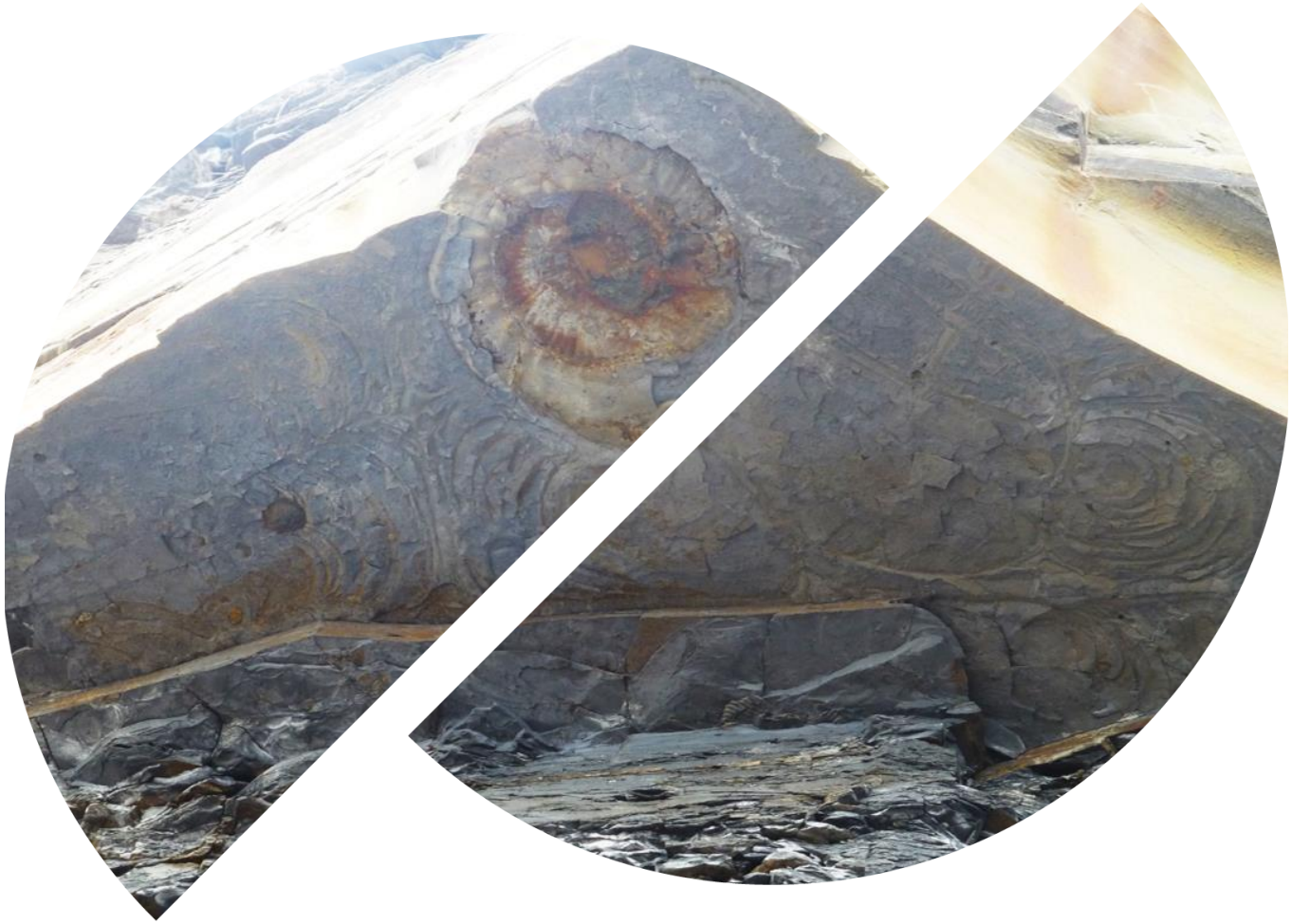

Gabon’s Wild West Frontier Promises a Golden Age of Discovery for the Deep Offshore

Tony Younis, Michael Clutterbuck, Phil Birch

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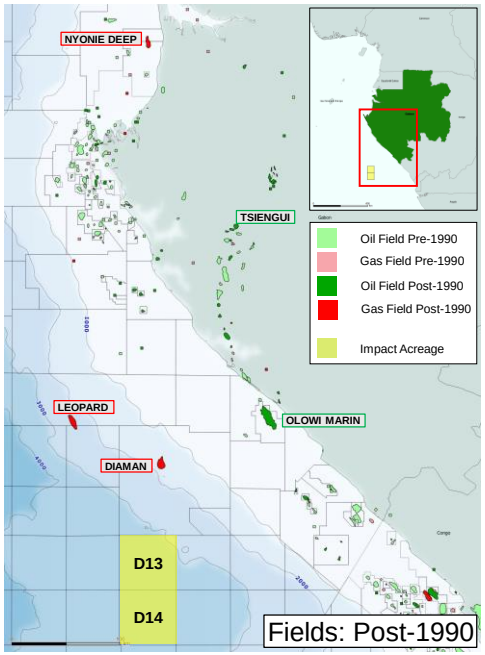
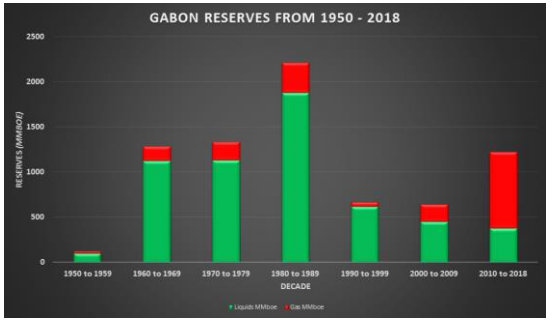
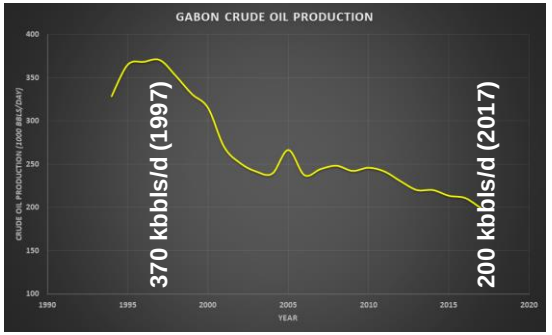
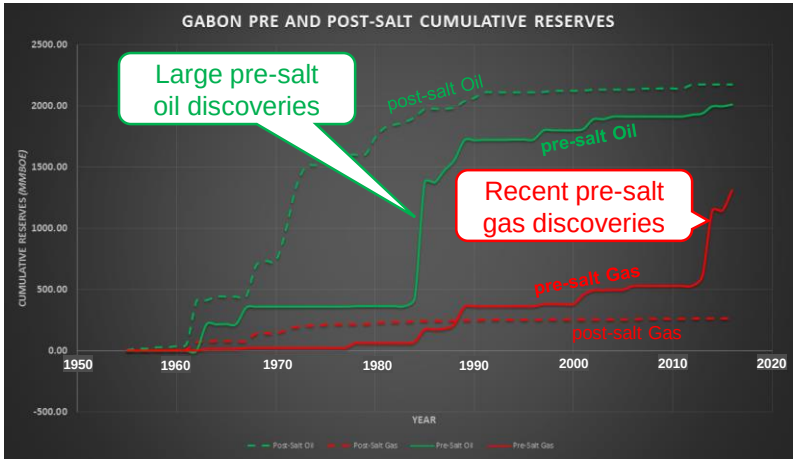
Gabon Exploration and Production History





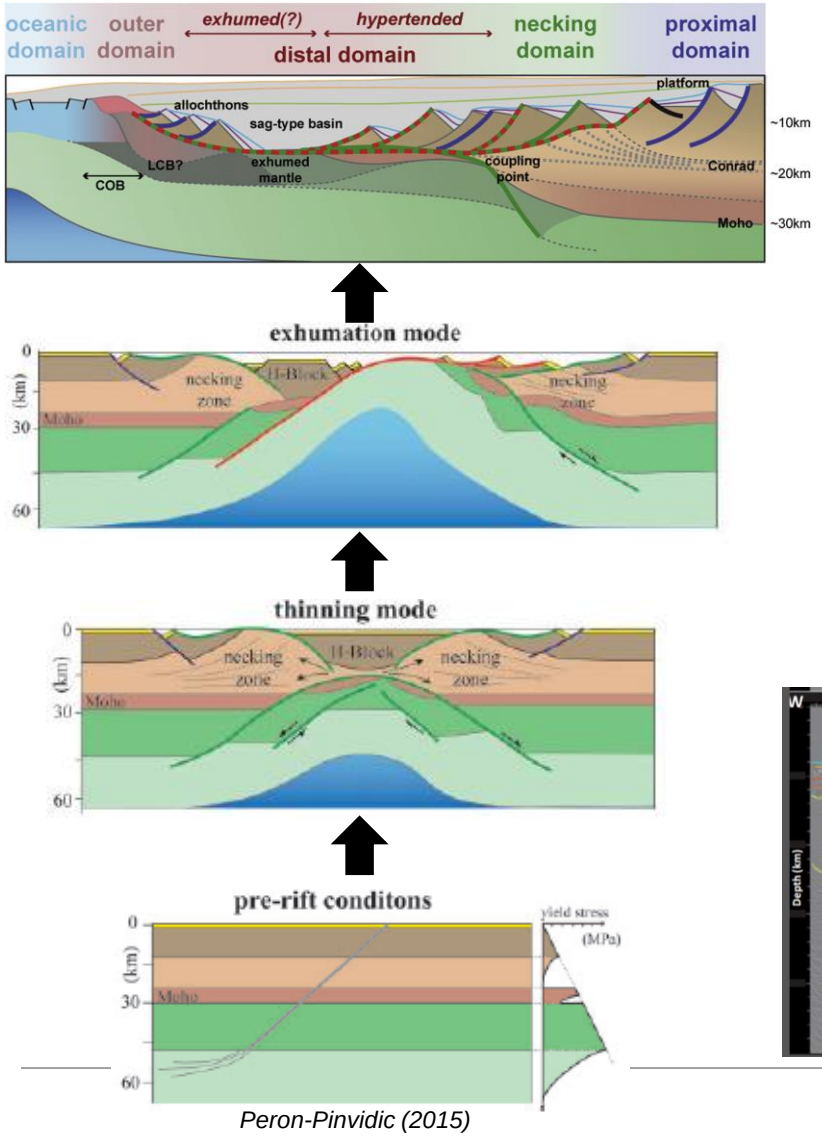


- OPEC member and net oil exporter
- Oil sector makes up 45% of GDP and 80% of exports *(World Bank)*
- **But** oil reserves have steadily declined over the last 30 years
- Peak oil production in 1997 stood at 370,000 bbls/day
- Oil production as at the end of 2017 stood 200,000 bbls/day



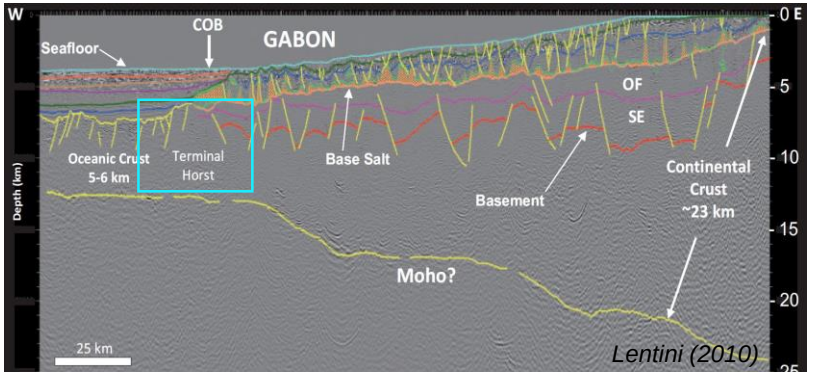
- Dramatic increase in oil reserves in mid 80s with onshore pre-salt discoveries
- Increase in potential gas reserves since 2013 thanks to pre-salt exploration in the deep offshore
- **Can we hope for another wave of oil discoveries from the deep offshore play?**
  - **Yes and it's located in Gabon's ultra-deep 'Wild West'**

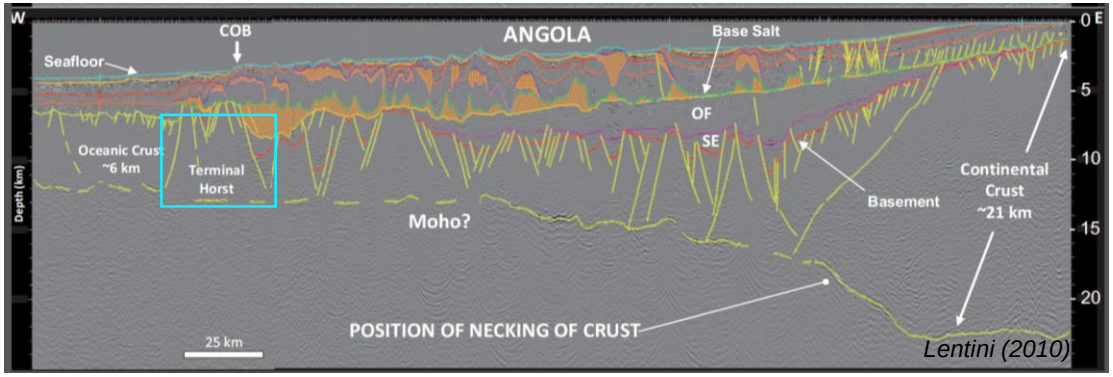
Hyperextension and the ‘Terminal Horst’



Peron-Pinvidic (2015)

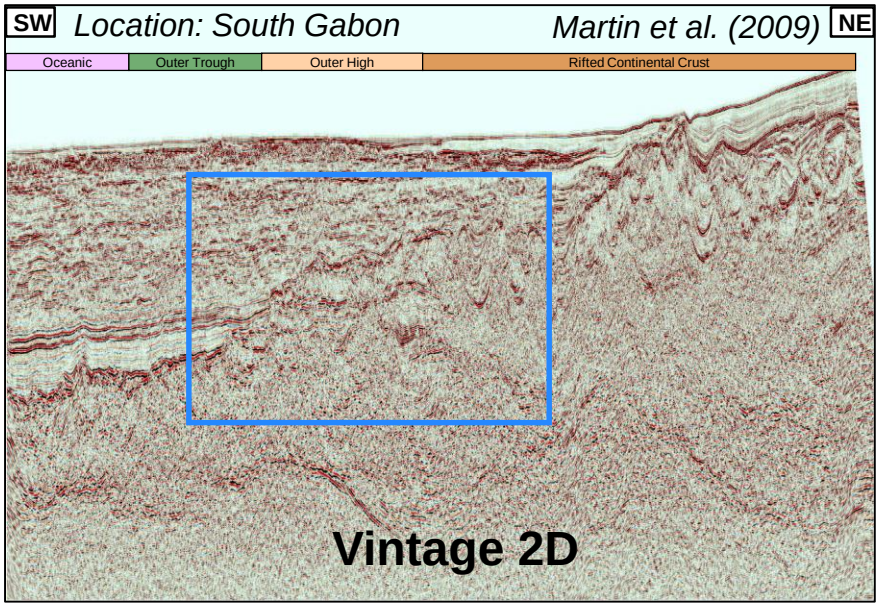
- An **Outer High** is conventionally perceived as a large ‘terminal horst’ boundary separating transitional and oceanic crust – composed of basement or igneous rock
- But is it always the case?



