3D numerical modeling of ridge-transform faults using a newly developed multigrid finite element code written in MATLAB

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Our project is part of the DFG priority program SPP 1144 “From Mantle to Ocean: Energy-Material- and Life-cycles at Spreading Axes”. The aim of the priority program is to carry out a multi-disciplinary study of the mid-ocean spreading system in the Atlantic. One of the study areas (South Atlantic Ridge, east of Ascension Island, 4-11°S) is characterized by two long-offset transform faults (Bode-Verde and Ascension fracture zones) as well as smaller ridge axis displacements. Large along-axis variations in basalt geochemistry, depth of the axial valley and thickness of the oceanic crust were explained by different authors through either a weak mantle plume or mantle heterogeneities. Our final goal is to provide a self-consistent 3D mantle flow & melting model for this area, from which we can estimate thermal input into the oceanic crust and connections between the active volcanic regions, such as Ascension Island.

To better understand and isolate the effects of one or more transform faults on mantle flow and mantle melting we conduct 3D numerical simulations. We first consider plate geometries that have been modeled in earlier studies (e.g. Jha et al, 1994; Magde et al, 1996) to better understand and isolate the effects of varying transform offsets and segment lengths. The simulations include density variations due to mantle depletion, melt-retention and thermal expansion as well as viscosity changes due to temperature, melt fraction and mantle dehydration during melting. Our first results suggest that the reduction in mantle upwelling and melting may significantly depend on the style of the ridge offset, i.e. several transforms vs. single transform offset. A second set of simulations takes into account the exact characteristics of the M.A.R. near Ascension Island.

We developed a new numerical code written in MATLAB that solves for viscous flow, thermal evolution and mantle melting processes. 3D flow is modeled using a parallel finite element (conjugate gradient / multigrid preconditioner) solver for variable viscosities that operates on unstructured tetrahedra meshes. Temperature advection is performed using a semi-Lagrange algorithm on the same unstructured mesh, while diffusion is solved using standard operator-splitting techniques and a Crank-Nicholson finite element method. The code is parallel using Matlab’s “Distributed Computing Toolbox” and simulations are performed on a small 16-node cluster.

References:

Jha, K., E.M. Parmentier, and J. Phipps Morgan, The role of mantle-depletion and melt-retention buoyancy in spreading-center segmentation, EPSL 125, 221-234, 1994

Magde, L.S., Ch. Kincaid, D.W. Sparks and R.S. Detrick, Combined laboratory and numerical studies of the interaction between buoyant and plate-driven upwelling beneath segmented spreading centers, JGR 101, 22,107-22,122, 1996