Submitted Abstract

From Plate Tectonics to Basins, Plays and Risked Barrels, Offshore Somalia

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Introduction

The conjugate and passive margins of continental Africa evolved in a variety of ways through the Jurassic and Cretaceous as the palaeocontinent of Gondwana broke up. An understanding of the character of the margins and the basins that evolved along them has proven critical to understanding the controls on the development of petroleum systems, and most specifically source rock distribution, in those basins.

An interpretation of the petroleum system on the passive margin of the Somali coast was developed by modeling the evolution of the three sub-basins within it: The Jubba Deep, Mogadishu, and Mid-Somalia High (Figure 1). The basin model was underpinned by the development of a new Plate Tectonic visualization using the UTIG Plates model (Plates Project, 2020) for the margin that evolved as Madagascar separated from Africa, and the subsequent separation of India.

Regional gravity and Magnetic data and a sub-regional 2D seismic data set were used to constrain the Plates model, Figure 2)

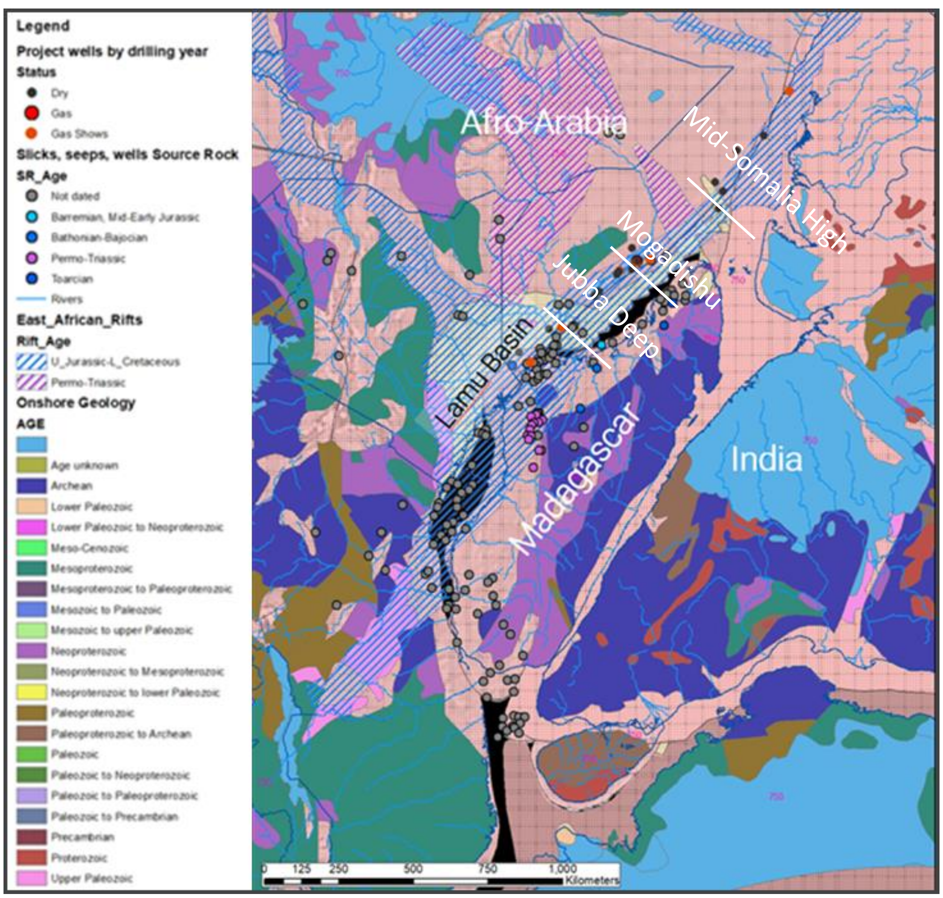

Figure 1 *Proprietary plate tectonic reconstruction with source rock penetrations, slicks and outcrop source rock locations restored to their position at 175 MA, while continental Africa is fixed in its current position.*

Methodology

Gravity, magnetic and 2D seismic data were available for the study (Figure 2).

