Late syn-rift (65-55 Ma) uplift in the Voring Basin, Norwegian Sea - was it a 'hot' or a 'cold' event?

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The Voring Basin is a large sedimentary basin province in the Norwegian Sea and is commonly described as a volcanic end-member of rifted passive margins. A series of rifting events since Permian-Triassic times resulted in structurally complex basins. A striking feature of the Voering basin is a regional uplift event during the last rifting phase (65-55Ma). The geologic process responsible for this uplift remains, however, enigmatic. A common explanation for uplift is strong differential thinning and possibly magmatic underplating. While this mechanism is theoretically viable it requires very high mantle stretching/thinning factors resulting in a high basement heat flow into the sedimentary section. We explore an alternative scenario, based on studies by Podladchikov et al. 1994 and Kaus et al. 2004, in which metamorphic phase changes in the stretched lithospheric mantle results in lower mantle densities and uplift. In this scenario, parts of the thinning lithospheric mantle cross the phase boundaries from dense garnet peridotite to lighter spinel/plagioclase peridotite. This 'cold' uplift scenario can lead to uplift at much lower stretching factors and a thereby lower basement heat flow as in the 'hot' scenario described above.

In this study we will focus on the structural evolution of the Voring Basin close to the Gjallar Ridge and use numerical modeling techniques to explore which scenario is more consistent with the observables. A two-dimensional forward model combined with an inverse algorithm for automated stratigraphy fitting is used to reconstruct the thermal and structural evolution of the Voring basin. Different reconstruction case studies that fit the observed stratigraphy are tested against other observables like subsidence curves and vitrinite reflectance. Both, metamorphic phase transitions and very strong mantle thinning reduce the effective density of the mantle leading to uplift. The resulting uplift and subsidence pattern are, however, different with phase transitions leading to rapid subsidence when the mantle transforms back into dense garnet peridotite during thermal re-equilibration. This and vitrinite reflectance, being sensible to paleo heat flow, can further help to discriminate between the 'hot' and the 'cold' model.

Our reconstructions show that it is possible to discriminate between the ‘hot’ and ‘cold’ scenario on the basis of vitrinite reflectance data and subsidence curves. In addition, a comparison with available geological background and well data suggests that the ‘cold’ scenario is more likely than the ‘hot’ scenario.