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The effect of mantle petrology on lithosphere dynamics during extension

N. S.C. Simon (1) and Y. Y. Podladchikov (1)

(1) Physics of Geological Processes, University of Oslo, PO Box 1048-Blindern, 0316 Oslo, Norway (nina.simon@geo.uio.no)

Studies of passive continental margins have revealed that the extending lithospheric mantle is progressively infiltrated by magmatic fluids and melts. These processes change the temperature and composition of the mantle and strongly influence the physical properties of the stretched lithosphere. The physical property that is most important for subsidence and uplift is density. The density distribution of the lithosphere is non-linear and discontinuous due to complex mineralogy and, most importantly, phase transitions. Here we evaluate the influence of changes in mantle composition on lithospheric density and behaviour during stretching.

Lithospheric mantle enters the plagioclase stability field if the crust is thin and the geotherm is relatively hot (stretching factor 2 to 3, depending on composition and initial configuration). This causes a large decrease in density (80-100 kg/m3). The extent of syn-rift uplift and post-rift subsidence recorded in the basin is directly proportional to the total amount of plagioclase in the column. This is controlled by the depth of the plagioclase-in reaction and the bulk Al2O3 in the mantle. The depth to which plagioclase is stable is mainly governed by bulk Na2O. Since Al2O3 and Na2O increase with increasing fertility of the mantle the effect of phase transitions on basin subsidence is most pronounced for relatively fertile mantle (and strong extension) and can exceed the effect of thermal expansion. The incompatible nature and strong mobility of sodium may lead to large changes in bulk Na2O during minor melting (Na extraction) or metasomatism (Na addition). The sensitivity of mantle mineralogy to variations in sodium can therefore cause sudden changes in density without changes in P-T regime. The combination of 2-D finite element deformation modeling and phase diagram calculations allows us to evaluate and quantify the feedback between geochemical variations and lithospheric stretching.