

Reactive transport simulations of lateral 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 are the most important processes leading to the formation of submarine hydrothermal systems and associated mineral deposits. We use variably coupled reactive transport models to explore the evolution of fluid flow, heat transport and chemical reactions in the oceanic crust and the implications for the formation of mineral deposits at the seafloor.

Permeability measurements in the upper crust suggest that the permeability distribution is heterogeneous and stratified so that fluid flow is essentially lateral and confined to high permeability layers. We approximate hydrological and geochemical conditions in the oceanic crust with different model designs. The first model consists of a horizontal, 1D flow system that is bounded at the top and bottom by conductive layers. We use a range of heat flow values and flow velocities that are consistent with those measured or estimated for ridge crest or ridge flank settings. This model is aimed at reproducing the alteration processes that have been observed in the reaction zone at mid-ocean ridges and at assessing the hydrological implications of these processes and the rates at which they occur. The hydrological simplicity of this model allows us to increase the complexity of the chemical system, check for the consistency of thermodynamic data and define a minimum set of species to be used in more complex simulations.

In a second set of simulations we use a 2D model domain with recharge, discharge and reaction zones and assign a heterogeneous, anisotropic permeability distribution to the oceanic basement aquifer. Fluid flow is still dominantly lateral along high-permeability pathways but we account for macro-dispersion and localized cellular convection as a result of the heterogeneous permeability. In this fully coupled simulation, we examine the evolution of the system with regard to the nature and distribution of alteration processes, the flow pattern and thermal conditions. We focus on processes within the discharge zone and how these affect the fluxes and the chemical composition of vent fluids and associated mineral deposits.