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Mantle phase transitions during rifting

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During stretching of the continental lithosphere, the density of the mantle column changes. In contrast to the simplification often used in geodynamic modeling, mantle density does not linearly decreases with increasing temperature, but is strongly pressure dependent and non-linear due to mineral phase transitions. The two phase transitions with the largest effect on peridotitic mantle densities are the garnet-out and the plagioclase-in transitions. The garnet-spinel peridotite transition leads to a moderate decrease in density of the mantle part of the lithospheric column at the initial stages of stretching, and might explain early syn-rift uplift followed by subsidence that is larger than expected from crustal faulting. When the crust is sufficiently thinned and temperature is relatively high, plagioclase peridotite becomes stable in the upper part of the mantle. The density reduction due to the plagioclase-in reaction is mainly controlled by the bulk aluminum content and the sodium/aluminum ratio. Since these elements decrease with decreasing fertility of the mantle the effect of phase transitions on basin subsidence is most pronounced for relatively fertile mantle (and strong extension), where the combined effects of the phase transitions lead to a density reduction by 2.3%. This is equivalent to heating the entire lithosphere by 700 ˚C if only the effect of thermal expansion on density is taken into account. The formation of plagioclase peridotite therefore can explain syn-rift uplift in sedimentary basins that experienced large mantle stretching without invoking an unrealistically strong increase in temperature. In general, density formulations dependent only on temperature significantly overestimate mantle densities for large stretching, while they underestimate mantle densities for small stretching, compared to thermodynamically and petrologically sound density calculations.