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

Grillot, L.R., P.W. Anderton, T.M. Haselton, and J.F. Dermargne, 1999, Case History 2: Three-dimensional seismic interpretation: Espoir Field area, Offshore Ivory Coast, *in* AAPG Memoir 42 and SEG Investigations in Geophysics, no. 9 (sixth edition), p. 326-329.

MacGregor, D.S., J. Robinson, and G. Spear, 2003, Play fairways of the Gulf of Guinea transform margin, *in* T.J. Arthur, D.S. MacGregor, and N.R. Cameron, eds., Petroleum geology of Africa—New themes and developing technologies: Geological Society, London, Special Publication 207, p. 131-150.

McKenzie, D., 1978, Some remarks on the development of sedimentary basins: Earth and Planetary Science Letters, v. 40, p. 25−32.

Waples, D.W., 2002, A new model for heat flow in extensional basins: Estimating radiogenic heat production: Natural Resources Research, v. 11, no. 2, p. 125-133.

Emerging Global Deepwater Plays
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Denver, Colorado USA

The Sierra Leone - Liberia Emerging Deep-Water Province

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Repsol Exploración S. A. Madrid , Spain.

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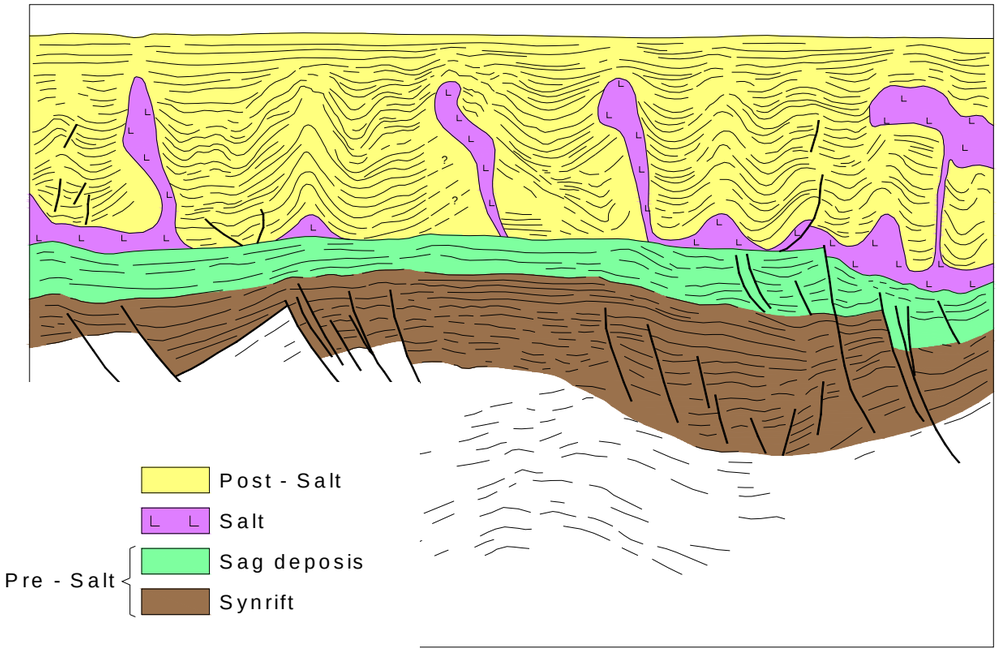
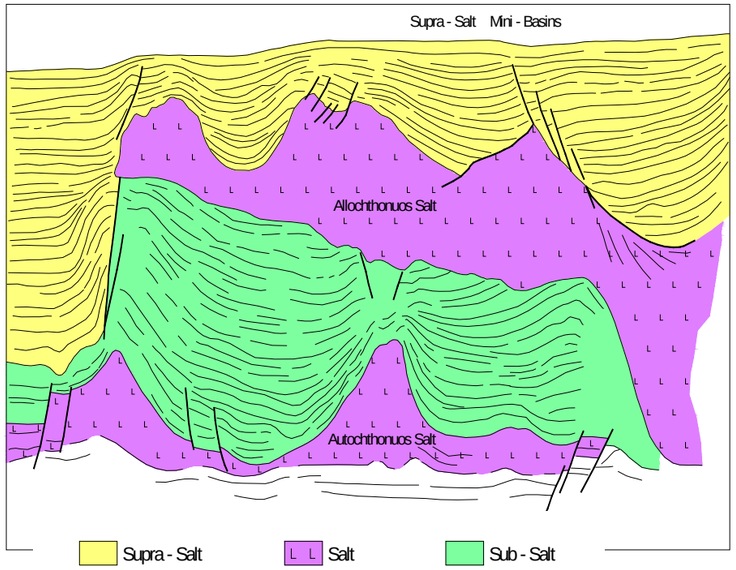
Emerging Global Deep-Water Plays

Emerging Worldwide Deep-Water Plays

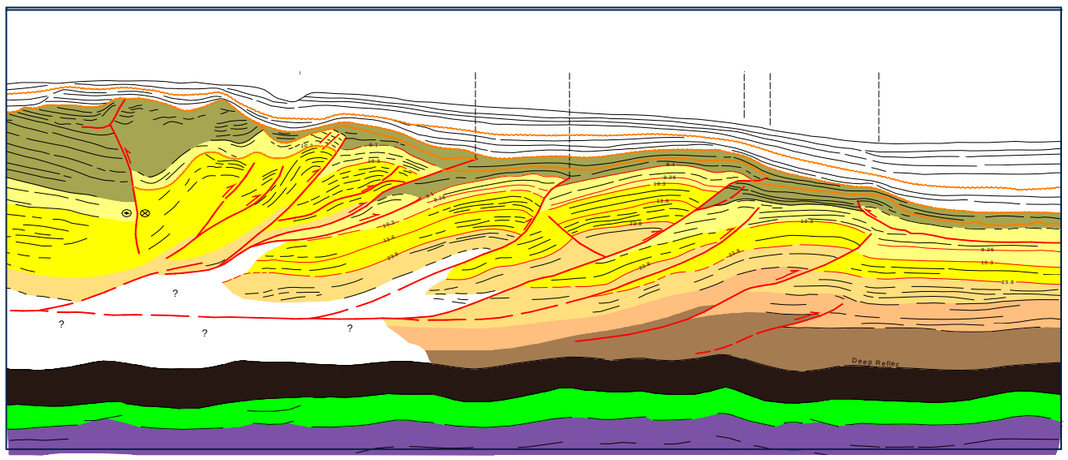
Pre-Salt Play



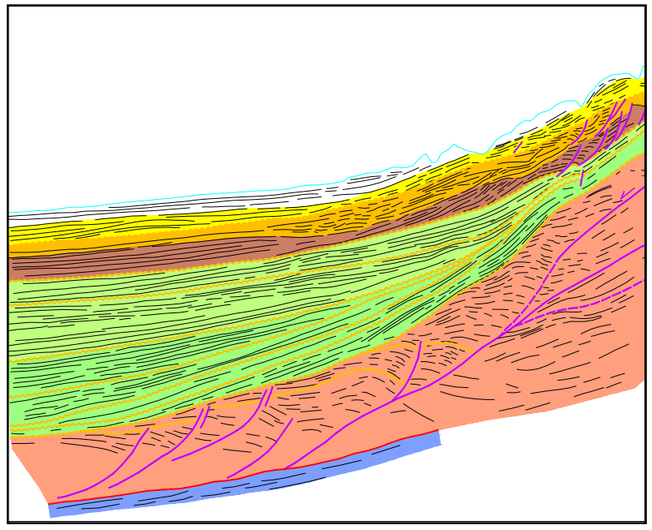
Sub-Salt Play



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

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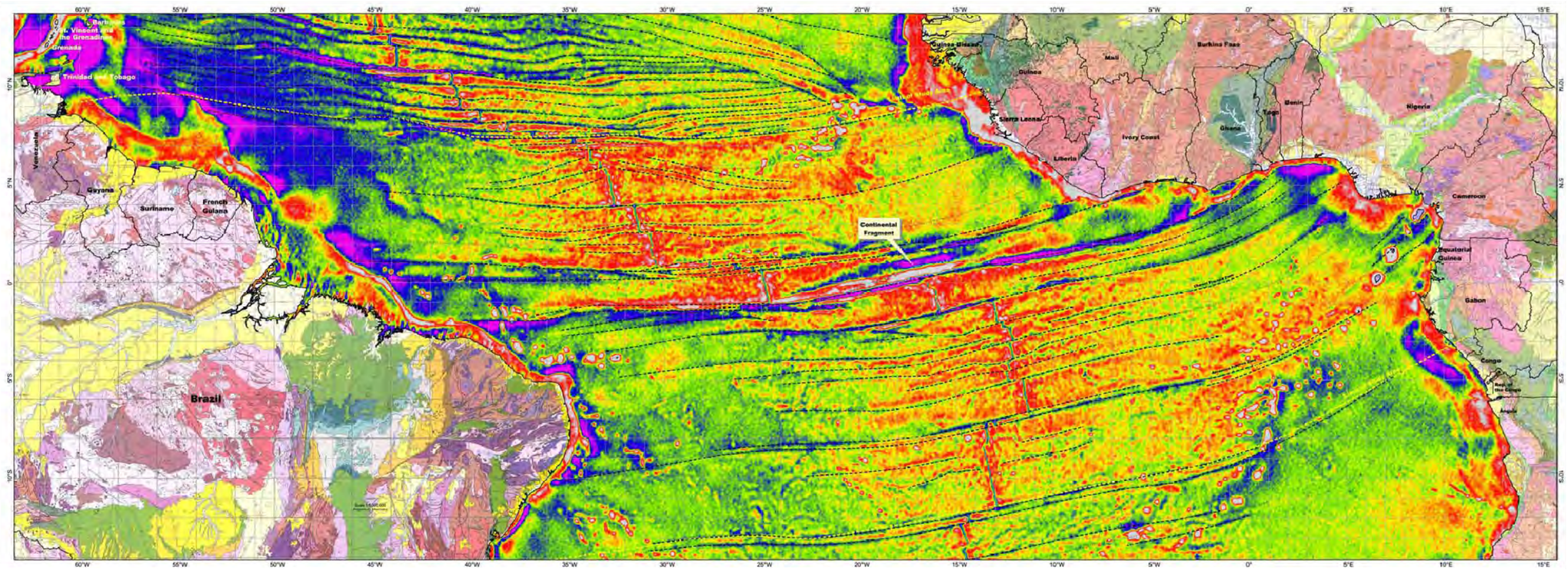
Transform Tectonics along the South-Central Atlantic



