Context, Challenges, and Future of Deep-Water Plays: An Overview*

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Abstract

The most classical or current deepwater plays which are presently explored worldwide are Pre-Salt, Sub-Salt, Fold belts and stratigraphic pinch outs. Presalt exploration is booming along Offshore Brazil, particularly in the Santos Basin and in the Levantine Basin in the eastern Mediterranean area, and exploration activities are increasing in Angola, Gabon, and Namibia in West Africa. Exploration in deepwater fold belts is very active in the Niger Delta, and booming in offshore Mozambique. The Stratigraphic pinch out play has been recently developed mainly offshore Ghana, with the Jubilee discovery, and subsequent exploration in Sierra Leone and Liberia.

We classify deepwater plays according to their tectonic setting as follows: 1) Extensional Passive margin with Rift, 2) Post-Rift and strike-slip basins and Active Margin, 3) Orogenic, which are subdivided into: a) Accretionary Wedges and b) Retro Foreland Fold-and-Thrust Belts and Back Arc Basins. The critical challenges while exploring deepwater plays is the presence of both, source rocks, and carbonate and/or siliciclastic potential reservoirs. Future deepwater plays will probably include volcanic rocks, SDR related traps, ultra-deep carbonates, and extremely deep sandstone turbidite systems.

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Thank You

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Introduction

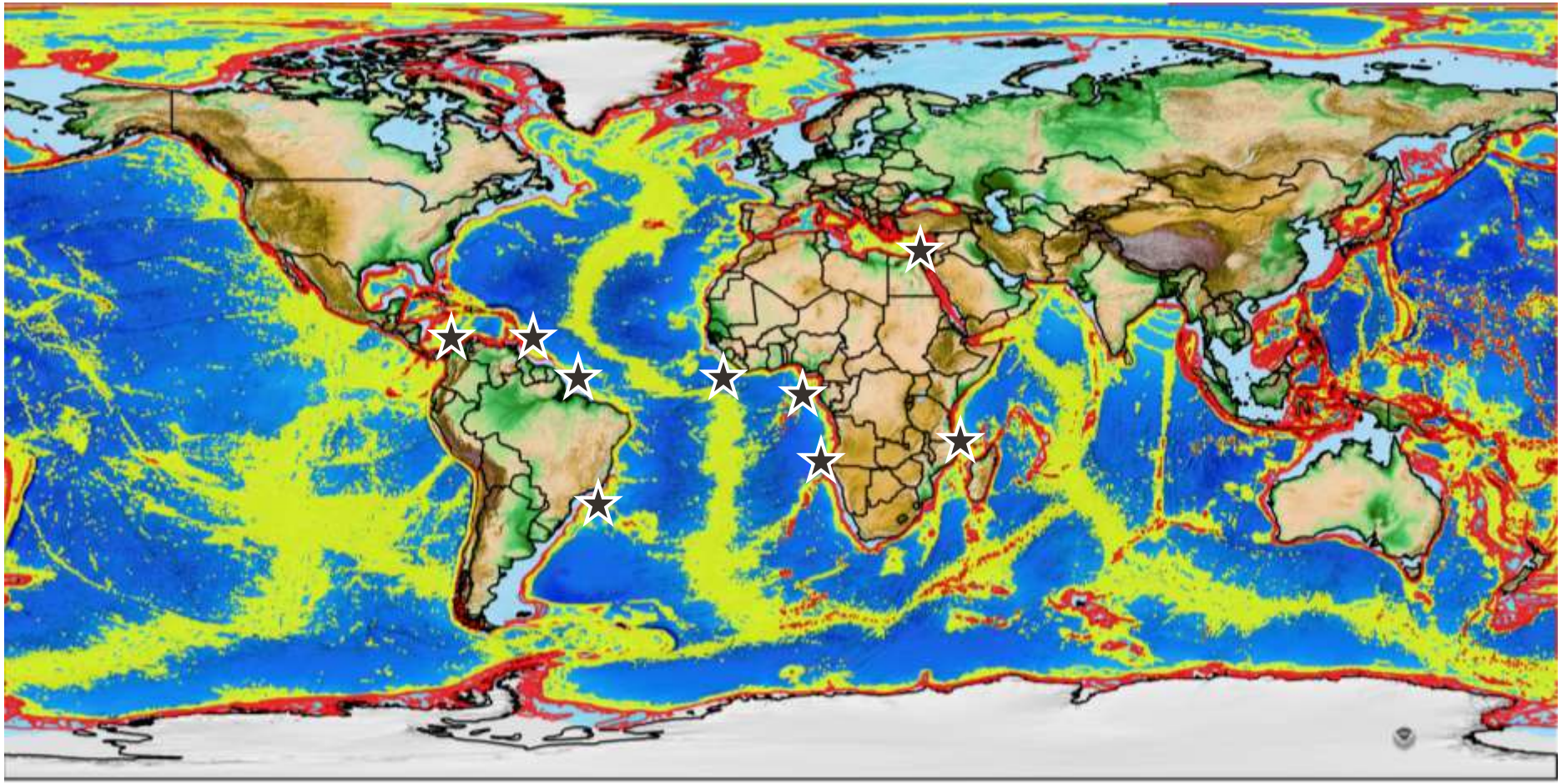
1. **Bring some thoughts on Deepwater Plays and their geological (tectonic context) based on the author's experience.**

2. **Classify in a practical scheme Deepwater Plays to open the discussion and debate.**

3. **Discuss some issues related to the elements of Petroleum Systems in Deepwater Plays that are poorly understood.**

4. **Suggest ideas for Deepwater Plays that could be explored in the future.**

Extent of Deep and Ultradeep water regions : Location of examples

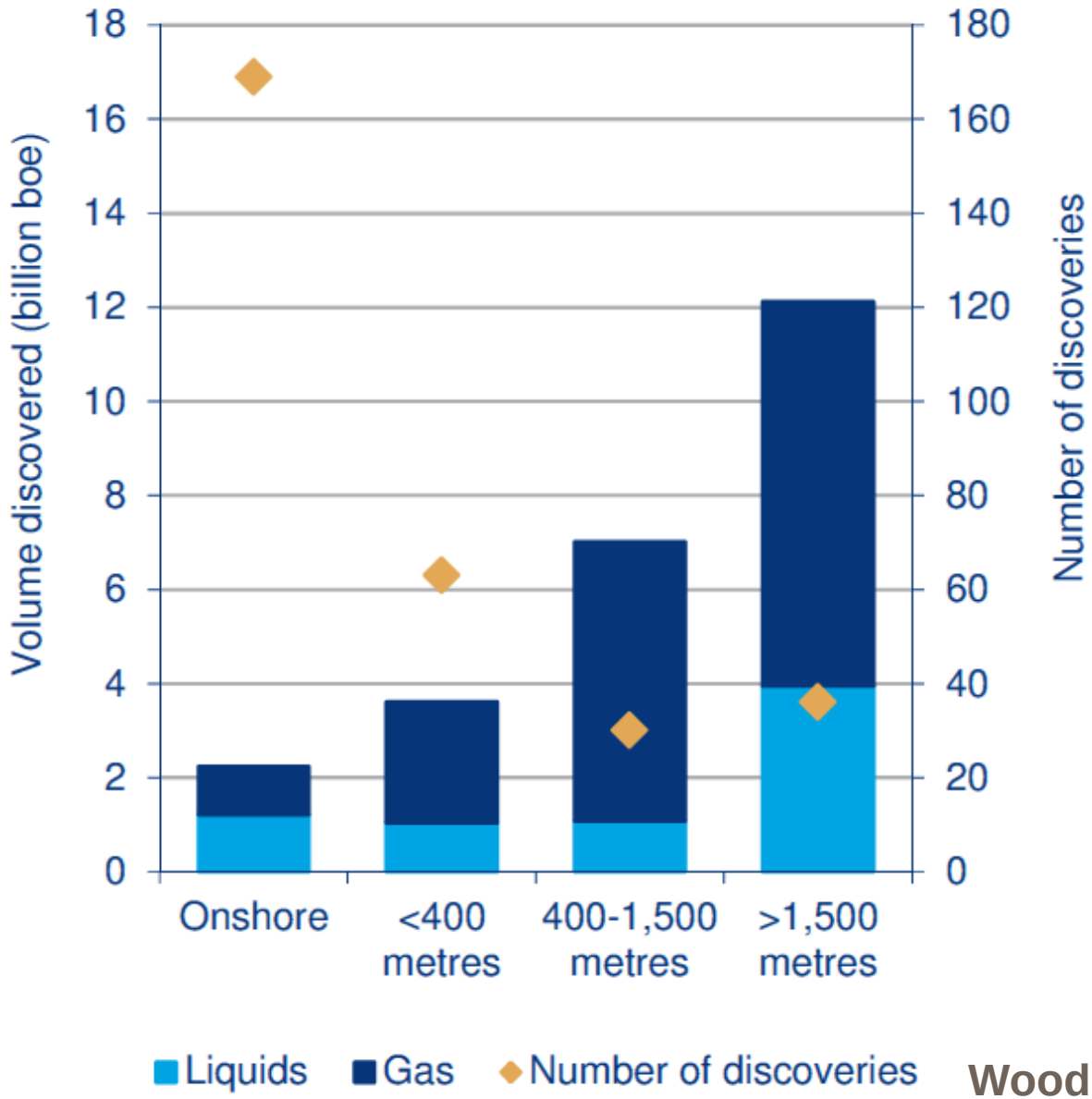


Deepwater (500 - 2000 m)
1640 - 6562 feet

Ultra Deepwater (2000 - 4000 m)
6562 - 13123 feet

★ Examples

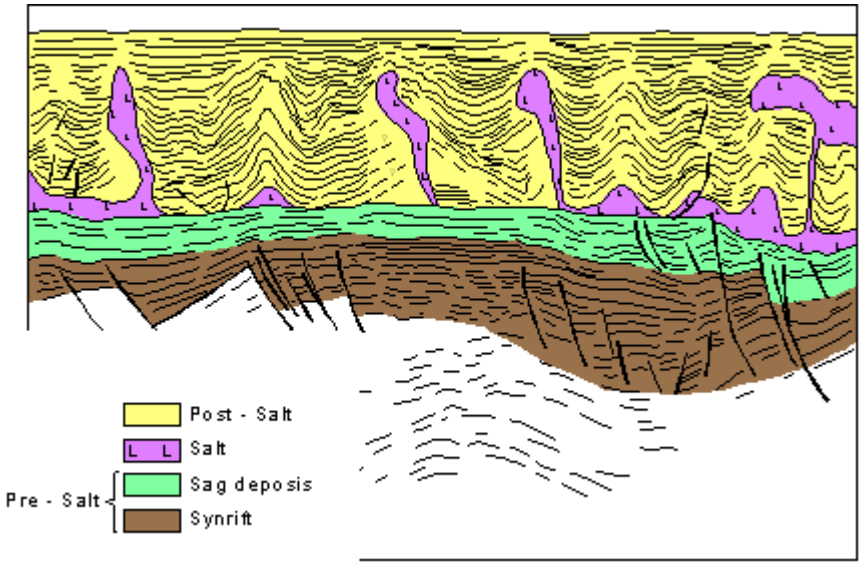
Oil- equivalent Resource Volumes 2012



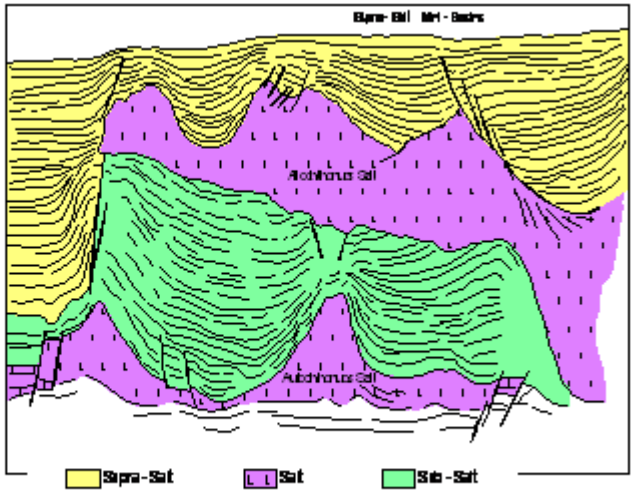
Wood Mackenzie (2013)

