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An advanced mechanism driving Rift Induced Delamination: Melt Induced Weakening

Melt induced weakening (MIW) is studied as a driving mechanism for rift induced delamination. Under MIW we conceive the mechanism of incipient melt generation in the upper asthenosphere by additional heating. Percolation and accumulation of this partial melt lump to regions with high melt fractions, where above a certain threshold melt is extracted and transferred to a higher level, assuming short time scale transport mechanisms such as dyking or channeling. Repeated emplacement within the mantle lithosphere or even in the lower crust causes the melt's heat to weaken its vicinity and so advective heat transport is accelerated. Petrological and geochemical arguments (Foley et al., 2009) enforce this view.
Rift induced delamination (RID) has been proposed as a geodynamic process explaining the extreme elevation of the Rwenzori Mountains in the western branch of the East African Rift System (Wallner and Schmeling, 2010). The special situation of two approaching rift tips with a finite offset is given by the southward propagating Albert Rift and the northward spreading Edward Rift encircling almost completely the old metamorphic horst. We assume, upwelling asthenosphere below the rifts surrounds the stiff lithosphere; if there the viscosity and strength, especially in the lower crust, is sufficiently reduced, the delamination of cold and dense mantle lithosphere root may be triggered. As a consequence the less dense crustal block is unloaded and uplift is induced along steep inclining faults. Seismological observations, particularly seismicity distribution, low velocity zones seen in receiver functions (Wölbern et al., 2010) as well as in tomography and the location of an anomalously deep earthquake cluster (Lindenfeld et al., 2010) strengthen RID hypothesis.
Numerical modeling is based on thermo-mechanical physics of visco-plastic flow approximated by Finite Difference Method in an Eulerian formulation in 2D. The equations of conservation of mass, momentum and energy are solved for a multi component and two phase system. Temperature-, pressure- and stress-dependent rheology, based on laboratory data of appropriate samples are assumed for upper crust, lower crust and mantle.
Successful models applied a strong initial temperature anomaly within the lithosphere, driving the process. To replace this non-geological ad hoc initial condition, we test the more self-consistent MIW process. It is a positive feedback-system and may lead, if strong enough, to detachment of cold mantle lithosphere. Studies on parameter variations of the initial temperature perturbation reveal a restricted range for functioning RID models. The coincidence with the settings of the Rwenzori situation establishes the RID concept furthermore. Until now the Rwenzoris are the sole case where RID is applicable. To what extent this experience can be transferred to MIW is analyzed.

References

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