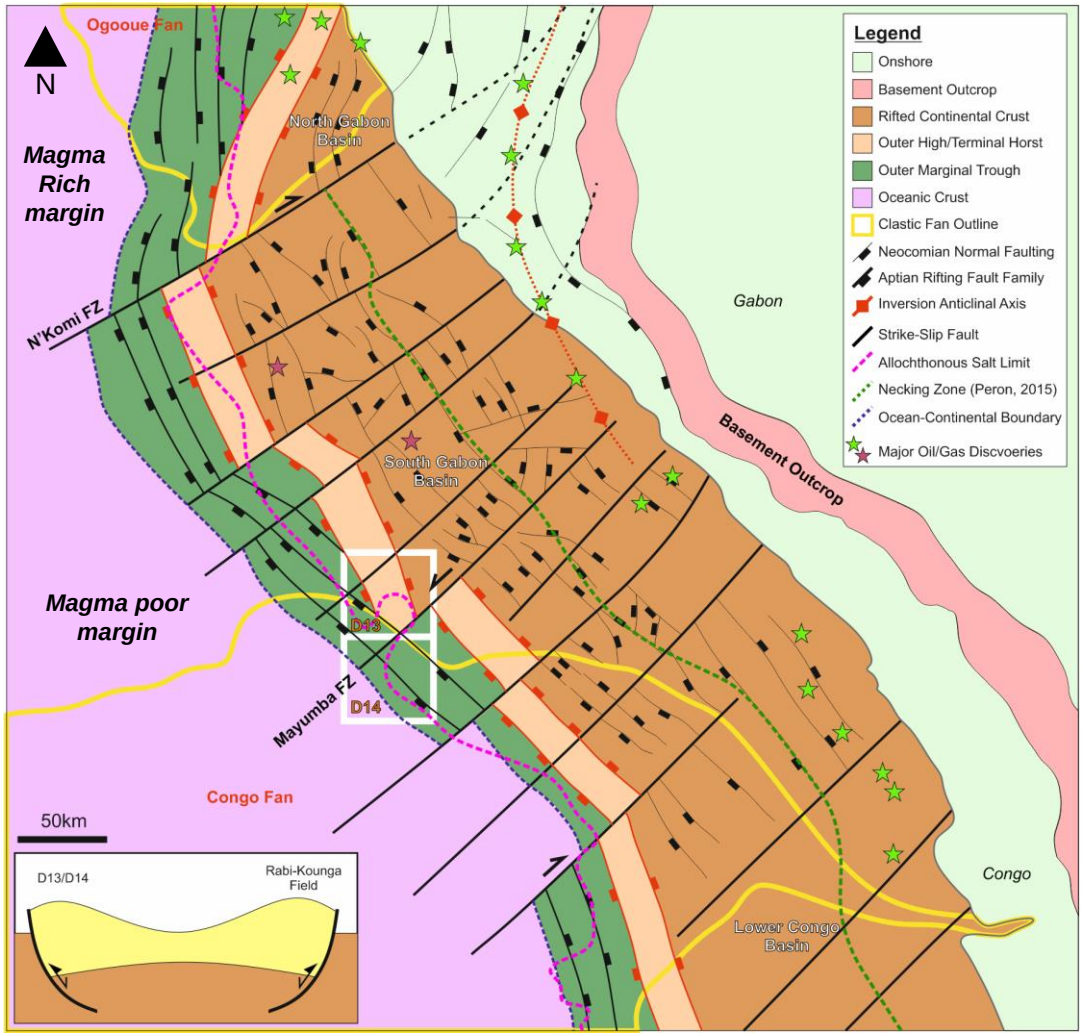


Gabon's Hyperextended Margin

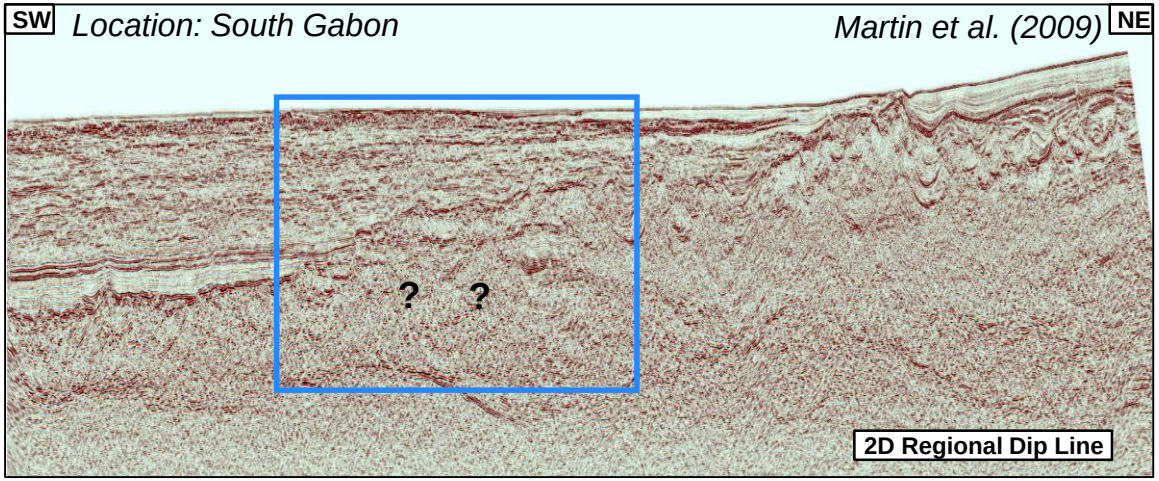
- Impact's D13/D14 blocks located within the distal and outer tectonic domains of the West African hyperextended margin
- The Outer High separates two basins; an inner salt basin, and an oceanward outer marginal basin
- Advent of high resolution 3D data provides insights into the true nature of some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

