Geophysical Research Abstracts
Vol. 12, EGU2010-13834-1, 2010
EGU General Assembly 2010

Constraining serpentinization at mid-ocean ridges: effects on fluid flow and the global water budget

Karthik Iyer (1), Lars Rüpke (1), and Jason Phipps Morgan (2)

(1) IFM-Geomar, The Future Ocean, Kiel, Germany (kiyer@ifm-geomar.de), (2) Department of Earth and Atmospheric Sciences, Cornell University, Ithaca NY 14853, USA

Hydration of the oceanic lithosphere is an important and ubiquitous process which alters both the chemical and physical properties of the affected lithologies. One of the most important reactions that affect the mantle is the process of serpentinization which results in a drastic decrease in the density (up to 40%), seismic velocity and brittle strength. More importantly, serpentinization may result in the uptake of up to 13wt% of water and is an important contributor to global water budget.

In this paper, we use numerical models to study the amount and extent of serpentinization that may occur at mid-ocean ridges and its effects on fluid flow within the lithosphere. The two dimensional, FEM model solves three coupled, time-dependent equations: (i) mass-conserving Darcy flow equation, (ii) energy conserving heat transport equation and (iii) serpentinization rate of olivine with feedbacks to temperature (exothermic reaction), fluid consumption and variations in porosity and permeability (volume changes).

The thermal structure of the ridge depends on the spreading velocity as well as hydrothermal convection. Serpentinization of the oceanic mantle, in turn, depends on the aforementioned, competing processes and may itself influence fluid flow due to the large variations in porosity and permeability as a result of the associated volume changes. Therefore, strong feedbacks exist between mantle hydration reactions and hydrothermal flow. Increasing rates of serpentinization may enhance permeability by reaction-induced fracturing. As serpentinization progresses, fracturing ceases and remaining pore space is reduced by the precipitation of hydrous phases. Due to these variations in permeability/porosity controlled by hydration reactions, in combination with differences in background permeabilities between the crust and mantle, the Moho may be a self-limiting barrier to fluid flow due to the formation of an impermeable serpentinized rock layer. We find that the variations in background permeability and the relation between porosity/permeability and serpentinization do not significantly affect the results of the model. The controlling factor, however, is the considerable reduction of porosity/permeability as serpentinization reaches completion. This is also supported by field observations where serpentinized rocks consist of numerous veins clogged with hydrous phases and by the result that unreasonable amounts of the mantle (up to $\sim$13km) would be hydrated if this were not the case.

The average water content of the mantle is a strong function of spreading rate. Moreover, we find two distinct trends: slow spreading ridges show high degrees of hydration that rapidly drop with increasing rate. Fast spreading ridges show only limited water contents which do not greatly depend on the spreading rate. The results suggest that fast and slow-spreading lithosphere are likely to have strikingly different serpentinization characteristics when they reach a trench and begin to bend and subduct. The total water budget of the mantle leaving the ridge has been estimated to range between 0.18×10^5 kg/m^2 and 2.52×10^5 kg/m^2 depending on the spreading rate. These values are consistent with independent estimates and show that the mantle is an important reservoir in the global geological water cycle.