Geophysical Research Abstracts
Vol. 14, EGU2012-11269, 2012
EGU General Assembly 2012

Crustal accretion and hydrothermal convection patterns at fast-spreading ridges

L. Ruepke (1), S. Theissen-Krah (1), K. Iyer (1), and JP Morgan (2)

(1) Helmholtz Centre for Ocean Research, GEOMAR, Germany (lruepke@geomar.de, +49 431 600-2845), (2) EAS Dept., Cornell University, USA

New oceanic crust is continuously created along the mid-ocean ridge systems that encircle the globe. At intermediate to fast spreading ridges, crustal accretion occurs by the crystallization of mantle melts accumulating in at least one shallow on-axis melt lens. Seismic reflection data shows that its depth is inversely correlated to spreading rate. A tomographic study of the East Pacific Rise imaged the temperature structure of the lower crust showing a narrow region of high temperatures throughout the crust that widens at moho depths (Dunn et al., 2000). Further off-axis, nearly horizontal isotherms that steepen towards the ridge axis are described. The restricted width of the region with anomalously high temperatures suggests that hydrothermal convection extend well into the lower crust and potentially to moho level.

This imaged thermal structure could be used as a proxy for the likely hydrothermal convection patterns if numerical models were able to resolve both the crustal accretion process and hydrothermal cooling. Due to the different time scales of hydrothermalism and crustal accretion, numerical models have so far focused on only one of the two processes. Here we present the results of newly developed model that resolves simultaneously crustal and mantle as well as hydrothermal flow within one finite-element model. The formation of new oceanic crust is approximated as a gabbro glacier, in which the entire lower crust crystallizes in one shallow melt lens. The solid velocities are described by Stokes flow for incompressible viscous fluids. Magma injection in the diking region and the melt lens, where crystallization of the upper and lower crust takes place, are implemented via a dilation term. Hydrothermal cooling is resolved by solving for Darcy fluid flow for pure water.

In a first application of this model, we have revisited the well-known observation that the depth of the melt lens correlated inversely with spreading rate. Our modeling results show that only a narrow range of crustal permeabilities are consistent with observed melt lens depths, which are primarily controlled by the on-axis permeability. The off-axis permeability determines the width of hot lower crust. These findings have motivated a second set of numerical experiments, in which we also the fitted the off-axis temperature structure. For this it was necessary to allow for hydrothermal cooling at depth and include a high near-axis permeability region possibly created by thermal cracking as previously proposed for the Oman ophiolite (Nicolas et al., 2003). Furthermore, permeability must decrease as the crust ages and moves away from the ridge. Our results further suggest that two hydrothermal convection systems develop: one shallow on-axis system and a second deep reaching near-axis (and across axis oriented) system. Both systems together are responsible for the thermal structure observed at fast spreading ridges.