

# Sudan's Red Sea Oil



The Sudanese Red Sea is one of the world's most exciting underexplored passive margins. Here, we show how legacy 2D seismic reveals a stunning array of super-giant syn-rift plays in the pre-salt, capped by halite walls and canopies, in addition to mini-basins in a proven post-salt fairway.

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As explorers, we often find that the ground work of frontier hydrocarbon system evaluation is completed with heroic efforts on early basin wells, but that is then followed by an exploration pause.

The early 1960's wells offshore Sudan proved the existence of a working hydrocarbon system, proved numerous pre-salt and post salt source rocks,

defined geothermal gradients and the stratigraphy, whilst proving the presence and effectiveness reservoirs.

Ultimately, success came in the 1970's for **Chevron** with the gas and condensate discoveries of **Bashayer-1** and **Suakin-1**. However, these discoveries had unfortunate appraisals and exploration subsequently stalled.

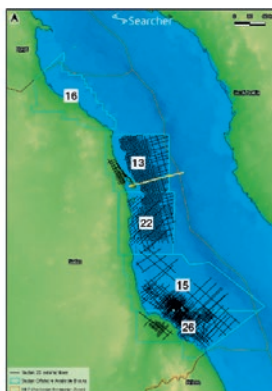
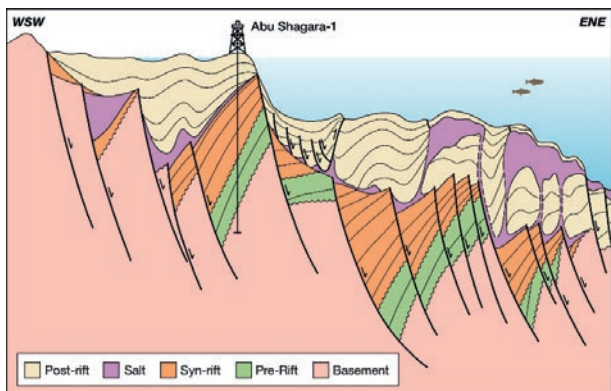
## RED SEA SOURCE AND SALT

Source rocks proven in many of the wells drilled in Sudan's Red Sea province are

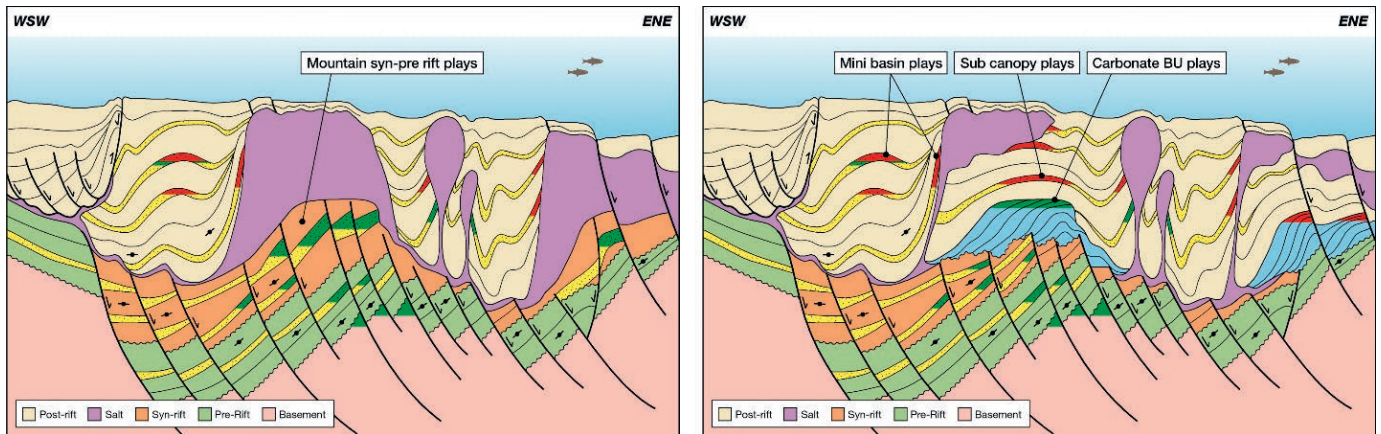
found to have similarities to the prolific Gulf of Suez source rocks. The **Oligocene Hamamit Formation** (broadly equivalent to the **Thebes Brown Limestone** of the GOS) has 1.7-5% TOC, and the Middle and Early Miocene source rocks have TOC's up to 2%. Zeit Formation equivalent source rocks in the post salt are likely to have charged discoveries in the mini-basin play.

There were three major cycles of thick halite deposition in the Miocene, separated by evaporite and clastics in sequences not unlike the **South Gharib** and **Zeit** formations of the **Gulf of Suez** (GOS). Halokinesis of these thick salt bodies due to loading and extension commenced during the syn-rift, and as drift began and the post-salt mini-basins began to slide into the basin, this mobilized salt evacuation seawards into drift-space.

These Late Miocene-Pliocene mini-basins rapidly developed into welded sequences creating both turtleback traps in addition to the salt wall lick-up plays. The recent interpretations of the outboard salt suggest that the evaporitic succession was loaded so much in the Pliocene that salt was erupted onto the sea bed and submarine salt-glaciers flowed from these eruptive centres which now are represented as salt canopies in the section (see cross-sections).