Currently Explored Deepwater Plays

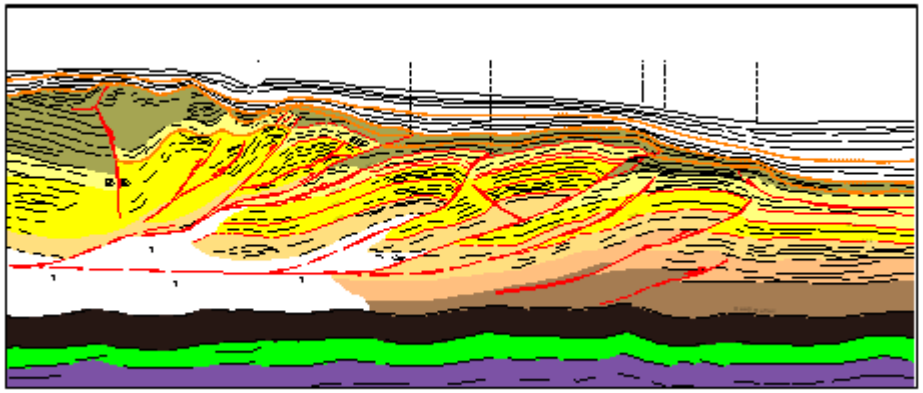
Presalt Play



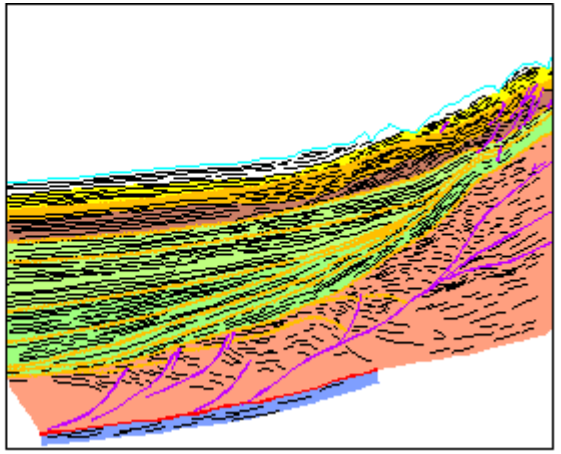
Subsalt Play



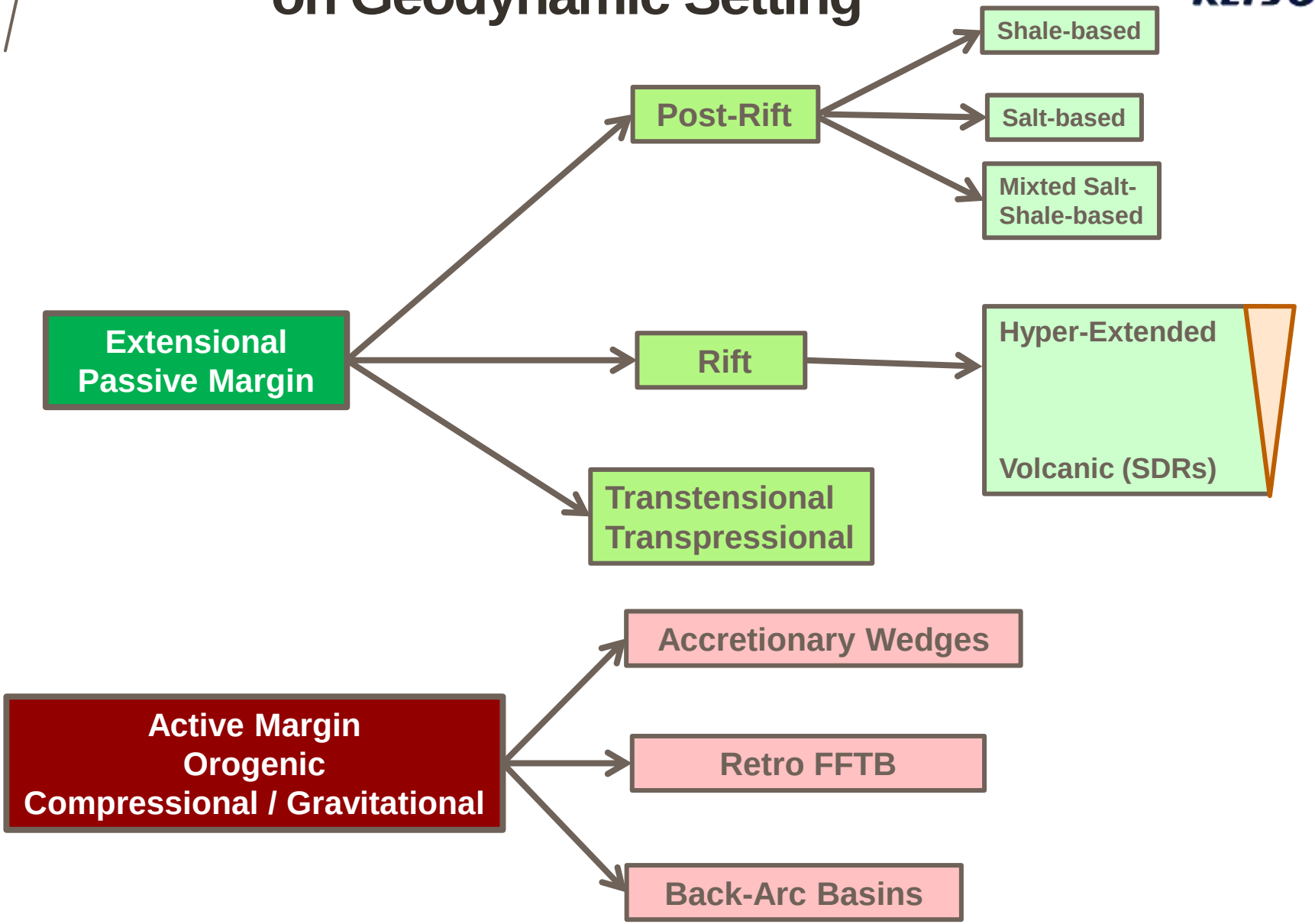
Folded Belt Play



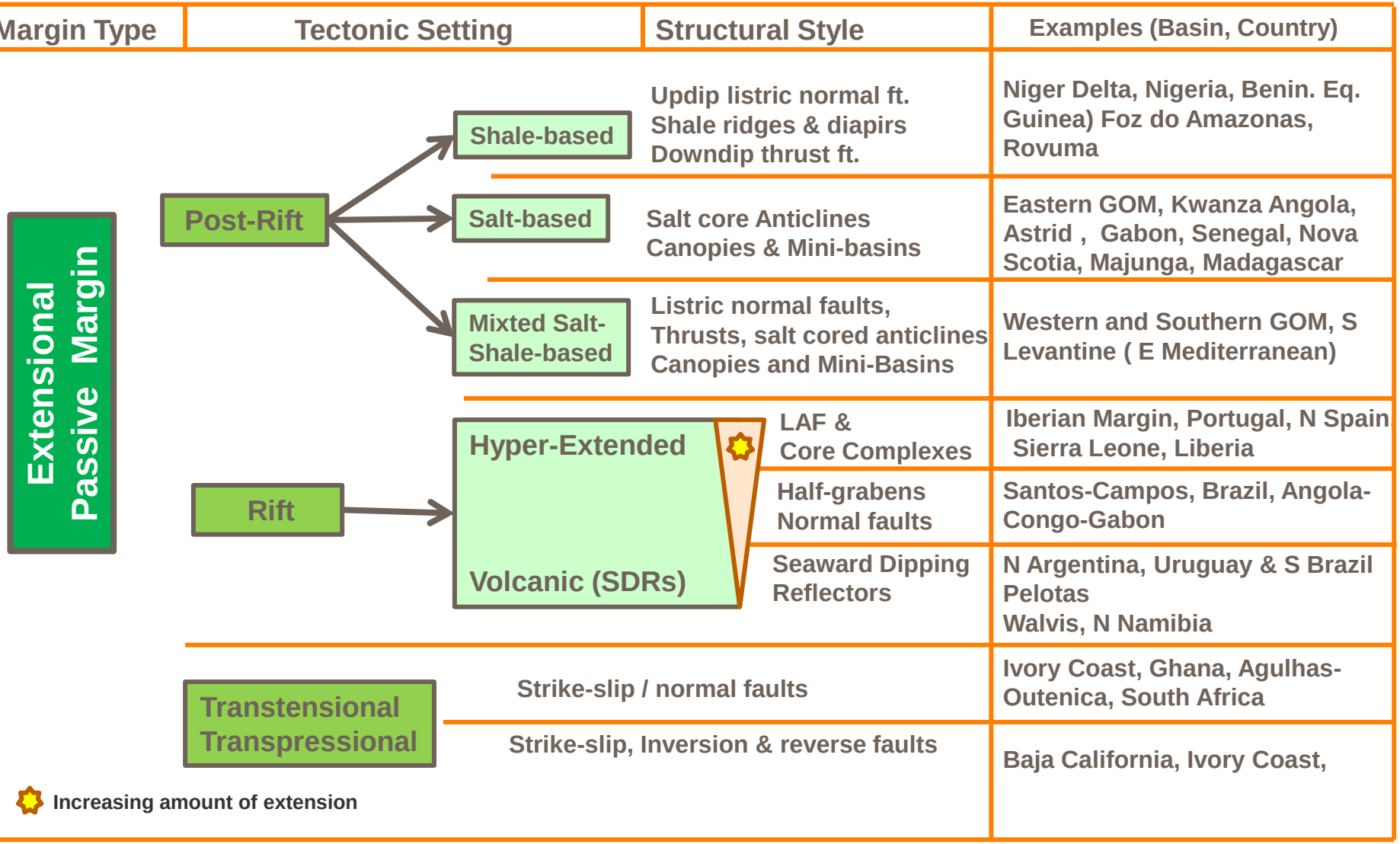
Stratigraphic pinch-out Play



Types of Deepwater Plays based on Geodynamic Setting



Extensional Passive Margin Settings



Active Margin / Orogenic Settings

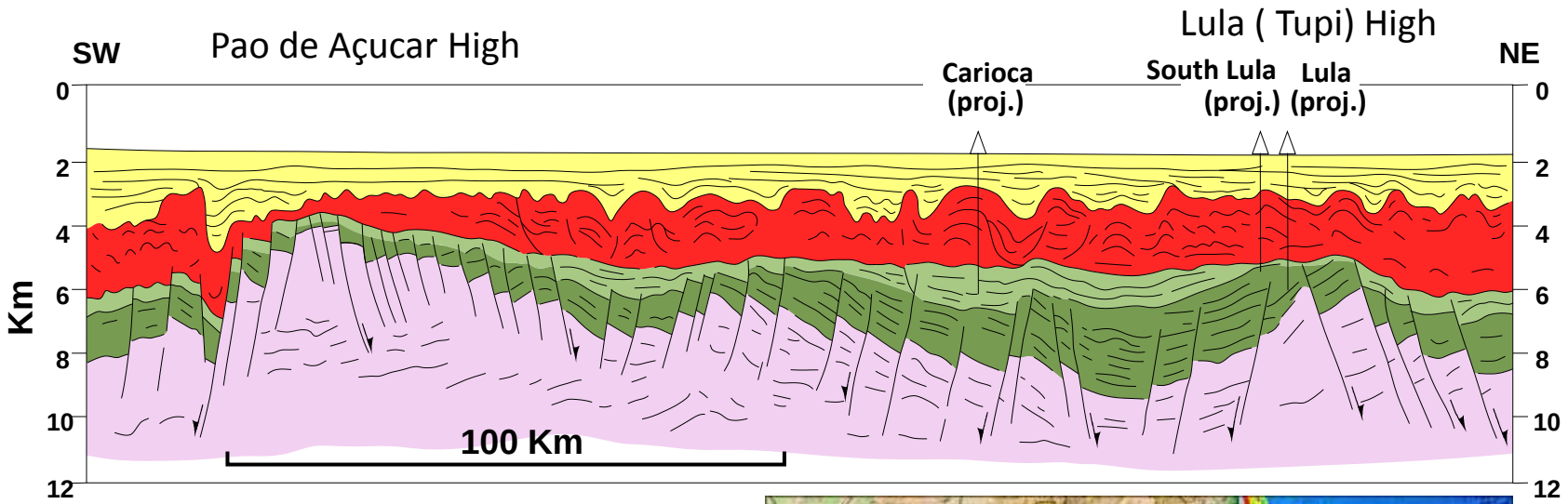
Margin Type	Tectonic Setting	Structural Style	Examples (Basin, Country)
Active Margin Orogenic Compressional/Gravitational	Accretionary Wedges	Thrust Imbricates Toe-thrusts/Normal ft.	Bangladesh, Barbados, Colombia, Makran,
