12th International Workshop on Modeling of Mantle Convection
and Lithospheric Dynamics

August 20th to 25th 2011, Döllnsee Germany

Towards modelling melt extraction to self-consistent emplacement above a melting zone

Herbert Wallner[1], Harro Schmeling[1]
[1]*Institute of Earth Sciences, Goethe-University, Frankfurt am Main, Germany*
wallner@geophysik.uni-frankfurt.de

Our motivation roots in the geodynamically unsolved situation of the Rwenzori Mountains. The old, stiff and cold crustal horst is located inside the western branch of the East African Rift System and it is conspicuous due to elevations above 5 km relative to its locale size of 50 x 120 km.

We proposed rift induced delamination (RID) as a mechanism explaining the first order observations of extreme topography, old metamorphic and young volcanic rocks nearby, thinned crust in the rift and beneath the mountain range, seismicity and structure tectonics (Geodynamic Workshops Neustadt 2008, Braunwald 2009). Melt induced weakening (MIW) as an alternative concept driving RID advanced modelling in sense of a more realistic and self-consistent process with moderate given anomalies (Geodynamic Workshop Münster 2010). For this, the thermo-mechanical physics was extended to two-phase visco-plastic flow allowing melt generation and advection in consideration of depletion and enrichment. A fast upwardly transport of melt was substituted by extraction above a certain low porosity and emplacement of this melt and its heat in a given level. The equations of conservation of mass, momentum and energy for a multi component system are solved. High Prandtl number and compaction Boussinesq approximations are used. Finite Difference Method in an Eulerian formulation in 2D is applied in numerical modelling.

By MIW we conceive the mechanism of incipient melt generation in the upper asthenosphere by additional heating. Segregation of partial melt lump to regions with higher melt fractions. Exceeding 1% fraction melt is extracted and transferred energetically to a higher given zone. Repeated emplacement pulses weaken its vicinity and so advective heat transport is accelerated using temperature- and stress-dependent rheology. MIW is a positive feedback-system and may lead to reduction of viscosity and strength. Models with MIW leading to delamination need an emplacement zone around the Moho, weakening the uppermost strong mantle and the more sensitive lower crust by temperature increase attended by viscosity decrease.

To overcome this arbitrarily given level, we try to find a self-consistent evolving mechanism for the emplacement of excess melt. A relation to a physically describable process is intended. A long-term objective is to model the following findings from petrology and seismology.

From petrology, especially Foley and Link from our RiftLink group, proposals are suggested, that sub-lithospheric melts infiltrate lithosphere under certain conditions. Melt batches affect punctual the base of lithosphere or cratons and erode it from below. In multiple active phases veins rise up and solidify, changing their environment and improving pathways for subsequent events. Recently seismology, by name Wölbern also in our RiftLink team, made two reflective phases, distinct below Moho, visible with receiver functions. The upper phase at a depth of 50 to 60 km below the rift descending to ca 90 km outward is interpreted as a melt intrusion front or a metamorphized intra-lithospheric impregnation front (MIF) – a network of veins infiltrating the lithosphere from below growing upward with a front seismologically visible. The lower phase is identified as LAB, the lithosphere/asthenosphere boundary, dipping from about 140 km below the western rift to 200 km under Lake Victoria at the Tanzania craton.

An idea of a probable mechanism which complies our requests is presented in the following scenario: A branch of the plume under Tanzania craton provides additional heat located in an anomaly of the asthenosphere under the western rift branch. Melt production increases and accumulates in batches where the melt fraction exceeds a limit above which a fast and effective transport mechanism for melt is employed. This may be a network of mostly aseismic opening dikes, or of high permeable channels or of veins, a common phenomenon observed in geology. The viscosity of melt is several orders lower than the viscosity of the solid rock matrix and permeability is very high compared to that of segregation. During a time step the process has fully converged. Melt has rosen up to a certain height above the originating melt zone due to buoyancy and consolidated releasing its energy to the environment. The ascent height or effectiveness of transport may be controlled by the excess melt fraction. Material properties are altered, increasing permeability for the next event. Thus, a the front of altered mantle in correlation with metamorphized lithosphere should grow upward.

The proposed approach shall be implemented in the FD code. While writing this abstract development is at the beginning. We hope to present preliminary results at the workshop.