1000 Km

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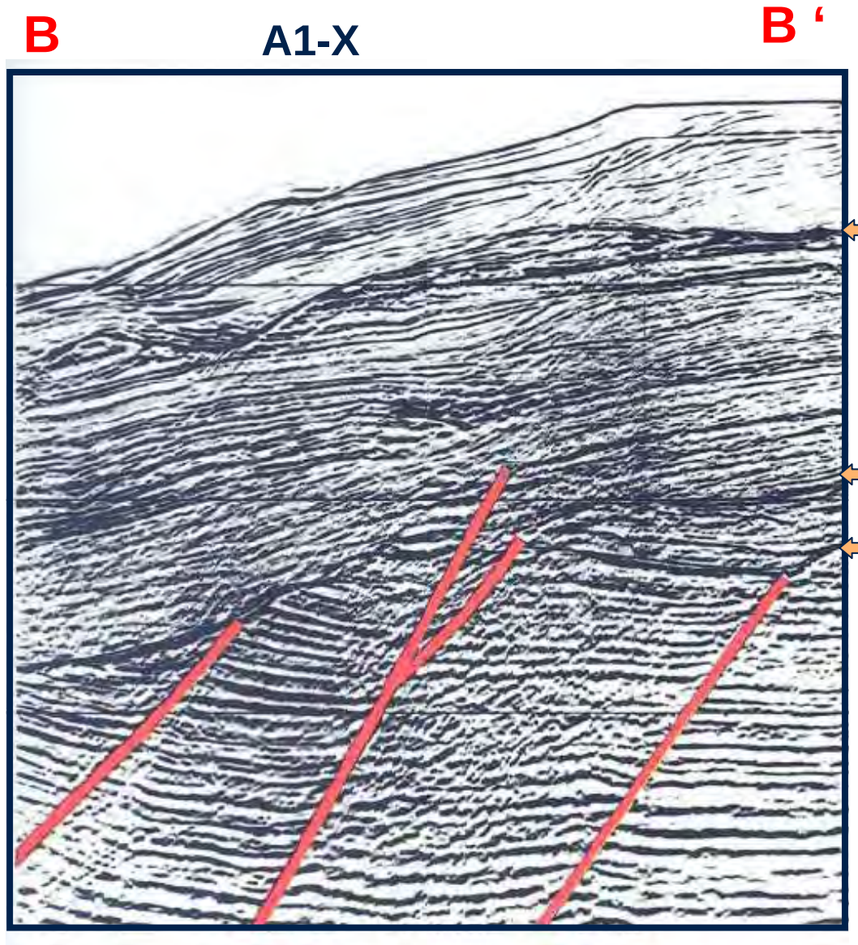
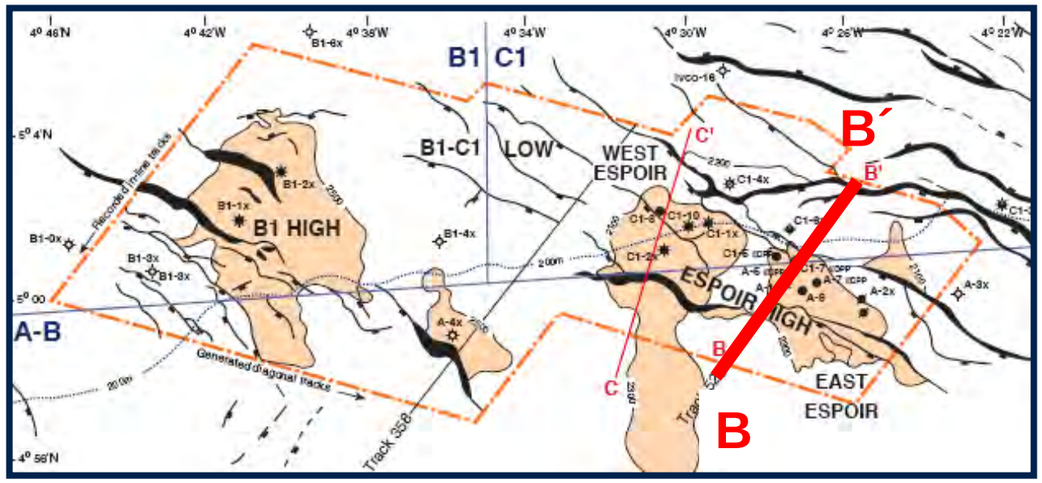
West Africa Transform Margin Classical Play

Espoir Field (Ivory Coast)

N-S Seismic cross-section through East Espoir

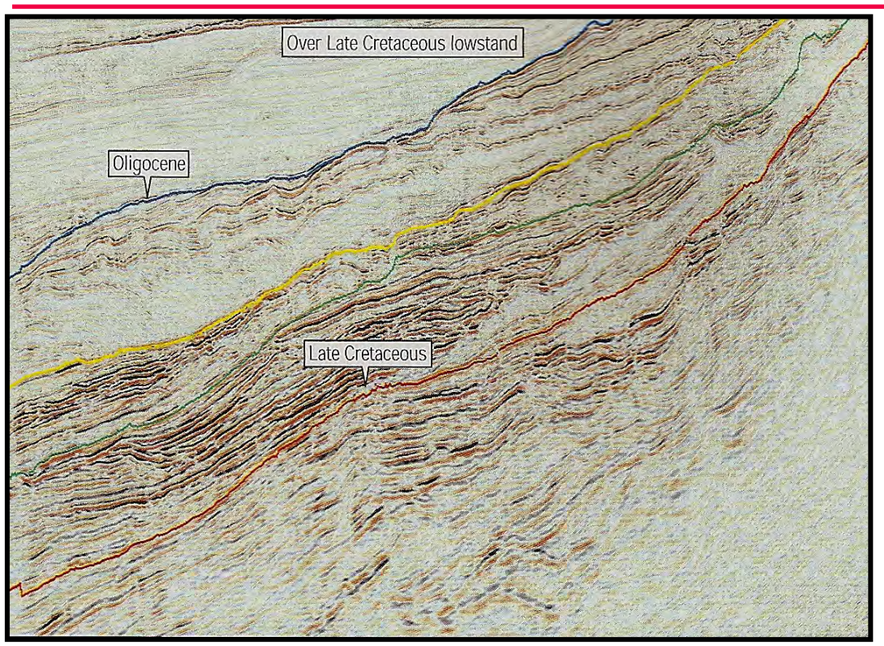


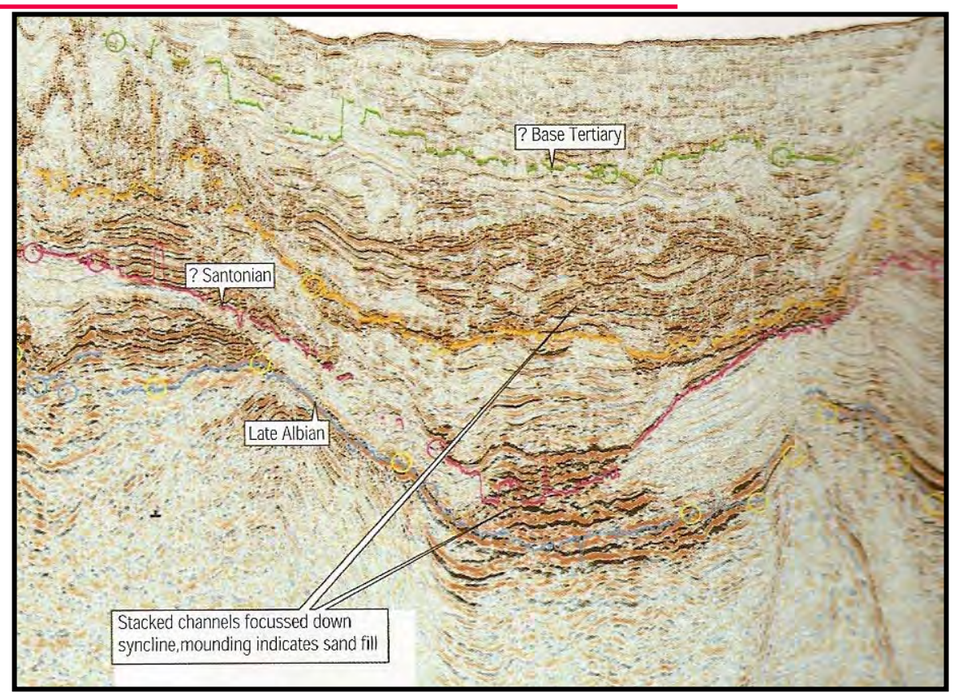


Structural Map Espoir Field

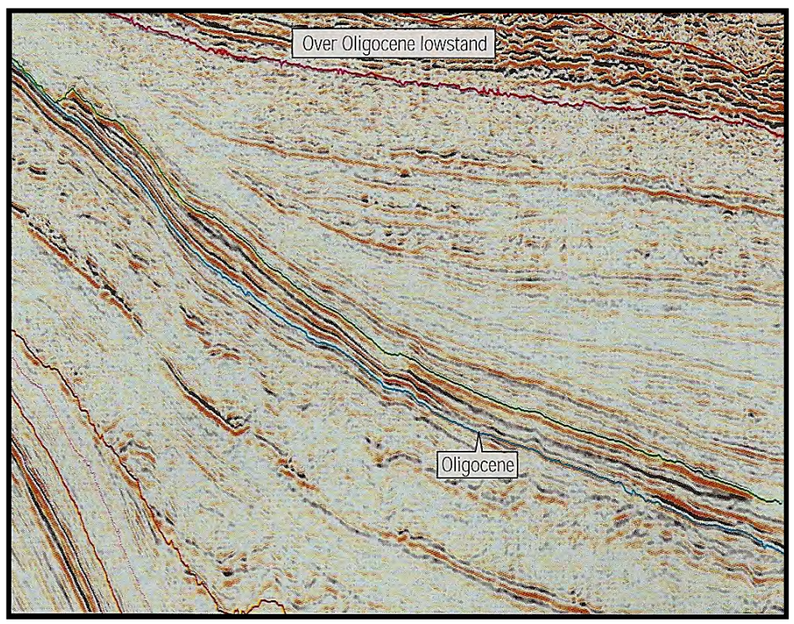
Grillot et al, 1999

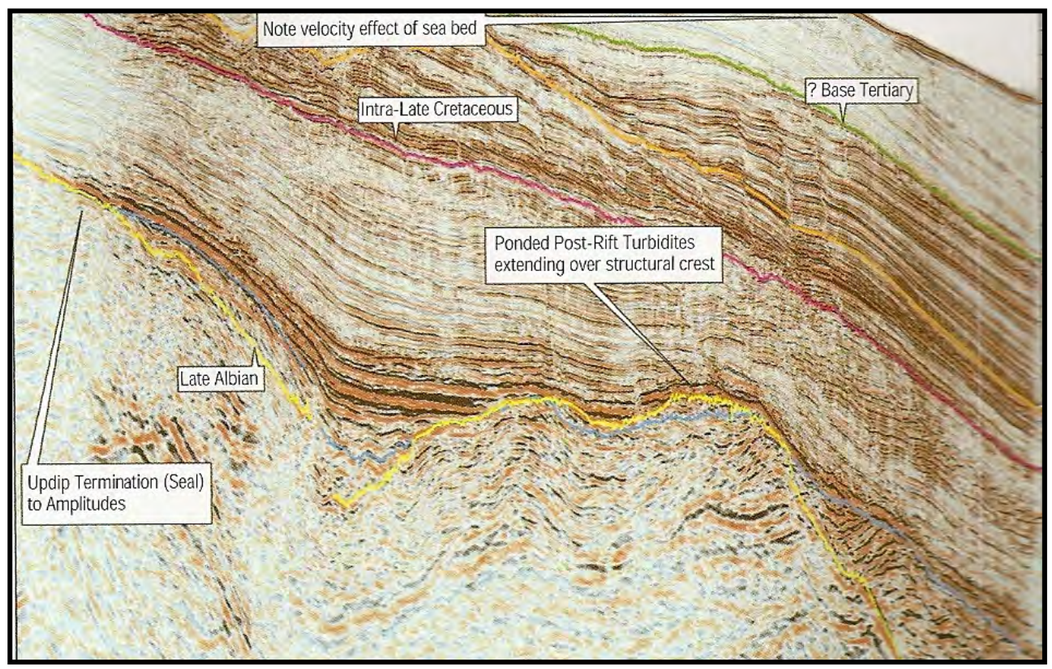
The West Africa Transform Margin Emerging Play