	Retro FFTB	Thrusts & folds	Campeche-Reforma Mexican GOM Baram Delta-Brunei, Borneo, Orinoco, TT
	Back-Arc Basins	Normal faults Rotated blocks Inversion structures	Black Sea, Ionian Sea, Northern Levantine Basin

Neighboring Compression
Intra-Plate stress

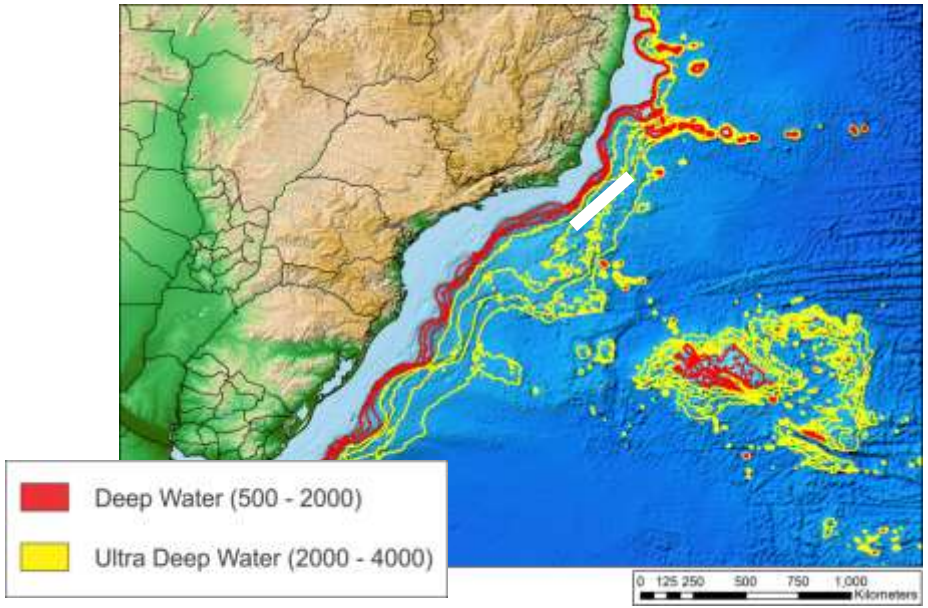
Extensional Structures
in a Compressional setting

Santos Basin Presalt Play

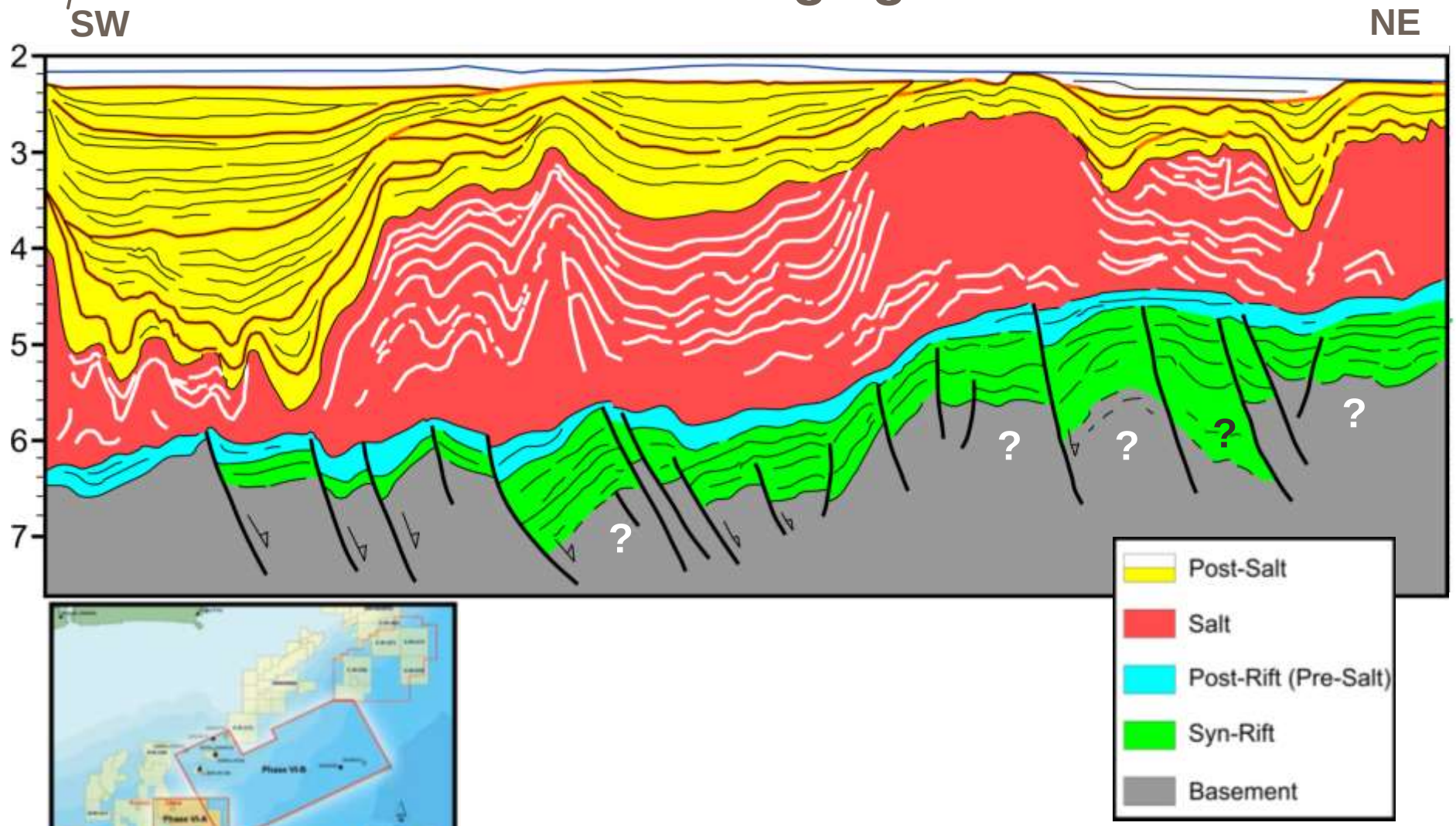
Carioca, Lula and Pao de Açucar Discoveries



Line drawing : modified from Gomes et al. (2009)

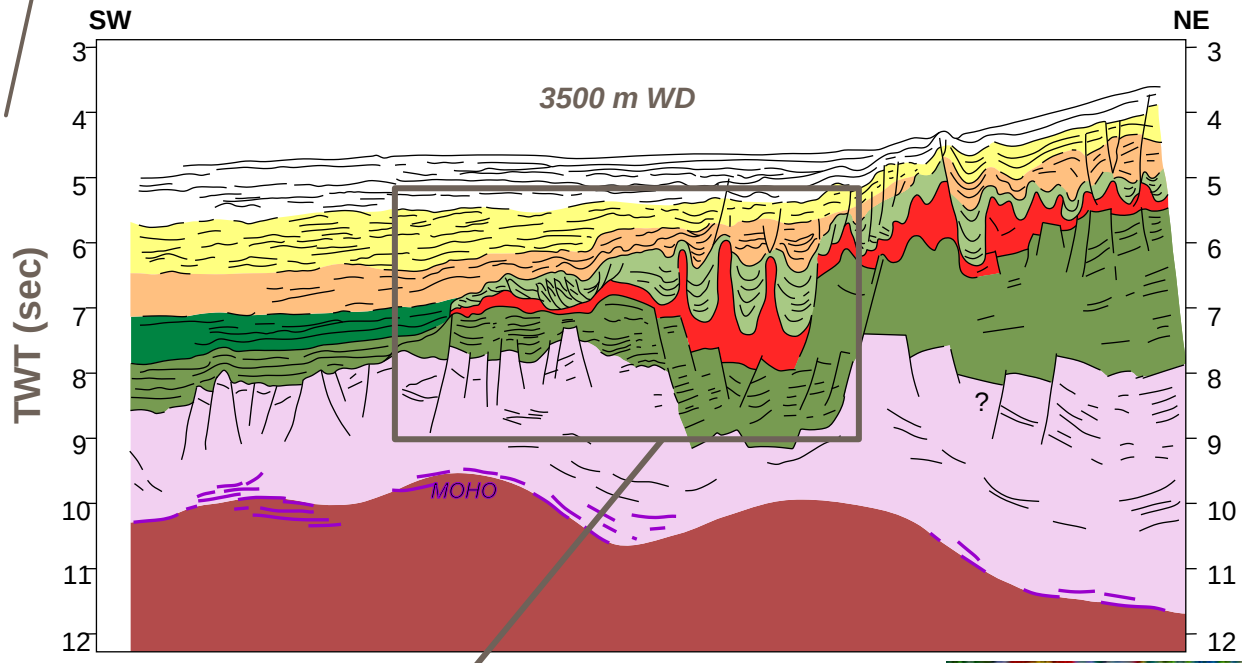


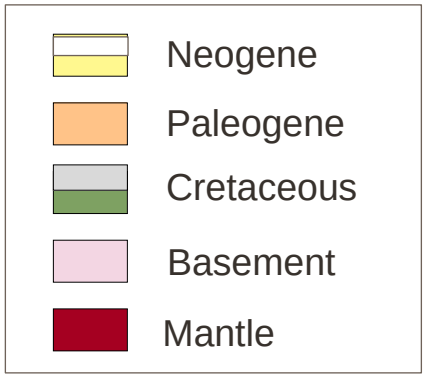
Santos Basin Presalt Play imaged with Broadband Imaging

