The Tectonic Framework and Reservoir Geomorphology of the Syn-Rift Sequence, Offshore Benin Basin - Implications for further Basin Exploration

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ABSTRACT

The Nigerian sector of the Offshore Benin Basin has been relatively unexplored compared to the prolific Niger Delta Basin, located to its eastern margins. In comparison to the other basins within the Gulf of Guinea Petroleum Province (namely e.g., Ivory Coast, Tano, Central, Saltpond, and Keta Basins), there is currently only one producing field in the Offshore Benin Basin. The recent discovery of commercial quantities of gas within OPL 310 located several kilometers offshore of Lagos has sparked interest in further basin exploration to support growing industrial activities within the region. In this study, the tectonic and stratigraphic framework of the Neocomian Syn-rift sequence has been evaluated to understand the controls on trap formation, reservoir deposition, and hydrocarbon trapping styles. Using regional stratigraphic information, well, and 3D seismic reflectivity data including additional seismic inversion volumes, a detailed interpretation and reservoir characterization study was carried out to identify prospects for new exploration drilling. The results of the study indicate a strong influence of transform tectonics on reservoir geomorphology, following the rifting and break-up of the African and South American platesin the Cretaceous times. Reservoirs have been deposited as drift-related sedimentary wedges on basement highs with source rocks found in thick sequences formed in the intervening half grabens. Several potential leads were identified. The evaluation of the basin adds to the growing knowledge of the petroleum geology of the Benin Basin using modern 3D seismic attribute data, which up till now had been dominated by outcrop studies and sparse regional 2D seismic data.

Keywords: Basin, Syn-rift, Sequence, Inversion, Prospect, Neocomian, Transform, Wedge, Graben, Plate, Embayment.

INTRODUCTION & STUDY OBJECTIVES

Benin Basin is located in the Gulf of Guinea Province which stretches across several West African countries. To date, there is limited exploration and hydrocarbon production in the Nigerian portion (Benin Basin) in comparison to the other basins within the province.

However, the recent discovery of commercial quantities of oil and gas in Upper and Lowers Cretaceous reservoirs in shallow waters offshore Lagos has sparked interest in further basin exploration and development see Figure 1.

This study therefore, is aimed at understanding the tectonic framework and controls on sedimentation & hydrocarbon occurrence to guide future exploration efforts.

Figures 1: Hydrocarbon Fields, Gulf of Guinea Province (after (Petroconsultants, 1996) In Brown and Charpentier 2006).

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Offshore Benin Basin – Regional Geologic Setting / Hydrocarbon Potential

Our study area is OPL-310 which is in the Benin Basin and located in the Gulf of Guinea Petroleum Province, Offshore West Africa. As shown in Figure 2. Gulf of Guinea Petroleum Province comprising of other basins such as the Ivory Coast, Tano, Central, Saltpond, Keta, and Benin Basins and the Dahomey Embayment (Brownfield and Charpentier 2006, Dumestre (1985), Kjemperud and others (1992), Tucker (1992), and Chierici (1996).

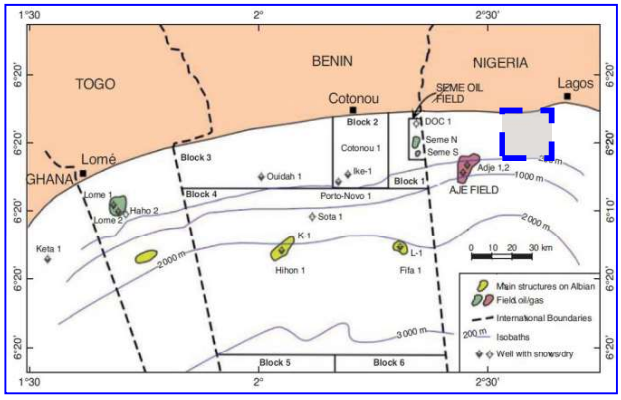
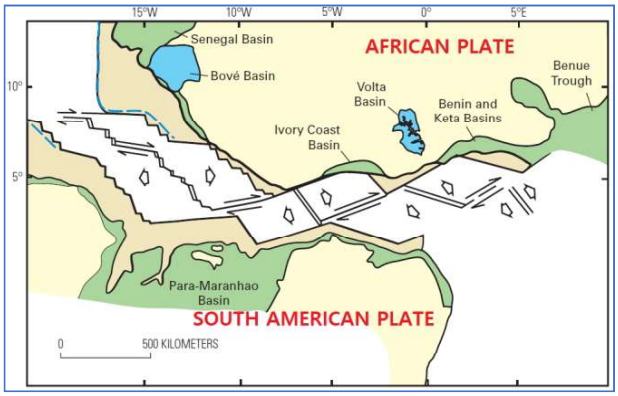