With Permission of The Geological Society of London





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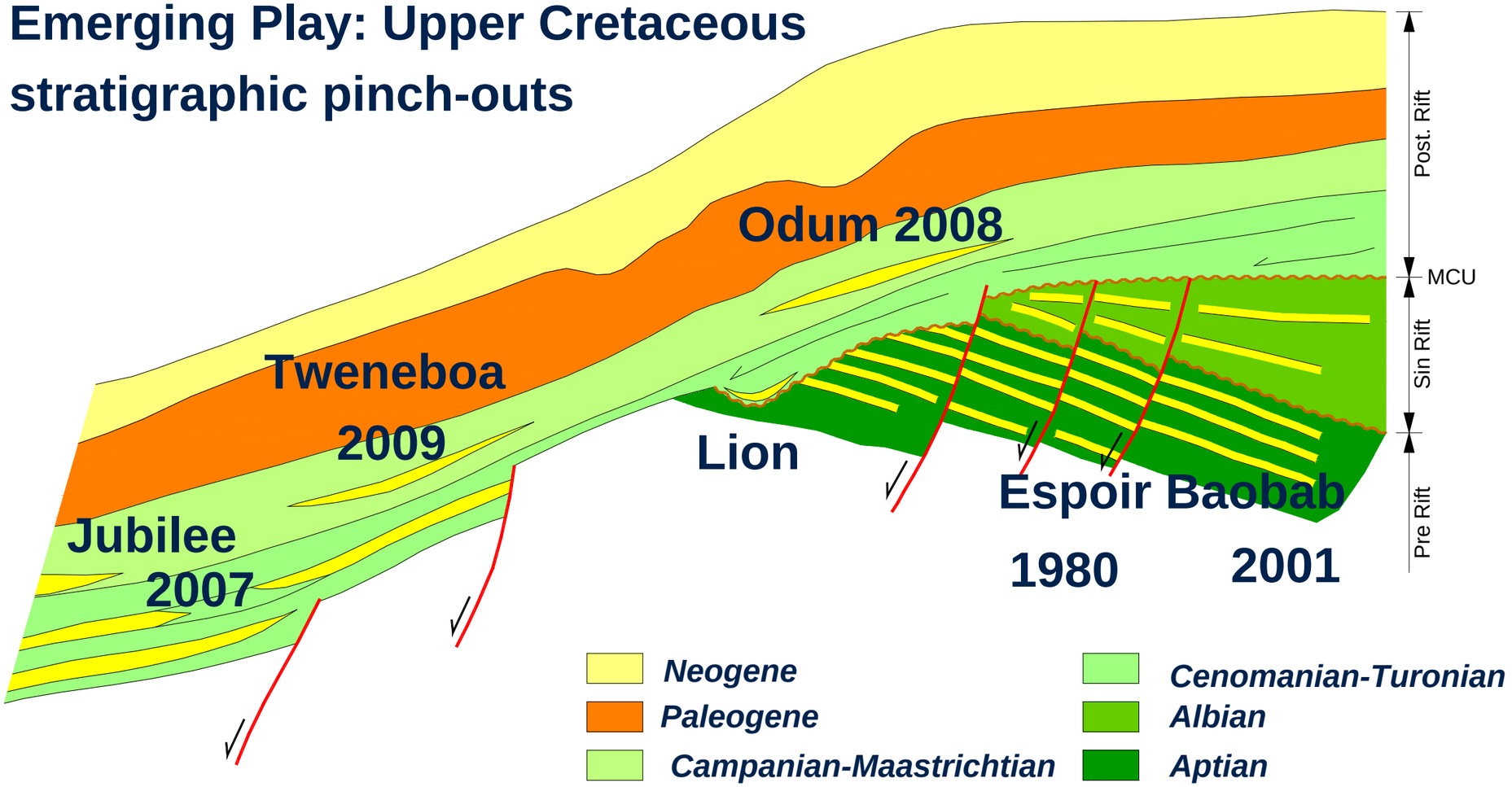
MacGregor et al. 2003

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

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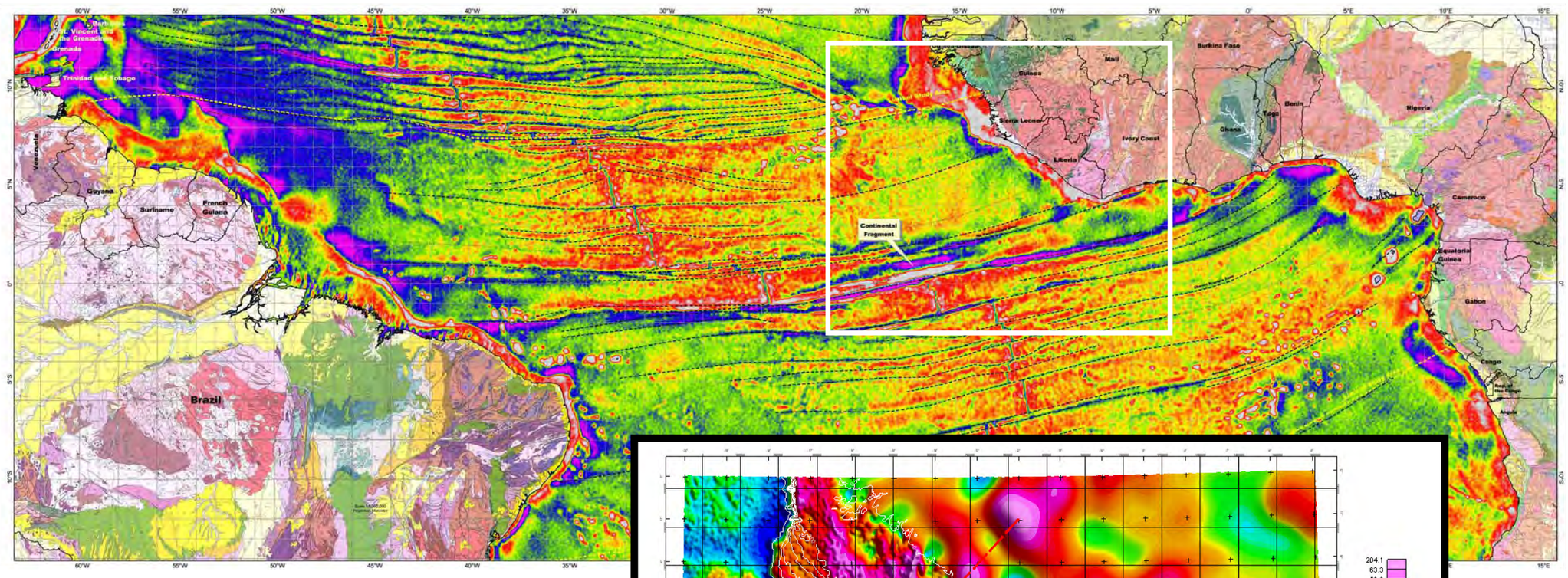
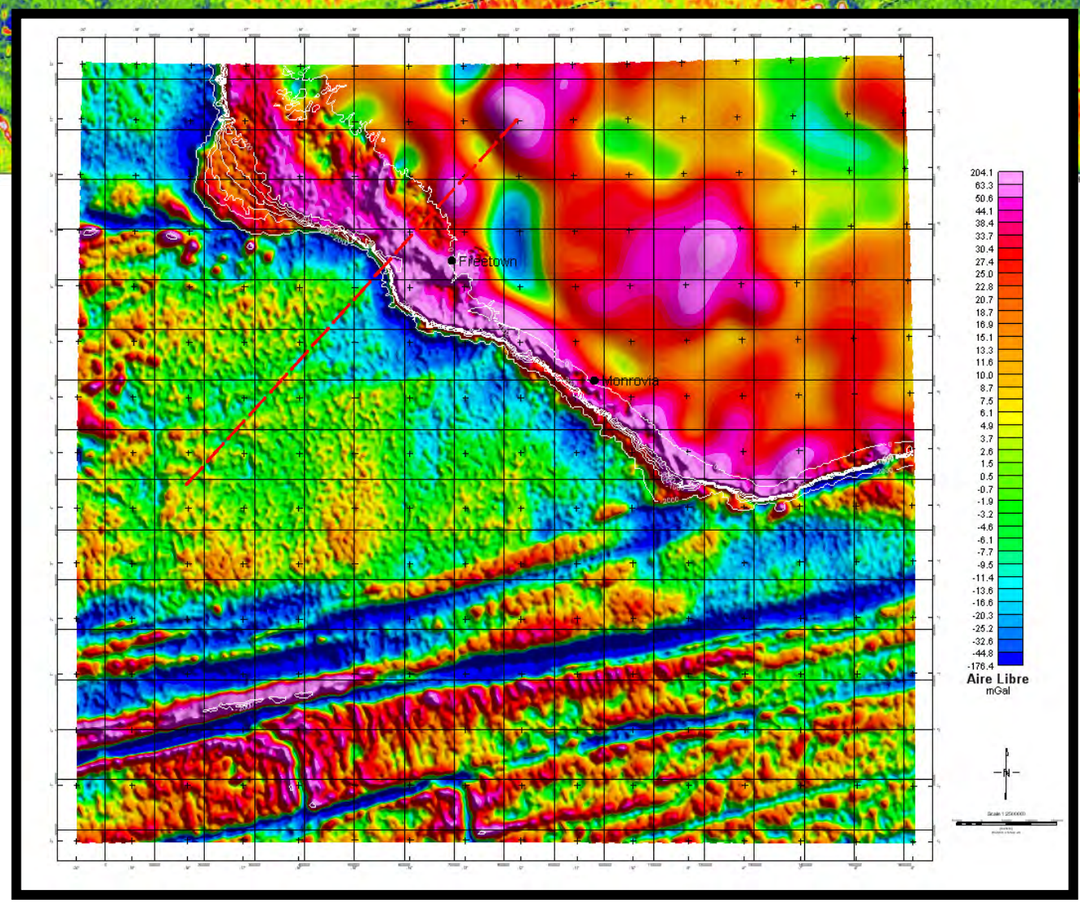
The Sierra Leone – Liberia Segment of the Margin



1000 Km



Free Air Gravity

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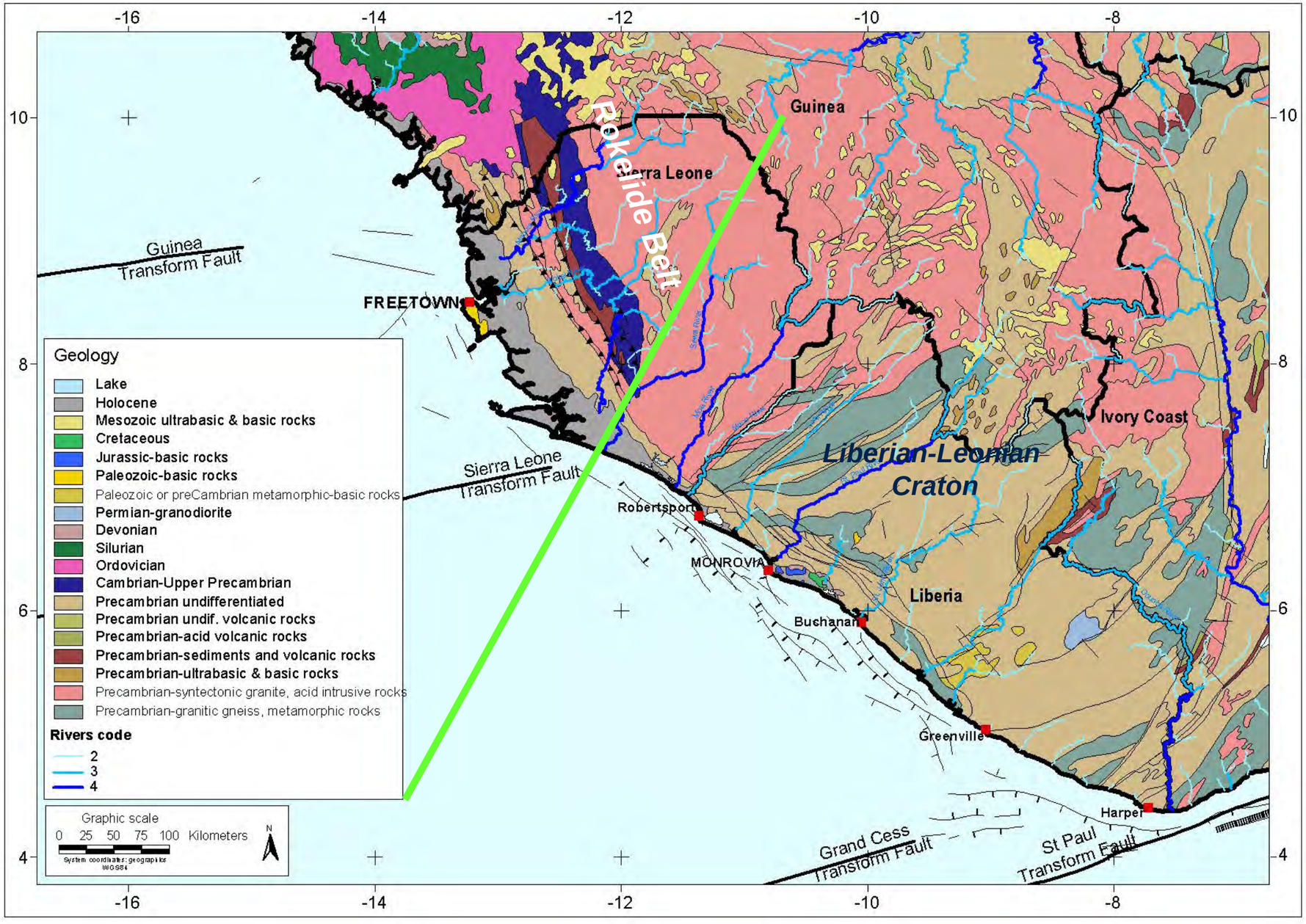
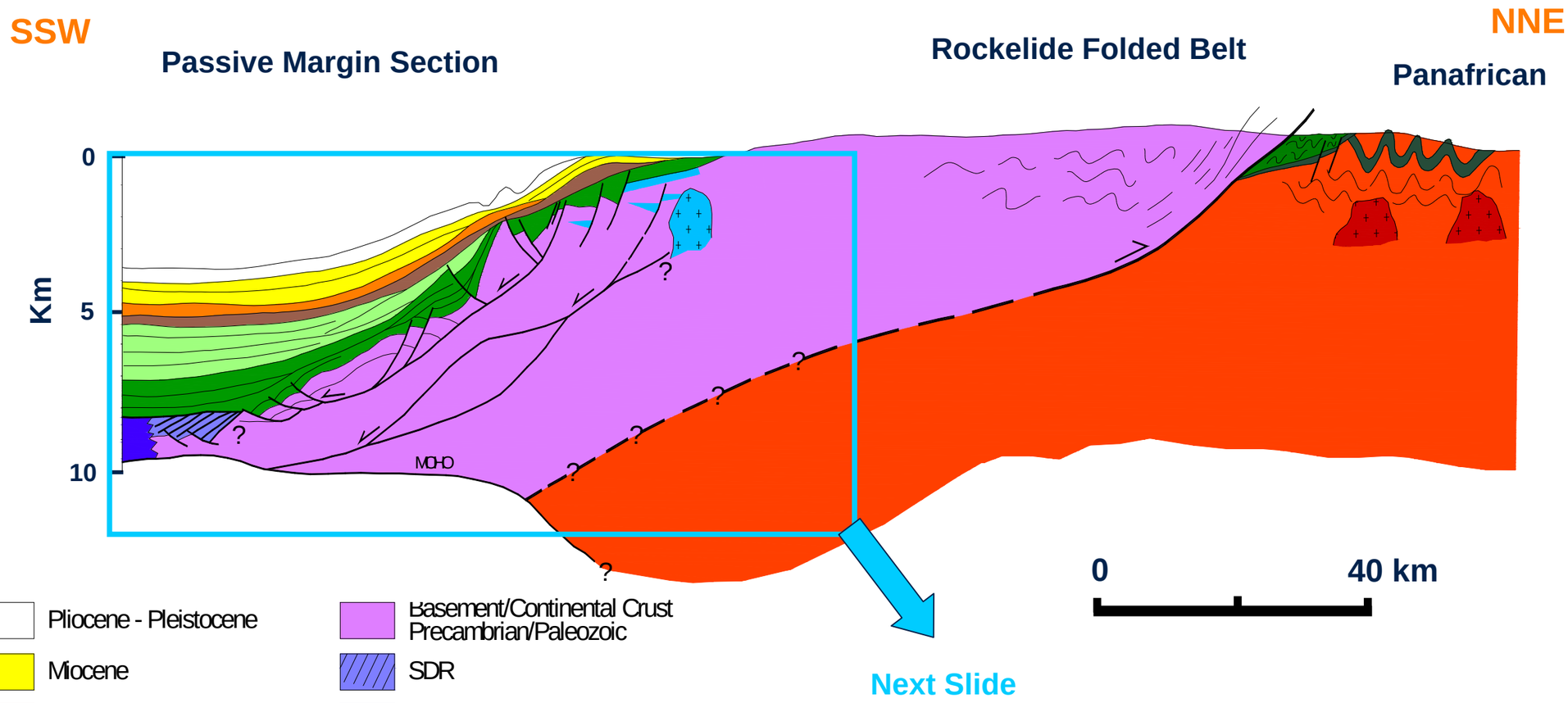
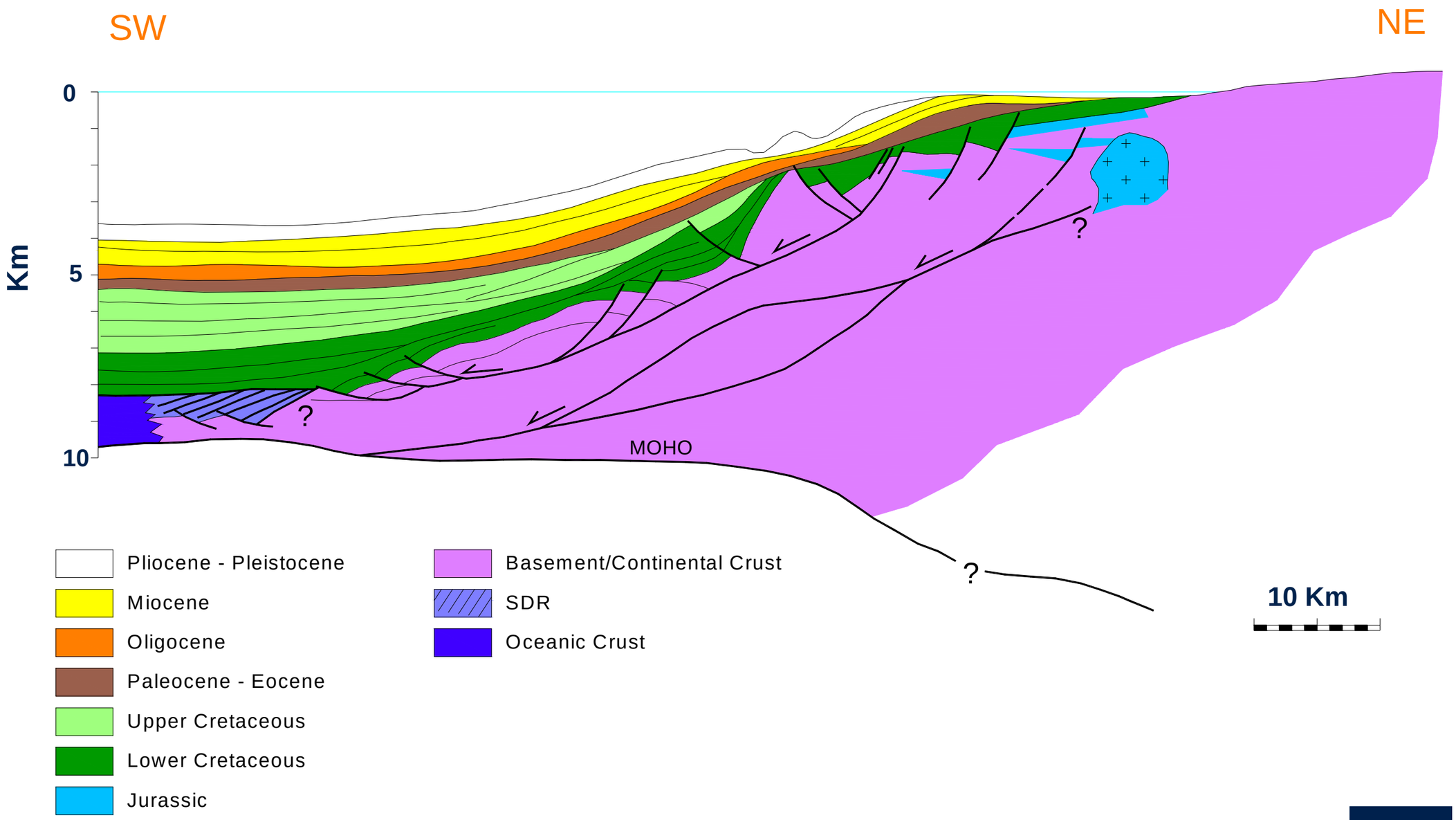
Geologic Map of Sierra Leone & Liberia



Regional Section : West African Craton to Central Atlantic Ocean

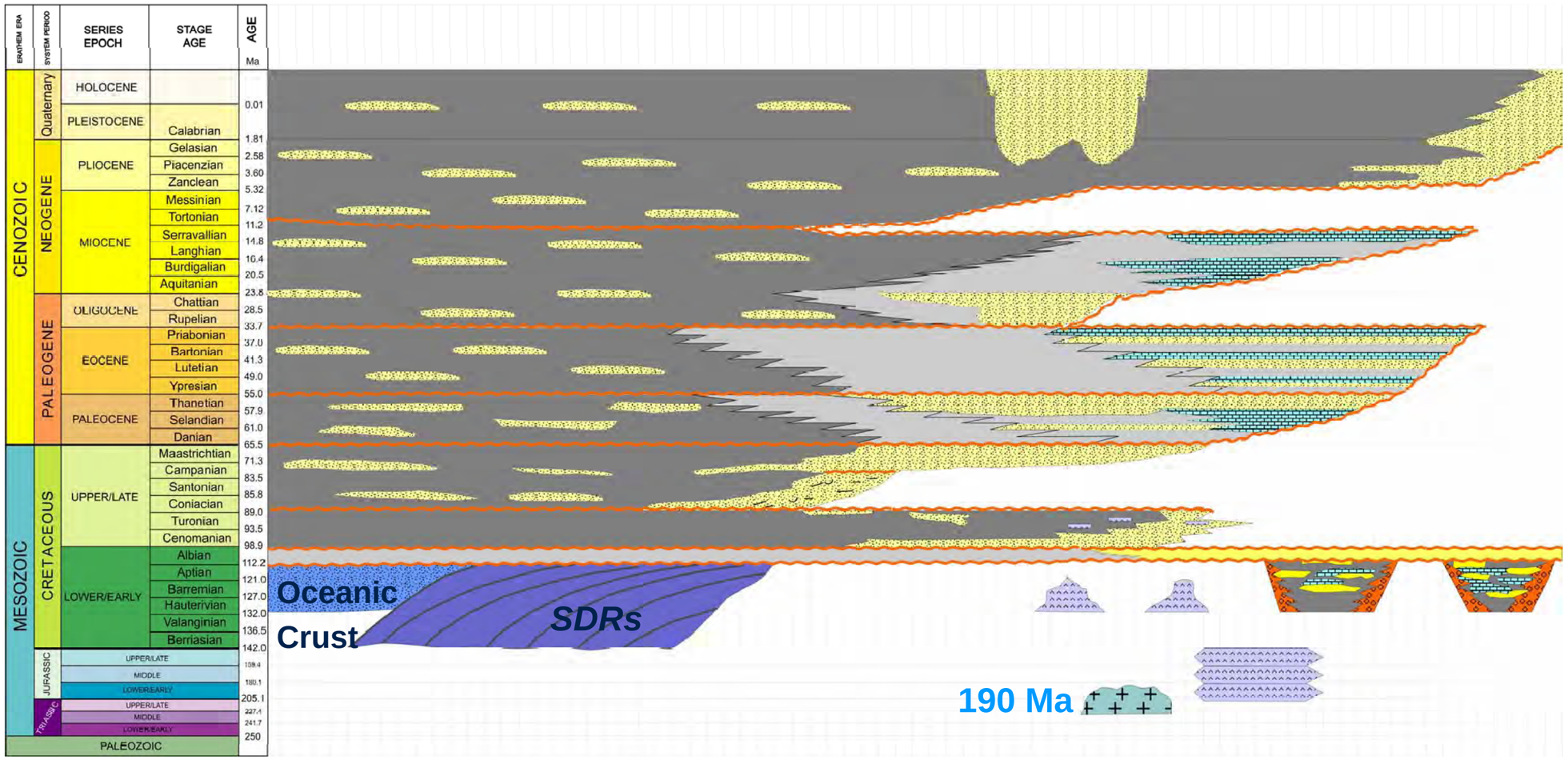


Sierra Leone-Liberia Passive Margin Section

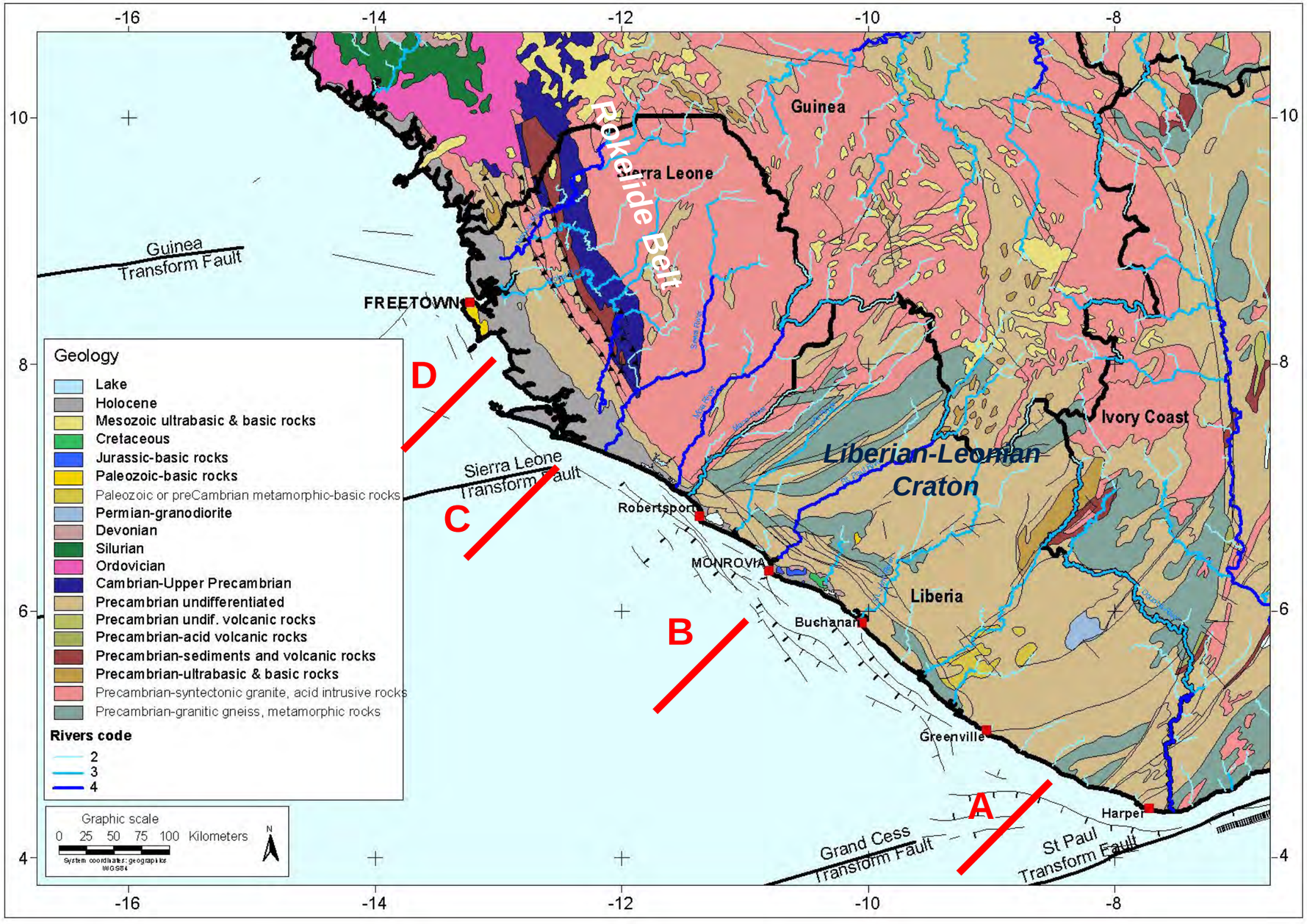


Sierra Leone-Liberia Chrono-Stratigraphic Sketch

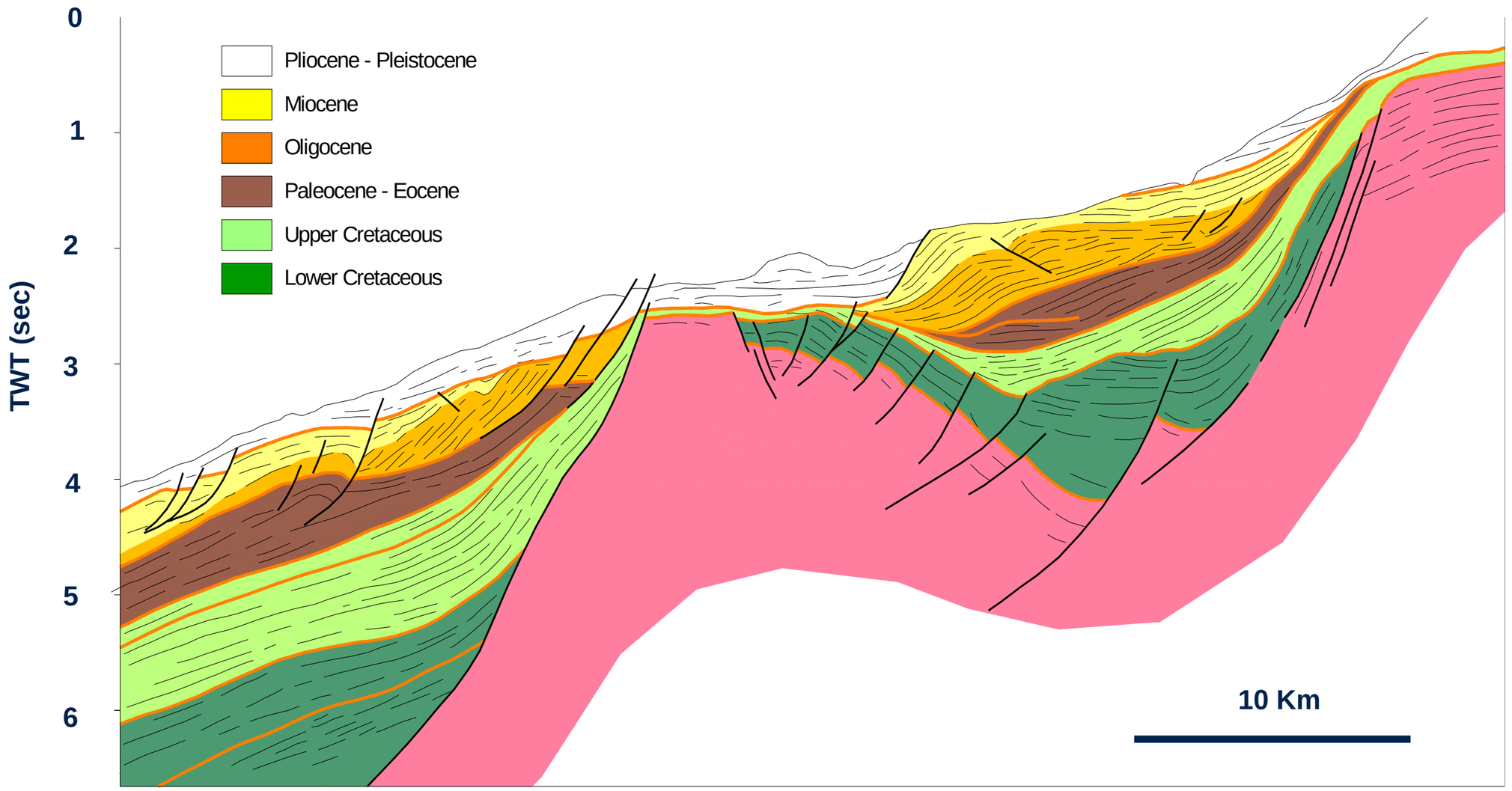
SE **NW**



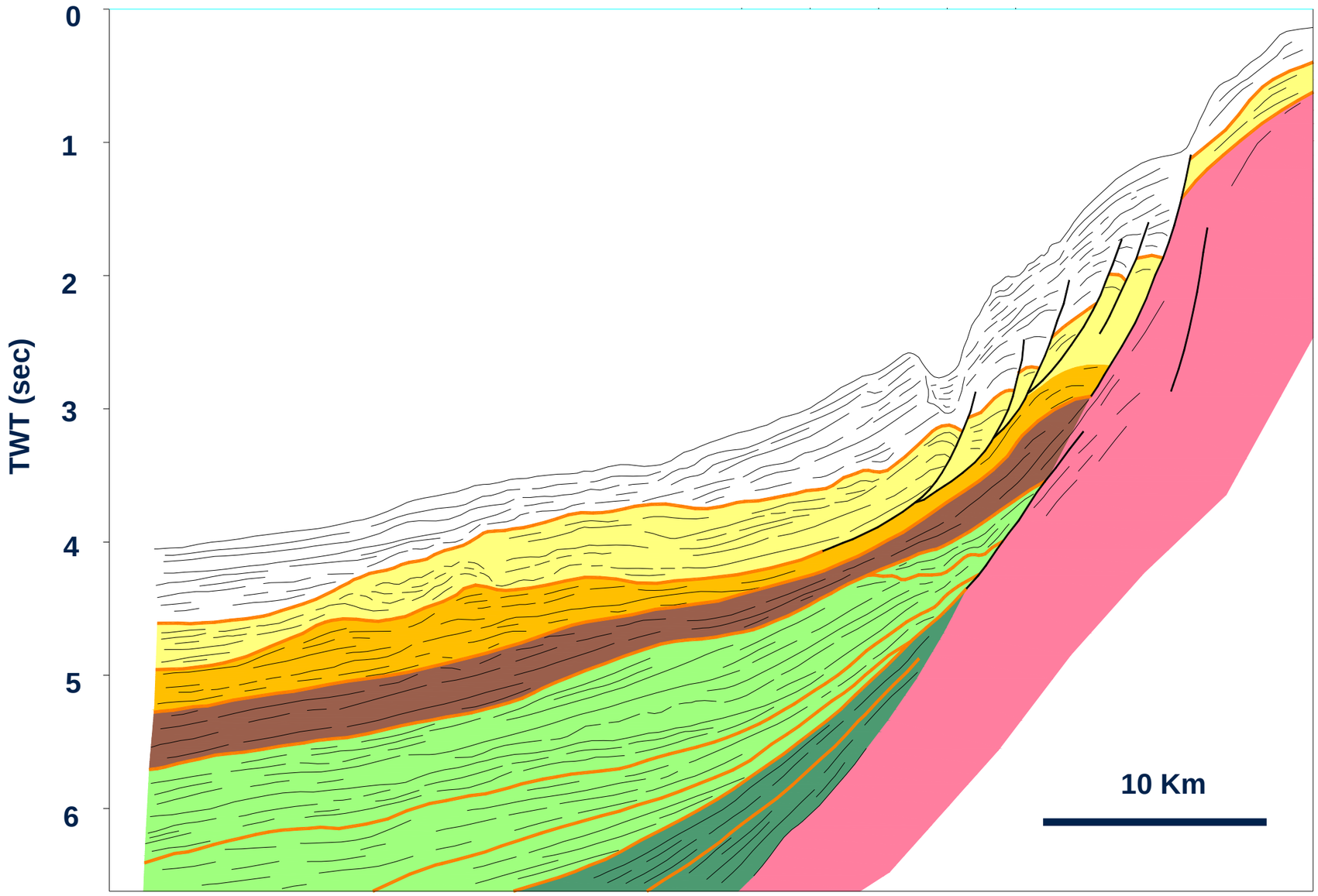
2D Sections Location Map



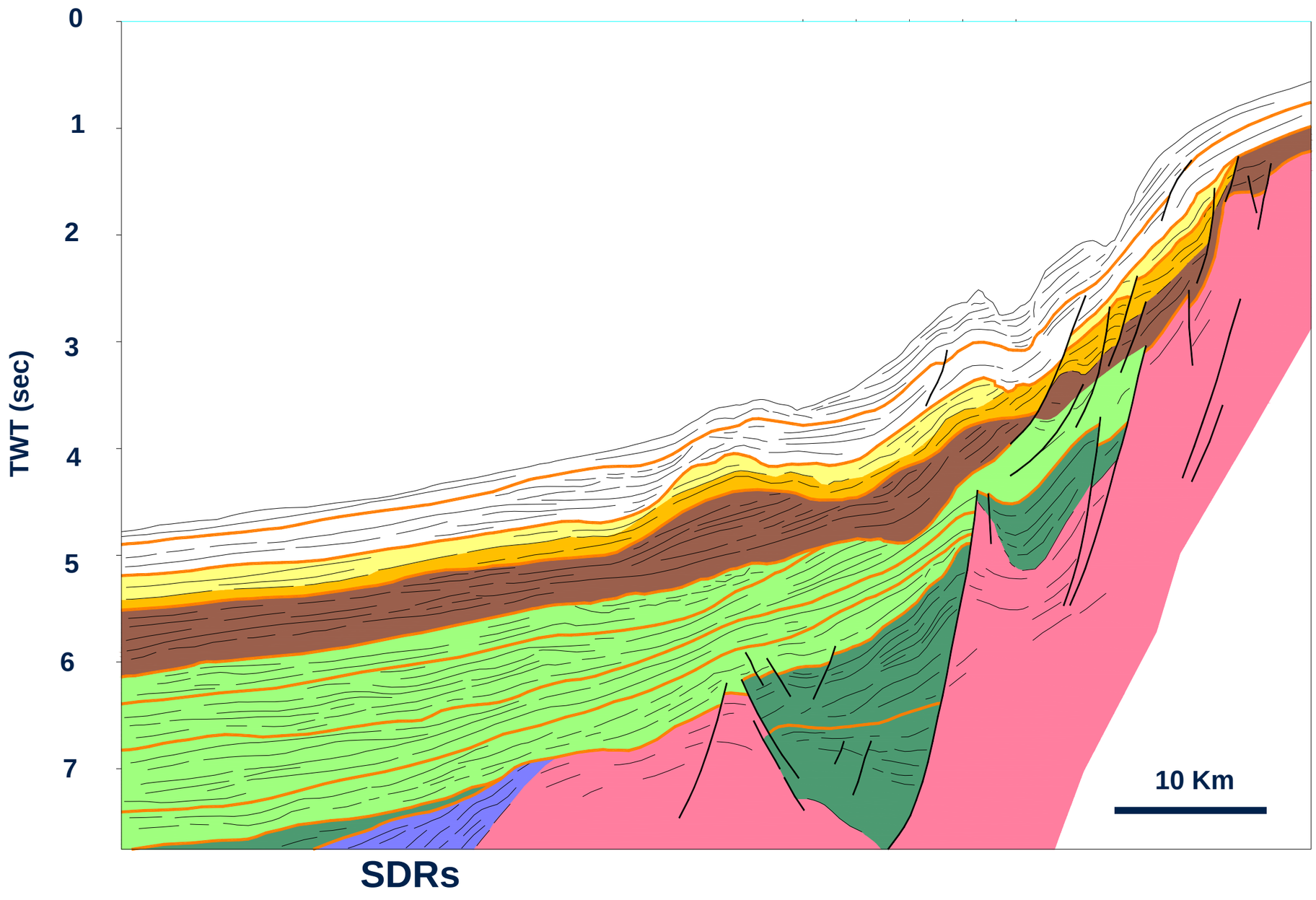
Line-Drawing Section A



Line-Drawing Section B



Line-Drawing Section C



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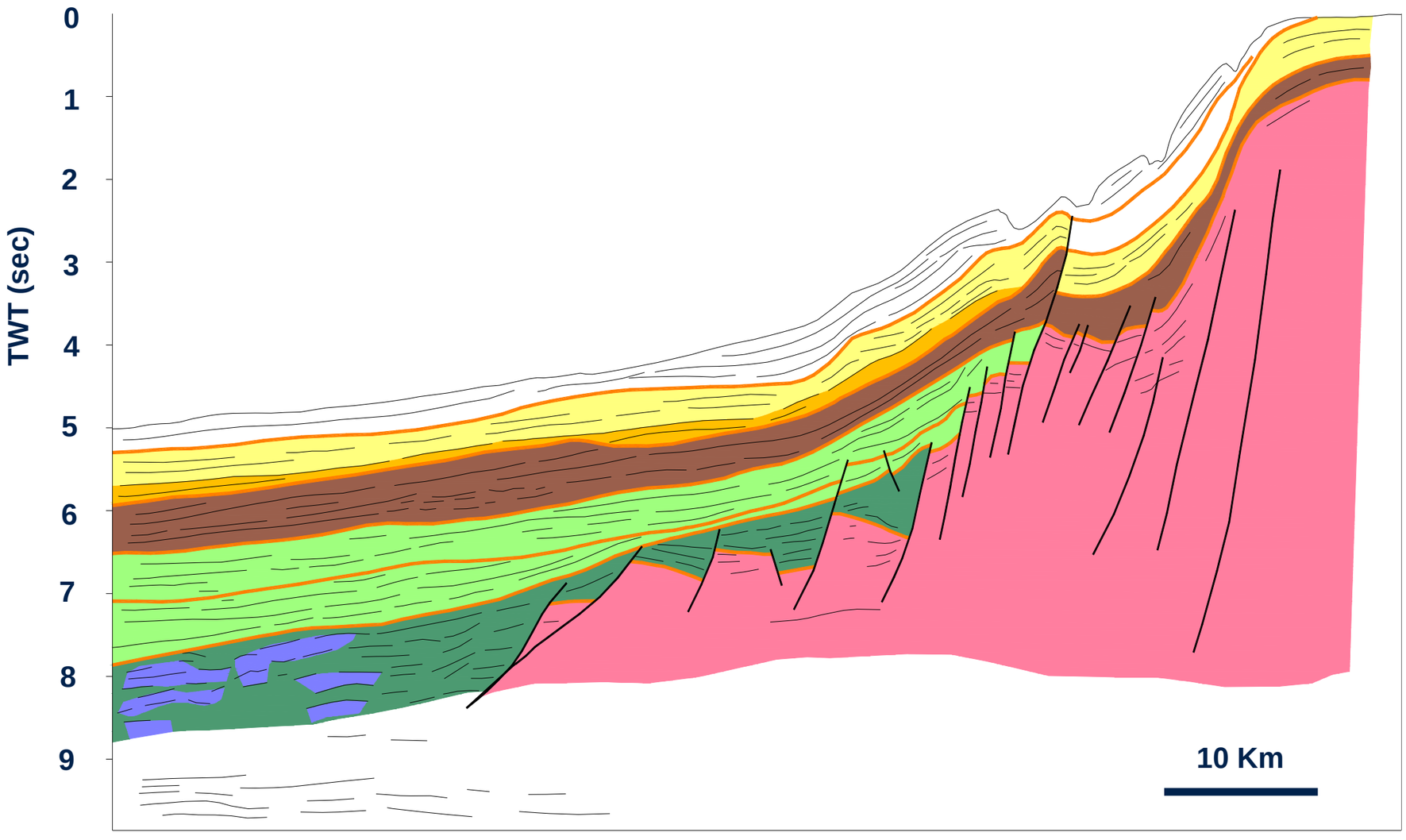
Line-Drawing Section D