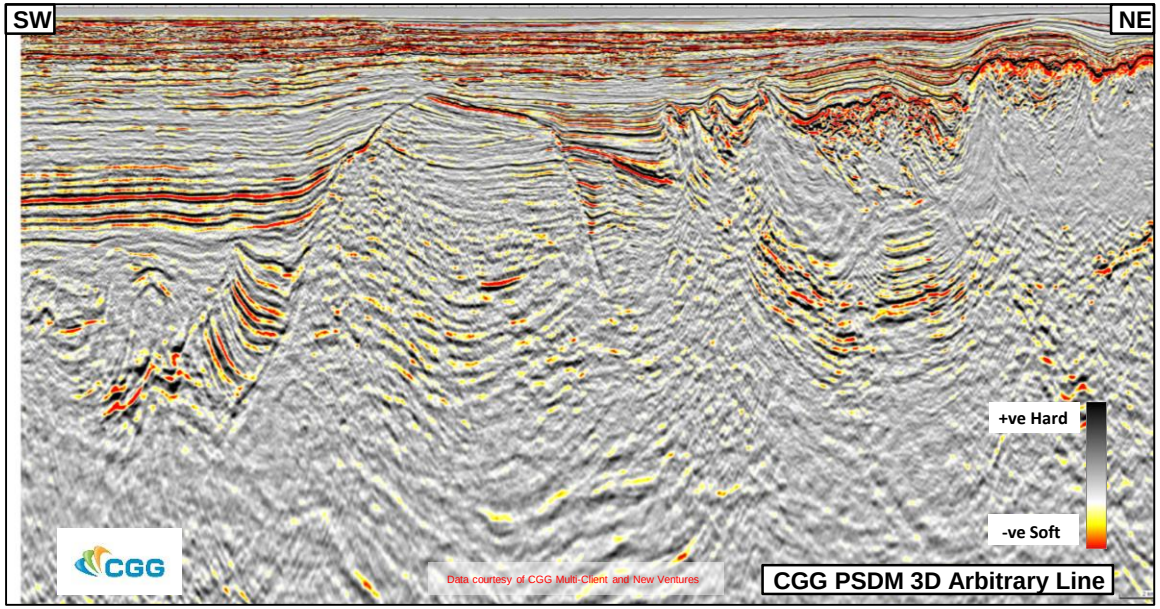


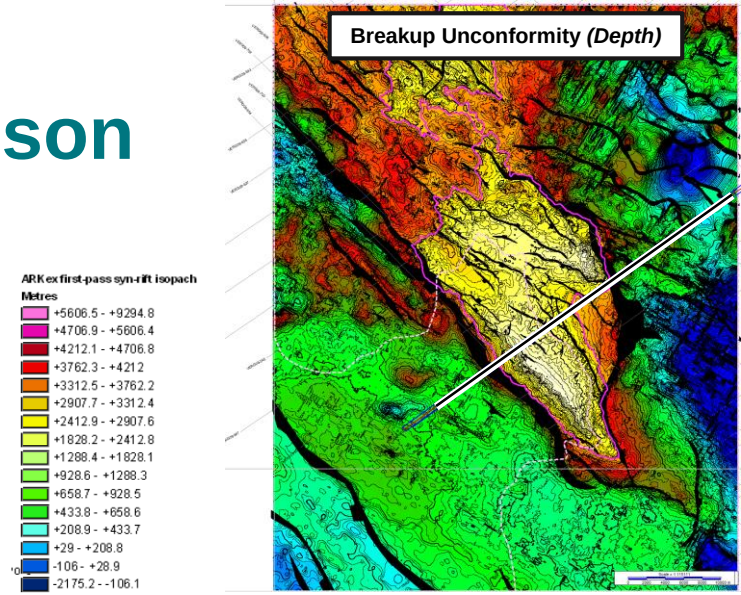
Regional Tectonic Framework

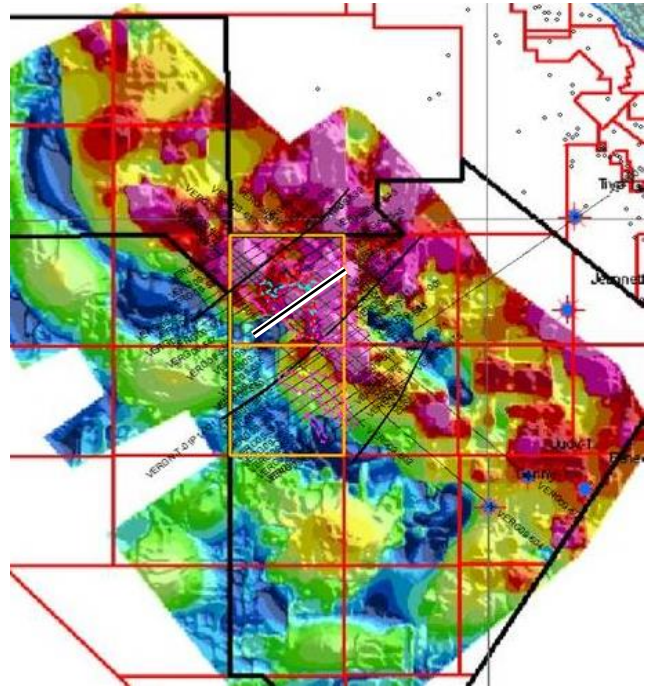


2D vs 3D PSDM Seismic Comparison

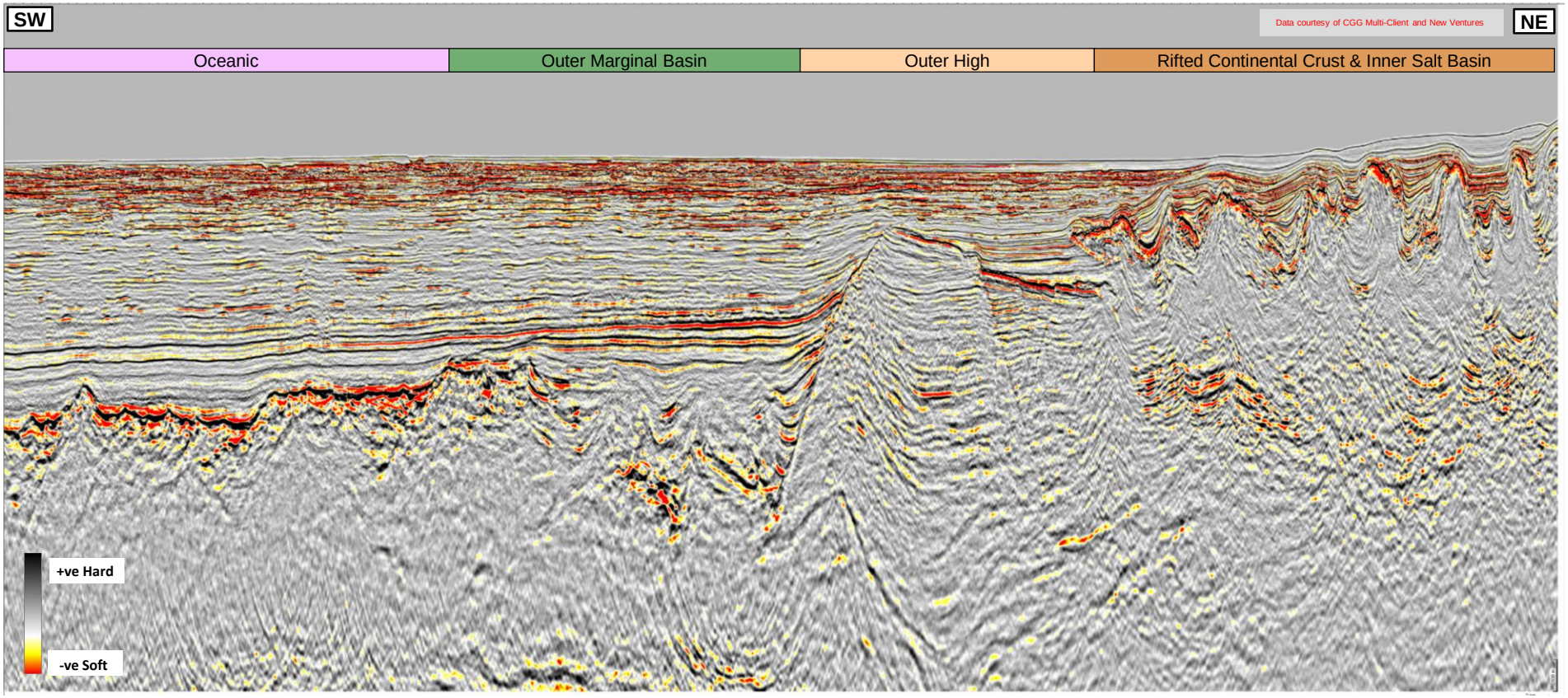






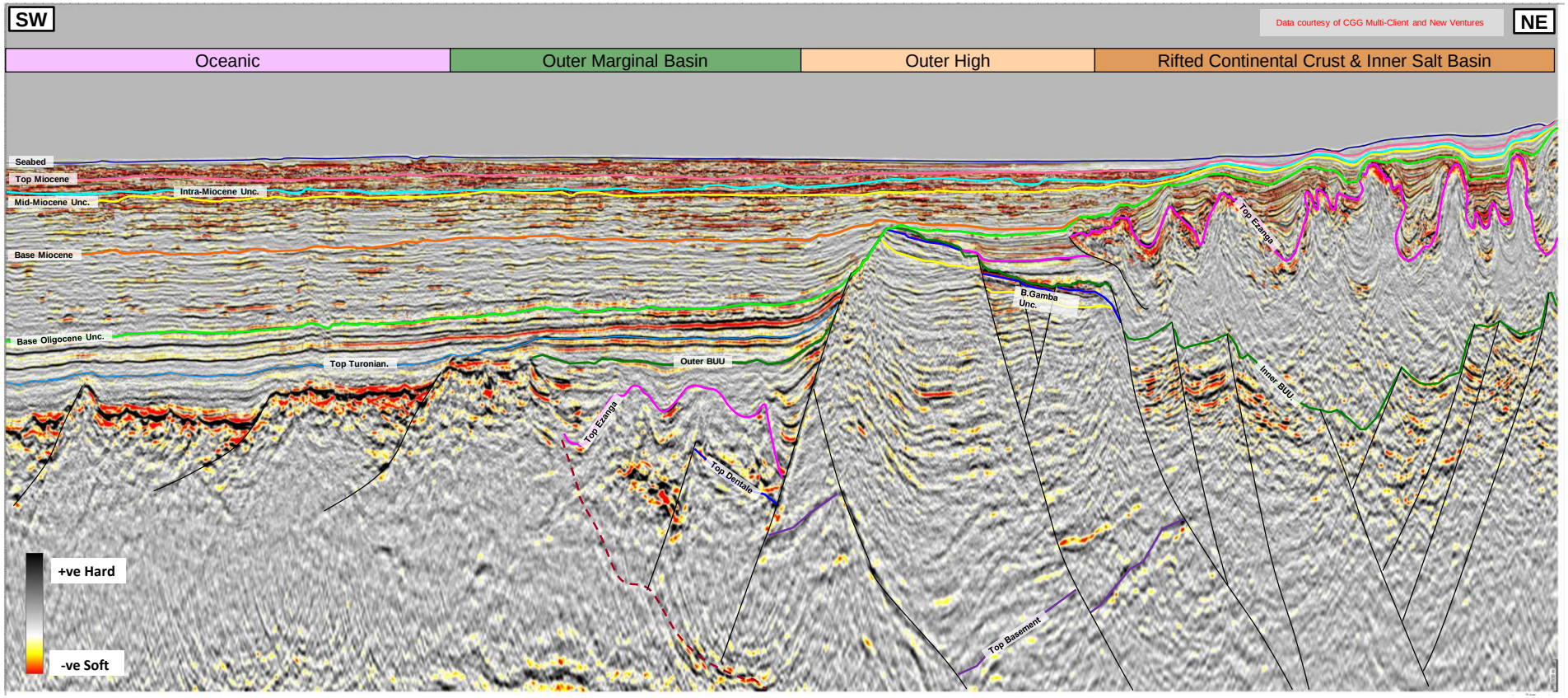


Outer Highs can be made of sediment



- 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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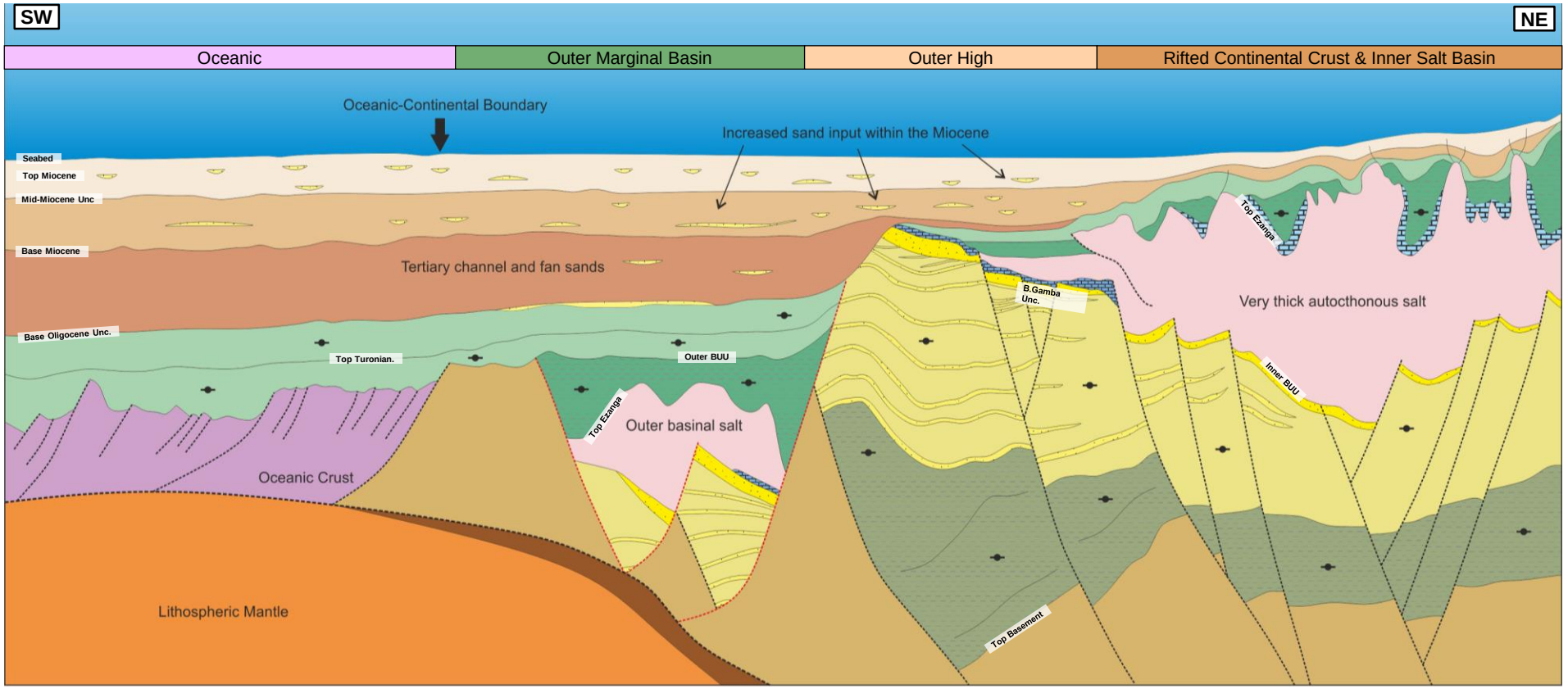
Outer Highs can be made of sediment

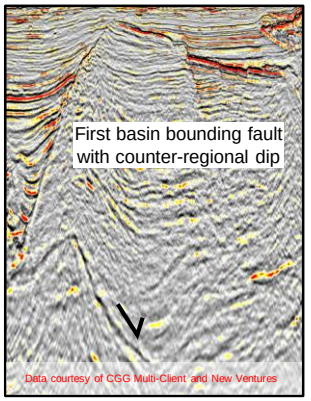


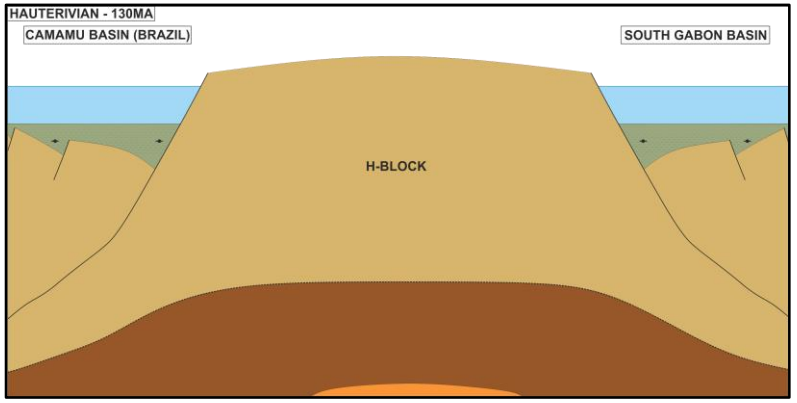
So how do we get here?

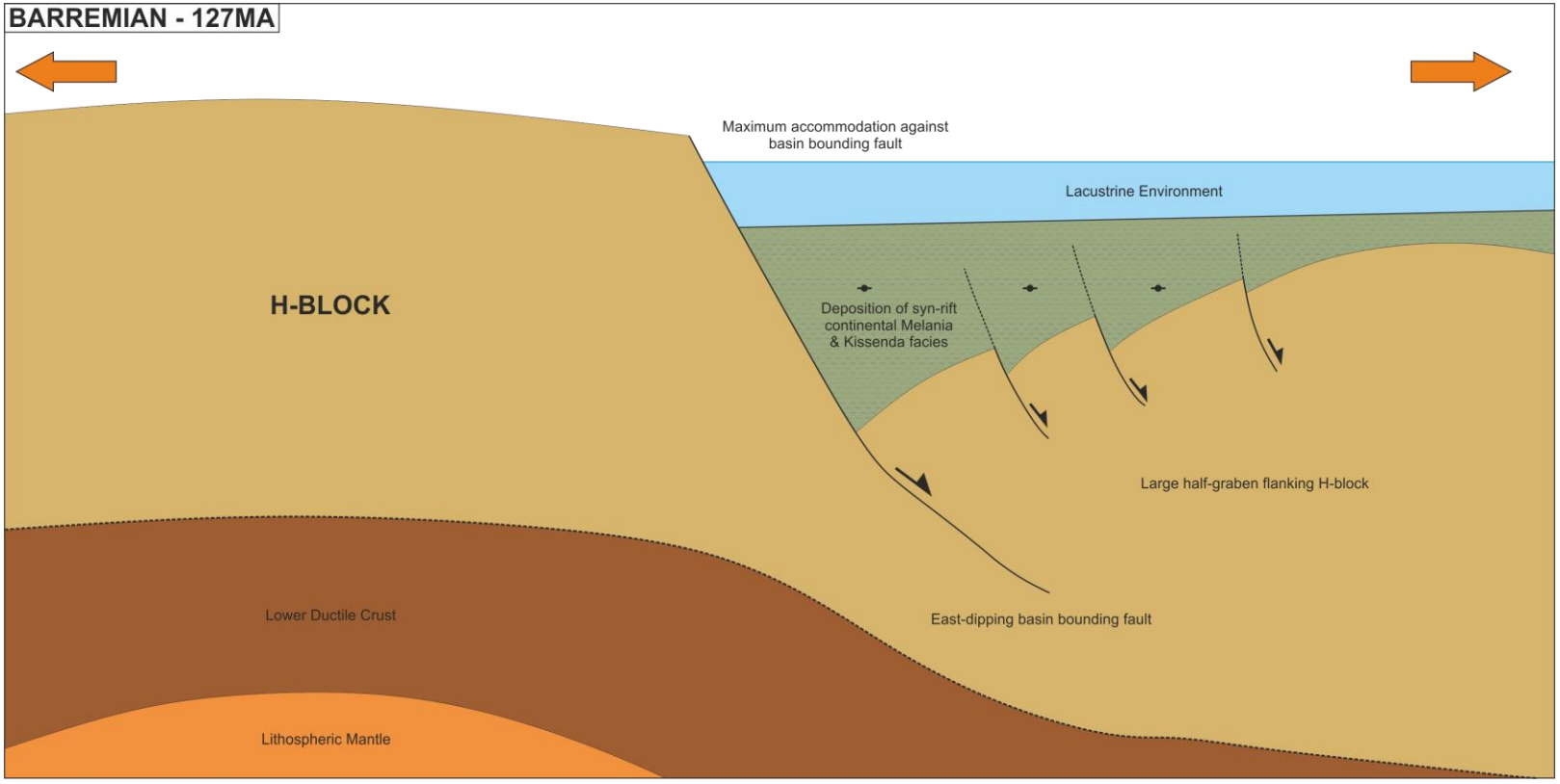
Tectonic Evolution

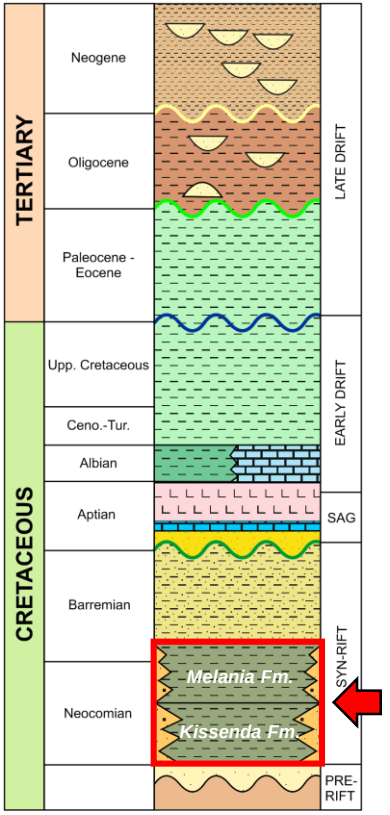
Early Rift I – Barremian

- Basin bounding fault against an ‘H’ block creates maximum accommodation for thick lacustrine shales