Figure 2: Located in the Gulf of Guinea Petroleum Province, Offshore West Africa comprising the Ivory Coast, Tano, Central, Salt Pond, Keta, and Benin Basins and the Dahomey Embayment.



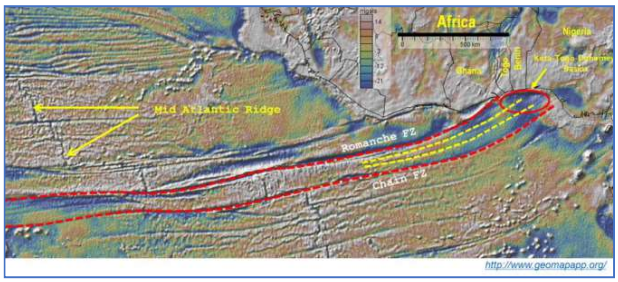


Figure 3 A&B: Tectonic and Evolution of GoG.

Tectonic Framework & Controls on Deposition

The Gulf of Guinea Province is divided structurally by three major transform fault zones:
(1) St. Paul fracture zone along the northwestern boundary, (2) Romanche fracture zone that separates the Ivory Coast and the Central and Saltpond Basins from the Keta Basin, and (3) Chain fracture zone along the eastern boundary (See Figure A & B).

Transform Faults constitute boundaries that delimit the structural basins within the province.
Both are aligned generally east-west, with north-south structural arches. The tectonic evolution of the Gulf of Guinea is in 3 stages:

- Pre-Transform Stage (Pre-rift or intracratonic)
- Syn-Transform Stage (Synrift of just rift)
- Post-Transform Stage (post rift or drift stages)

Overview of Exploration Prospectivity

The study area is located in Offshore Lagos, West Africa in water depths of 200 – 1000m. Limited Well Penetration (2 wells) with additional input from the neighboring producing field. Within the field are different geologic environment - (Cretaceous / Neocomian Basement) compared the nearby well-studied Niger Delta Basin. Preponderance of outcrop studies focused on Dahomey Flank offers some insight to this study yet limited (Brownfield, M.E., and Charpentier, R.R., 2006., Jibrin *et al* 2017, Jonathan *et al* 2017).

We have up to 23 wells that penetrated the Cretaceous in Nigeria and Benin Republic sectors of the Dahomey Basin. In the Keta basin about 10 wells penetrated the cretaceous. The synrift under this study was only penetrated by just 2 well Aje-04 and Ogo-02. No report so far shows hydrocarbon production in the offshore Dahomey Basin. Therefore, prospectivity remains largely a challenge due to limited data, hence this study is to unravel the conceptualframework of the play.

Study Result

From this study we evaluated and interpreted the 3D seismic data (high-resolution) and some seismic attributes from which the syn-rift fault and the stratigraphy were delineated (see figures 4, 5 and 6). The structural controls and the syn-rift play concept were analyzed. And all the results put together showed that thickness of the syn-rift depositional sequence shows a correlation between the interpreted wedges and the underlying basement highs. The seismic section reveals a more complex interplay of horsts and grabens within the prospective syn-rift wedges. This helped to map the prospects in this syn-rift section. The structure and play distribution also show a strong correlation with reservoir characteristics study.