The methodology of integrated interpretation of iterative Plate Tectonic reconstructions to build an understanding of large-scale basin evolution was developed during a period of intense investigation and massive investment into the petroleum systems of the North, Central, and South Atlantic margins in the 1990's - 2010's. During this period, high resolution satellite gravity and multibeam bathymetry data collected by international academic community, and first mega-regional deep record seismic data set was collected in the South Atlantic. Major discoveries in the subsalt of the Santos basin in Brazil drew interest to the conjugate margin of Africa and models were developed to better understand the evolving relationships between the two margins, leading to the Cameia discovery in the Kwanza basin of Angola. The authors used a similar approach to understand the East Africa continental edge and relationship between the Somali and conjugate Madagascar basins (where more well and seismic data are available).

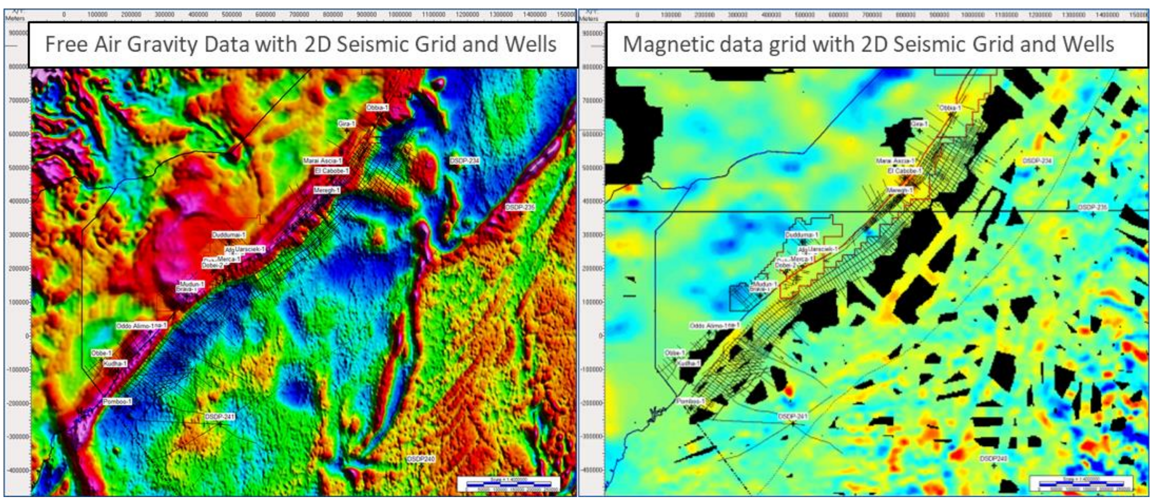

Figure 2 *Project database of gravity, magnetic and 2D seismic data used to constrain iterative interpretations of the UTIG Plates model*

Results

Madagascar rifted from Afro-Arabia during the Jurassic with two distinct periods of margin extension (Figure 3):

1. NW-SE continental rifting in the Lower- to Middle-Jurassic (200-170 Ma) and early oceanic rifting in the Middle- to Upper-Jurassic (170– 145 Ma).
2. Predominantly N-S strike-slip dominated separation in early Cretaceous until about 115 MA when the Madagascar rifting stopped.

The recognition of a change in rift orientation differs from prior interpretations (e.g. Reeves, 2018), and is significant to understanding the evolution of the petroleum system. These episodes of rifting created the accommodation space into which source and reservoir sediments were deposited in carbonate and clastic environments in both the Jurassic and Cretaceous.

