Compositions and water–rock ratios of deep hydrothermal fluids that alter the oceanic crust

L.W. Diamond[1*], L. Richter[1], and S. Weber[1]

[1]Institute of Geological Sciences, University of Bern, Baltzerstrasse 3, CH-3012 Bern, Switzerland
(*correspondence: diamond@geo.unibe.ch)

Metasomatism of magmatically active upper oceanic crust by heated seawater transfoms basalts to chlorite + albite ± actinolite-bearing "spilites" along deep recharge paths, and to epidote + quartz-bearing "epidosites" along deep discharge paths. Both alteration types have been separately proposed as the source of Fe, Cu and Zn in seafloor massive-sulfide deposits. Whereas spilitization is attributed to a fluid of seawater salinity, the salinity of epidotizing fluids is debated. In addition, although the chemical compositions of the two fluids are constrained by experiments and by observations of seafloor vents, no direct analyses are available.

To characterize the two fluid types we have analyzed fluid inclusions in spilites and massive epidosites in the Semail ophiolite, Oman. The results confirm that both alteration fluids have salinity close to that of seawater (2.6–4.1 wt.% dissolved solids). Hypersaline inclusions are present but are exclusively due to exsolution of small amounts of magmatic fluid from plagiogranites, with no genetic relation to spilites or massive epidosites. The fluid inclusions reveal that alteration occurred over a range of P–T conditions: 170–430 °C for spilitization and 235–400 °C for epidotization, all at hydrostatic pressures of 27–50 MPa. Laser-ablation-ICP-MS analyses show that both fluids are Mg-poor and Ca-rich compared to seawater, but that the spilitizing fluid is much richer in Fe, Cu and Zn than seawater or the metal-poor epidotizing fluid.

Based on the fluid inclusion analyses we have performed reactive-transport modeling to calculate the amount of epidotizing fluid required to convert spilite to end-member epidosite. Our simulated mineralogical changes closely match those measured in the ophiolite samples. The resulting water–rock mass ratios vary from 1200 up to as high as 80,000, depending on the composition of the reactant spilite.

Such high ratios support the significance of epidosites as markers of extreme fluid focussing deep below sites of seafloor discharge. Nevertheless, the metal-poor nature of the epidotising fluids versus the metal-rich nature of the spilitizing fluids points to the latter as the carrier of metals to seafloor sulfide deposits.