Tectonothermal evolution of East Greenland's petroleum systems: Insights from field and numerical studies

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The fjords of East Greenland boost spectacular exposure of Carboniferous to Cenomanian sediments cut and capped by ca. 55 Ma mafic intrusives and basalts. These rocks are formed and deformed through several tectonothermal events, some of which are of regional importance: (1) Late Jurassic to Early Cretaceous rifting, (2) pre-break-up rifting and erosion, and (3) subsequent break-up volcanism, (4) mid Cenozoic magmatism and translation of Jan Mayen from the Greenland to European plate, and finally (5) Late Cenozoic uplift and deep erosion. The mountains display exhumed oil traps (Price & Whitham, 1997), but standard basin models do not explain how these fields formed or were exhumed. Accordingly, tectonothermal models must consider the effects of the break-up and associated magmatism, and particularly the thermal effects of rocks now eroded both within the section (the sub-basalt unconformity) and above presently exposed sections (Eocene and younger rocks). In short, we must model the unknown or no longer existing sections.

We play a "what-if-game", where Turonian and younger geology of the Norwegian Sea is inferred into the missing section of East Greenland, in 2D basin models, and modeled uplift and erosion in 3D flexural isostatic models. Our combined field, geophysical and modeling efforts of broken margins suggests that:

(1) The East Greenland plays in the Traill Ø region can only be understood if sections now below and above the basalts are included in models, even though these sections are eroded now. Maturation stopped in the Mid Cenozoic, due to both erosion and diffusion of break-up heat. Had East Greenland been buried under the Norwegian post-basalt setting then its prospects would have been extraordinary.
(2) The remarkable Jurassic to Cretaceous rift sequence at Hold With Hope appear not to have been buried under the quite as thick basalt and post-basalt strata.
(3) It is crucial to understand the processes that lead to uplift of the Mesozoic marine sediments exposed in the mountains of East Greenland. Our calculations show that East Greenland from Scoresby Sound and northwards was uplifted due to erosional, thermally-independent, processes, whereas the uplift of Cretaceous marine sediments and > 3 km high mountains south of Scoresby Sound remains enigmatic.
(4) Cenozoic intrusives and extrusives dominate hydrocarbon maturation locally, but do not mature regional-scale basins. In contrast, asthenospheric upwelling between broken continental plates had strong effects on both the past and present water depth and thermal exposure.
(5) Basalt can be highly conductive, whereas the porous Cenozoic ooze insulates the underlying strata. Variations in the thermal parameters of these rocks are exceptionally important for sub-basalt basin models.

"What-if-games" of this kind cannot prove scientific hypotheses or play concepts, but they can rule out some models, and test the outcome of others. Therefore, we suggest that combining fieldwork, offshore geophysical methods, and numerical models across margins stimulate scientific thinking and exploration models.