Numerical heat and fluid flow modelling in submarine terrains

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Goal

Numerical simulations based on the Lau basin were carried out to investigate the potential of massive sulfide ore deposit formation in back-arc seafloor environments and assess the influence of rock properties, structure and submarine topography on fluid circulation patterns, heat and fluid flow distribution and ore body formation. The model is a 7 km x 60 km solution domain with topography, typical seafloor stratigraphy, 7 faults penetrating into the sheeted dyke layer and a central magma chamber.

Heat and fluid flow

Main fluid discharge is observed through multiple faults with temperatures between 150ºC and 400ºC and fluid velocities reaching $2.5x10^{-6}$ m/s. Hydrothermal circulation patterns predict main fluid recharge through faults at topographic lows while discharge faults are located at topographic highs, indicating mainly buoyancy-driven hydrothermal circulation. Cumulative water-rock ratios predict main rock alteration occurring within fault structures as well as in the breccia zone and andesite layer and maximum water-rock ratios ranging between 140 and 610.

Elevated rock permeabilities produce decreasing fluid discharge temperatures, higher fluid velocities but shorter discharge duration of venting fluids. Increasing fault permeabilities improve fluid discharge temperatures, fluid velocities and discharge duration and lead to a reversal of some recharge faults into discharge faults. Only slight changes have been observed when thermal conductivity, rock porosity and vertical fault extent are altered. Submarine topography is less important for hydrothermal circulation patterns but influences fluid discharge and fluid velocity.

Results suggest that topography, rock/fault permeability and fault density directly influence hydrothermal fluid discharge. Best results are obtained with high topographic relief, high fault permeability and low fault density possibly indicating a preference for isolated faults rather than complete graben structures for massive sulfide ore body formation.

Ore body formation

Economic ore bodies are predicted to form above faults at topographic highs in about 70,000 years. At high fault permeabilities fault in lower topographic positions are also predicted to produce viable ore bodies.

Boron partitioning in the haplogranite-NaCl-H_2O system at 800ºC and 100 MPa

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Fractionation of granitic magmas leads to significant enrichments in many incompatible and volatile elements. This may cause the melt to become saturated in an aqueous phase or phases, into which some of these elements may partition. During its subsequent migration, this fluid may interact with and metasomatically alter the composition of the rocks through which it passes.

One of the elements commonly transferred from magmas in this manner is boron, which is of particular interest because of its frequent association with metallic mineral deposits, as tourmaline. Although such tourmalinization may be very extensive, we have little understanding of the partitioning of boron between hydrous granitic melts and their associated aqueous fluids, and no information on the relative importance of aqueous liquids and vapors in this partitioning.

We report here the results of fluid-saturated experiments conducted to investigate the partitioning of boron between a haplogranitic melt, aqueous liquid and aqueous vapor at 800ºC and 100 MPa. The experiments were carried out in cold-seal pressure vessels for durations of 1 to 21 days. Starting materials consisted of powdered synthetic haplogranitic glass [Al/(Na+K) = 1] doped with 1000 ppm B, with variable amounts of NaCl and H_2O (fluid/haplogranite ratio = 1 by mass). The NaCl-H_2O proportions define a range in salinities: 0 and 1 wt. % NaCl in the aqueous vapor and 70 and 80 wt. % NaCl in the aqueous liquid. Additional experiments at 2 and 60 wt. % NaCl intersect the NaCl-H_2O solvus. Run product glasses were analyzed for boron concentrations by secondary ion mass spectrometry (SIMS) and for major elements and chlorine by electron microprobe, whereas the composition of the coexisting fluid was calculated by mass balance.

Preliminary results indicate that boron partitions preferentially into the aqueous fluid over the hydrous melt. At low salinities (0 and 1 wt. % NaCl), $D_B^{vapor/melt} = 4.0$ to 7.1 (average 5.6 ± 1.2), and at high salinities (70 and 80 wt. % NaCl), $D_B^{aqueous\ liquid/melt} = 1.0$ to 1.4 (average 1.3 ± 0.2). This suggests the preferential partitioning of boron into the aqueous vapor over the aqueous liquid ($D_B^{vapor/aqueous\ liquid} = 4.4 \pm 1.1$). Compositional heterogeneity of the run products from the experiments with 2 and 60 wt. % NaCl fluids suggests co-existence of aqueous vapor, aqueous liquid and hydrous melt at these conditions.

These results demonstrate the preferential partitioning of boron in the following order: vapor > aqueous liquid > hydrous granitic melt. This has important implications for ore deposit formation and magmatic degassing.