Gabon’s Wild West Frontier Promises a Golden Age of Discovery for the Deep Offshore

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OPEC member and net oil exporter

Oil sector makes up 45% of GDP and 80% of exports (World Bank)

But oil reserves have steadily declined over the last 30 years

Peak oil production in 1997 stood at 370,000 bbls/day

Oil production as at the end of 2017 stood 200,000 bbls/day

Dramatic increase in oil reserves in mid 80s with onshore pre-salt discoveries

Increase in potential gas reserves since 2013 thanks to pre-salt exploration in the deep offshore

Can we hope for another wave of oil discoveries from the deep offshore play?

- Yes and it’s located in Gabon’s ultra-deep ‘Wild West’
An **Outer High** is conventionally perceived as a large ‘terminal horst’ boundary separating transitional and oceanic crust – composed of basement or igneous rock.

But is it always the case?
Gabon’s Hyperextended Margin

- Impact’s D13/D14 blocks located within the distal and outer tectonic domains of the West African hyperextended margin
- The Outer High separates two basins; an inner salt basin, and an oceanward outer marginal basin
- Advent of high resolution 3D data provides insights into the true nature of some of these structures

Regional Tectonic Framework

- Location: South Gabon

Vintage 2D
2D vs 3D PSDM Seismic Comparison

Location: South Gabon

Martin et al. (2009)

2D Regional Dip Line

Breakup Unconformity (Depth)

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Outer Highs can be made of sediment

- Outer High's can be composed of sedimentary rocks instead of non-prospective basement and forming new play concepts
- These horst-like structures are superimposed above the final remnants of continental crust before entering transitional and oceanic basement domains westward
- The Outer High additionally acts as the barrier between the landward inner salt basin and the oceanward outer marginal basin
Outer Highs can be made of sediment

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Outer Highs can be made of sediment

So how do we get here?
Tectonic Evolution

Early Rift I – Barremian

Basin bounding fault against an ‘H’ block creates maximum accommodation for thick lacustrine shales
Continued rifting allows for the accumulation of thick fluviatile deposits

**Late Rift I – Late Barremian**

**BARREMIAN - 126MA**

- Continued rifting
- Large syn-rift wedge of sediment develops in distal margin
- Rapid deposition of Dentale fluviatile source and reservoir facies
- Continued extension along border fault
- High basal heatflow during rifting

**TERTIARY**

- Neogene
- Oligocene
- Paleocene – Eocene
- Upper Cretaceous
- Ceno-Turonian
- Albian
- Aptian
- Barremian
- Neocomian

**CRETACEOUS**

- Synrift
- Early rift
- Late rift

**LITHOSPHERIC MANTEL**

- Lower Ductile Crust
- Rapidly Maturing Moho

**Dentale Fm.**

- narrow deep lakes
- high clastic input
- fresh water conditions
- warm, wet climate
- high algal bloom, plant detritus, nutrients
- anaerobic bottom conditions

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Initiation of sag leads to deposition of up to 300m of marine Gamba sands

**APTIAN - 124MA**

- Transition into sag megasequence
- Accommodation greatest basinward toward border fault depositing thickest Gamba reservoir sands
- Gamba sands typically 30-50m on shelf and onshore
- Angular unconformity between Dentale and Gamba reservoir packages

**Data courtesy of CGG Multi-Client and New Ventures**
Tectonic Evolution

Inversion – Mid Aptian

Transpression causes reactivation along the basin bounding fault inverting the sedimentary half-graben.

APTIAN - 122MA

Carbonate growth on inversion anticline in a shallow marine environment

Transpression along Mayumbe FZ causes inversion

Active passive inversion along border fault

+ve Hard

-ve Soft

Carbonate builds above inverted outer high

Inverted anticline

Data courtesy of CGG Multi-Client and New Ventures

Neogene

Oligocene

Paleocene - Eocene

Upper Cretaceous

Ceno-Tur.

Albian

Aptian

Barremian

Neocomian

PRE-REFT

SYN-REFT

EARLY CRET

LATE CRET

LATE DRIFT

EARLY DRIFT

TERTIARY

CRETACEOUS

LITHOSPHERIC MANTLE

LOWER DUCTILE CRUST

1300C

Peak isotherm

Tectonic Direction

Brittle Failure of H-block

H-BLOCK
Tectonic Evolution

Early Rift II – Late Aptian

Onset of hyperextension creates new fault family to the west as salt is deposited in a hypersaline environment.
Early Drift – Mid. Albian

Rapid subsidence within ‘Outer’ trough as seafloor spreading commences → deposition of outboard source

- Salt and source deposited in restrictive marine conditions
- Complete delamination of Upper Crust
- First Oceanic Crust accretion
- Isotherm isostatically driven to area of least continental crust

South Gabon (D13)

North Gabon

Data courtesy of CGG Multi-Client and New Ventures
Tectonic Evolution

Drift & Congo Fan - Miocene

Onset of Congo shaley sequence finally seals the structural high
Continued sedimentation from the Congo provides necessary overburden to mature ‘Outer’ source rocks.

