

Beyond the Shelf: Why Deepwater Benin is the Next Big Play

Introduction

Deepwater Benin, situated within the Dahomey Embayment presents a high-potential hydrocarbon exploration frontier. The Dahomey Embayment, part of the West Africa Transform Margin (WATM), encompasses the Keta basin across eastern Ghana, Togo, Benin, and western Nigeria (Figure 1). Extending from onshore to deepwater, it has seen minor hydrocarbon discoveries on the shelf and slope. These discoveries confirm the presence of active petroleum systems within the margin.

However, its deepwater environment remains largely unexplored, presenting significant frontier opportunities for future exploration. Two distinct petroleum systems characterize the Dahomey Embayment. The first comprises Devonian to Neocomian source rocks that generate hydrocarbons to charge Devonian and Cretaceous reservoirs, primarily onshore and across the shelf. These include Turonian, Cenomanian and Albian reservoirs in fields such as Seme, Ogo, and Aje, charged by Neocomian source. The second system involves Lower Cretaceous Albian and Cenomanian source rocks, which charge hydrocarbons to Cretaceous reservoirs on the slope and deepwater settings. Proven by discoveries like Hihon-1 and Fifa-1, these source rocks exhibit sufficient maturity and are analogous to productive sources in the Tano basin. The proven maturity of Cretaceous source rocks in deepwater Benin elevates this region as a premier exploration hotspot, underpinned by extensive channel and fan systems that promise substantial hydrocarbon potential. The thick sedimentary sequences observed on seismic in deepwater Benin, mitigates concerns about source rock immaturity in this setting.

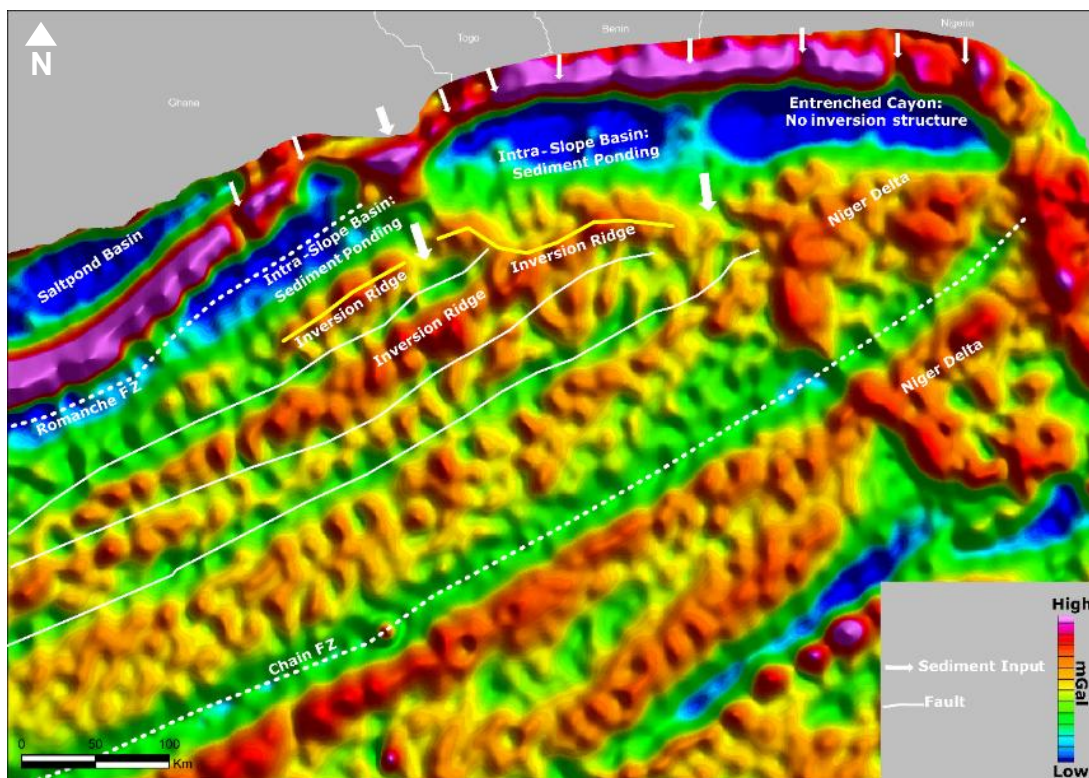


Figure 1 200 km high pass filtered Bouguer gravity map (2.0 g/cc) showing basin architecture and subbasins.

