Petroleum System Modeling and Prospectivity of the Red Sea Basin, Sudan

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To date, the Sudanese Red Sea, like the Red Sea as whole, represents a grossly under-explored petroliferous basin. Recently, the basin has seen increased exploration interest, with more than 15 wells being drilled, some of which have been petroleum discoveries (gas and condensate with oil shows). A similar exploration trend has been seen in the Saudi and Eriteria sectors of the Red Sea. The Red Sea rift marks the break-up of the Afro-Arabian plate in Eocene-Oligocene time. The tectonostratigraphic evolution can be subdivided into three major phases: Pre-rift, Syn-rift and Post-rift phase. Generally, fluvio-deltaic and marginal to fully marine sediments were deposited with both good reservoir quality and potential source rocks being present. In the Red Sea, the principle exploration plays are in the Miocene synrift, and pre-salt and post-salt post rift successions. The pre-Salt Rudeis-Kareem shales are expected to be good petroleum source rocks for the basin. Moreover, shales of base Zeit (post-Salt) are considered the main source of the known accumulated hydrocarbon (gas and condensate) in the shallow targets. The measured amount of TOC, HI, and hydrocarbon generation from pyrolysis of kerogen of the examined samples indicates the source rock generative potential of these intervals. The Red Sea's high pressure and temperature regimes have a significant impact on hydrocarbon maturation, generation and the quality of accumulations preserved. The salt tectonics makes for challenging exploration. The Salt movement is considered recent as it is only the recent sediments that appear to be controlled by salt movement. In this study, 1D and 2-D petroleum system modeling has shown that the two source beds are thermally mature for hydrocarbon generation. The Rudiies Formation is currently in the gas window and has probably completed all its potential hydrocarbon generation. The Zeit source varies in maturity across the basin. This paper presents and discusses the results from organic petrological and organic geochemical analyses of more than 7 exploration wells. Moreover, the results of 1D and 2-D petroleum system modeling for thermal, burial histories and hydrocarbon accumulation prediction are also shown.

The TOC contents for base Zeit and interbeded shales of Dungnab Formation range from 0.60 - 5.40 wt. %, while the hydrogen index (HI) values are in the range of 50-300mg HC/g TOC suggesting dominantly type III and type III-II kerogen. The values of TOC and S2 observed in the Suakin-1 well explain the condensate (API 52o) discovered in this well. Consequently, the source rocks are considered good - very good for condensate and gas generation. Based on these geochemical results, the source of condensate in the Suakin-1 and Bashayer-1 dry gas discoveries is probably in the lower part of the Zeit Formation, an organic-rich, deltaic-shallow marine facies. However, oil generation from Rudeis-Kareem cannot be ruled out based on the oil shows encountered in many drilled wells, where migration through salt windows is possible.

Vitrinite reflectance (VRo) in the range 0.64-1.3% and Tmax values ranging from 423-450°C suggest post salt source rocks are thermally mature for oil and gas generation. Due to the minimal exploration activities in the Red Sea basin, the distribution of potential petroleum source rocks is not fully understood. The imaging of the sub-salt is a main challenge in pre-salt target recognition. Hence, this paper hopefully will spark regional interest among Red Sea Basin countries and lead to collaboration to investigate the deeper targets since all previous activities were focussed on the marginal and shallower sectors.