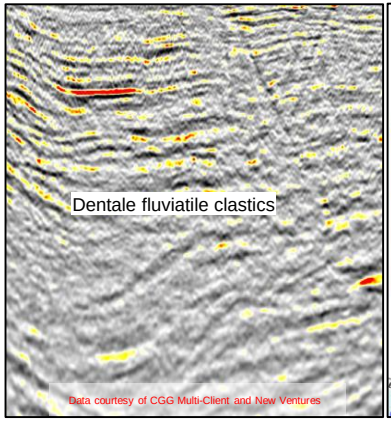


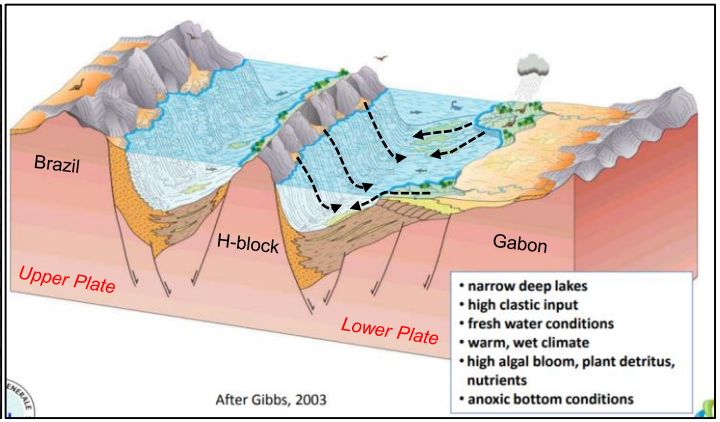


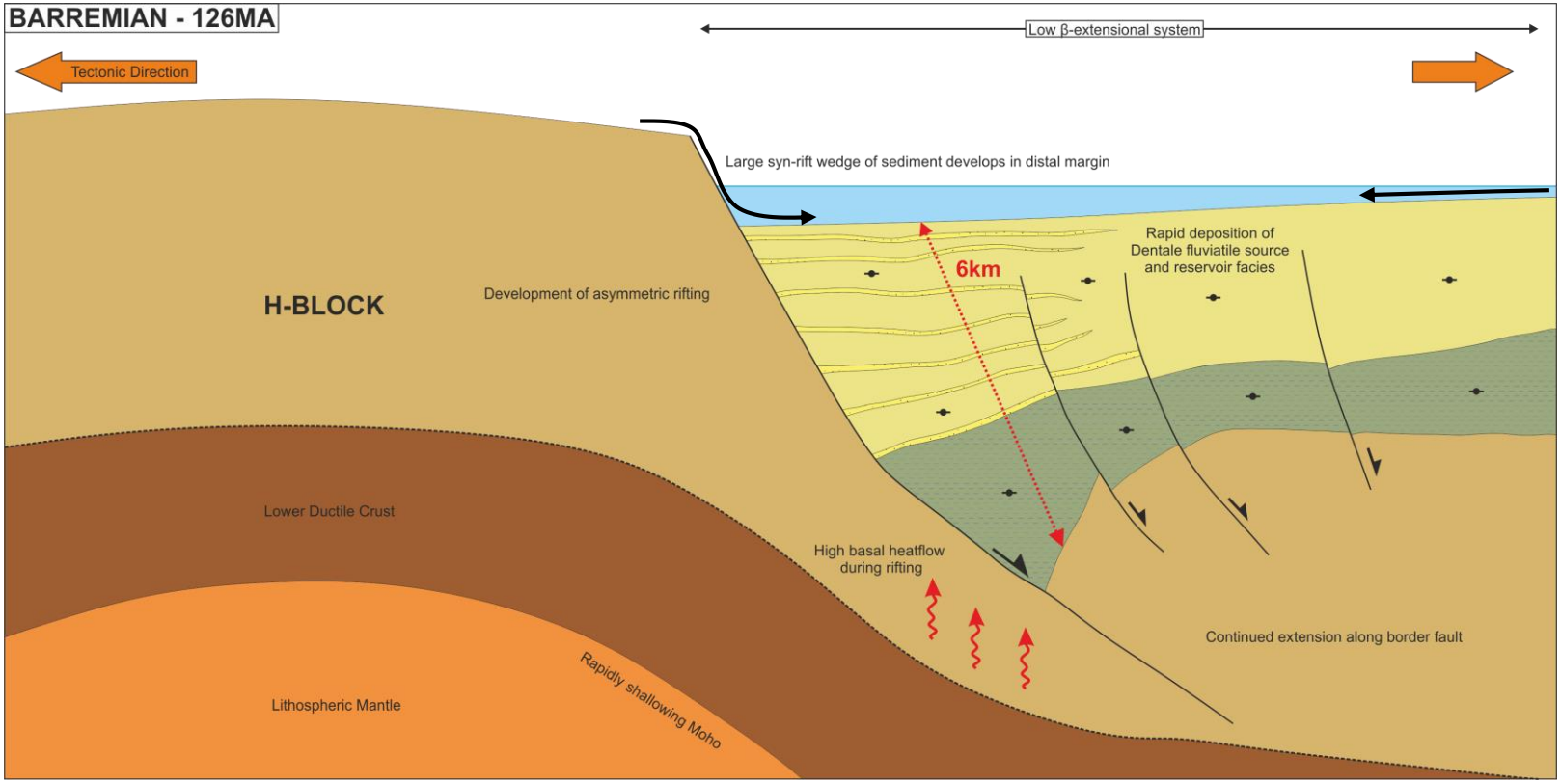
Tectonic Evolution

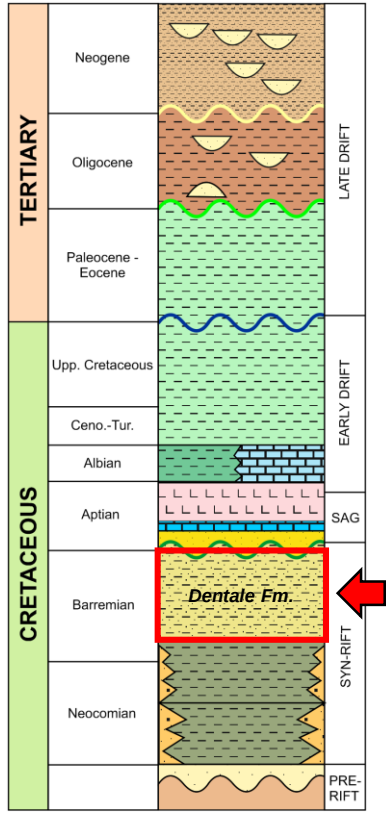
Late Rift I – Late Barremian

- Continued rifting allows for the accumulation of thick fluviatile deposits





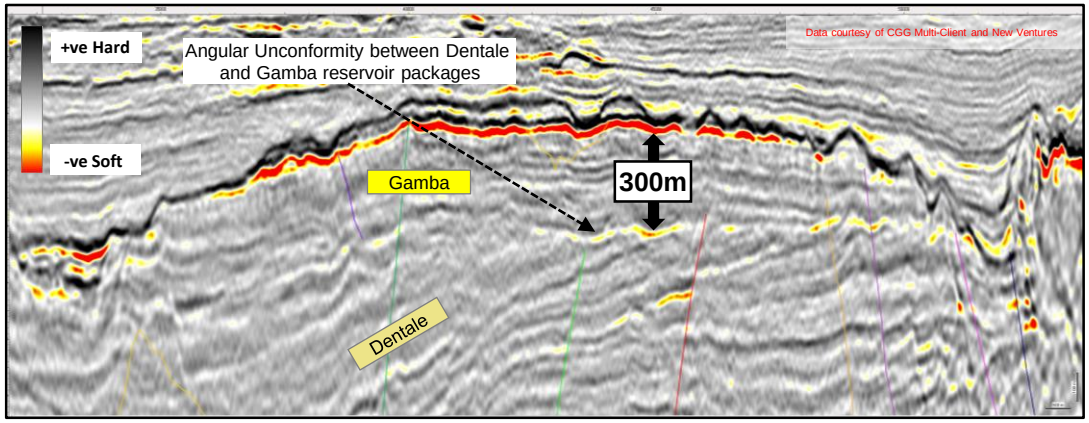


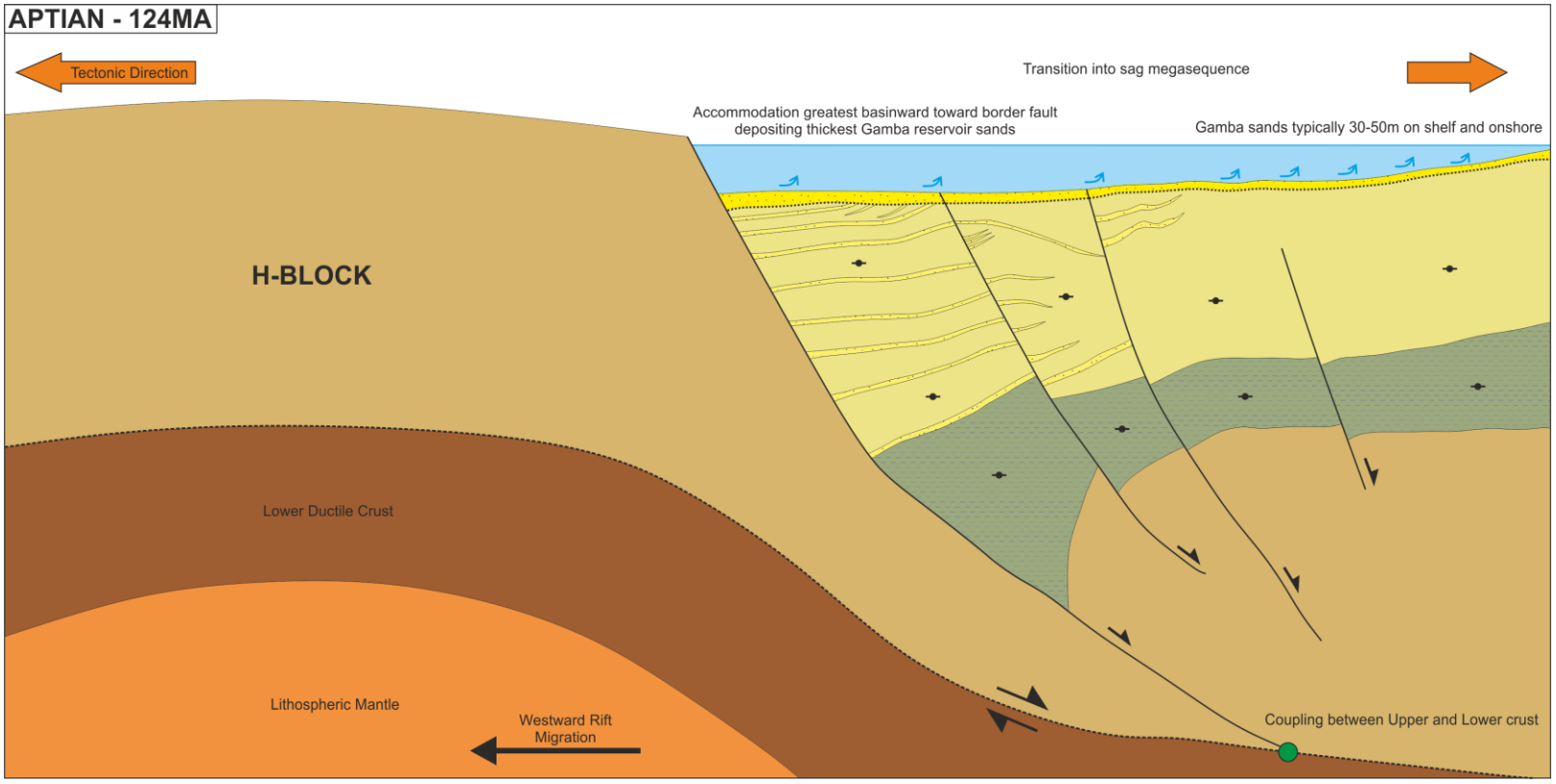


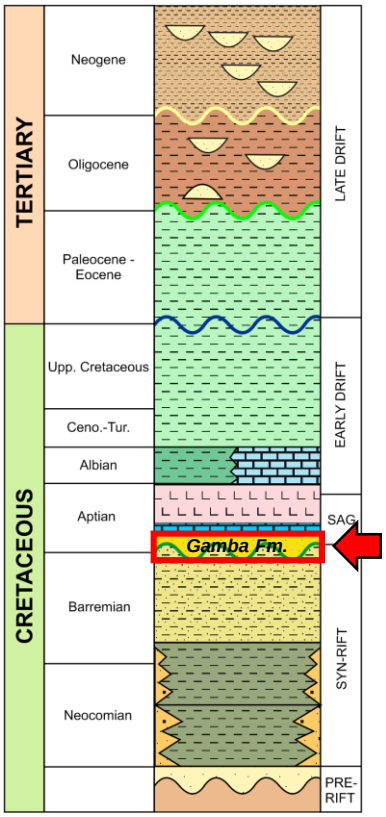
Tectonic Evolution

Transitional Sag – Early Aptian

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



