, non-fractionating shallow magma chamber. Cu contents in intermediate density FIA are ca. 0.25 wt%. Cu contents of the bulk input fluid estimated from the early brine - vapor FIA are ca. 1.1 wt%, and show >5 times enrichment of Li, Fe and Mo, and an apparent depletion in As relative to the putative parental fluid represented petrographically by the intermediate density FIA. All other element concentrations are indistinguishable. Porphyry stage FIA data thus testify to the injection of an exceptionally Cu, Mo, Li and probably also S rich volatile phase into an evolving upper-crustal magmatic-hydrothermal system, a process that may have triggered the formation of this unusually large and rich Cu deposit.

The tracing of source contributions to subvolcanic magma chambers exsolving porphyry-type ore fluids could provide key information as to whether giant porphyry Cu-Au-Mo deposits can form from ordinary calcalkaline magmas. Multiple-collector LA-ICP-MS analysis of individual fluid inclusions for Pb isotope signatures holds great promise to address this, and investigations are currently under way.