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The role of melt induced lithospheric weakening on the dynamics of continental rifting

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Active or passive continental rifting is accompanied by lithospheric weakening and thinning, ascent of asthenosphere and decompressional melting. Melt percolates through the partially molten source region, accumulates beneath its top and is extracted. After extraction it may either be extruded at the surface or intruded at any depth between the top of the melting zone and the surface. In case of intrusion the release of latent and internal heat heats up the lithosphere and weakens it. In a feed-back mechanism this weakening may assist rifting and melt production. First a one-dimensional kinematic lithospheric thinning model is developed including decompressional melting and intrusional magma deposition at shallower depth, as well as compaction and decompaction. The intrusional heating effect is determined as a function of lithospheric thinning rate and mantle potential temperature. It is found that the maximum temperature due to this heating effect increases approximately proportional to the square root of the thinning rate, which may be expressed as a thinning Peclet number and proportional to the square of the supersolidus potential temperature. Then, two-dimensional numerical extension models of the continental lithosphere-asthenosphere system are carried out based on Eulerian visco-plastic formulation. The conservation equations of mass, momentum and energy are solved for a multi-component (crust-mantle) two-phase (melt-matrix) system. Temperature-, pressure-, and stress-dependent rheology is used based on laboratory data for granite, pyroxenite and olivine, representing the upper crust, lower crust, and mantle, respectively. Rifting is modelled by externally applying a constant rate of extension. Model series are carried out in which the emplacement depth of extracted melts is varied between the top of the melting zone and the surface. In good agreement with the 1D kinematic models it is found that in comparison with cases without melt intrusions these lithospheric regions may be heated by up to several 100 K. Furthermore, this heating enhances viscous weakening by one order of magnitude or more. Consequently, in a feed-back mechanism rifting is dynamically enforced, leading to a significant increase of rift induced melt generation.