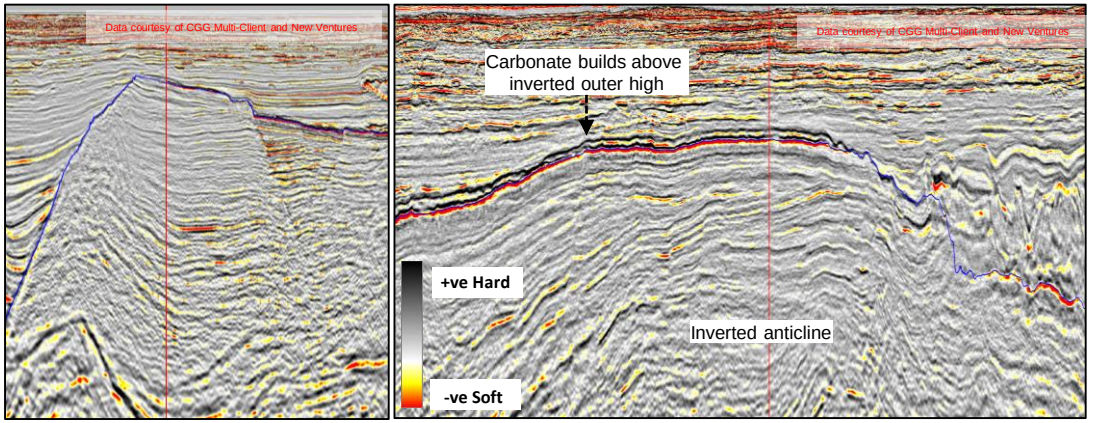


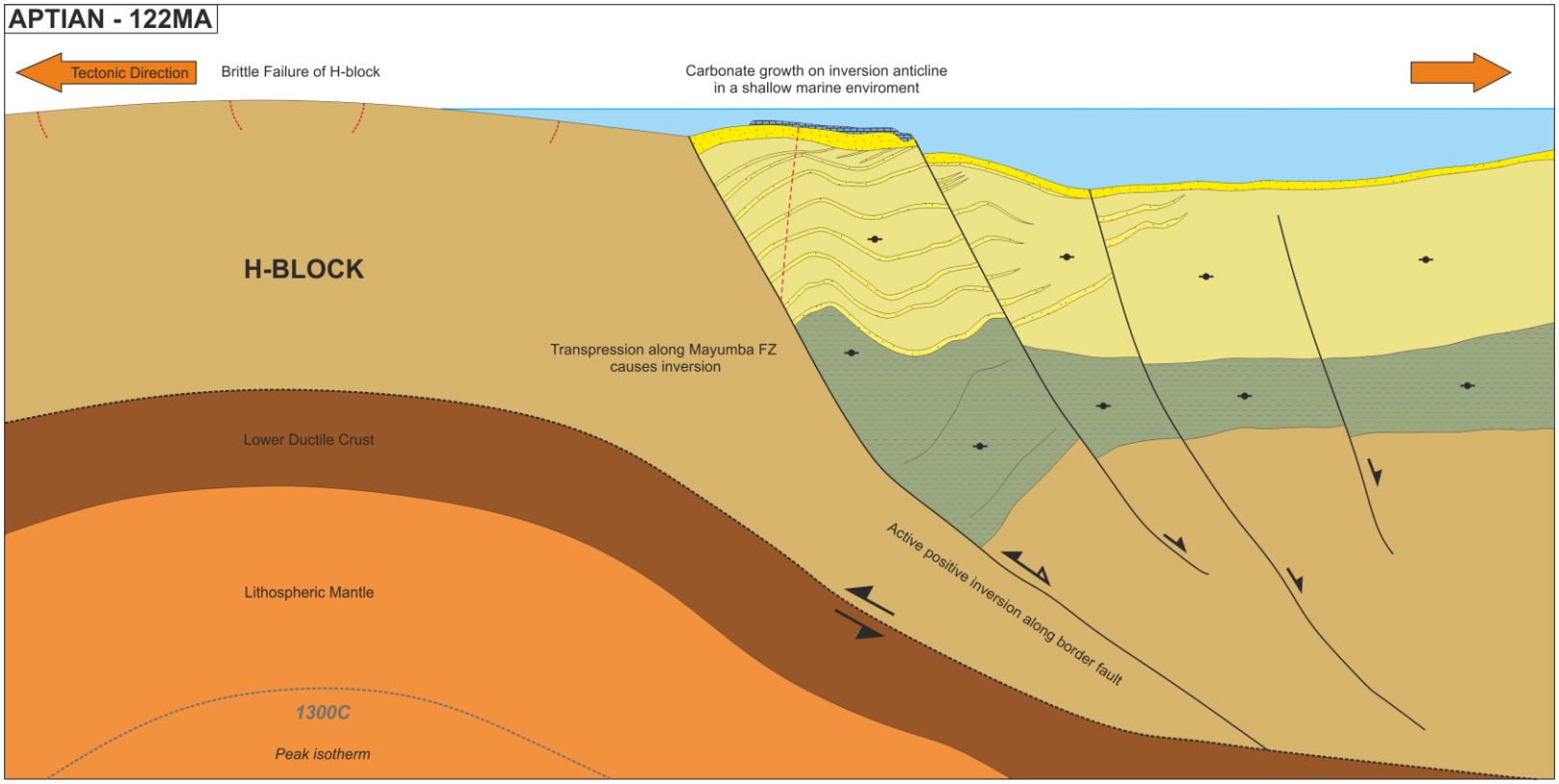


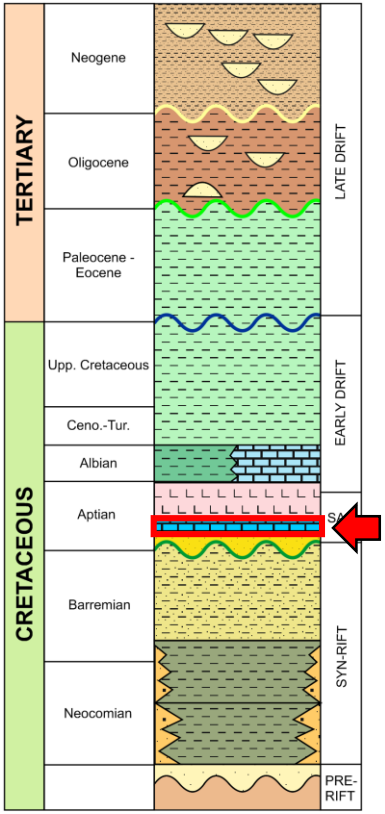
Tectonic Evolution

Inversion – Mid Aptian

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



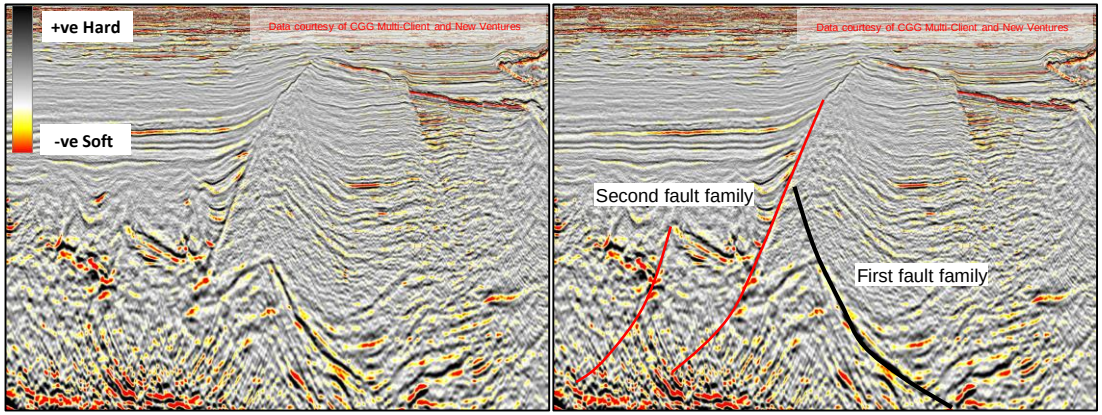


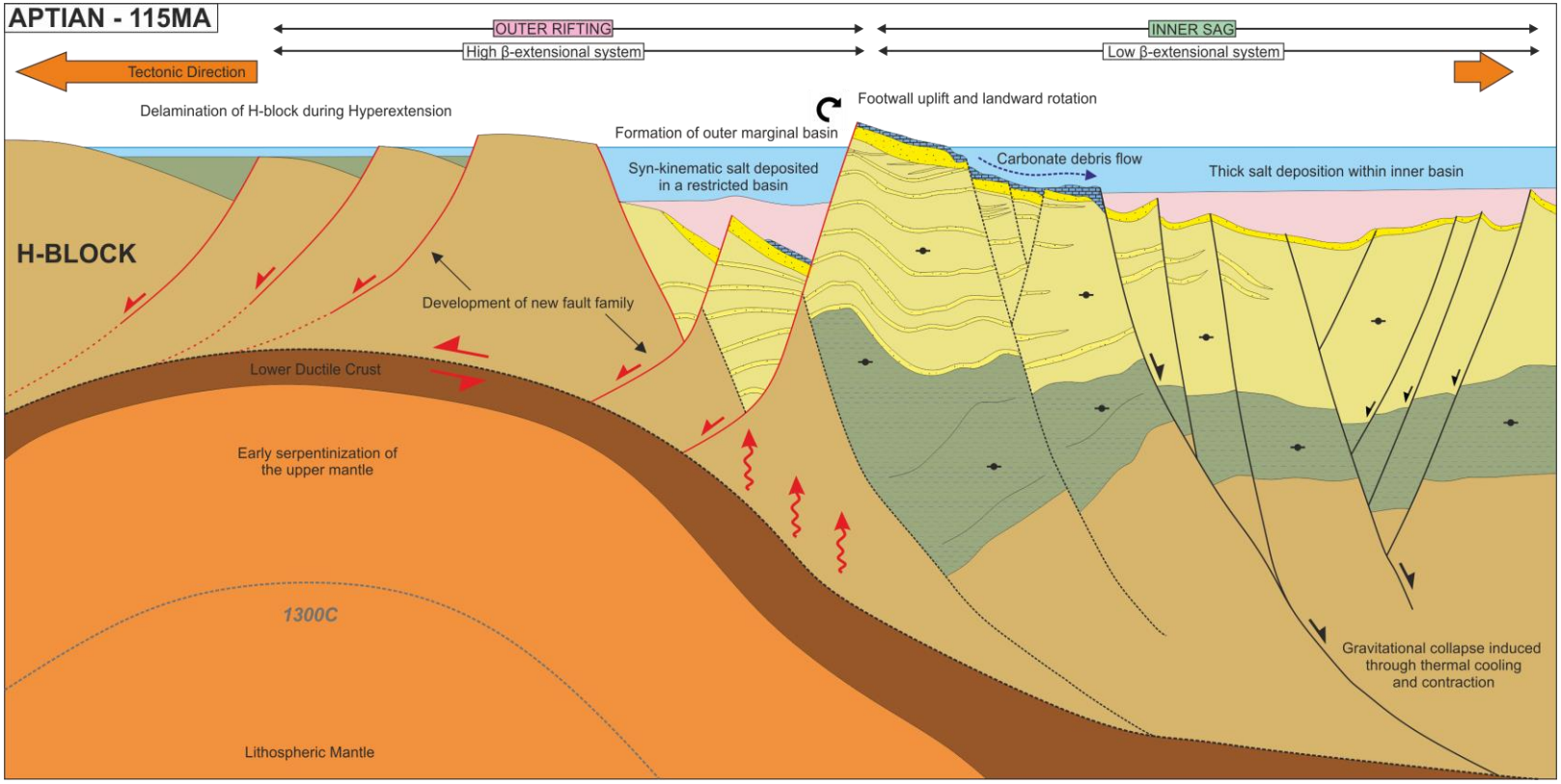


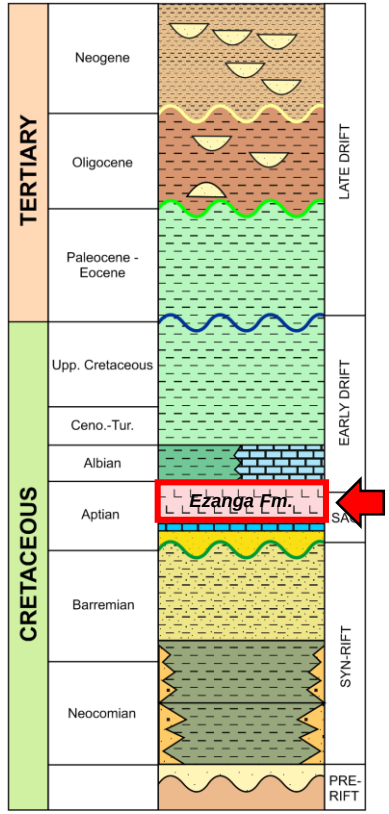
Tectonic Evolution

Early Rift II – Late Aptian

- Onset of hyperextension creates new fault family to the west as salt is deposited in a hypersaline environment