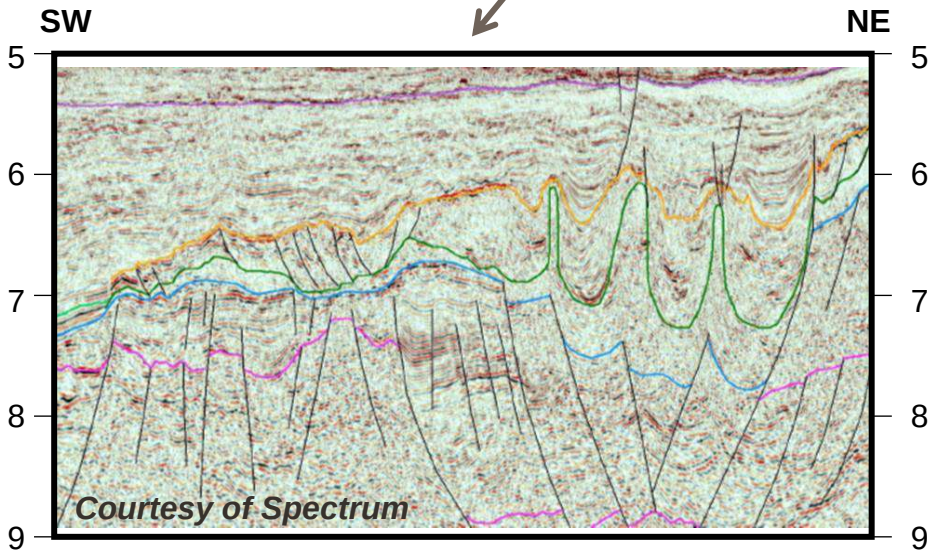


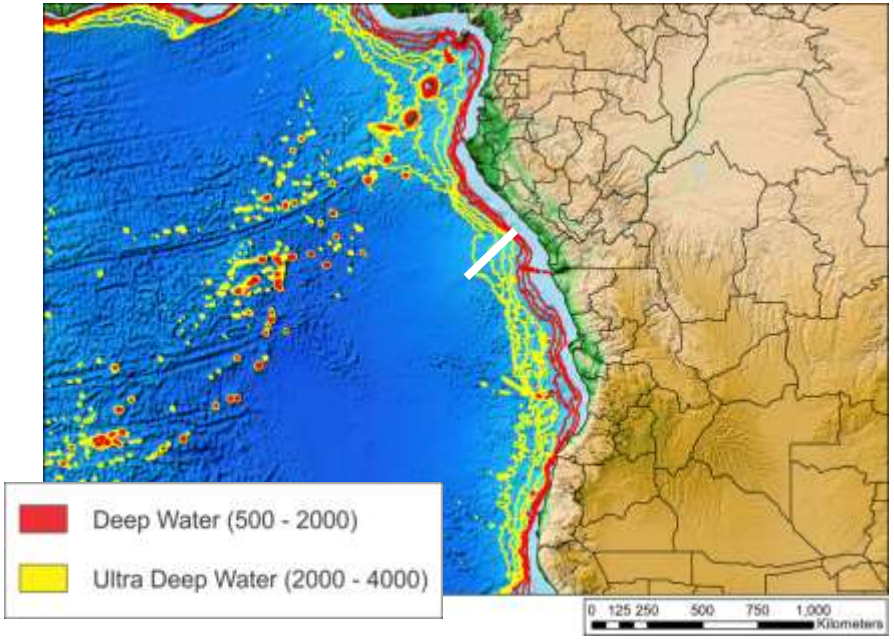
Line drawing from seismic: modified from Mann, 2013