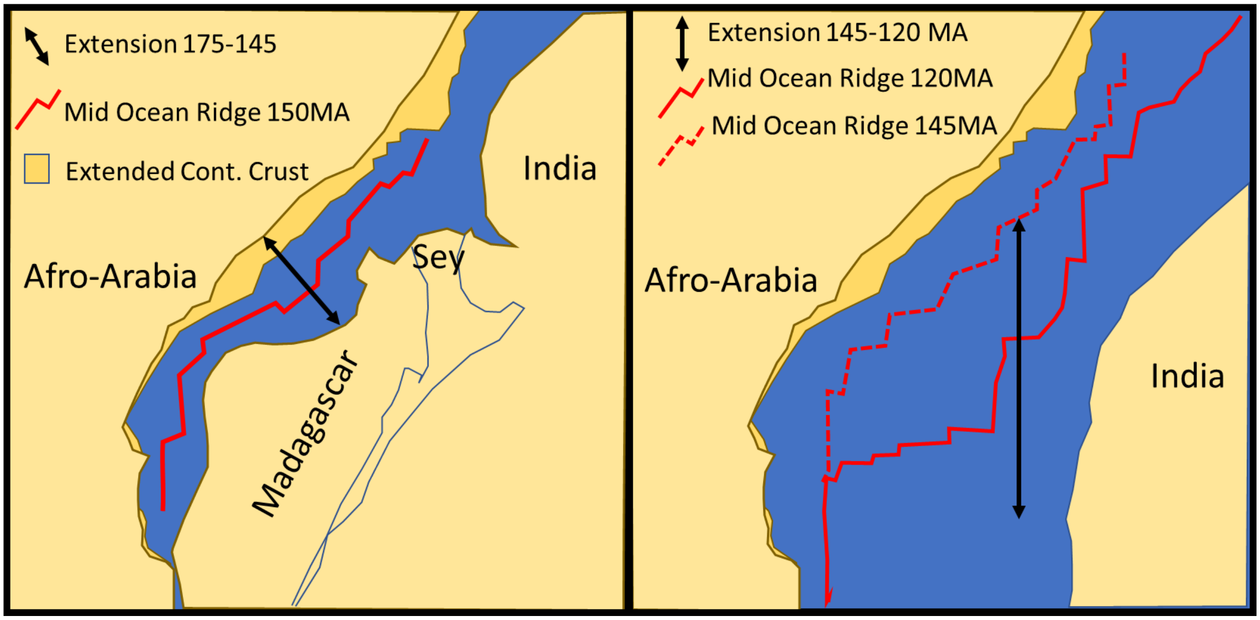

Figure 3 *Comparative extension directions and mid-ocean ridge positions for early and later Jurassic rifting between the Somali and Madagascar margins in the modified plate model from UTIG*

Sedimentation in the early phase of deformation, comprising the pre-rift, rift, and well-developed Sag intervals of Mid to Late Jurassic age are observed on regional seismic data. (Figure 4). This was the period when source rocks were deposited, predominantly in the sag phase, and carbonate reservoirs were deposited in the drift phase (Figure 4).