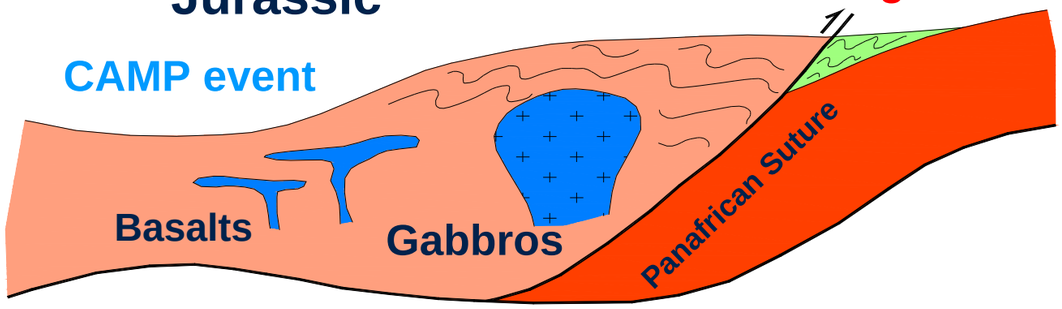


Structural Evolution of the Sierra Leone – Liberia Margin

Jurassic

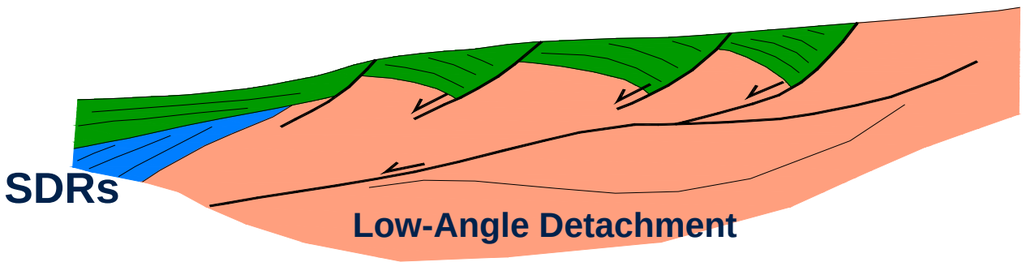
Mantle Plume / Strong Thinning

CAMP event



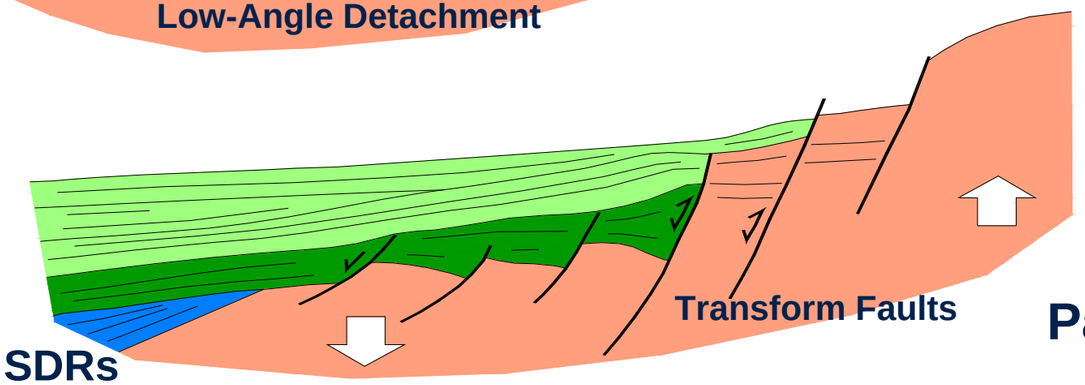
Aptian-Albian (Lower Cretaceous)

Rifting / Low-angle Extension

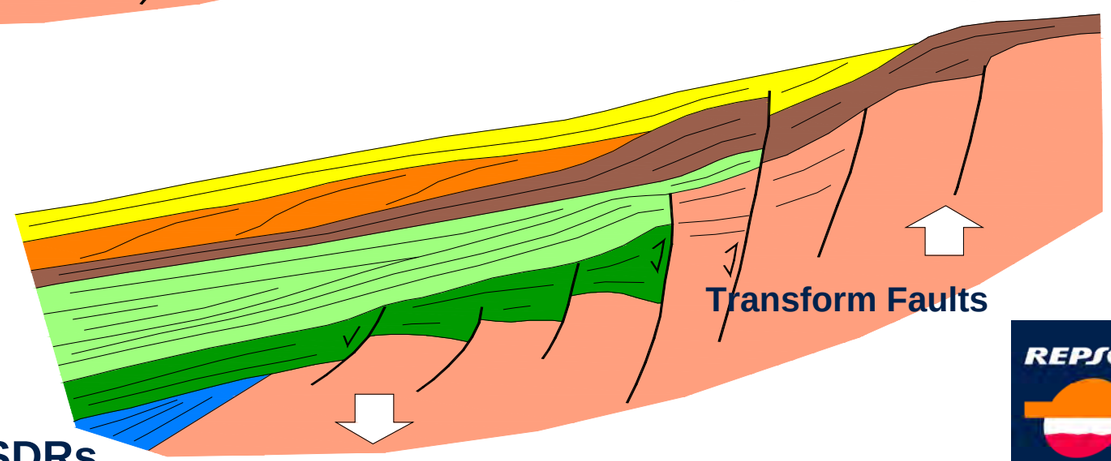


Upper Cretaceous

Transform Fault Activity
Differential Uplift



Paleogene-Neogene



Petroleum System Elements of the Emerging Deep-Water Play

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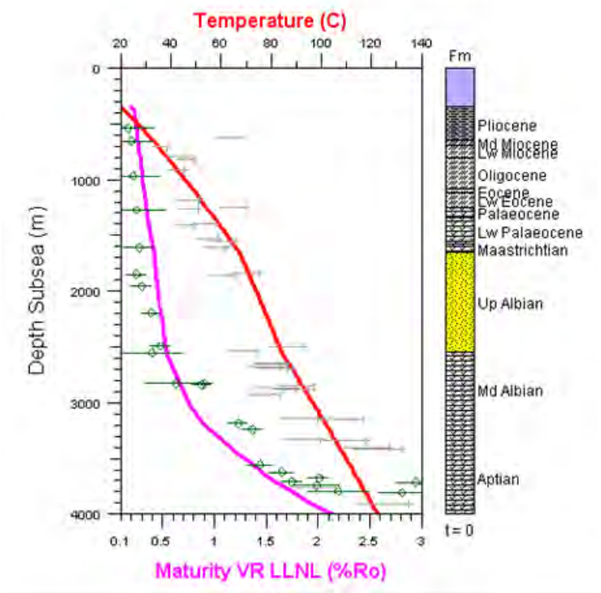
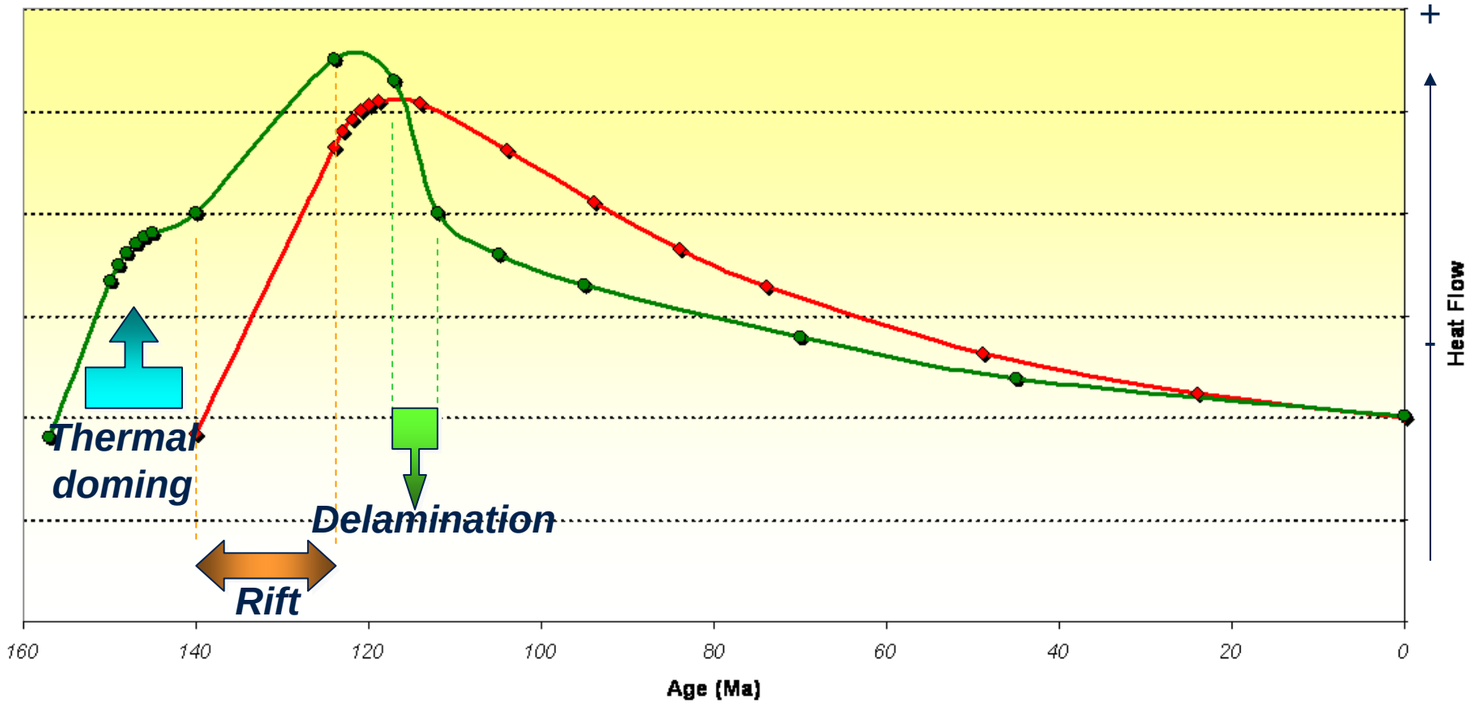
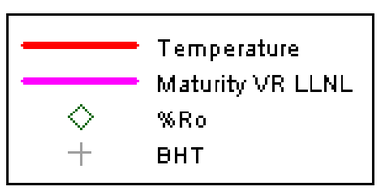
Thermal History Hypothesis







