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Basin modelling of the complex multi-rift system on Southern Vøring Margin : mechanisms and implications

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Passive continental margins and sedimentary basins are key domains for understanding long-term geological processes driven by complex Earth dynamics, such as continental rifting, magmatism, and sub-lithospheric interactions. These processes shape regions and leave distinct, spatially variable imprints in the sedimentary record. Deciphering these records helps us understand the dynamic relationships between geological processes on passive margins and quantify the interplay among tectonic, magmatic, and sedimentary forces that influence basin architecture.

In this study, we model the thermal-kinematic history of the southern Vøring Basin, offshoreMid-Norway, along a regional 2-D transect, integrating basin- and lithosphere-scale processes through time-forward basin modeling and an automated inverse basin reconstruction approach. The results indicate that the evolution of the inner Vøring Margin can be explained by standard lithosphere extension models. However, these models fail to account for key observations at the outer volcanic province, such as regional uplift at breakup, excess magmatism, and higher geothermal gradients. These discrepancies suggest additional processes are involved. Excess magmatism and uplift may be linked to sub-lithospheric mantle processes, such as the arrival of the Icelandic mantle plume or small-scale convection. Melt retention in the asthenosphere, along with mantle phase transitions during extension, could enhance uplift.

The best-fit model must explain the following key observations at both the inner and outer margins: (1) observed stratigraphy and subsidence, (2) beta factors along the transect, (3) vitrinite reflectance, particularly the high %Ro values at the outer margin, (4) base Eocene paleobathymetry, with an emergent outer margin and structural highs, and (5) the interpreted magmatic underplate beneath the outer margin.

We test various tectono-thermal models that include or exclude these processes. Models incorporating a plume emplaced at Eocene time, accounting for magmatic processes like melt retention and underplating, successfully reproduce the observations at the outer volcanic margin. This supports the contribution of the hot Icelandic plume to the Vøring Margin's evolution.