Thermo-tectono-stratigraphic modelling of rift margins and implications for the petroleum systems: insights from mature and young basins

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The Red Sea is an active rift system that initiated in the late Oligocene between the Arabian and Africa plates. Hydrocarbon exploration in the Red Sea has focused largely in the northern, shallow water Gulf of Suez region, where more than 1500 exploration wells have been drilled since the 1880's, resulting in numerous discoveries and estimated reserves in excess of 10 bboe. Several discoveries have also been reported along the southern Red Sea, between the onshore and the deep offshore. Together with widespread seeps and shows, these suggest prevalent working petroleum systems in the region, and a recent licence round covering most of the Egyptian Red Sea attracted several major oil and gas exploration companies.

The structural and tectonic setting changes significantly between the northern Red Sea Gulf of Suez and Gulf of Aqaba, and the southern Red Sea, showcasing a large diversity of rift-related features, including syn-rift faulting and subsidence, high geothermal gradients, salt deposition and halokinesis, magmatism, rift flank uplift, post-rift transpression and exhumation, continental break-up and rift margin asymmetries. The Red Sea is thus a unique natural laboratory to understand the early stages of rifting and onset of seafloor spreading. On the other hand, the available constraints on the deep structure of the basins, crust and upper mantle are scarce, and useful insights on the geometry and dynamics of rifting could be learned from more mature rift settings.

In this study, we apply a thermo-tectono-stratigraphic basin reconstruction modelling technique (TecMod-2D, Geomodelling Solutions, GmbH) to seismic transects in different sectors of the Red Sea, to put constraints on the basin-forming processes and evaluate the implications for the known (and/or speculative) petroleum systems. TecMod-2D solves simultaneously for basin-scale (e.g. sedimentation, compaction, maturation) and lithosphere-scale (e.g. crust/mantle thinning, break-up, flexure, serpentinization) processes, and iteratively inverts for the stratigraphy, and has been successfully applied in a number of rift basins and passive margins, such as the North Sea (Norway), the Porcupine Basin (Ireland), the Gulf of Mexico (Mexico) and the South Atlantic Margins (Angola-Namibia), allowing to quantify the impact that rifting style and detailed deposition history has on paleo-heat flow and thereby maturity evolution. These basins are (in places) extensively surveyed, host mature petroleum systems, and share a number of the distinctive features of the Red Sea, therefore providing valuable proxies for the understanding of this rift system and the evolution of the petroleum systems.