Southern Gabon Presalt Play



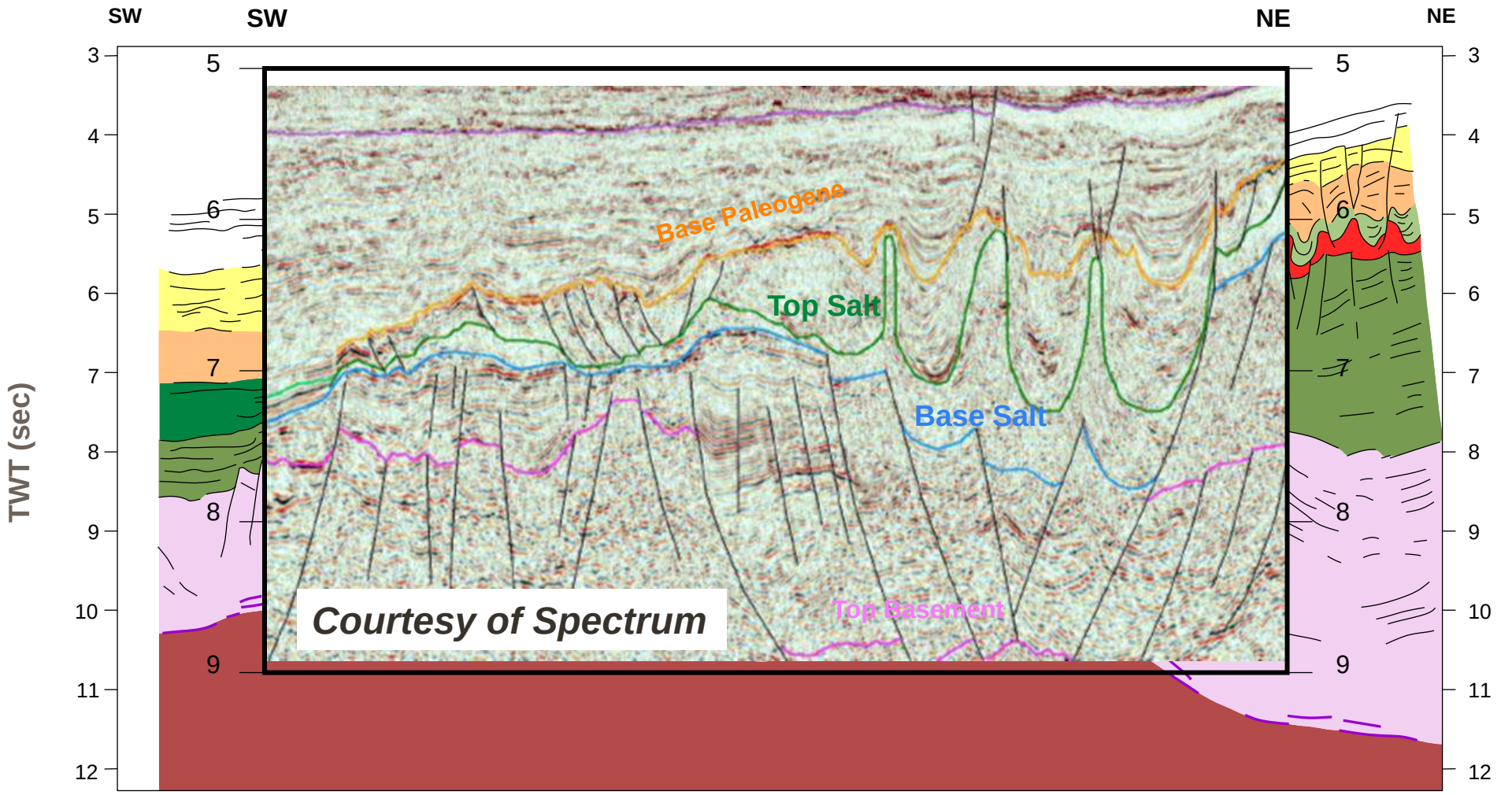






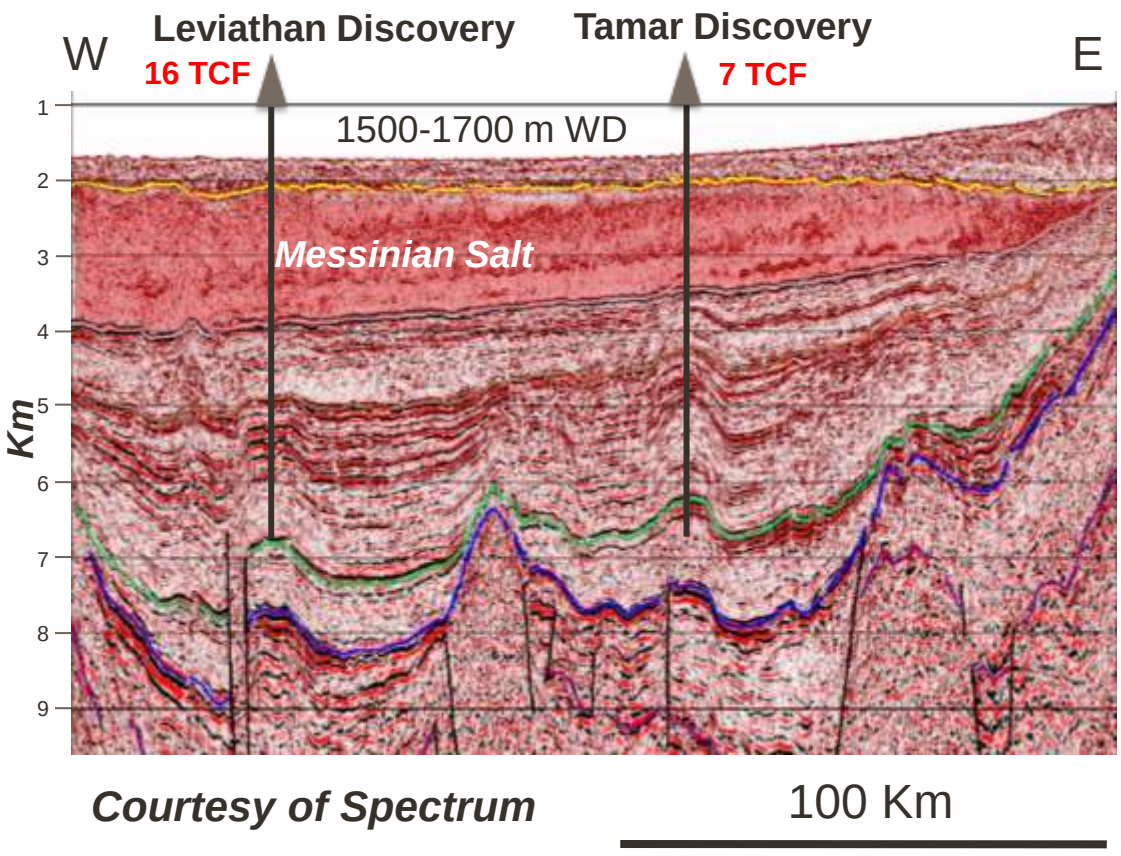
Close up of Seismic Section

Southern Gabon Basin, West Africa

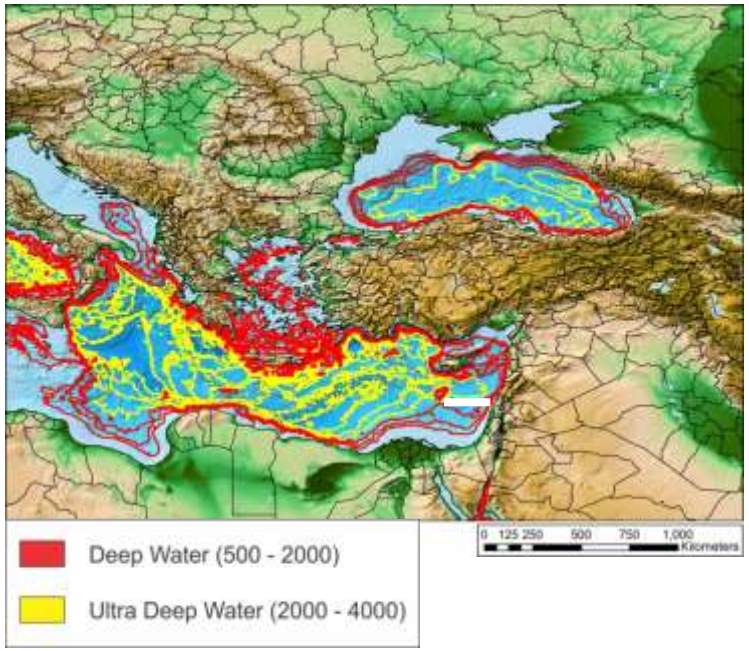


Presalt Structures , Eastern Levantine Basin , Eastern Mediterranean

Strike Depth Seismic Section



Courtesy of Spectrum



Top Messinian Salt

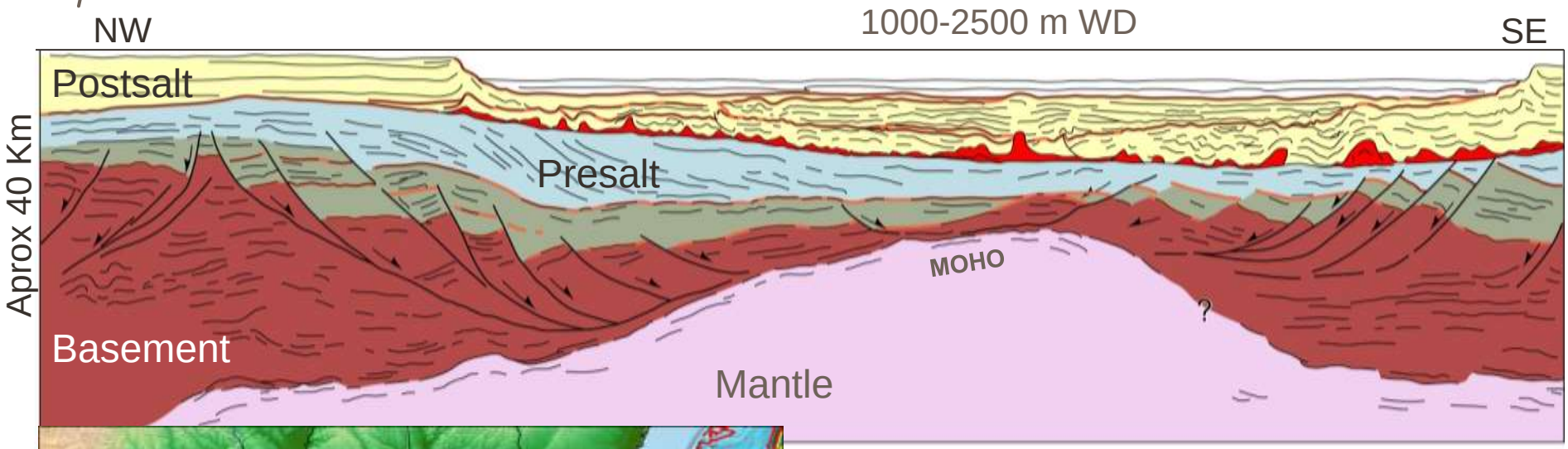
Messinian Salt

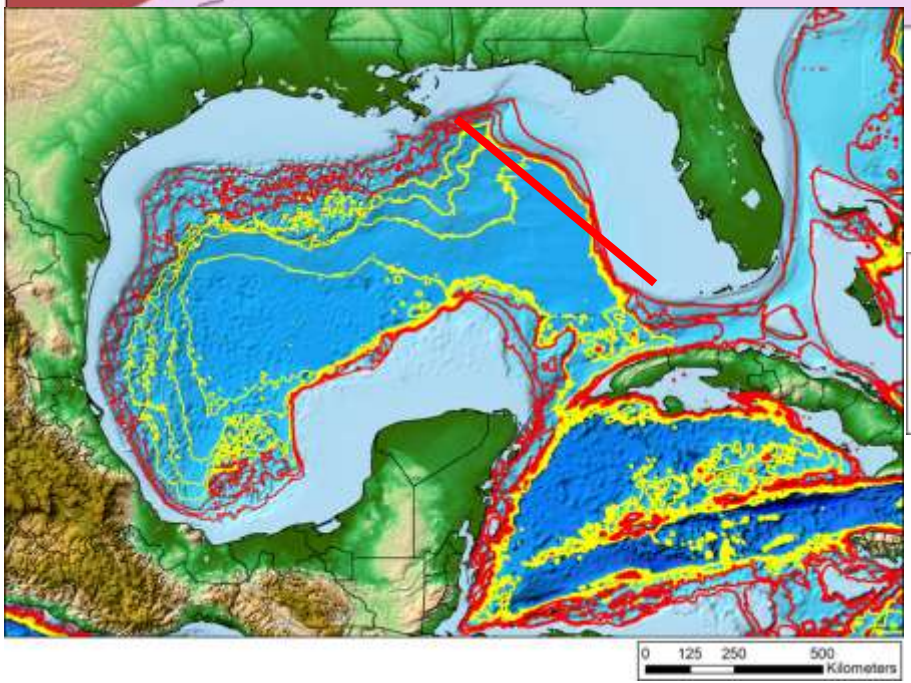
Base Messinian Salt

Top Lower Cretaceous

Top Jurassic

PreSalt Play with possible Hyper- extension , Eastern GOM





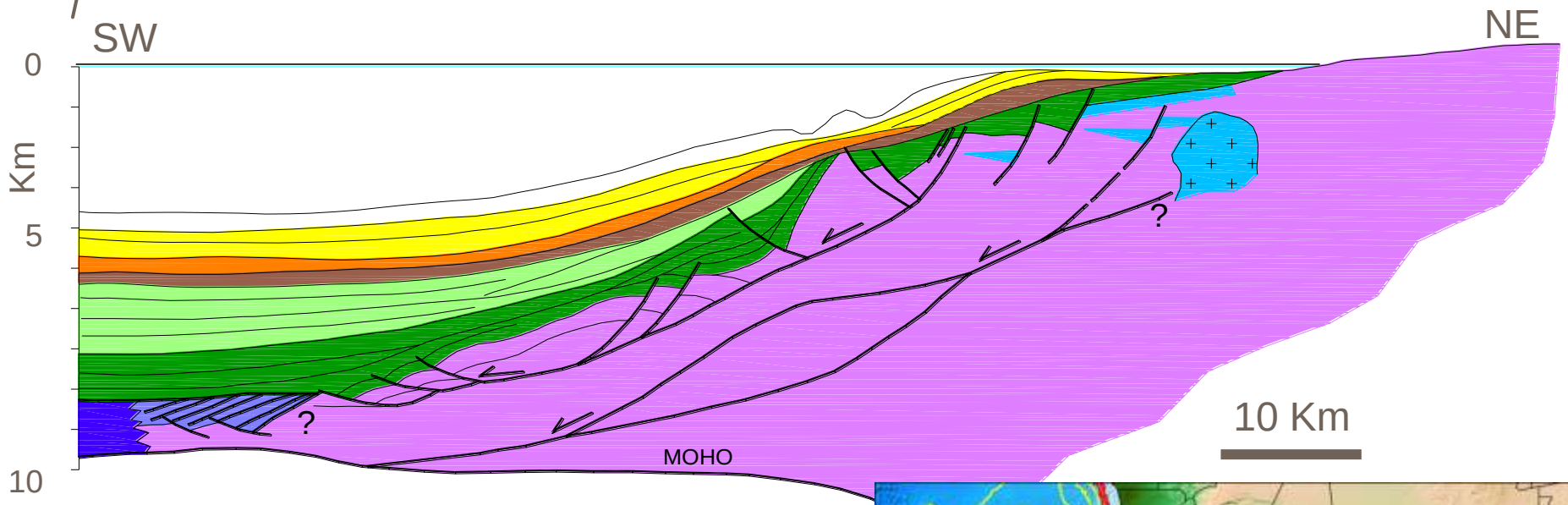
Louann Salt

Deep Water (500 - 2000)

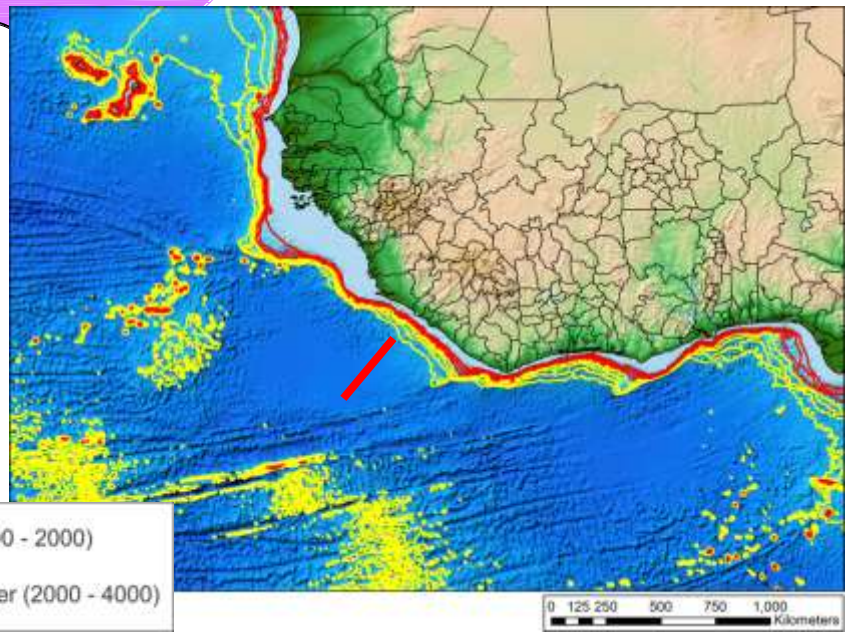
Ultra Deep Water (2000 - 4000)

Line Drawing from Seismic (Dynamic Data Services)

Sierra Leone Margin, West Africa
Cross-Section sketch

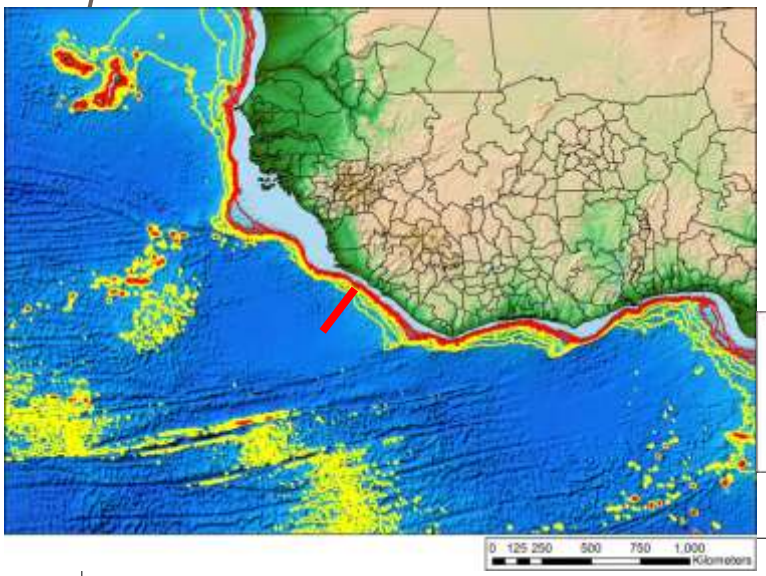


Pliocene - Pleistocene
Miocene
Oligocene
Paleocene - Eocene
Upper Cretaceous
Lower Cretaceous
Jurassic
Basement/Continental Crust
SDR
Oceanic Crust



