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Testing models of basin inversion in the eastern North Sea using exceptionally accurate thermal and maturity data

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One difficulty of testing models of basin inversion against data is that erosion has erased the stratigraphic record along the inversion ridge. The depth of erosion therefore cannot be determined. However, thermal maturity data may contain a signal of deeper burial in the past. Here we consider the thermal history information contained in high quality thermal maturity data comprising temperature profiles, vitrinite reflectance and apatite fission track data. Having remained open for experimental purposes, the data of two of the deep wells (Aars-1 and Farsoe-1) are of exceptionally high quality. Here, continuously logged temperature profiles have been obtained long after the cessation of drilling induced disturbances using a high precision (0.05K) quartz thermometer. Vitrinite reflectance and apatite fission track data have been measured on cuttings and cores by a consultancy.

The structural setting of the wells is the Sorgenfrei-Tornquist Zone (STZ) in the eastern North Sea of (mainly) Carboniferous-Permian origin. Additional minor extension episodes occurred during the Triassic, Jurassic and Cretaceous, mainly centred in the STZ. The STZ experienced strong compressional inversion during the late Cretaceous. A thick (c. 1600 m) late Cretaceous and Danian chalk sequence has recorded the associated marginal trough formation. A hiatus of duration c. 60 Myr follows until the deposition of thin Quaternary sediments. The question we address here is if the thermal data from the wells contain information about the magnitude of deposition and erosion during this hiatus.

We use Markov Chain Monte Carlo with a transient one-dimensional thermal model to explore the parameter space of potential thermal history solutions, using the different available data as constraints. The variable parameters comprise background heat flow, matrix thermal conductivity of sand, shale and chalk, and depositional and erosional episodes during the Cenozoic hiatus.

The results show that the data are consistent with none or very limited deposition and erosion during the Cenozoic hiatus after the late Cretaceous compressional inversion of the STZ. This is in agreement with numerical rheological models of inversion zone dynamics, which explain how marginal trough subsidence occurred as a consequence of late Cretaceous compressional inversion and erosion along the inversion axis (Nielsen et al. 2005, 2007). Following this, the in-plane stress in the European continent relaxed and the inversion structures experienced low-amplitude relaxation flexures, which, according to the thermal data of the wells, did not trigger significant erosion of the inversion structures and the proximal parts of the marginal troughs.

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Nielsen, S.B., Thomsen, E., Hansen, D.L. and Clausen, O.R., 2005. Plate-wide stress relaxation explains European Paleocene basin inversions. Nature, 435, 195-198.