Basin Architecture and Sediment Distribution

The Dahomey margin is defined by a narrow continental shelf transitioning into a steep slope, influenced by long-lived fluvio-deltaic depositional systems (Cronin et al 2023). High-pass filtered

Bouguer gravity data (Figure 1) delineates basement structures that highlight this architecture. These structural features developed through tectonic movements associated with the Romanche Transform Fault and the Chain Fracture Zone, which played a critical role in shaping sediment distribution and basin development.

The northern limit of the margin is defined by a fault likely related to the Romanche Transform Fault. This fault splays into a horsetail system eastward, forming an inversion ridge that promotes sediment ponding inboard. The Chain Fracture Zone constrains the southern limit of the margin. The basin architecture observed in the Dahomey Embayment, reflects a Transform Margin *Sensu Stricto* basin setting (Cronin et al 2023) where sediments are transported from a narrow shelf onto a steep slope by entrenched canyons (Figure 2 (a)). The long-lived deltaic systems associated with entrenched canyons have resulted in substantial sediment accumulation from the slope to the basin floor. A secondary architectural element comprises Intra-Slope Basins developed around inversion structures, which promote sediment ponding on the slope. These inversion highs frequently exhibit erosional gullies that act as conduits for sediment transport to the basin floor, facilitating the development of confined turbidite channels and fan complexes shown in (Figure 2 (b)).

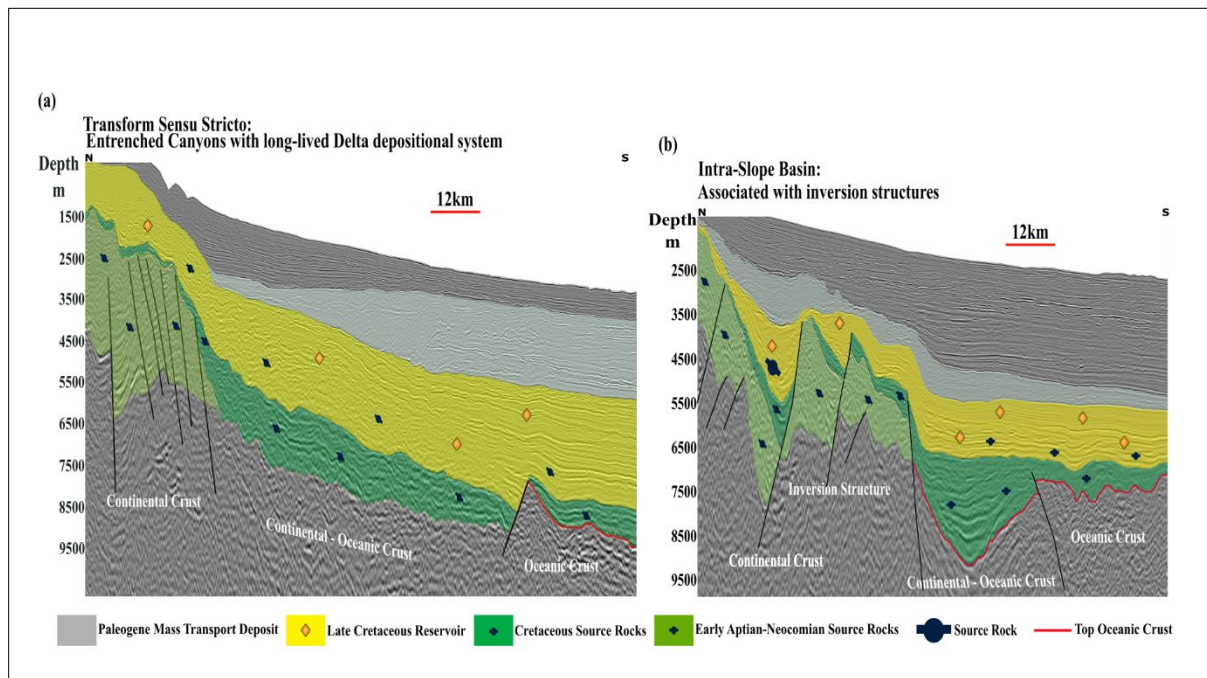


Figure 2 Regional Seismic model of Cretaceous depositional system of the Dahomey Embayment.

The Benin part of the margin illustrates an Intra-Slope basin architecture (Figure 3)

Lower Cretaceous source rocks identified on seismic sections within grabens and across the deepwater provide effective source kitchen. The overburden thickness reaches at least 6 km in the deepwater setting (Figure 3), while temperature data from slope wells indicate an average geothermal gradient of 30°C/km. The presence of thin continental and oceanic crust facilitates high heat flow through the system (MacGregor et al 2003), ensuring that source rocks with approximately 5% TOC in the outboard are oil mature. Reservoir quality varies by depositional setting: sandstones within intra-slope basins are typically well-sorted and mature due to sediment reworking and ponding, and these sands are confined to erosional gullies on inversion structures, leading to the development of localized turbidite channels and fan complexes with limited lateral spread. Conversely, entrenched canyon systems exhibit minimal reworking and no ponding, resulting in broad, meandering channel and fan systems. Trap configurations in both settings combine stratigraphic and structural elements: pinch-outs against inversion highs dominate intra-slope architecture, while *Sensu Stricto* systems rely primarily on stratigraphic trapping with occasional dependence on regional structural highs.