Flinch et al. (2009)

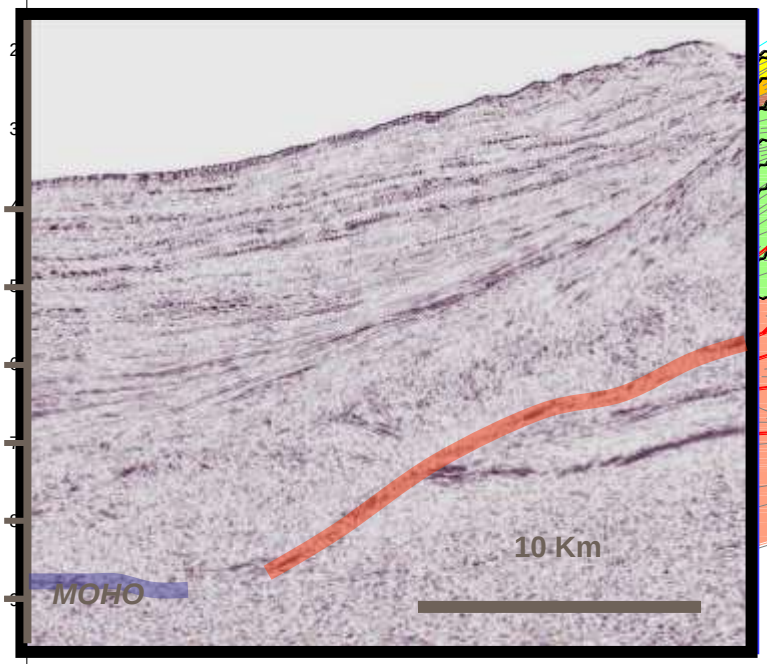
South Liberia Margin
West Africa
Line Drawing & Seismic

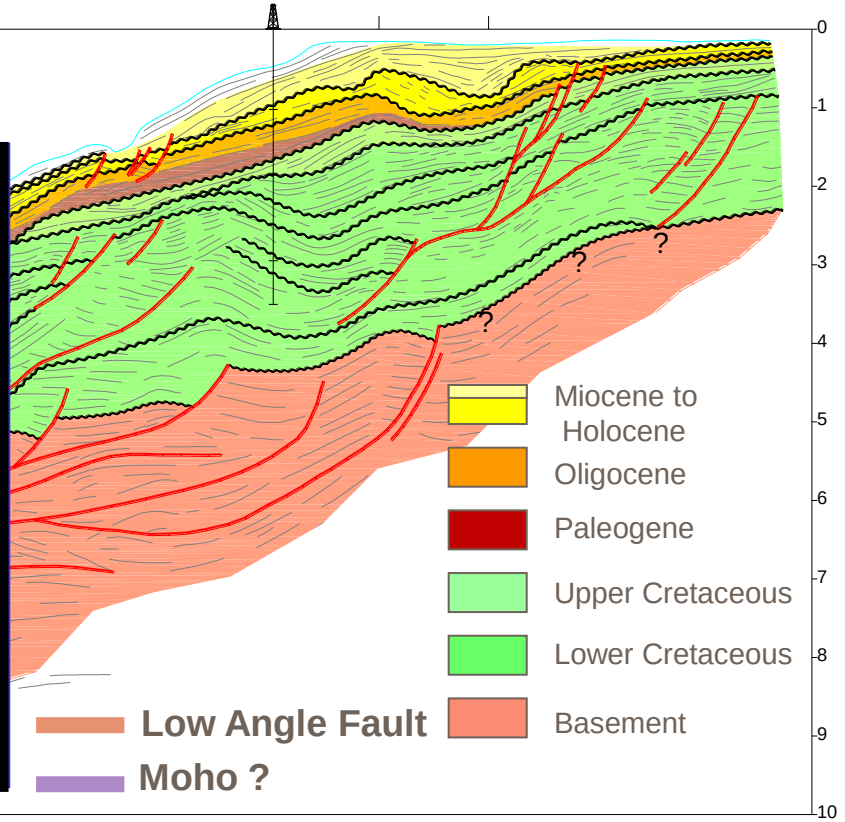


Deep Water (500 - 2000)

Ultra Deep Water (2000 - 4000)

Courtesy of TGS



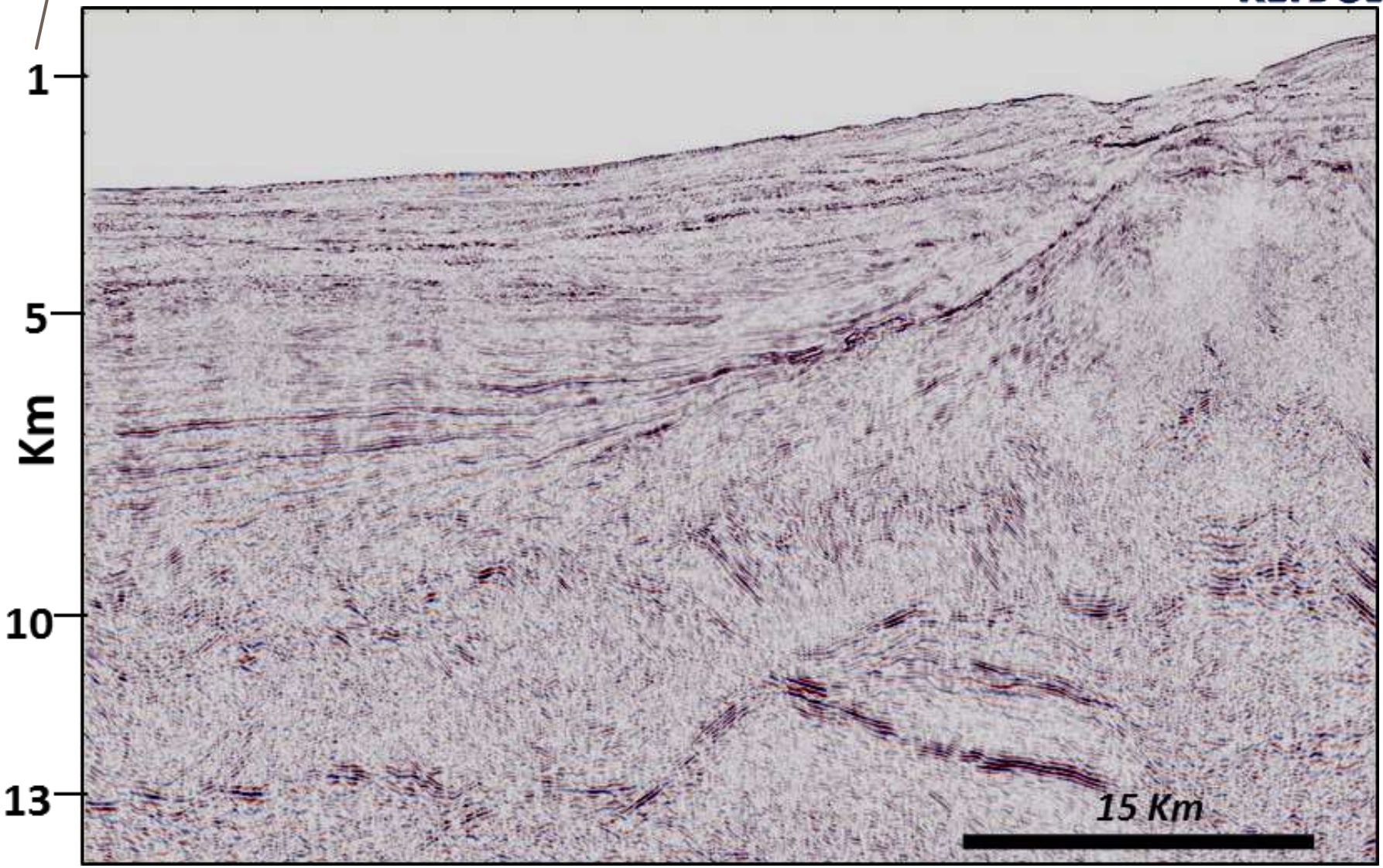


TWT sec

TWT, sec

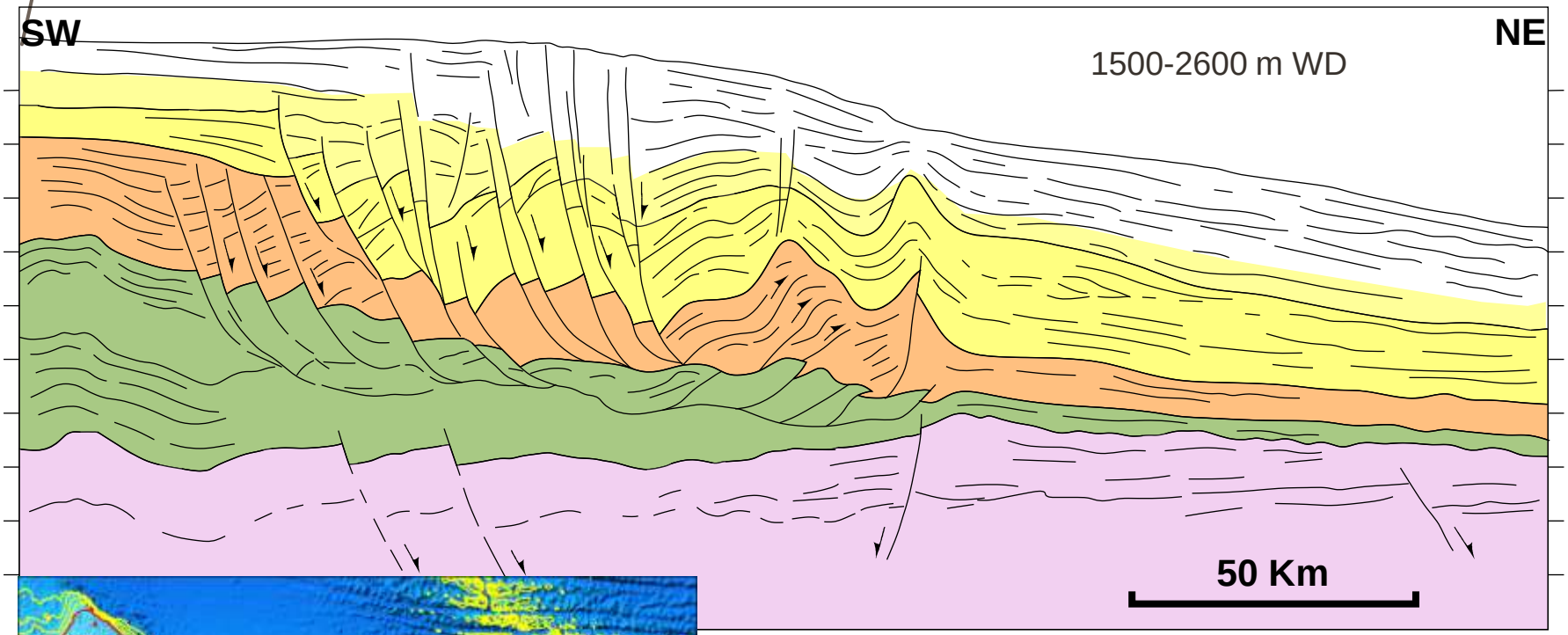
Flinch et al. (2008)

