Fault-controlled diagenesis and fluid circulation along a major syn-rift border fault system – insights from the Dombjerg Fault, Wollaston Forland Basin, NE Greenland

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In marine rift basins, rift-climax deep-water clastics in the hanging wall of rift- or basin-bounding fault systems are commonly juxtaposed against crystalline basement rocks in the footwall. Displacing highly permeable, unconsolidated sediments against low-permeable rock distinguishes these faults significantly from others displacing hard rock. Due to limited surface exposure of such fault zones, studies elucidating their structure and evolution are rare. Consequently, their impact on fluid circulation and in-fault, near-fault, and hanging wall sediment diagenesis are also poorly understood. Motivated by this, we here investigate a well-exposed strand of a major basin-bounding fault system in the East Greenland rift system, namely the Dombjerg Fault which bounds the Wollaston Forland Basin, NE Greenland. Here, Upper Jurassic and Lower Cretaceous syn-rift deep-water clastics are juxtaposed against Caledonian metamorphic basement.

Previously, a ~1 km-wide zone of increased calcite cementation of the hanging wall sediments along the Dombjerg fault core was identified (Kristensen et al., 2016). Now, based on U/Pb calcite dating, we are able to show that cementation and formation of this zone started during the rift climax in Berrisian/Valanginian times. Using clumped isotope analysis, we determined cement formation temperatures of ~30-70˚C. Temperatures likely do not relate to the normal geothermal gradient, but to elevated fluid temperatures of upward directed circulation along the fault.

Vein formation within the cementation zone clusters between ~125-100 Ma in the post-rift stage, indicating that fracturing in the hanging wall is not directly related to the main phase of activity of the adjacent Dombjerg Fault. Vein formation temperatures range between ~30-80˚C, signifying a shallow burial depth of the hanging wall deposits. Further, similar minor element concentrations of veins and adjacent cements argue for diffusional mass transfer, which in turn infers a subdued fluid circulation and low permeability of the fracture network. These results imply that the chemical alteration zone formed an impermeable barrier quickly after sediment deposition and
maintained this state even after fracture formation.

We argue that the existence of such a cementation zone should be considered in any assessments that target basin-bounding fault systems for, e.g., hydrocarbon, groundwater, geothermal energy, and carbon storage exploration. Our study highlights that the understanding fluid flow properties as well as fault-controlled diagenesis affecting the fault itself and/or adjacent basinal clastics is of great fundamental and economic importance.

References: