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The Oslo Graben: a magmatic rift that 'failed'

T. Pedersen (1), I. J. Almaas (2)

(1) Institute for Energy Technology, Norway, (2) University of Oslo, Norway

The Oslo Graben in southeast Norway is the emerged northeastern part of the Late Carboniferous -Permian Oslo Rift. Magmatism started around 300 Ma and lasted until 240 Ma. The upper 1-3 km of the Permian upper crust has been removed during post-rift uplift and erosion, exposing an excellent view of the syn-rift rocks. Numerous petrological and geophysical (seismics, gravity) data in the graben suggest the existence of an about 10 km thick fossil rift pillow consisting of mafic rocks at about 20 km depth. Subtracting the thickness of this body, the overall crustal thinning yields a beta factor of 1.7-2.0. A numerical model that incorporates lithospheric extension, emplacement of hot mafic rocks at crustal levels and partial melting (anatexis) of the lower crust, also supports a thinning of about 50%. The stretching of the upper crust however, is much smaller than this (beta$<$1.05). We have calculated the total lithospheric strength evolution of the Oslo Graben using realistic rheological parameters for the crust and mantle. With 50% thinning there is a reduction in total lithospheric strength from around 9 TN/m pre-rift to 5 TN/m at 240 Ma. Including the mafic body yields a minimum total strength of approximately 4 TN/m. Consequently, it seems that failure of the Oslo Graben cannot be attributed to an increase in lithospheric strength during rifting. We put forward a model in which magmatism itself is a major driving force for the evolution of the graben. In this scenario, initial magmatism is triggered by e.g. movements along the Fennoscandian Border Zone, and the lowermost crust is thermomechanically eroded during rifting when the mafic magmas are deposited near the crust-mantle boundary. The hot lower crust experiences a significant reduction in viscosity making it prone to ductile flow, which may produce crustal thinning. The graben dies out when the potential for magma production is exhausted, either because the fertile mantle source has been used up, or because extra heat input to the graben due to for example secondary convection stops.