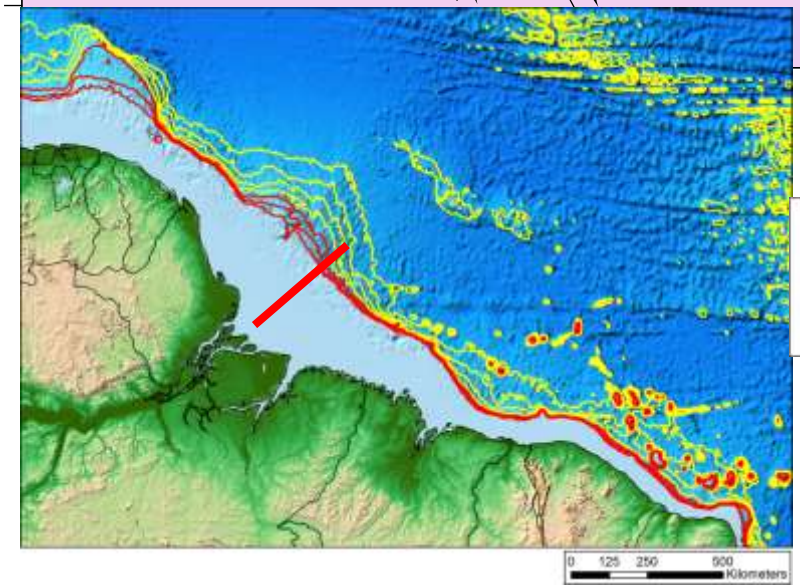
Depth Section through the Liberia Margin



Courtesy of TGS

Foz do Amazonas, Brazil





Deep Water (500 - 2000)

Ultra Deep Water (2000 - 4000)

Neogene

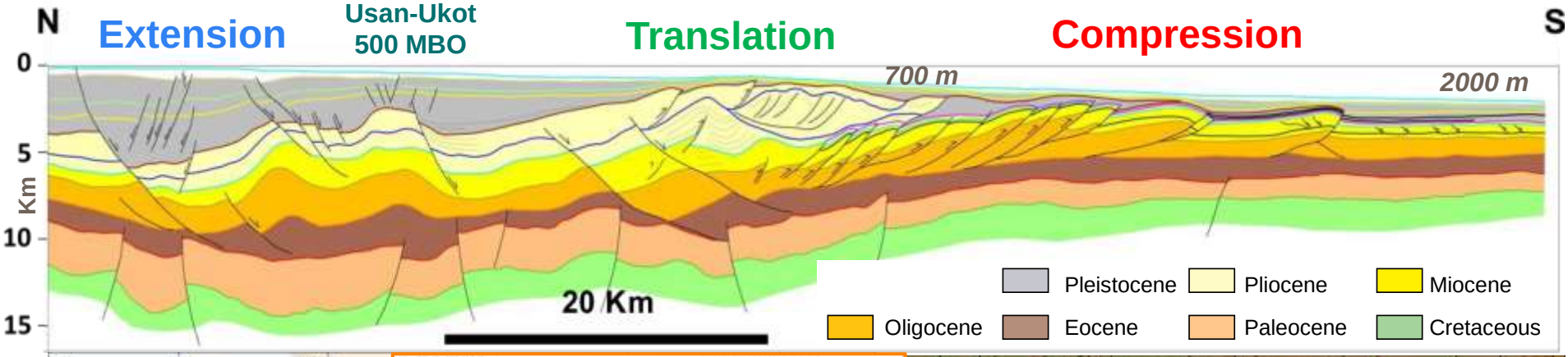
Paleogene

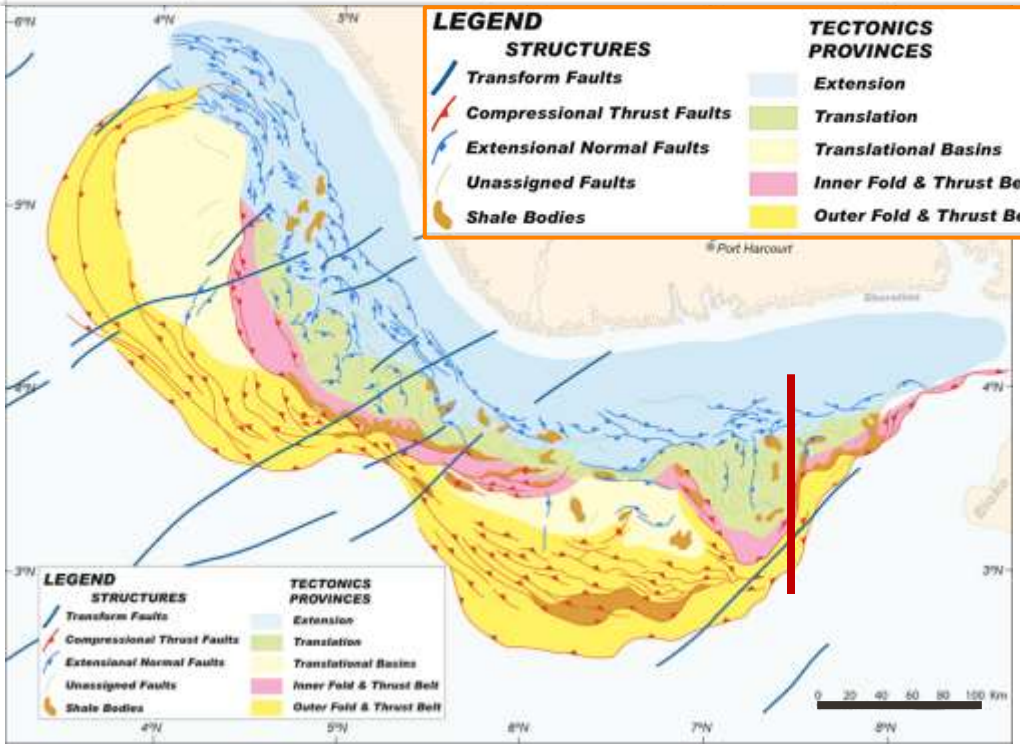
Cretaceous

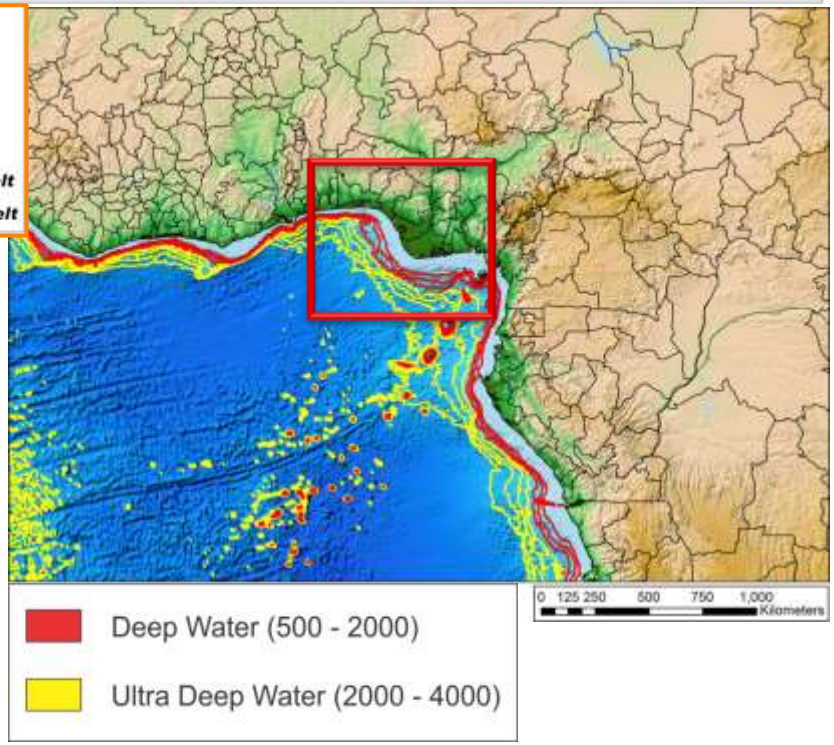
Basement

Line drawing : modified from Carrus (2011)

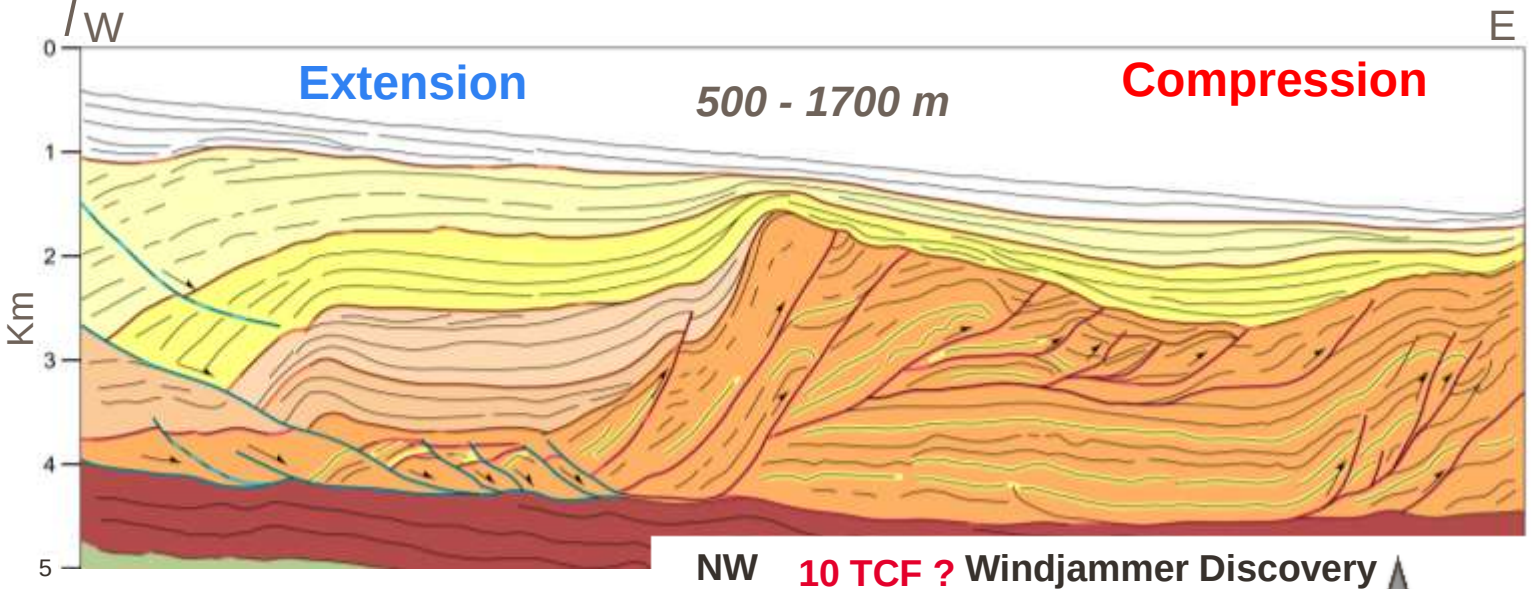
Niger Delta, Nigeria - Equatorial Guinea

