Geophysical Research Abstracts
Vol. 14, EGU2012-11065, 2012
EGU General Assembly 2012

Mineral Dissolution and Reaction permeability in ocean floor hydrothermal systems

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The enhanced permeability required to allow black smoker hydrothermal circulation within oceanic sheeted dykes is generally assumed to be the result of fracturing caused by thermal contraction and/or tectonic faulting. Here we present evidence for reaction-enhanced permeability from diabase in three diverse settings; epidosites from the Troodos ophiolite, diabase intrusions which chill against fault rocks and altered gabbros in the immediate footwall of a detachment fault at 30 °N in the Atlantic (IODP Site 1309), and the “type section” of Pacific ocean crust in ODP Hole 504b. In each case, freshly broken surfaces were examined in the SEM, revealing euhedral secondary minerals (amphibole or epidote) growing into porosity located in areas formerly occupied by igneous minerals such as pyroxene. Relict porosity is up to 20 μm in size but may originally have been considerably larger. BSEM and CL imaging of polished surfaces reveals euhedral zoning and resorbtion surfaces in both amphibole and quartz . Amphiboles at IODP site 1309 show a wide range in composition with early zones being exceptionally rich in Ti and Al (temperatures using the Ernst and Liu geothermometer in excess of 800 °C), but later zones and porosity-filling amphibole needles being actinolitic.

Key field relations in the Troodos ophiolite show that the most intense alteration is often in the undeformed core of dykes, and that each successive dyke was epidotised before the next was intruded. Reaction permeability provides a mechanism for concentrating fluid flow into the site of alteration, and has the capacity to create exceptionally large transient permeabilities before the porosity is occluded by secondary minerals. Affinities have been calculated using EQ3/6 for clinopyroxene in contact with a black smoker fluid at 350 and 400 °C at 50 MPa, and are of the order 130 kJ/mol. This corresponds to “far from equilibrium” conditions in which dissolution could proceed at rates > 1 μm/day. The limiting factor is the speed with which reactive fluid can be replenished at the reaction site, but a moving fluid will allow positive feedbacks between porosity creation, permeability and flow rates. The porosity-filling phases generally represent greenschist facies conditions, consistent with black smoker vent temperatures.

Reaction porosity textures have been observed in 8 out of 10 specimens so far examined in broken surface from Atlantic and Pacific dyke rocks. This permeability-generating mechanism may therefore be widespread.