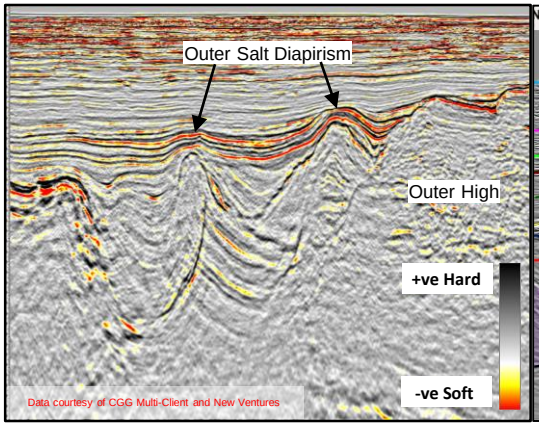


Tectonic Evolution

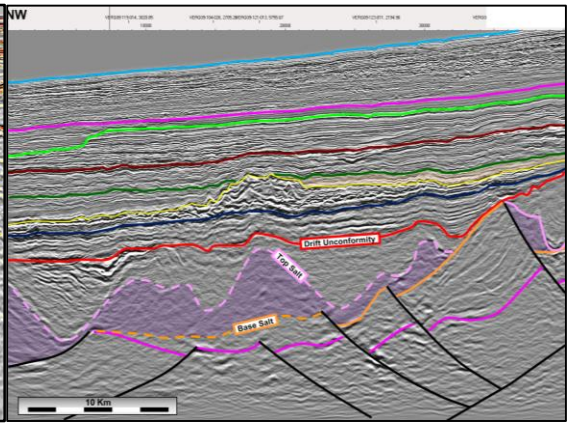
Early Drift – Mid. Albian

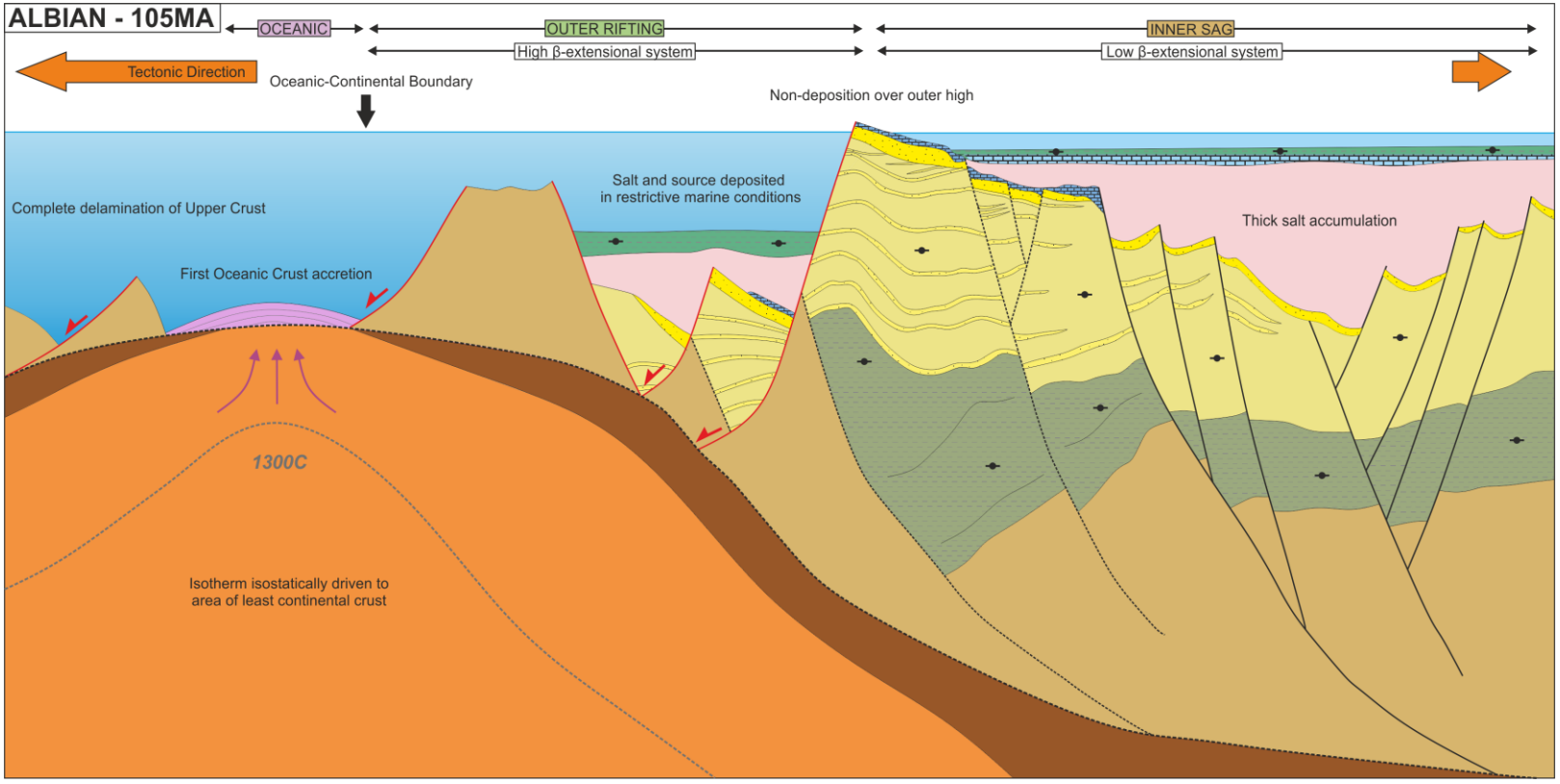
- Rapid subsidence within ‘Outer’ trough as seafloor spreading commences → deposition of outboard source

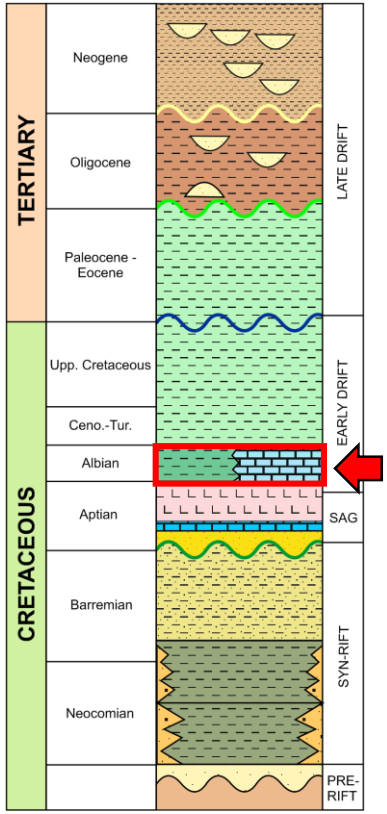
South Gabon (D13)



