Towards Dynamic Basin Inversion
Motivation, Approaches, and Some Results

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Sedimentary basins, hosting Earth's hydrocarbon resources, belong to the best studied tectonic settings on Earth. The mechanisms of basin formation have been extensively explored and decades of hydrocarbon exploration have created a unique database against which geodynamic rifting models can be tested. This has led to the situation that models are now able to reconstruct a basin's formation history and present–day tectonic structure. However, practicably all basin inversion models are either kinematic in their design or use joint back–stripping/fault–matching techniques; they are tuned to be consistent with the geologic data but may not adequately describe the dynamics of rifting.
Here we show the results of a case study from the Norwegian Viking Graben in which we make the case for dynamic basin inversion models. First, we use an advanced kinematic basin model (TecMod) to reconstruct the formation history of the Northern Viking Graben. We find that the inverse model is under–constrained when only using stratigraphy, heat flow, and palaeo water depths as inverse parameters. This becomes obvious when also incorporating vitrinite based palaeo temperature data into the reconstruction problem. Second, we review the case for accounting for mineral phase transformations during rifting. Mineral phase transformations have the potential to cause rapid syn–rift uplift if mantle material crosses the garnet/plagioclase phase boundary and rapid subsidence upon going back to the garnet stability field. In fact, basins with high stretching factors sometimes show such rapid uplift and subsidence events which 'conventional' models often fail to explain.
We take these insights as motivation to formulate a more advanced basin inversion model. This model is based an a dynamic deformation solver that accounts for viscous and elastic deformation and a temperature solver. Given the fully dynamic formulation of the model, we will be able to account for active rifting events, predict the stress state of the basin and consequently its dynamic pressure solution – which is essential for a more consistent implementation of metamorphic reactions. Furthermore, dynamic basin models have less input parameters which makes the inverse problem better constrained. This results in the situation that the dynamic basin models have the potential virtue of being more consistent, being able to account for the dynamics of coupled geodynamic and metamorphic processes and of having their inverse models better constrained. The back side of this development is that the key input parameters (e.g. rheology, chemical composition of the crust and mantle, thermodynamic parameters) are not very well known. However, here we show the first results of our work on dynamic basin inversion models. These results are promising and suggest that dynamic basin inversion is feasable.