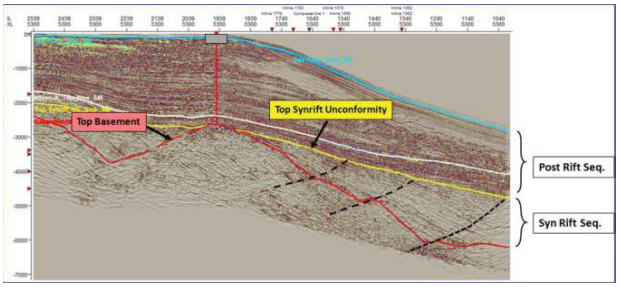


Figure 4: Seismic section showing Syn-Rift Play Concept.

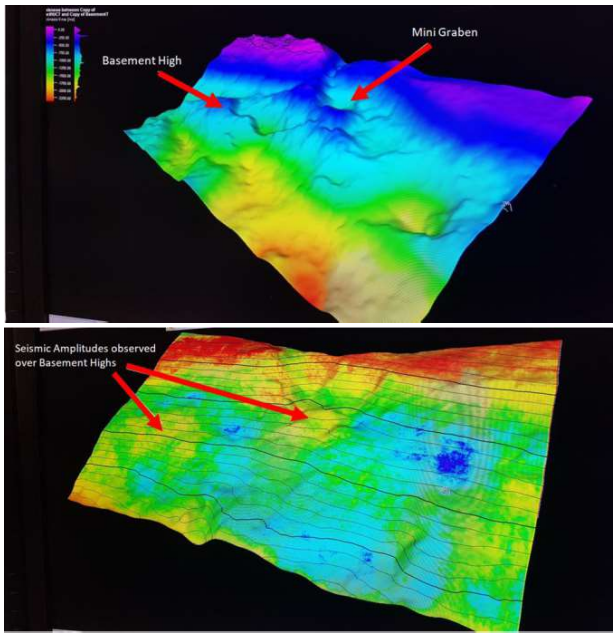


Figure 5: Thickness of the syn-rift depositional sequence showing a correlation between the interpreted wedges and the underlying basement highs.

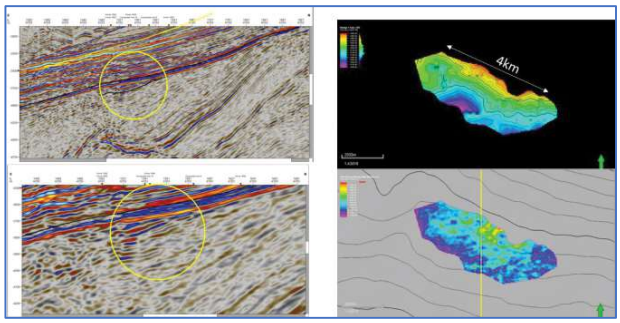


Figure 6: Application of Syn-rift play concept in prospect mapping.

IMPLICATION FOR EXPLORATION

1. Despite the availability of large swaths of seismic data across Offshore Benin Basin, there is limited Well Data (<10 wells) to adequately calibrate and refine the subsurface understanding.
2. Most of the existing wells only penetrated the post-rift sequence, further increasing the uncertainty in the applicability of the observed trends in this study beyond the study area.
3. The results of the seismic interpretation and visualization have helped identify prospective areas for detailed maturation studies. However, additional QI/AVO studies would be required for adequate de-risking.

CONCLUSIONS

1 Basin Formation within the Syn-Rift sequence is largely controlled by the underlying basement tectonics. Whilst the major fault trends have been influenced by the regional transform faults, minor basement lineaments have also resulted in the formation of mini horst & grabens within basins.
2. Stratigraphic wedges deposited as High stand high-relief Deltas upon the basement highs form the most prospective zones for hydrocarbon exploration.
3. It is unclear if the observed seismic amplitudes are related to reservoir presence/quality or due to hydrocarbon occurrence. So, additional seismic attribute evaluation or additional well data is required to calibration or to know what the amplitudes represent?

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