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Volume 6, issue 5 | Copyright

Model description paper | 14 Oct 2013

Numerical model of crustal accretion and cooling rates of fast-spreading mid-ocean ridges

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Received: 15 Mar 2013 – Discussion started: 10 Apr 2013 – Revised: 28 Jul 2013 – Accepted: 02 Sep 2013 – Published: 14 Oct 2013

Abstract. We designed a thermo-mechanical numerical model for fast-spreading mid-ocean ridge with variable viscosity, hydrothermal cooling, latent heat release, sheeted dyke layer, and variable melt intrusion possibilities. The model allows for modulating several accretion possibilities such as the "gabbro glacier" (G), the "sheeted sills" (S) or the "mixed shallow and MTZ lenses" (M). These three crustal accretion modes have been explored assuming viscosity contrasts of 2 to 3 orders of magnitude between strong and weak phases and various hydrothermal cooling conditions depending on the cracking temperatures value. Mass conservation (stream-function), momentum (vorticity) and temperature equations are solved in 2-D cartesian geometry using 2-D, alternate direction, implicit and semi-implicit finite-difference scheme. In a first step, an Eulerian approach is used solving iteratively the motion and temperature equations until reaching steady states. With this procedure, the temperature patterns and motions that are obtained for the various crustal intrusion modes and hydrothermal cooling hypotheses display significant differences near the mid-ocean ridge axis. In a second step, a Lagrangian approach is used, recording the thermal histories and cooling rates of tracers travelling from the ridge axis to their final emplacements in the crust far from the mid-ocean ridge axis. The results show that the tracer's thermal histories are depending on the temperature patterns and the crustal accretion modes near the mid-ocean ridge axis. The instantaneous cooling rates obtained from these thermal histories betray these discrepancies and might therefore be used to characterize the crustal accretion mode at the ridge axis. These deciphering effects are even more pronounced if we consider the average cooling rates occurring over a prescribed temperature range. Two situations were tested at 1275–1125 °C and 1050–850 °C. The first temperature range covers mainly the crystallization range that is characteristic of the high temperature areas in the model (i.e. the near-mid-oceanic-ridge axis). The second temperature range corresponds to areas in the model where the motion is mainly laminar and the vertical temperature profiles are closer to conductive. Thus, this situation results in less discriminating efficiency among the crustal accretion modes since the thermal and dynamic properties that are described are common to all the crustal accretion modes far from the ridge axis. The results show that numerical modeling of thermo-mechanical properties of the lower crusts may bring useful information to characterize the ridge accretion structure, hydrothermal cooling and thermal state at the fast-spreading ridges and may open discussions with petrological cooling rate results.

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How to cite: Machetel, P. and Garrido, C. J.: Numerical model of crustal accretion and cooling rates of fast-spreading mid-ocean ridges, Geosci. Model Dev., 6, 1659-1672, https://doi.org/10.5194/gmd-6-1659-2013, 2013.