Geophysical Research Abstracts, Vol. 9, 06633, 2007
SRef-ID: 1607-7962/gra/EGU2007-A-06633

Fully coupled reactive transport simulations of hydrothermal circulation in oceanic hydrothermal systems

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Circulation of seawater through the oceanic crust and the chemical reactions that occur along the flowpath control the composition of vent fluids. We use 1D and 2D fully coupled reactive transport models to explore the evolution of fluid flow, heat transport and chemical reactions in the oceanic crust and the implications for mineral alteration patterns and vent fluid composition.

Fully coupled models are required to assess the complex interaction between chemical alteration, fluid flow and thermal conditions in the oceanic crust. The recharge of seawater into the basaltic crust causes the precipitation of significant volumes of anhydrite and chlorite which reduces the porosity and thus the permeability of the recharge zone. Similarly, cooling of the hydrothermal fluid as it ascends to the seafloor below hydrothermal vents may lead to the precipitation of minerals such as quartz and a reduction in permeability. Alteration reactions in the high-temperature reaction zone also introduce some heterogeneity of the permeability distribution which are, however, somewhat less pronounced than the permeability reduction in the recharge and discharge zones due to lower thermal and/or compositional gradients and closer to equilibrium conditions. Therefore, over time chemical reactions have the potential to modify the flow field and the thermal conditions in oceanic hydrothermal systems which could lead to observable changes in discharge rate, temperature and/or chemical composition of seafloor hydrothermal vents.

However, one of the key observations from oceanic hydrothermal systems (e.g. 21ºN, East Pacific Rise) is the temporal uniformity (on a decadal time scale) of the composition of vent fluids. The fluid composition at these vents is consistent with rock buffering at greenschist metamorphic conditions. Our simulations are aimed at quantifying the magnitude, saptial distribution, time scales and rates of chemically induced permeability changes and the associated effect on flow and thermal conditions and the impact on the evolution of the vent fluid composition. Critical parameters and aspects that are explored in these simulations are water/rock ratios (which are dependent on the permeability and the reactivity) and the formulation of the porosity/permeability coupling used in the reactive transport code.