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Mechanical and hydrothermal models of fast spreading ridges

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New oceanic crust and lithosphere is continuously created along the approximately 60,000 km-long mid-ocean ridge (MOR) system that encircles the globe. The formation of oceanic crust at intermediate to fast spreading ridges occurs by the crystallization of mantle melts accumulated in at least one shallow melt lens situated below the ridge axis. Seismic studies suggest that the depth of this melt lens is inversely correlated with spreading rate. The melt lens is a key feature to explain the formation of the new oceanic lithosphere; it is the place where crystallization takes place and it also provides the heat source that drives the hydrothermal system. The heat released in it by crystallization and melt injection is removed by a combination of hydrothermal cooling and diffusion.

Due to the different time scales of hydrothermal cooling and crustal accretion, numerical models have so far focused on only one of the two processes [1, 2]. Our modeling approach solves simultaneously for crustal, mantle and hydrothermal flow within one finite-element model (Fig. 1). 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 in crust and mantle are described by viscous flow of incompressible fluids. Magma injection in the diking region and the melt lens is implemented via a dilation term. Hydrothermal circulation is resolved by solving for Darcy fluid flow for pure water.

We find that the depth of the melt lens and the shape of hot (potentially molten) lower crust are highly dependent on the ridge permeability structure. The predicted depth of the melt lens is primarily controlled by the permeability at the ridge axis, whereas the off-axis permeability determines the width of hot lower crust. Observed melt lens depths can be fitted with on-axis surface permeabilites of 3-6x10^{-15} m^2. The modeling results suggest that hydrothermal convection above the melt lens and deep circulation are both responsible for the thermal structure observed at fast spreading ridges.

References

References
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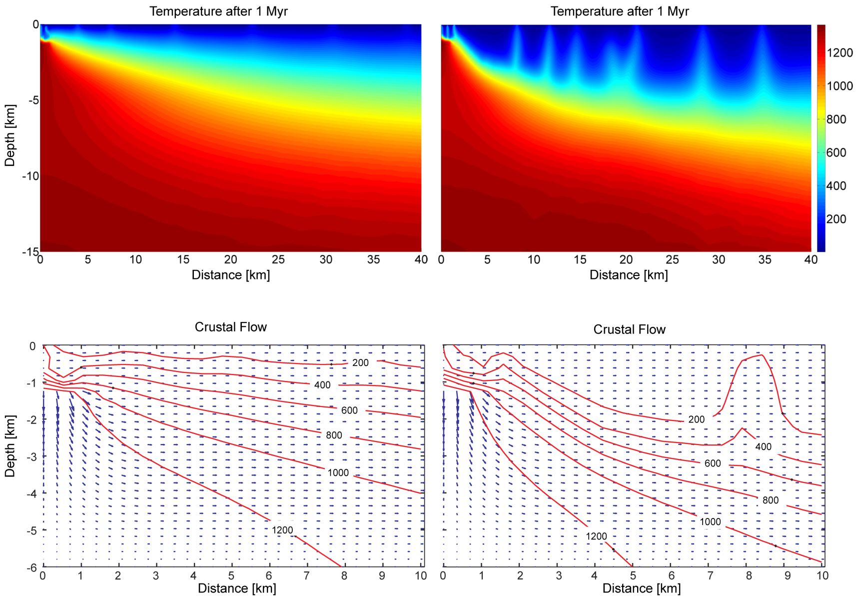

Figure 1: Temperature structure after 1 Ma modeling time.