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The style of lithospheric extension influenced by magmatic underplating

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In the dynamic model of rifting, initial lateral heterogeneities are required in order to concentrate deformation in a particular area. That is, rifting itself shows deformation localization. In the previous dynamical modelling, such localization has usually resulted from locally thickened crust. In addition, magmatic underplating commonly observed along volcanic rifted margins might be an important origin of the localization as well. Volcanic passive margins have been known for displaying crustal evidence of high Vp velocity along their breakup axis. High velocity lower crustal bodies have been usually interpreted as mafic underplating formed during the continental breakup. However, few studies have attempted to investigate a role of magmatic underplating in rift and basin dynamics. In this study, a two-dimensional plain strain thermo-mechanical finite element model is constructed to investigate the effect of underplating on the concentration of extensional deformation.

We examine the dynamical response of the lithosphere to the applied constant velocity at the boundary of the model. The lithosphere is represented as a visco-elasto-plastic rheology, which includes brittle failure at low temperature and pressure and ductile flow at high temperature and pressure. The thermal and mechanical differential equations are coupled through the effective viscosity. As the first step in our investigation it is simply assumed that the underplated material is initially located at the base of the crust. Our modelling does not include melting processes, and instantaneous underplating is simply assumed in this study. Rheological weakening due to the underplating is brought about by the following two effects: (1) Higher temperature of underplating results in the weakening through the temperature-dependent viscosity and (2) the crustal composition of underplated material itself is significantly weaker than the mantle.

Our numerical results indicate that the extensional deformation is significantly concentrated at the region of underplating. The width of underplating directly controlls the width of the rift. The depth of underplating affects the deformation localization, in which shallower underplating leads to a higher degree of localization. The thickness and temperature of underplating also seem to be important factors which control the rift structure. Such dependencies are related to how much the lithospheric strength can be reduced by the underplating. Although more realistic modelling of melt generation during and prior to rifting remains as a matter to be investigated, this study suggests magmatic underplating is an important factor controlling the style of rifting. Further research on the effects of underplating might clarify a variety of rift dynamic problems, including asymmetric extension and/or depth-dependent stretching.