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

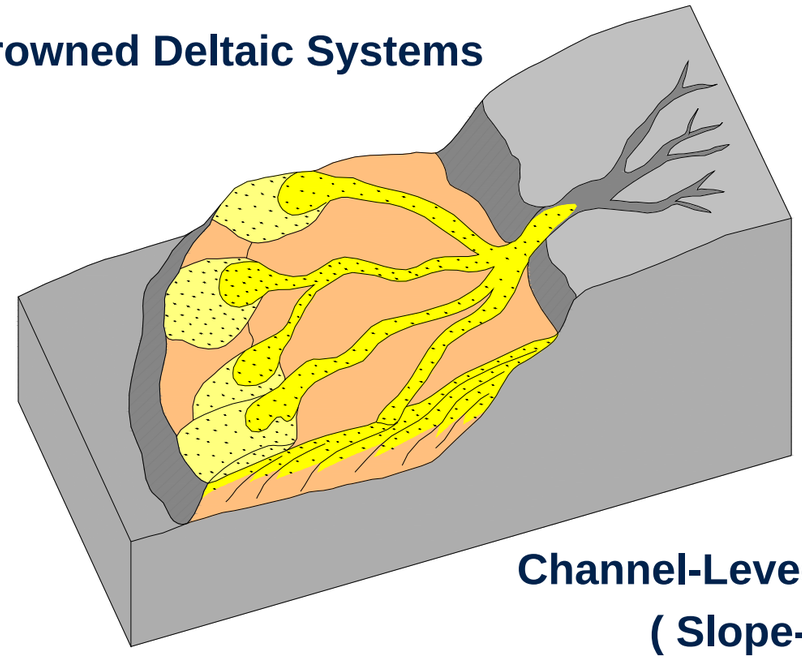
No satisfactory calibration

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)

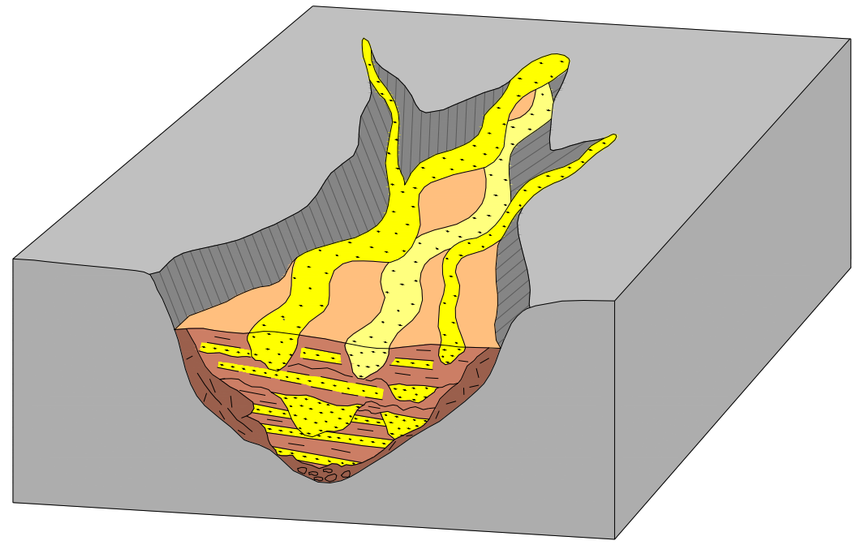
Preferred thermal history, good calibrations

Main Deep-Water Reservoirs

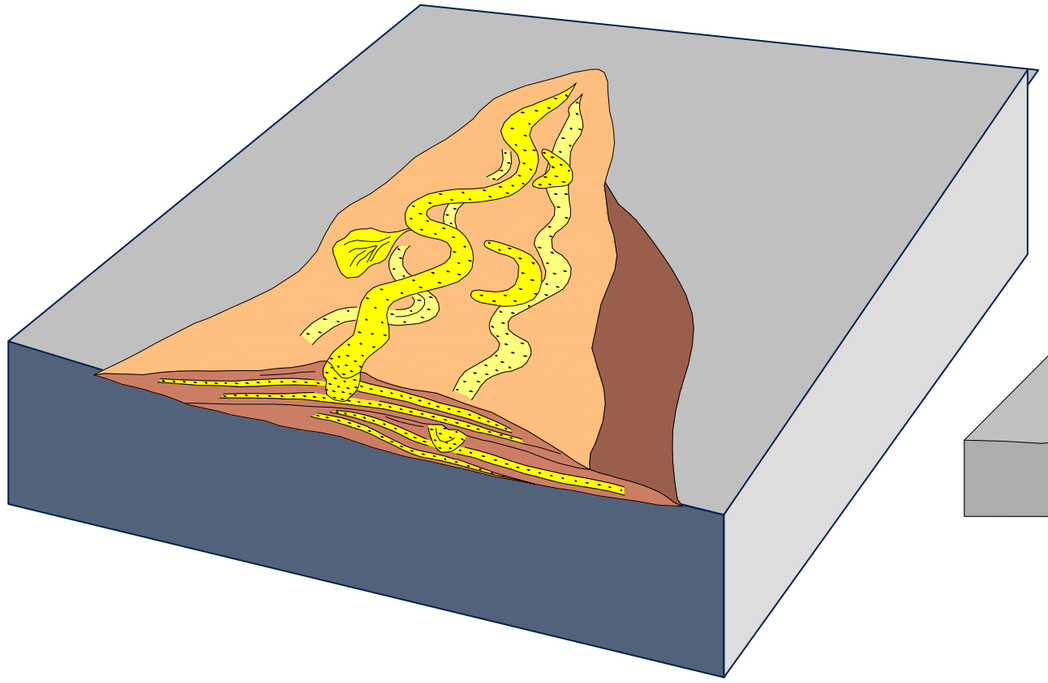
Drowned Deltaic Systems



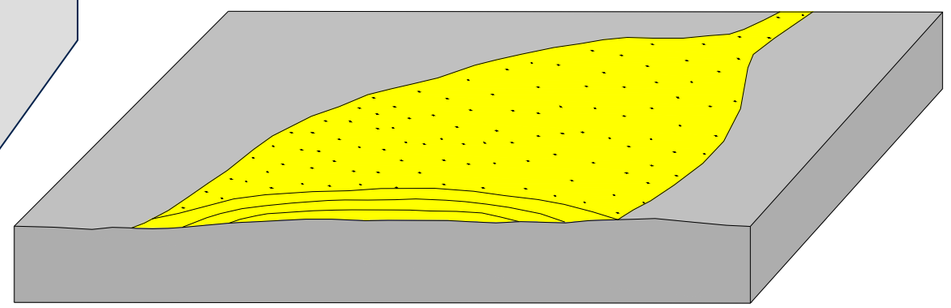
Canyon Fills



Channel-Levee Complexes
(Slope-Fans)

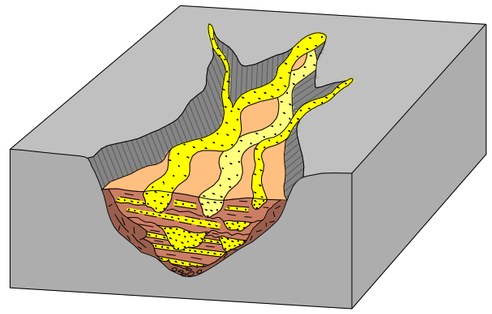


Basin Floor Fans

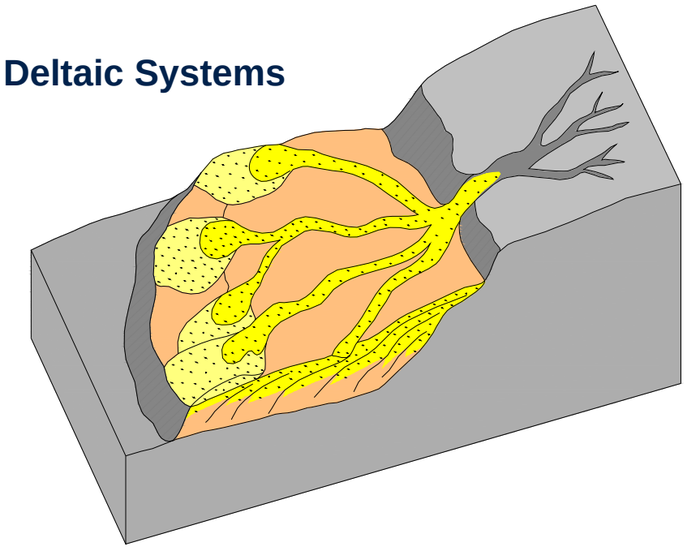


Distribution of Deep-Water Reservoirs

Canyon Fills

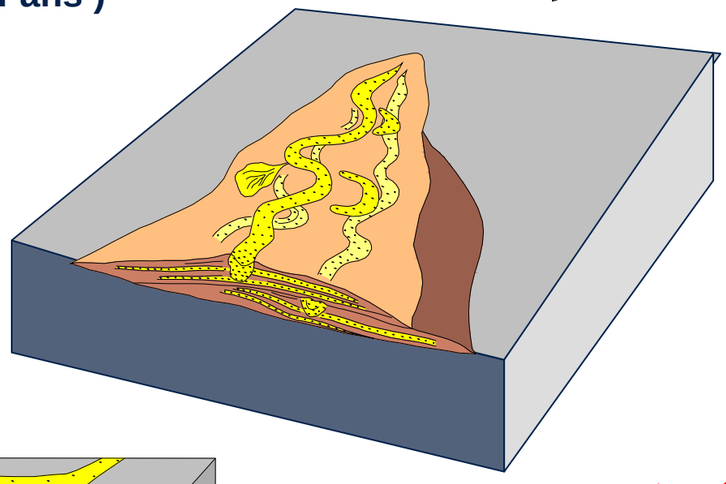


Drowned Deltaic Systems

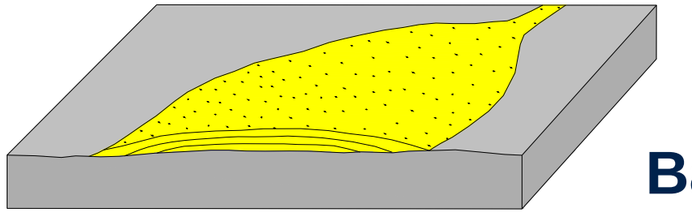


Continental Slope

Channel-Levee Complexes
(Slope-Fans)



Basin Floor Fans



Basin Floor

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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 unconformity, Tilted top-lap surface, truncation below unconformity. 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.