North Gabon



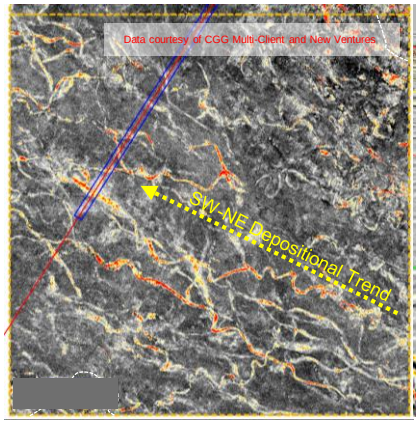


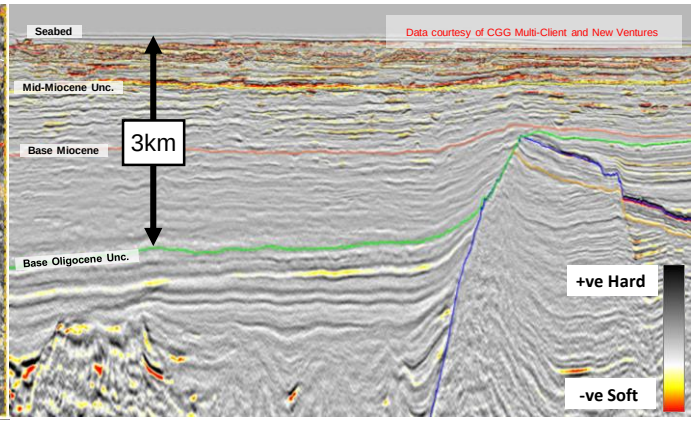


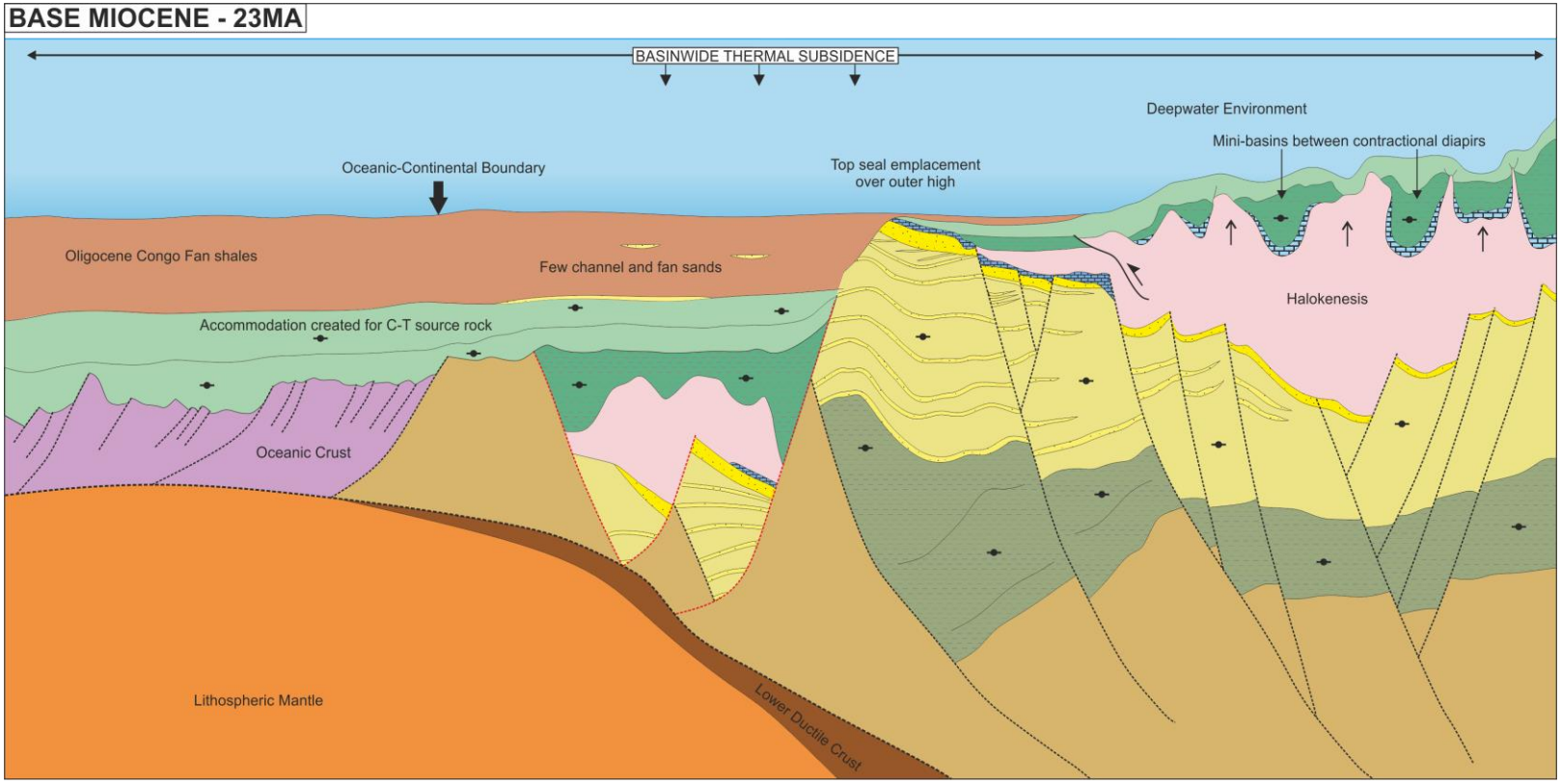
Tectonic Evolution

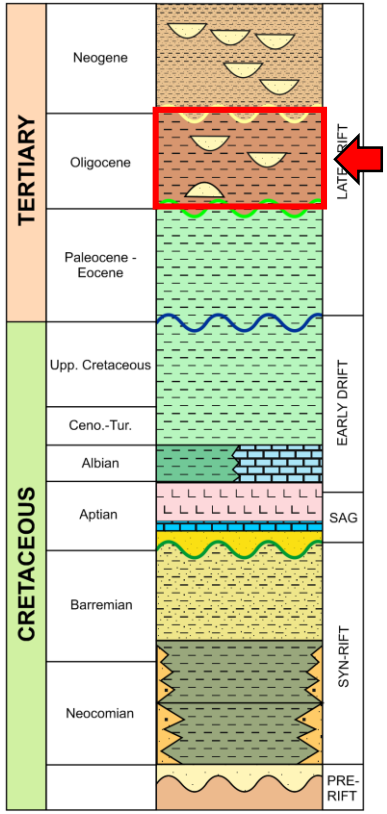
Drift & Congo Fan - Miocene

- Onset of Congo shaley sequence finally seals the structural high





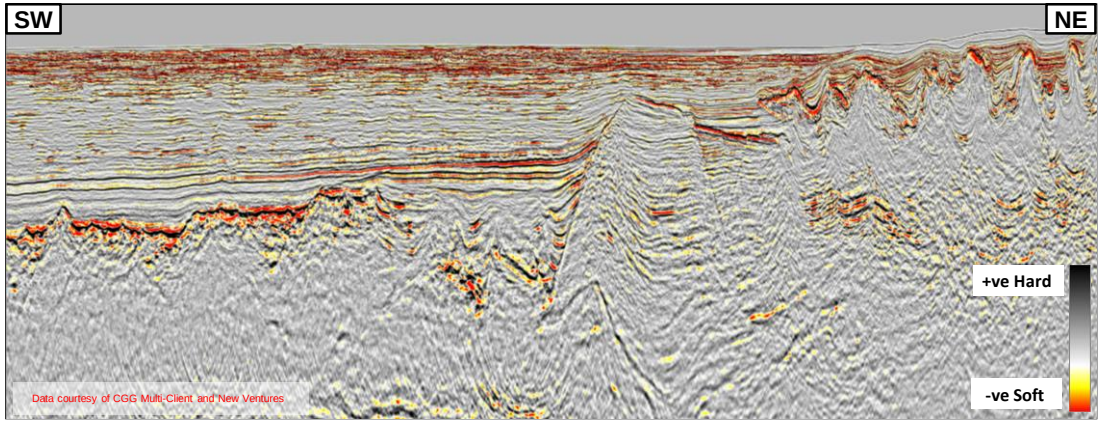


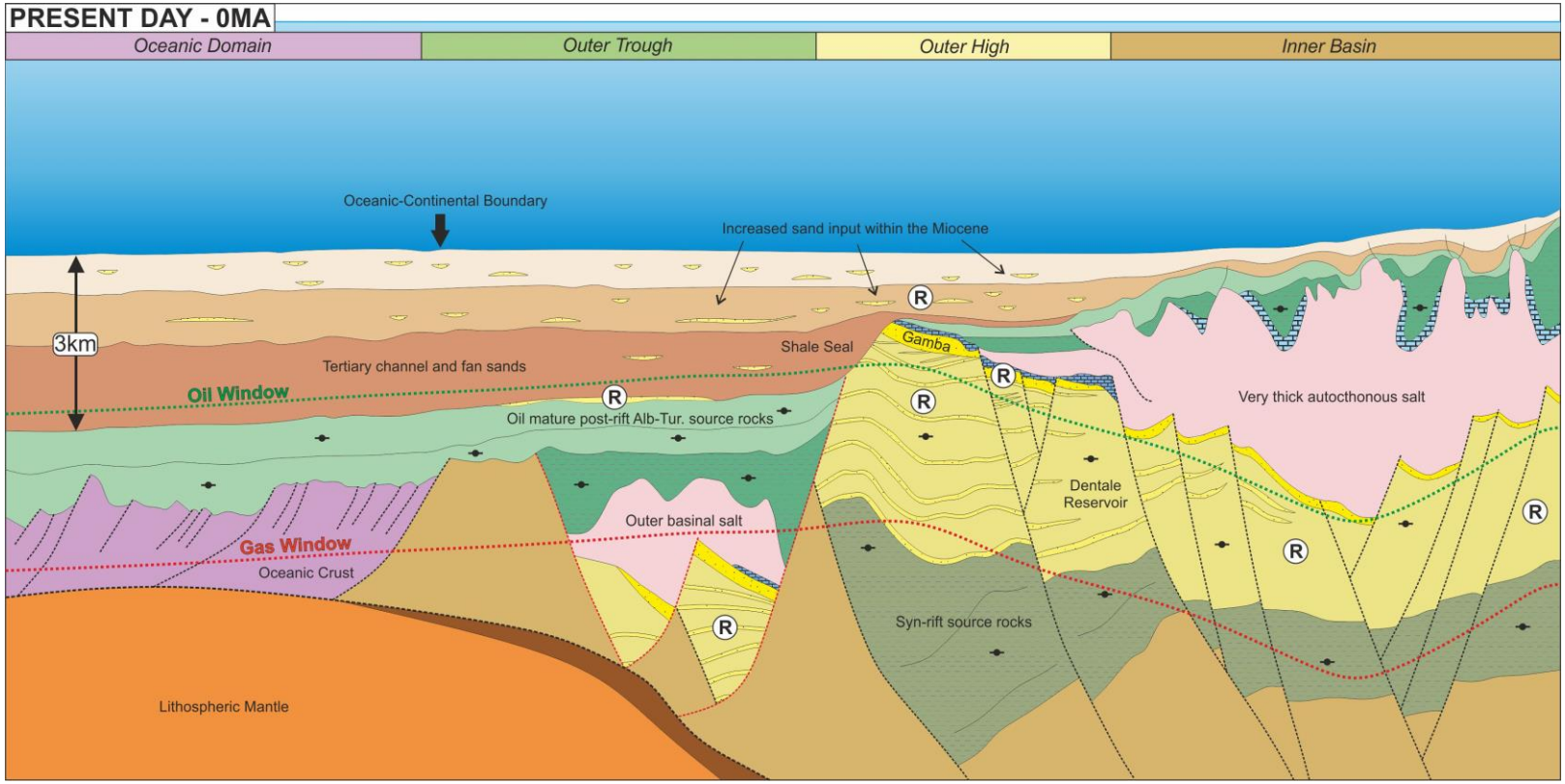


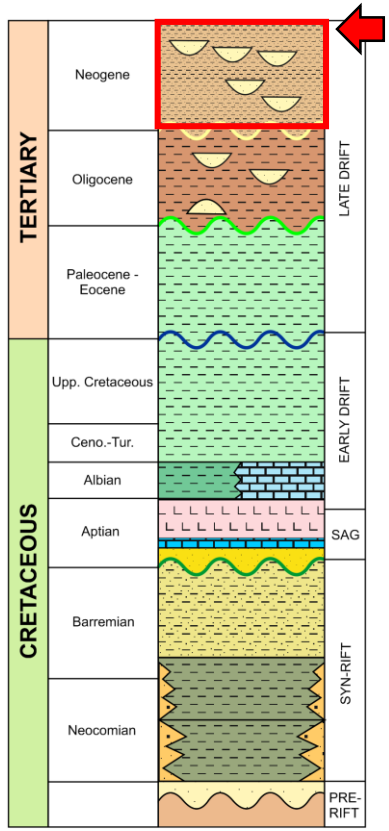
Tectonic Evolution

Present Day

- Continued sedimentation from the Congo provides necessary overburden to mature ‘Outer’ source rocks

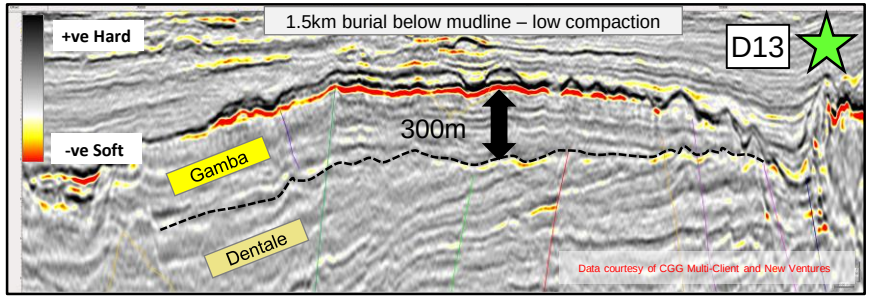


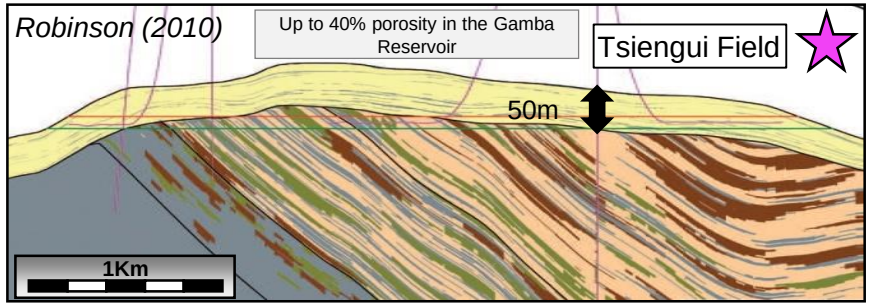


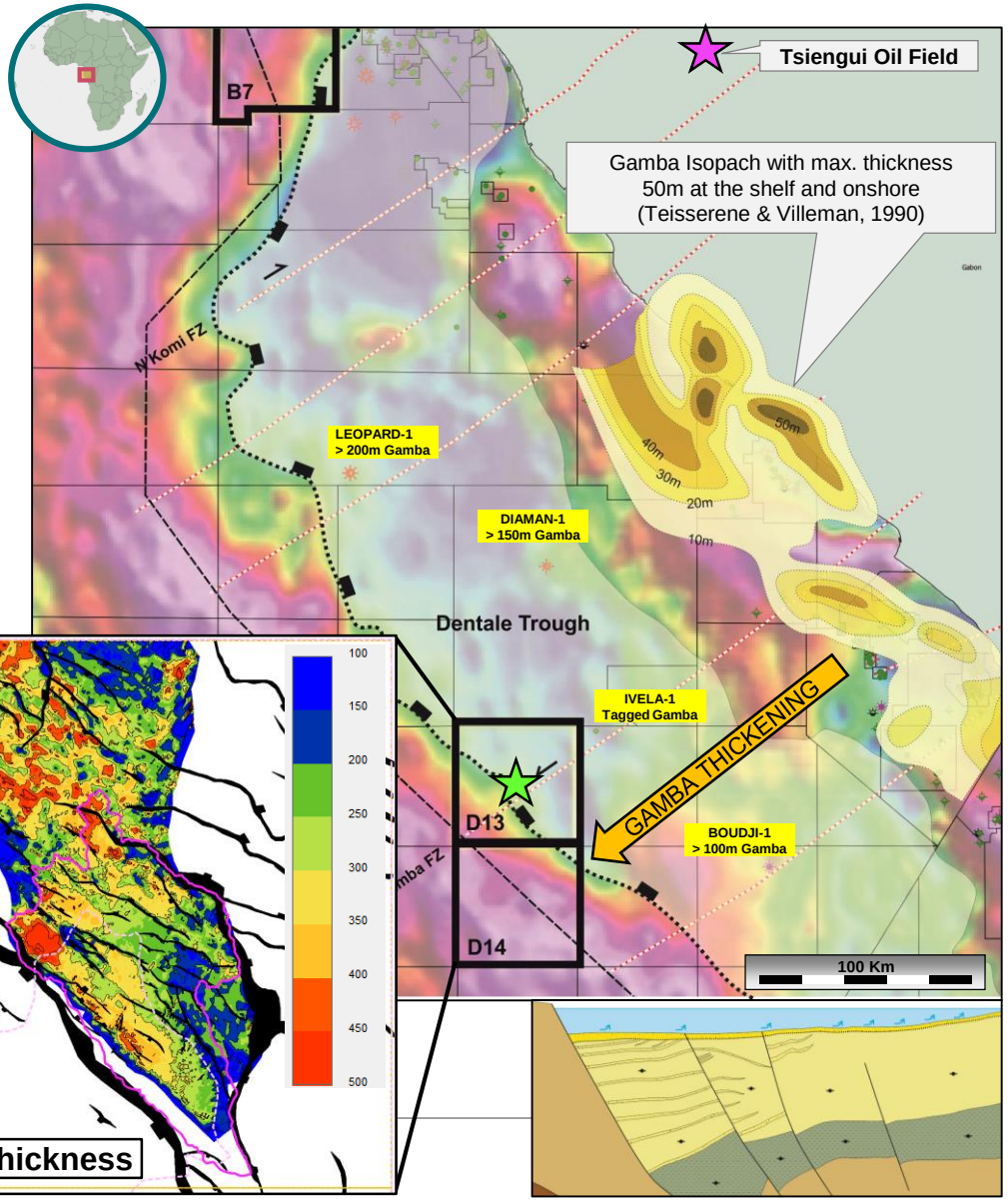


What are the implications on prospectivity?

Reservoir Thickness and Quality





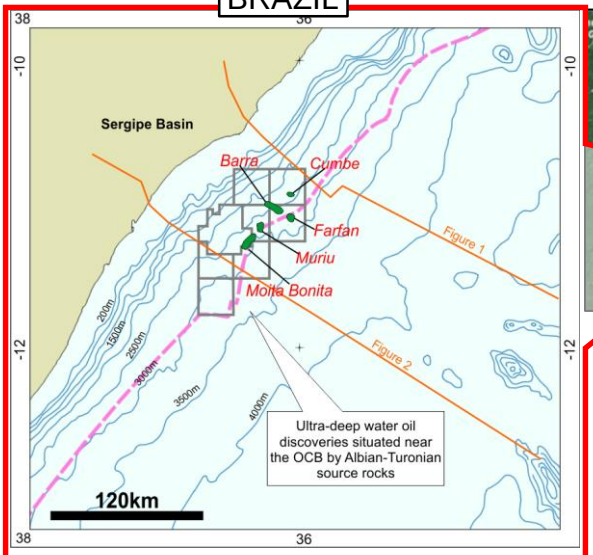


- Aptian Gamba transgressive marine sand is the principal reservoir in Gabon
- Westward thickening Gamba package toward original basin-bounding fault where accommodation is greatest
- D13/D14 near deepest part of Aptian depocentre, accumulating thickest Gamba
- Prominent high means less burial and greater preservation of primary porosity

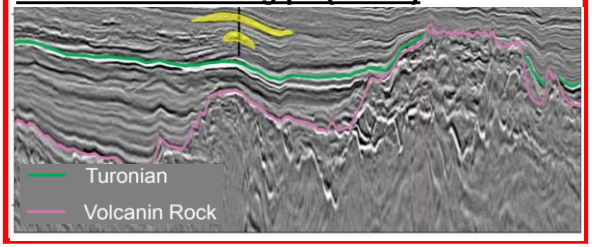
Albian-Turonian Source Rock

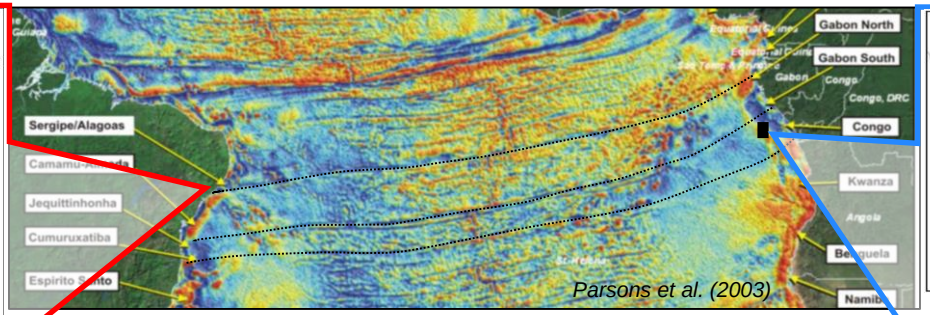
- Albian-Turonian source rocks deposited in a depocentre west of the Outer High over attenuated continental and transitional crust
- Albian-Turonian source rock charging fields in Angola, North Gabon, Rio Muni and the Brazilian conjugate margin. Has yet to be explored in South Gabon!
- Albian source 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

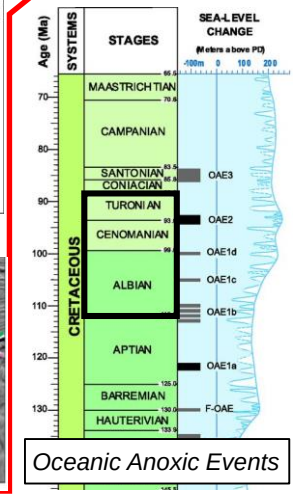
BRAZIL



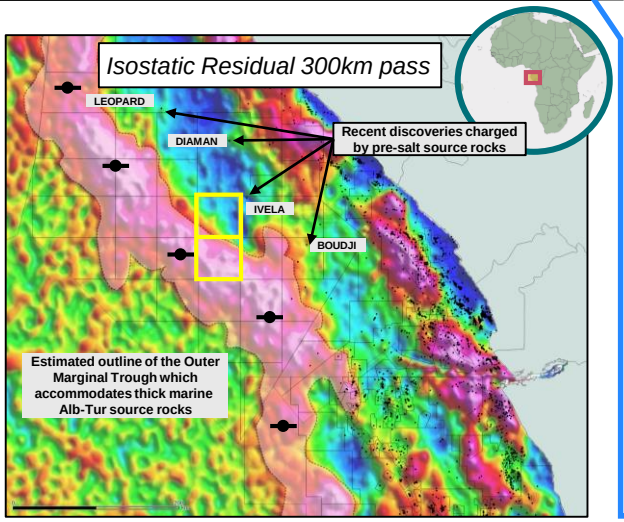
Moita Bonita – Sergipe (Brazil)