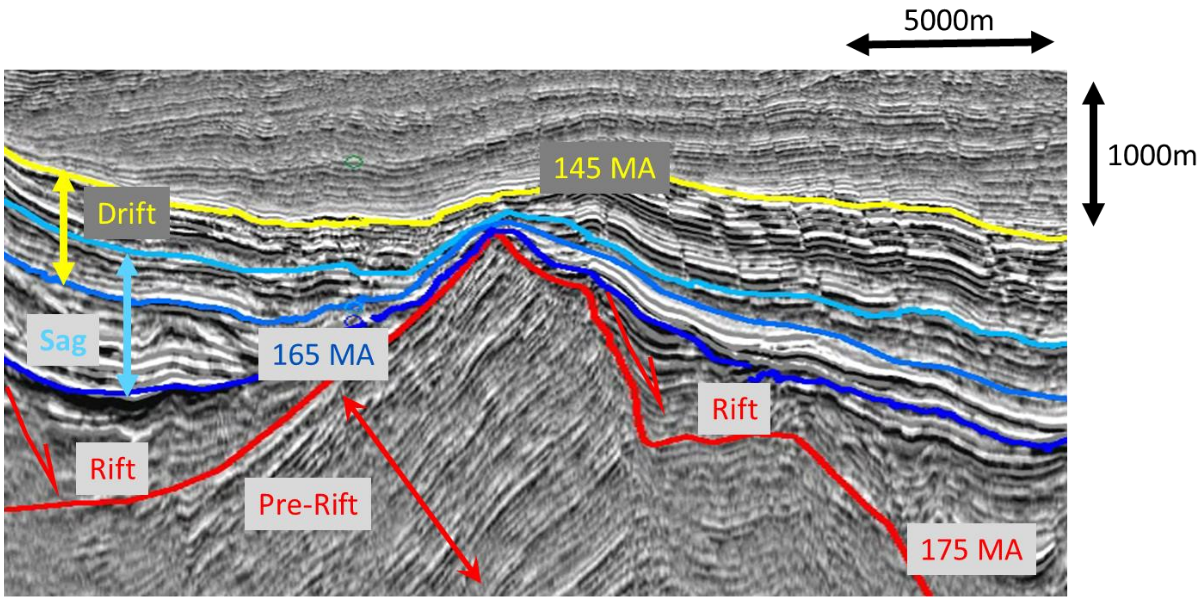

Figure 4 *Geometric relationships define the phases of sediment deposition in the active rifting and immediate post-rift phases when source and potential carbonate reservoir sediments were deposited.*

During the Lower Cretaceous, ca. 120 to 90Ma, the passive margin was relatively quiescent, with clastic input from small drainage systems along the low-relief African margin to the north-west, and more significant input in the south from the Anza Graben, which provided sediment to the Jubba Deep and southern part of the Madagascar Deep.

The evolution of the Somalia passive margin differs from that of the Madagascar conjugate because there were a number of phases of inversion, which appear linked to transforms in both the early and later rifting phases. These provided both the locus of later deformation and define the long-lived distinction between the three sub-basins of Jubba Deep, Mogadishu and Mid-Somalia High.

The earliest inversion is interpreted on the Mid-Somalia High, where latest-Jurassic to earliest Cretaceous uplift (ca. 140Ma) resulted in erosion of the carbonate footwall and erosion/deposition in the adjacent rift basin. A major trigger for Late Cretaceous/Early Palaeogene deformation on the margin was far-field stress imposed on the margin by the Seychelles and India rifting. This episode, lasting from 90Ma till 65 Ma put the basin under compression and caused the significant inversions observed on the seismic data. These structural inversions of sediment depocenters created a focus for hydrocarbon migration into Cretaceous and Early Tertiary structural and stratigraphic traps.

Similar inversion is also seen on the continental side of the margin, where Palaeogene uplift of the Bur Massif was a source of clastic reservoir deposition in the Mogadishu and Northers Jubba Deep areas.

Conclusions

The offshore Somalia deep water basin is subdivided into three subbasins, from north to south, the Mid-Somalia High, the Mogadishu, and the Jubba Deep (which extends into the Lamu Basin in Kenya).

The development of these basins was controlled by the different nature of the basement type, which in turn relates back to the rifting history of the basin. The Jubba Deep/Lamu basin is floored by the proto-oceanic crust formed in the earliest rifting phase of Afro-Arabia and Madagascar separation. Contemporary rifting in the Mogadishu Deep basin formed an early transitional-oceanic crust while at the same time the Mid Somalia High experienced continental rifting and retains a continental basement.

The difference in basement types, subsidence and inversion history has controlled the sediment types, accommodation/deposition rates for clastic sediments and the aggradation rates for the carbonates. As a result, the Mid-Somalia High, Mogadishu and offshore Lamu/Jubba Deep subbasins have distinctively different petroleum exploration risk profiles. Exploration plays and drillable targets must be analyzed and risked in this context.

References

PLATES Project [2020] UTIG https://ig.utexas.edu/marine-and-tectonics/plates-project/

Reeves, C.V. [2018] The development of the East African margin during Jurassic and Lower Cretaceous times: a perspective from global tectonics. Petroleum Geoscience 24(1) 41-56.