Geophysical Research Abstracts,
Vol. 11, EGU2009-12146, 2009
EGU General Assembly 2009


# Implications of an ultramafic body in a basalt-dominated oceanic hydrothermal system on the vent fluid composition and on processes within sediments overlying a hydrothermal discharge zone: results of reactive-transport modeling

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We use 2D reactive transport simulations to assess the hydraulic, thermal and chemical implications of an ultramafic body of lherzolitic composition within a basalt-dominated oceanic hydrothermal system. The simulations are fully coupled and hence account for the progressive serpentinization and the associated porosity/permeability reduction of the model lherzolite over time. We focus on the chemical fingerprints that reveal the presence of the ultramafic body at depth and that may be detected by direct seafloor exploration. These are the vent fluid composition and the porewater and mineral alteration within the rock column overlying a hydrothermal discharge zone. We compare ocean crust sections with and without sedimentary cover.

Simulations suggest that the boundary between the basalt and the lherzolite constitutes a sharp reaction front. The type and distribution of alteration phases that form at the reaction front are a result of fluid flow across the basalt-lherzolite interface and thus are determined by the geometry and rate of hydrothermal fluid flow. Consequently, observations of the occurrence and extent of alteration phases, such as Fe-rich chlorite in the lherzolite or of rodingitization of the basalt, may be interpreted in terms of the reactive-transport model to reconstruct paleo-fluid flow in the permeable oceanic basement.

The alteration of the lherzolite produces a fluid that is strongly reducing and depleted in silica. The most important chemical indicator of this rock–water interaction is an elevated H2 concentration. Under reducing (i.e. SO4-2 and CO2 free) conditions the enrichment in H2 is proportional to the extent of reaction between the fluid and the ultramafic rock. Under these conditions H2 behaves conservatively and the fluid remains enriched in H2 even though the concentration of all other major aqueous species is quickly buffered to new values when the fluid subsequently passes through basalt. This produces a vent fluid which is characterized by elevated H2(aq), SiO2(aq), H2S(aq) and a relatively low pH.

If the discharge zone is covered by sediments, the infiltrating hydrothermal fluid mixes with the sediment pore-water and entrained seawater and the presence of H2(aq) initiates a series of redox processes such as the reduction of CO2 to CH4 and SO4-2 to H2S. Thus, mixing-induced redox processes involving H2 and SO4-2 provide a mechanism to form metal sulfides and potentially ore deposits. Furthermore, the presence of H2(aq) in the ascending fluid favors the stability of the low-sulfidation form of redox-sensitive minerals, such as pyrrhotite over pyrite.

The sediments mark the transition zone that separates the hot, anoxic, low pH hydrothermal basement fluids from the cold, oxic, high pH seawater. Mixing between oxygenated seawater and/or the sediment porewater and the reduced, discharging H2, H2S and CH4-enriched hydrothermal fluid may provide conditions favorable for microbial chemosynthesis and an environment suitable for the growth of microorganisms.

However, as the lherzolite becomes progressively altered the reactivity of its primary minerals decreases and hence the production of H2 declines. The decrease in reactivity of the ultramafic is enhanced by the hydrolog-

ical sealing which is caused by the volume increase of the rock and by the corresponding porosity/permeability reduction associated with serpentinization. The decreasing H2 production changes the oxidation state of the discharging fluid and gradually leads to chemical fingerprints that are consistent with purely basaltic systems.

Numerical studies of this type demonstrate that reactive transport simulations are useful in correlating observable changes in chemical parameters (i.e. the composition of the vent fluid or alteration of the sediment column overlying discharge zones) with processes that occur in regions of the system that are not easily accessible by direct seafloor exploration.