Situated between Egyptian, Saudi Arabian and Eritrean waters on the western side of the Red Sea, the 57,000 square km of margin offshore Sudan is barely explored: just 14 wells were drilled, mostly pre-seismic. The cross-section shows AGIP's early 1963 Abu Shagara-1 well drilled on a prominent tilted fault block. It encountered gas shows in thick syn- and pre-rift sands and conglomerates below a thin salt interval. Figure drafted after Sudan's Ministry of Energy and Petroleum information pack on Block 13.



West-East dip sections across Sudan's northern offshore (Block 13). Pre-salt syn- and pre-rift targets either lie below thick salt walls (left) or below thinner salt canopies (right). Neither of these models have been tested in Sudan, although the intra-salt mini-basin play was successfully drilled in the **Suakin-1** gas condensate discovery in the Miocene Zeit equivalent in the southern Sudanese Red Sea. Figure after Sudan Ministry information Block 13.

## RED SEA SEISMIC

Determining whether the salt is present as thick salt walls (such as the Amber structure drilled in Eritrea) or as thin salt canopies over super-thick syn-rift sections, is not unequivocal using legacy data.

To resolve this, **Searcher** plan to acquire 6,000 square km of 3D over this area in 2023. The salt thickness is key to understanding the maturity of the various source rocks as geothermal gradients measured in well penetrations vary from 35 to 47°C/km, yet none of these wells show the temperature below salt walls. The high thermal conductivity of salt will transmit heat from deep basins into the shallow section, both above the salt and adjacent to it.

Searcher has now rectified over 40,000 km of 2D seismic data into a **sAismic project** to help plan for the 2023 3D seismic campaign. These data are now available for industry Licensing.

Interpretation of this data set has revealed that a series of huge structures (known as the "mountain prospects") can be mapped out at Base salt or Top early syn-rift level (see cross-sections). These highs comprise pre-rift and early syn-rift clastics, with in excess of 1 km relief and hundreds of square km in areal closure.

There is potential (as yet speculative) for these "mountains" to include carbonate build-ups. Above these pre-salt mountains lies either thick salt (and perfect top seal) or thick evaporite and clastic sequences that are themselves capped by Gulf of Mexico style salt canopies. Situated in between the salt walls are drift mini-basins. These are similar to, though structurally less complex, than the **Suakin-1** condensate discovery.

To the north, Egypt's Red Sea has become a focus of exploration efforts again with a successful licence round and award of licences where phenomenal repeating oil slicks have been captured in satellite image studies.

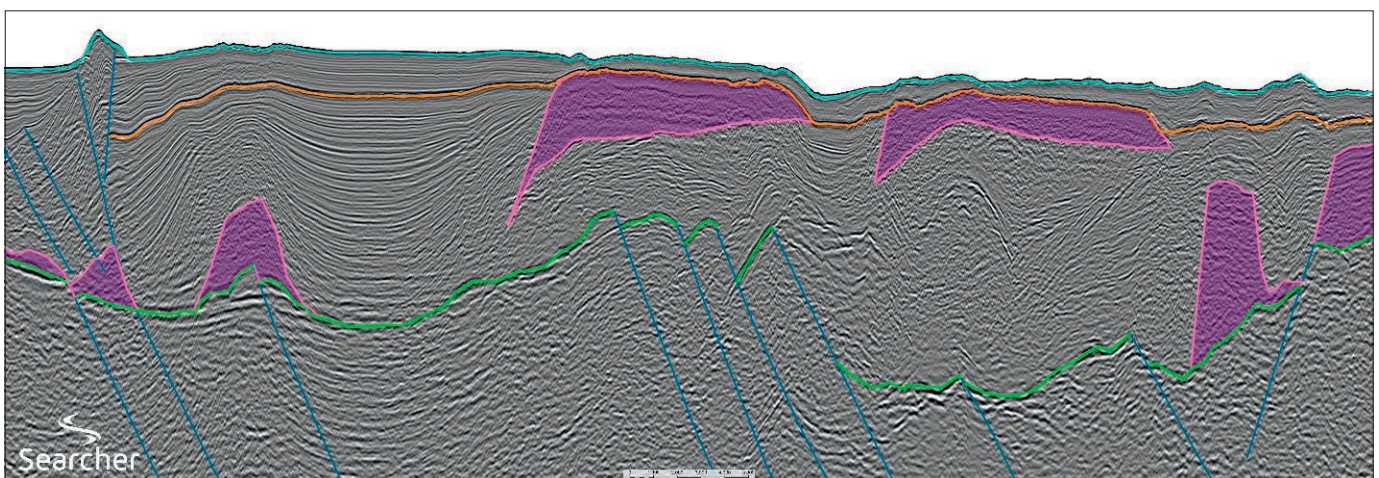
These world-class oil slicks reappear over the mountain prospects of Block 13 in Sudans Red Sea (Clément Blaizot pers. com. 2021).

## RED SEA RISING

Multiple prospects are mapped on legacy seismic but new 3D is required to image salt and understand hydrocarbon system development. That is the next piece to the offshore Sudan oil puzzle to be provided with Searchers forthcoming 3D acquisition. These will be the final step on Sudan's Red Sea's journey to offshore exploration greatness as they prepare for drilling the vast pre-salt and mini-basins plays in this soon-to-be super basin.

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References published online. ■



Example West-East legacy seismic line across Sudan's northern offshore (Block 13). Interpreted salt is "canopy" model (see cross-section). The highs at "green reflector" comprise the 'Mountains' prospects. Seismic data from Searcher.