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Coupled mechanical and hydrothermal modelling of crustal accretion at fast spreading ridges

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Several geophysical studies imaged a melt lens beneath intermediate to fast spreading ridges, with the depth to the melt lens depending on spreading velocity. It is also widely accepted that the heat released during cooling and crystallisation during the accretion/formation of new oceanic crust is removed by hydrothermal circulation. Two competing end member models explain the formation of the oceanic crust: In the gabbro glacier model the lower crust crystallises in a shallow melt lens and the solidified material is advected to its final position, whereas in the many sill model the crust crystallises in situ from multiple sills at different levels in the lower crust.
Many numerical models of crustal accretion and hydrothermal cooling have been developed in the last years, but regardless of whether the models simulate the gabbro glacier or sheeted sill assumption, the previous models focus mainly on one of the processes. They solve either for hydrothermal circulation and create the lithospheric material continuously with spreading velocity [e.g.Cherkaoui et al., 2003] or for viscous advection but parameterise the hydrothermal cooling with an enhanced thermal conductivity/diffusivity as described by Morgan and Chen [1993]. Our new approach couples both processes in one model. The formation of new oceanic crust is implemented as in the gabbro glacier assumption, where all the lower crust crystallises in a shallow melt lens.
It is a two dimensional model which uses the finite element method to solve simultaneously for crustal accretion and hydrothermal cooling. The solid velocities in crust and mantle are described by viscous flow of incompressible fluids. Magma injection is implemented by a dilation term and hydrothermal circulation is described by Darcy fluid flow for water.
Although the time scales for accretion of the crust and cooling due to hydrothermal circulation are different it was possible to couple the processes in one model and to solve for a steady state solution. Preliminary results show that the depth and shape of the melt lens is influenced by the permeability structure in addition to the spreading rate dependency.

References:

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