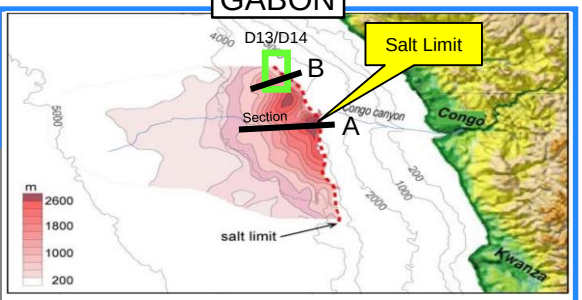




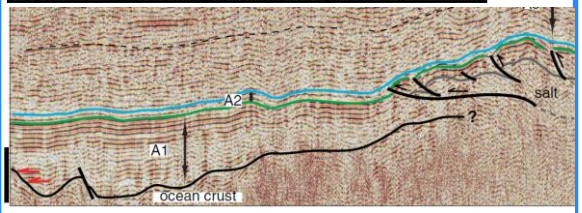
Oceanic Anoxic Events



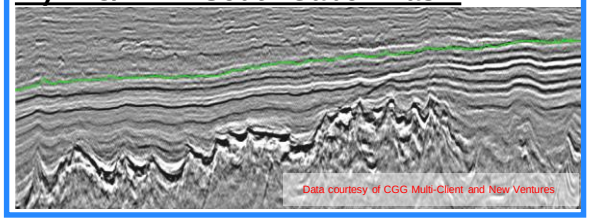
GABON



A.) Lower Congo Basin (Anka, 2009)

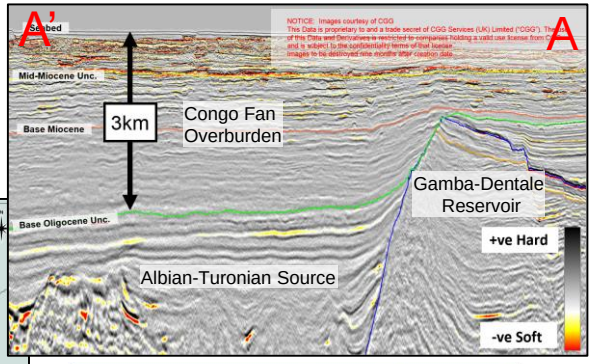


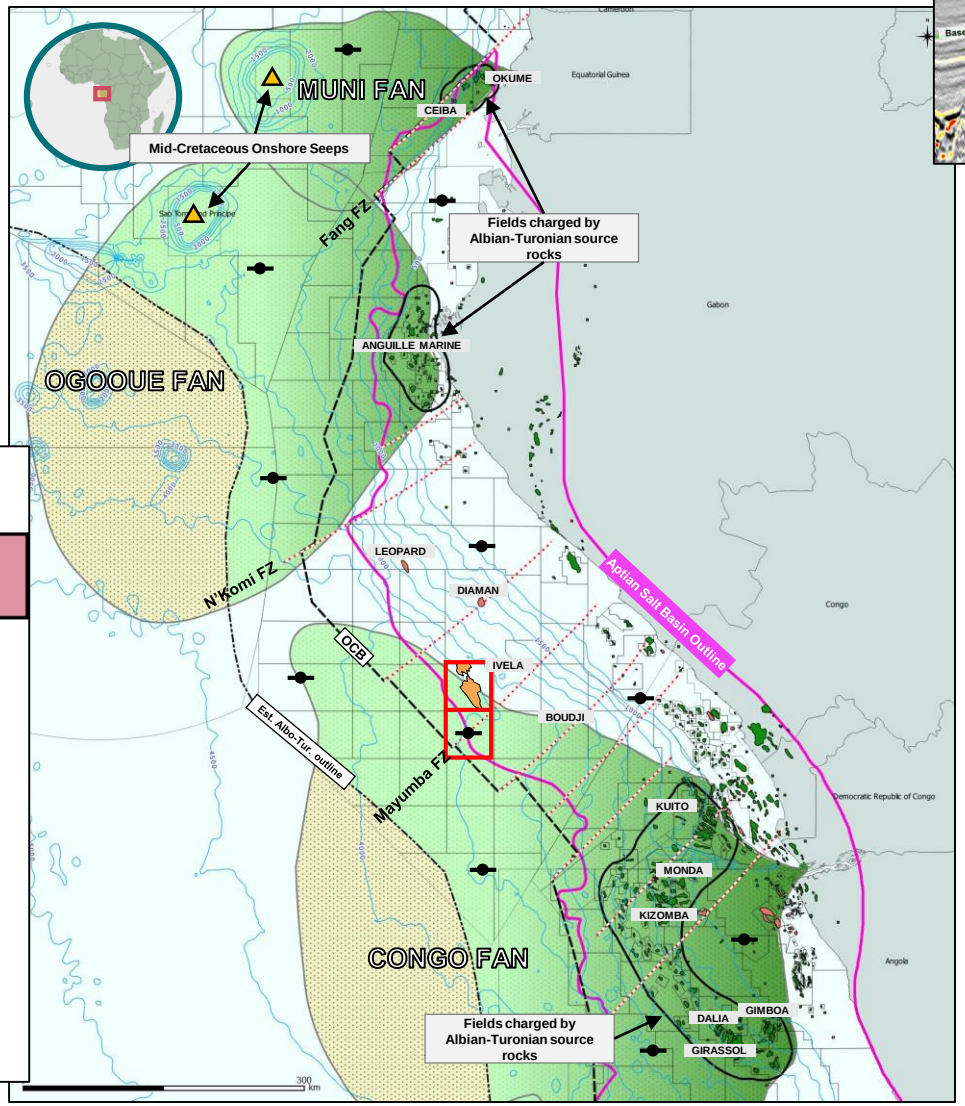
B.) D13/D14 – South Gabon Basin

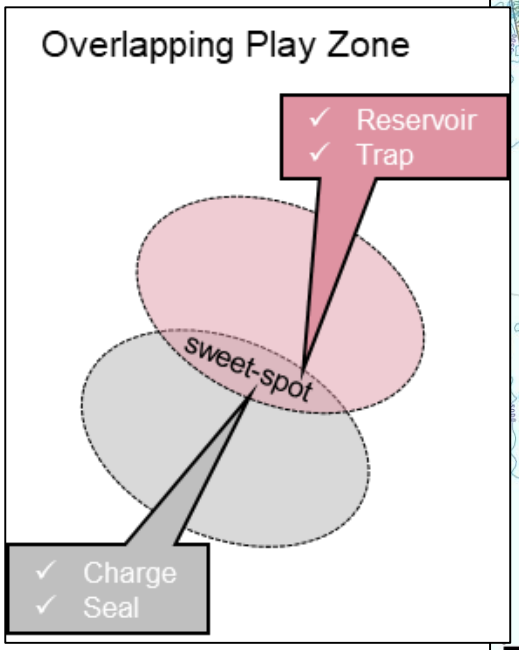


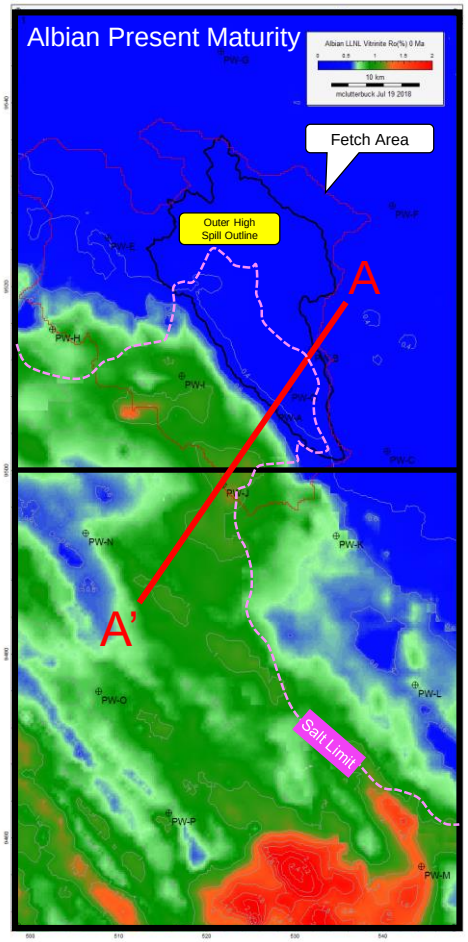
Source-Reservoir Sweet Spots

- 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?

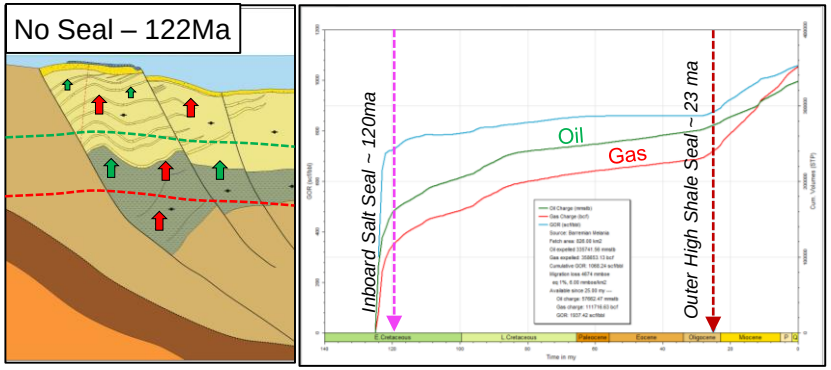
What is the principal source rock?

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

Inner Kitchen – pre-salt source rocks

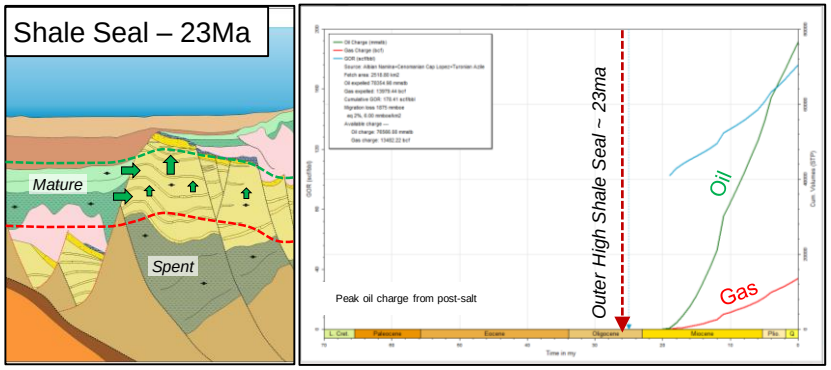


Post-Salt Source Rocks

✓ *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

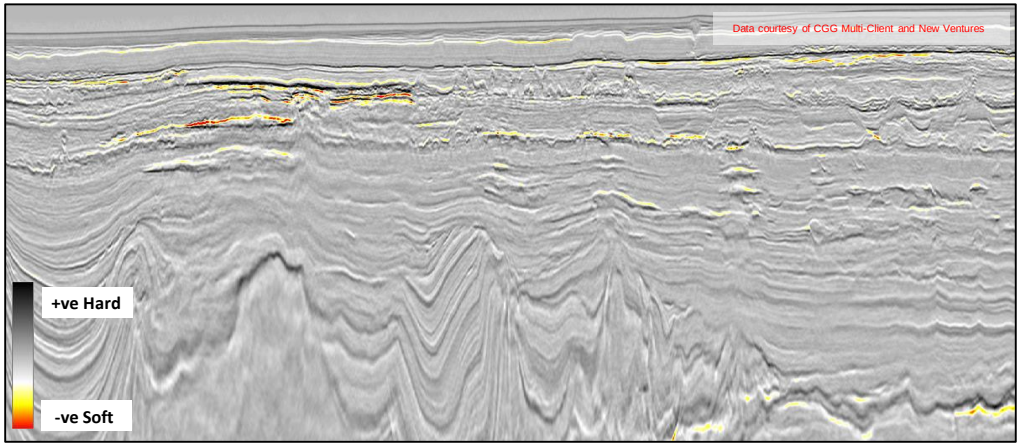
Outer Kitchen – post-salt source rocks

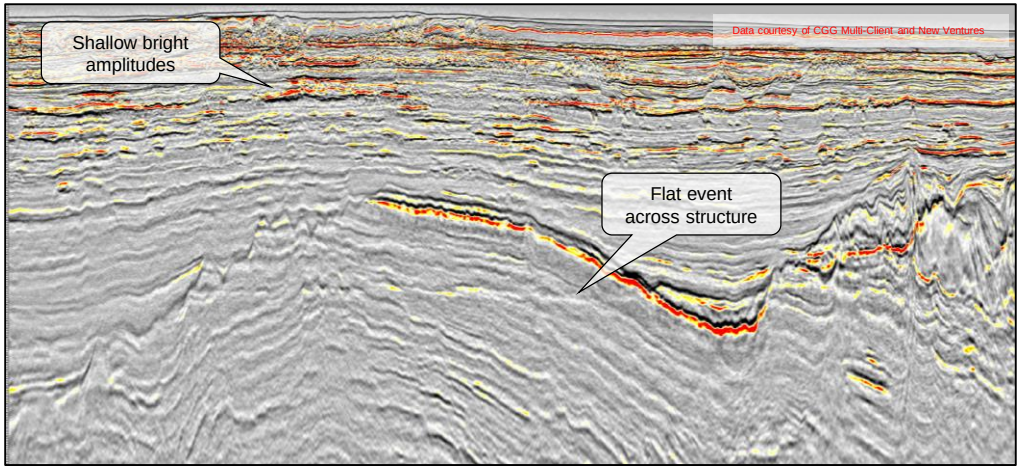


Principal source rock provided by Type II Albo-Turonian post-salt shales

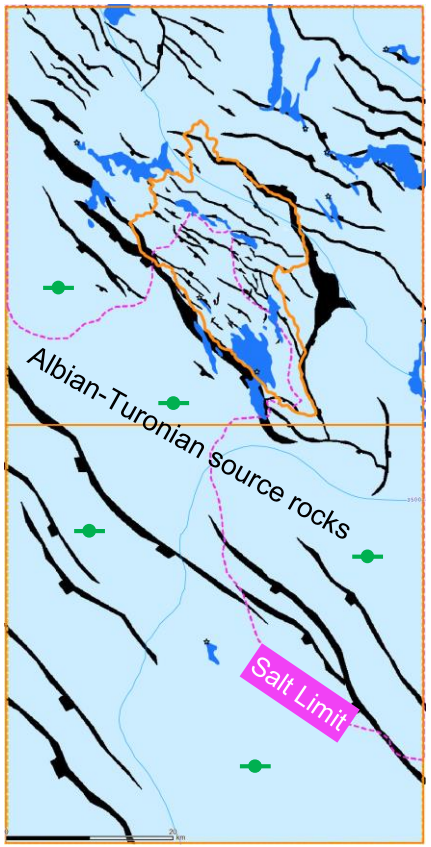
What about DHIs?

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





Airbus Seep Database with Prospect



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**

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Special thanks to the following companies:

DIRECTION GENERALE DES HYDROCARBURES GABON

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