The ultra deep water depositional setting is characterized by channels and fans system in an intercalated source rock and reservoir petroleum system (Figure 4 and 5).

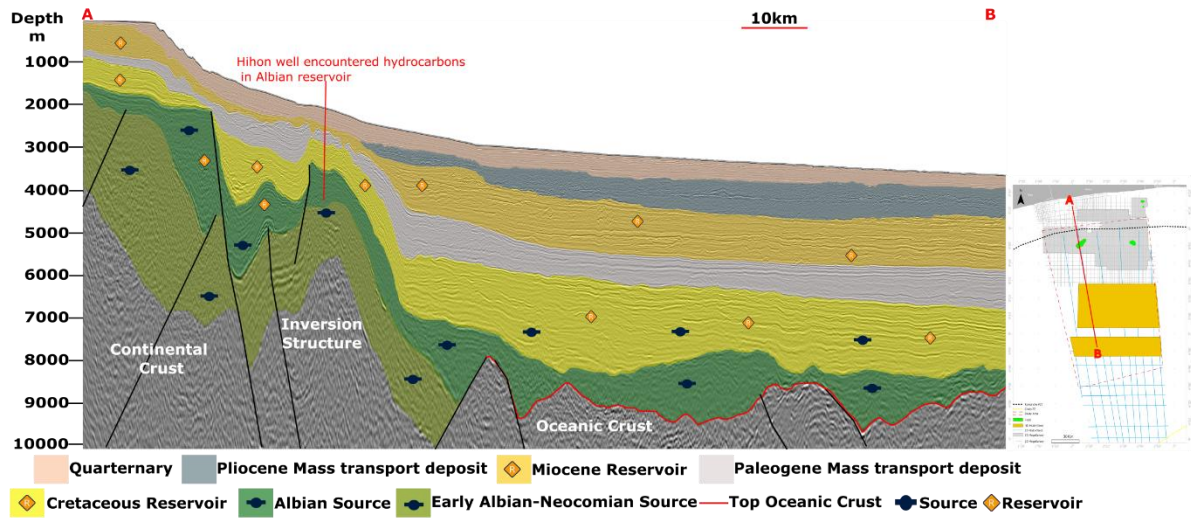


Figure 3 Seismic model of Benin: Shelf to Deepwater.

The deepwater environment of Benin reveals several reservoir targets for exploration. (Figure 4) shows a RMS extraction of Cretaceous reservoir interval as indicated in (Figure 3). Here, large slope turbidites, meandering channels and fan systems with intercalated Cenomanian source rock overlie the Albian source rock. This provides a conducive migration path for hydrocarbons into the Cretaceous reservoirs. The ultra-deepwater setting (Figure 5) reveals a complex depositional environment characterized by well-developed channel and fan systems. These reservoirs occur within an intercalated petroleum system where Cretaceous source rocks and channels, sand waves and fan system are closely associated, creating favorable conditions for hydrocarbon generation and migration. Spectral decomposition highlights extensive channel geometries and stratigraphic pinch-outs, underscoring the potential for significant stratigraphic and combined traps in this deepwater domain.

