The Sierra Leone-Liberia Emerging Deepwater Province*

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Abstract

The offshore West African margin located between Guinea Conakry and Ivory Coast is a frontier area. The neighboring offshore regions of Sierra Leone and Liberia have had only a few exploration wells drilled on the continental shelf. Exploration focused on the classical Aptian-Albian tilted block play that produces in the Baobab, Espoir, Lion, and Tano fields of Ghana and Ivory Coast.

The deep-water areas of this steep morphological margin are undrilled, and the details of its history remain largely unknown. The main play in the slope is Upper Cretaceous turbidites, consisting primarily of amalgamated channel-levee complexes, pinching-out towards the steep continental slope in stratigraphic traps. Post-rift Albian and Cenomanian-Turonian shales constitute the main potential source rocks of the deep-water part of the margin. The structure of the margin is the result of Early Cretaceous low-angle extensional tectonics, and gravitational extension and related toe-thrusting associated with Late Cretaceous to Tertiary uplift on the shelf.

Petroleum systems modeling of this margin is a major challenge due to many unknowns, including:

(1) the complex structural evolution related to the role of transform and extensional faults during the Tertiary,
(2) the location of the continent-ocean boundary and its implications for heat-flow through time, and
(3) the dating of the deep-water stratigraphy section due to the lack of deep-water wells.
References


The Sierra Leone - Liberia Emerging Deep-Water Province

Emerging Global Deep-Water Plays
Emerging Worldwide Deep-Water Plays

Pre-Salt Play

Sub-Salt Play

Folded Belt Play

Stratigraphic Pinch-out Play

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The Classical versus the Emerging Deep-Water Play Along the West Africa Transform Margin
Transform Tectonics along the South-Central Atlantic

1000 Km
West Africa Transform Margin Classical Play

Espoir Field (Ivory Coast)

N-S Seismic cross-section through East Espoir

Structural Map Espoir Field

Grillot et al, 1999
The West Africa Transform Margin Emerging Play

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The Classical versus the Emerging Play

Classical Play: Aptian-Albian tilted blocks.

Emerging Play: Upper Cretaceous stratigraphic pinch-outs

MCU: Mid Cretaceous Unconformity
The Sierra Leone – Liberia Segment of the West Africa Transform Margin
The Sierra Leone – Liberia Segment of the Margin

Free Air Gravity

1000 Km
Geologic Map of Sierra Leone & Liberia
Regional Section: West African Craton to Central Atlantic Ocean

SSW
Passive Margin Section

Rockelide Folded Belt

NNE
Panafrican

Legend:
- Pliocene - Pleistocene
- Miocene
- Oligocene
- Paleocene - Eocene
- Upper Cretaceous
- Lower Cretaceous
- Jurassic
- Basement/Continental Crust
- Precambrian/Paleozoic
- SDR
- Oceanic Crust
- Cambrian
- Greenstone Belt
- Precambrian Granited
- Precambrian

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Sierra Leone-Liberia Chrono-Stratigraphic Sketch

NW

SE

Oceanic Crust

SDRs

190 Ma
Line-Drawing Section A

- Pliocene - Pleistocene
- Miocene
- Oligocene
- Paleocene - Eocene
- Upper Cretaceous
- Lower Cretaceous

TWT (sec)

10 Km
Line-Drawing Section B
Line-Drawing Section D
Structural Evolution of the Sierra Leone – Liberia Margin

Jurassic
- Mantle Plume / Strong Thinning
- CAMP event
- Basalts
- Gabbros

Aptian-Albian (Lower Cretaceous)
- Rifting / Low-angle Extension

Upper Cretaceous
- SDRs
- Low-Angle Detachment

Paleogene-Neogene
- SDRs
- Transform Fault Activity
- Differential Uplift

SDRs
- Transform Faults
Petroleum System Elements of the Emerging Deep-Water Play
**Thermal History Hypothesis**

**Neocomian rift**: Gentle cooling from a short maximum heat flow after rifting end. (based on McKenzie, 1978)

*No satisfactory calibration*

**Late Jurassic thermal doming + Aptian crustal delamination**: Long high heat flow plateau, maximum at rifting followed by abrupt drop due to strong reduction in crustal radiogenic contribution. (based on Waples, 2002)

*Preferred thermal history, good calibrations*
Main Deep-Water Reservoirs

Drowned Deltaic Systems

Canyon Fills

Channel-Levee Complexes (Slope-Fans)

Basin Floor Fans
Distribution of Deep-Water Reservoirs

- Drowned Deltaic Systems
- Channel-Levee Complexes (Slope-Fans)
- Basin Floor Fans
- Canyon Fills
- Continental Slope

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Petroleum System Elements of the Pinch-out Play

Source Rock: It can be located laterally or below the reservoir in a Basinal position. Mostly Cenomanian-Turonianshale encountered by DSDP wells.

Timing-Migration: Positive for Cretaceous - Early Tertiary age Reservoir(s) that were deposited before Generation and Migration took place.

Trap: Stratigraphic, Deep-water beds onlap unformity, Tilted top-lap surface, truncation below unformity. Channel-fill features.

Seal: Top- or lateral-seal flooding surfaces. Upper Cretaceous to Paleogene deep-water shale.

Reservoir Presence: Turbidites and drowned deltaic systems of mostly Late Cretaceous Age.
Conclusions

The Sierra Leone-Liberia Margin represents an example of deep-water stratigraphic pinch-out play, which constitutes an Emerging Deep-water Play along the West Africa Transform Margin.

Main reservoirs of the Deep-water System include Canyon Fills, Drowned Deltaic systems, Slope and Basin Floor Fans.

Key risks of the Petroleum System are the Lateral and Top Seals. Angular unconformities, associated with continuous uplift -- with sea level changes (Tectonically Enhanced Sequence Boundaries), control the geometry of these traps.

Structural Evolution, including Jurassic Crustal Thinning or Mantle Plume followed by Rifting & Low-angle Extension during Aptian time, affect the thermal evolution and therefore the maturity of the expected Source Rocks.