**What are the implications on prospectivity?**
Aptian Gamba transgressive marine sand is the principal reservoir in Gabon.

Westward thickening Gamba package toward original basin-bounding fault where accommodation is greatest.

D13/D14 near deepest part of Aptian depocentre, accumulating thickest Gamba.

Prominent high means less burial and greater preservation of primary porosity.
Albian-Turonian Source Rock

- Albian-Turonian source rocks deposited in a depocentre west of the Outer High over attenuated continental and transitional crust.
- Albian-Turonian source rock charging fields in Angola, North Gabon, Rio Muni and the Brazilian conjugate margin. Has yet to be explored in South Gabon!
- Albian source rocks at DSDP 364 (Angola) recorded an average of 10 wt% TOC and ~ 500 HI.
- Continuous, layer-parallel reflectors identified in seismic across both margins for Albo-Turonian marine sequence.

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![Map of Brazil and Gabon with geological features](image)

- **BRAZIL**
  - Moita Bonita – Sergipe (Brazil)
  - Ultra-deep water oil discoveries situated near the OCB by Albian-Turonian source rocks

- **GABON**
  - B.) D13/D14 – South Gabon Basin
  - Estimated outline of the Outer Marginal Trough which accommodates thick marine Alb-Tur source rocks
  - Isostatic Residual 300km pass
  - Recent discoveries charged by pre-salt source rocks

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Source-Reservoir Sweet Spots

- Albian-Turonian ubiquitously deposited across South Atlantic
- Post-rift source rocks matured through fan overburden
- Juxtaposition of mature post-salt source rocks against the pre-salt reservoirs within the Outer High

What will the principal source rock be here?
What is the principal source rock?

**Pre-Salt Source Rocks**
- Seal *post-dates* charge

- If salt had sealed the structure at 120Ma → gas charge from the pre-salt Neocomian-Barremian ‘Inner Kitchen’ would have been trapped (as seen at recent Diaman, Leopard, and Boudji pre-salt discoveries)

- **BUT**...the Outer High is absent of Aptian Ezanga salt seal → allows for pre-salt sourced hydrocarbons to migrate through the structure and out to the surface

**Post-Salt Source Rocks**
- Seal *pre-dates* charge

- So...when was this Outer High finally sealed?
  - Top seal provided by the Tertiary deepwater shales of the Congo Fan at 23Ma
  - Multiple giant oil fields including Kizomba Field (*Angola*) demonstrate the excellent sealing capacity of the Oligo-Miocene shales within the Congo Fan
  - Continued Congo Fan deposition provides the necessary overburden to mature the post-salt Albo-Turonian source rocks into the oil generating window

**Principal source rock provided by Type II Albo-Turonian post-salt shales**
What about DHIs?

- Abundant evidence of an active petroleum system
- Outer High acting as a focal point for hydrocarbon migration
- Credible flatspot within the structural high

### SOURCE
- Albian-Turonian Oil Mature [✓]

### RESERVOIR
- Aptian Gamba-Dentale [✓]

### SEAL
- Oligo-Miocene Shales [✓]

### TIMING
- Maturity through Congo Fan [✓]

### DHI
- Flatspot through structure [✓]
Conclusions

- New, high quality 3D PSDM seismic brought the ‘Outer High’ into sharp focus.
- Not all ‘Outer Highs’ are comprised of non-prospective basement; they can be sediment-filled half-grabens, later tectonically inverted as the ‘Outer’ domain transitions into hyperextension.
- The proven Albo-Turonian source interval from Equatorial Guinea to Angola and Brazil is observed within the ‘Outer’ basin of South Gabon.
- Juxtaposing the pre-salt Gamba-Dentale Outer High reservoirs with the post-salt Albo-Turonian source rocks provides for the meeting of two mighty plays.
- Late Tertiary shale seal timing is critical to avoiding capture of gas charge from Barremian pre-salt source rocks but remains favourable for post-salt oil capture.
- **Materiality is the key to unlocking the potential of Gabon’s ultra-deep frontier.**

Data courtesy of CGG Multi-Client and New Ventures.
Thank you

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