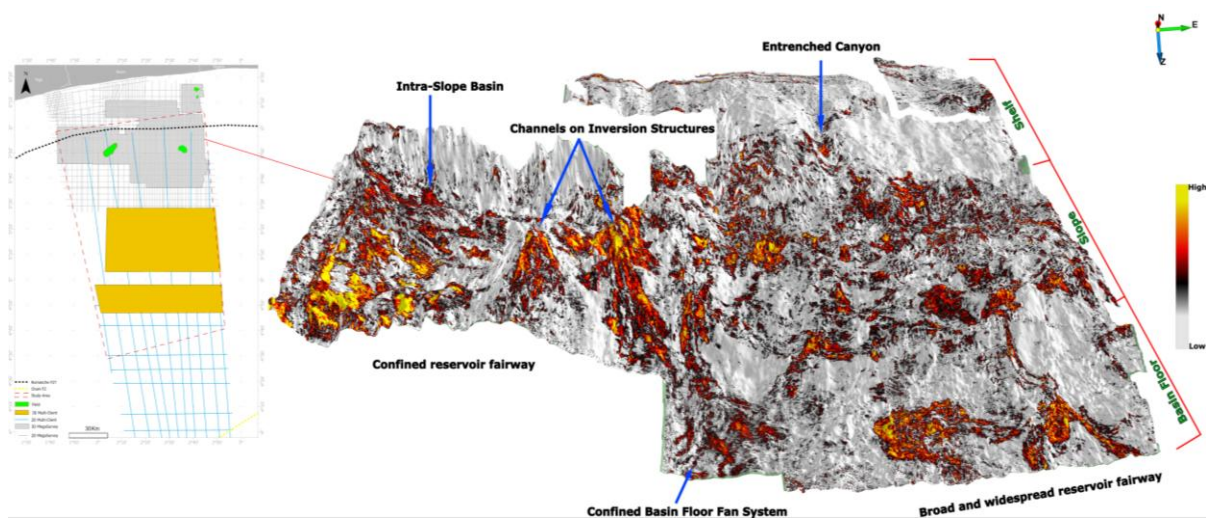


Figure 4 RMS extraction of Cretaceous play fairway deepwater Benin

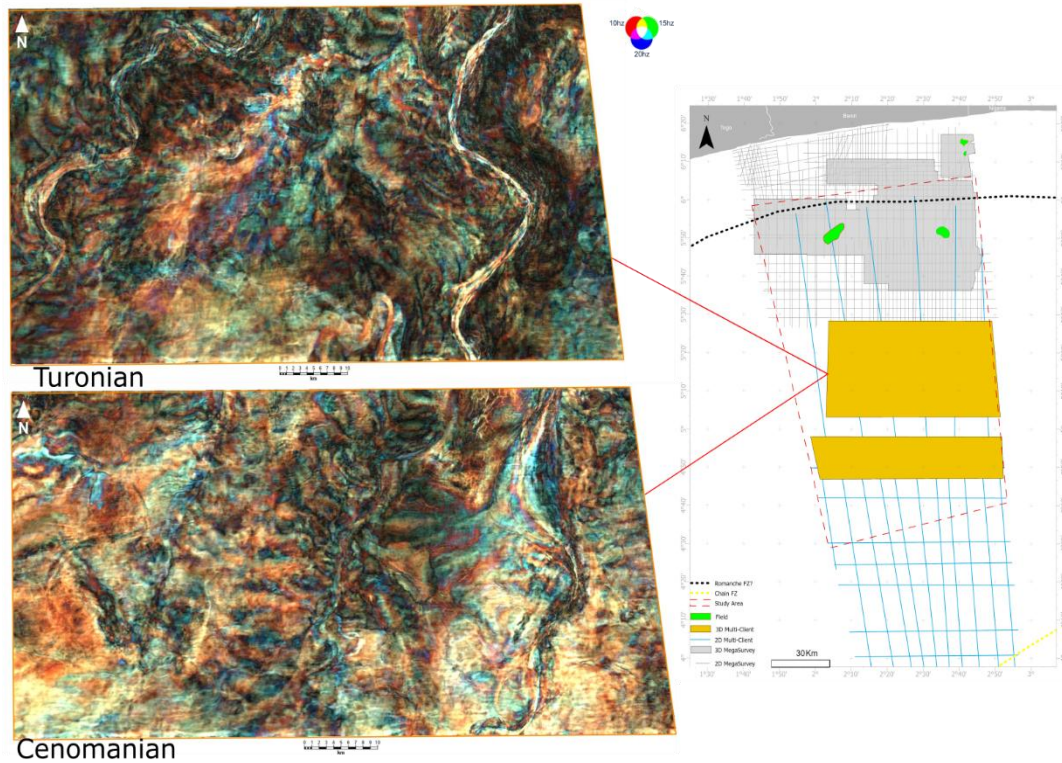


Figure 5 Spectral decomposition of Cretaceous interval deepwater Benin.

Conclusion

Deepwater Benin represents a highly prospective frontier for hydrocarbon exploration. Lower Cretaceous source rocks located within grabens and across the basin floor provide effective source kitchens for Cretaceous turbidite reservoirs and Miocene channel-fan systems. The deepwater environment features stratigraphic pinch-out traps, while the intercalation of Lower Cretaceous source rocks with Cretaceous reservoirs establishes a robust and favorable play fairway. Furthermore, the presence of extensive channel complexes spanning thick successions from the Albian to Miocene underscores the ultra-deepwater domain as a premier target for future exploration.

References

- Brownfield, M.E., and Charpentier, R.R., 2006, Geology and total petroleum systems of the Gulf of Guinea Province of west Africa: U.S Geological Survey Bulletin 2207-C, 32 p.
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