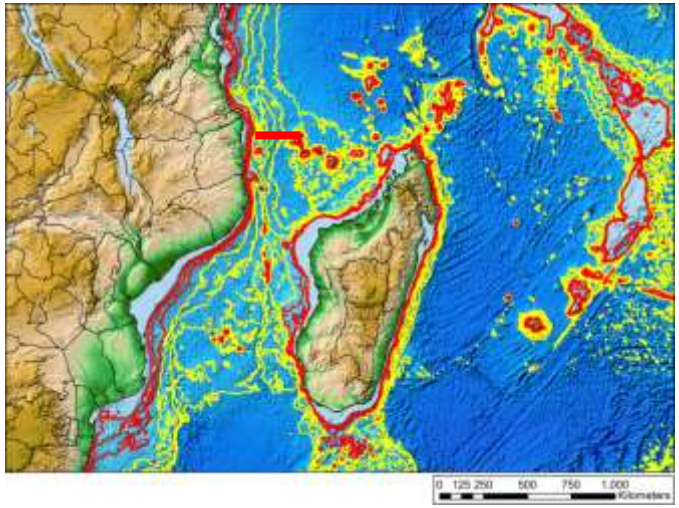






Rovuma Basin, Offshore Mozambique

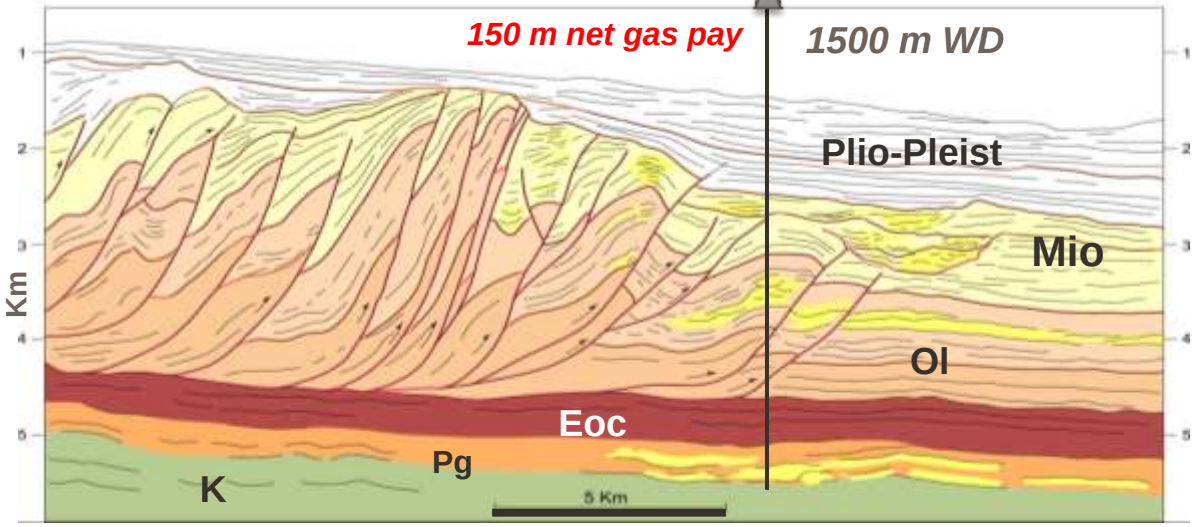




Deep Water (500 - 2000)

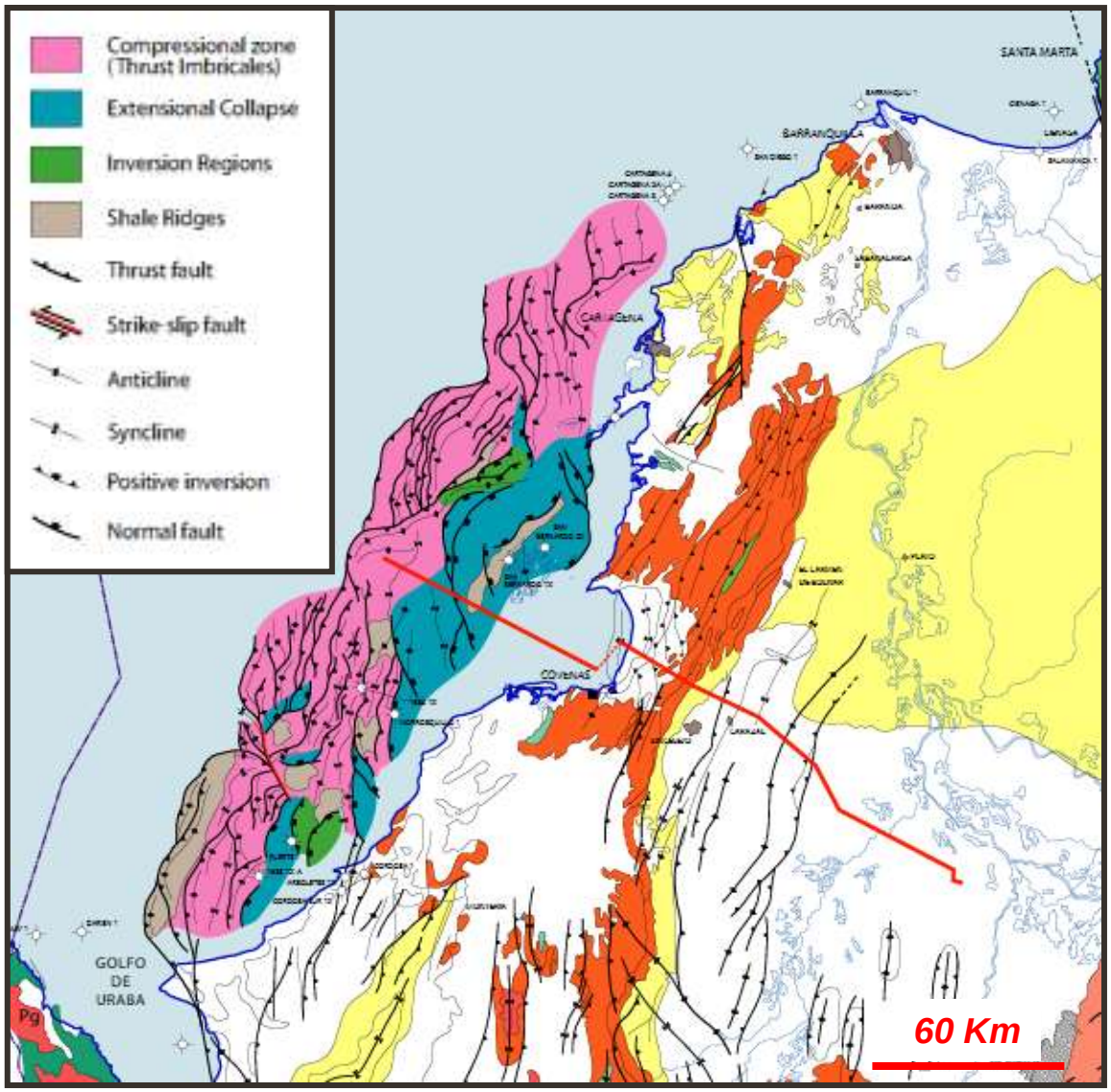
Ultra Deep Water (2000 - 4000)

NW 10 TCF ? Windjammer Discovery 15 TCF ? Mambo Contourites SE

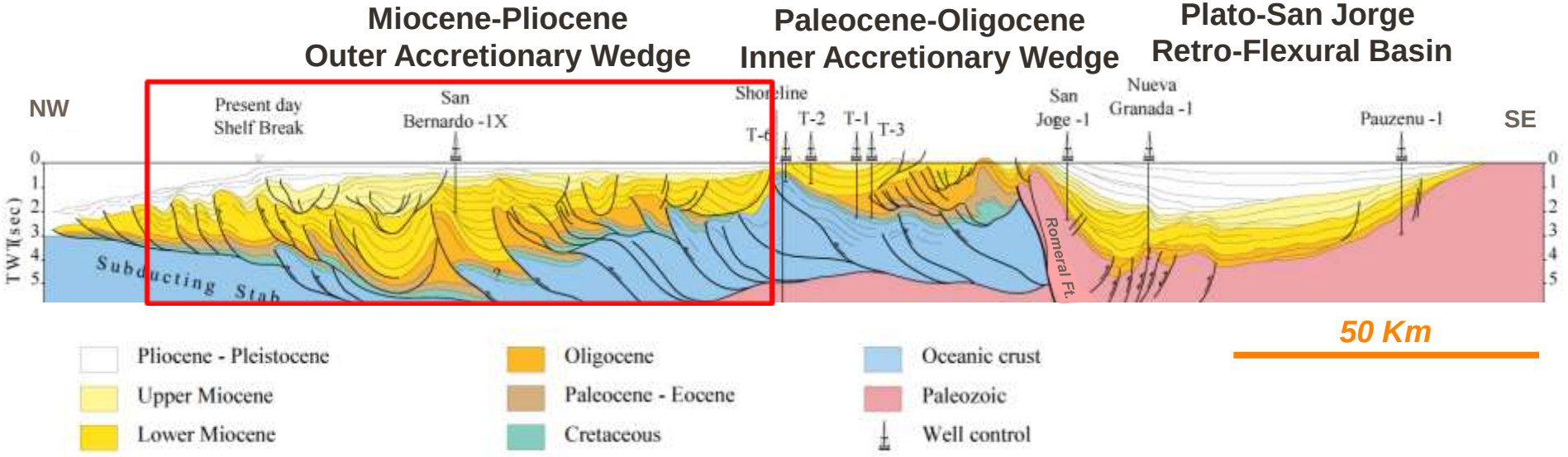


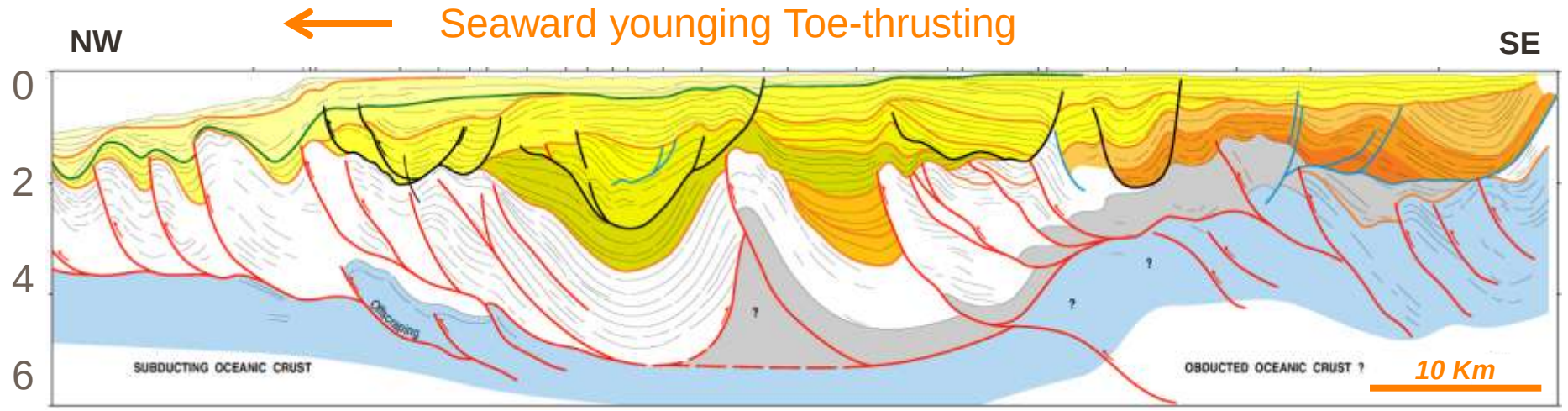
Line drawings: modified from Law (2011)

Northern Colombia Accretionary Prism



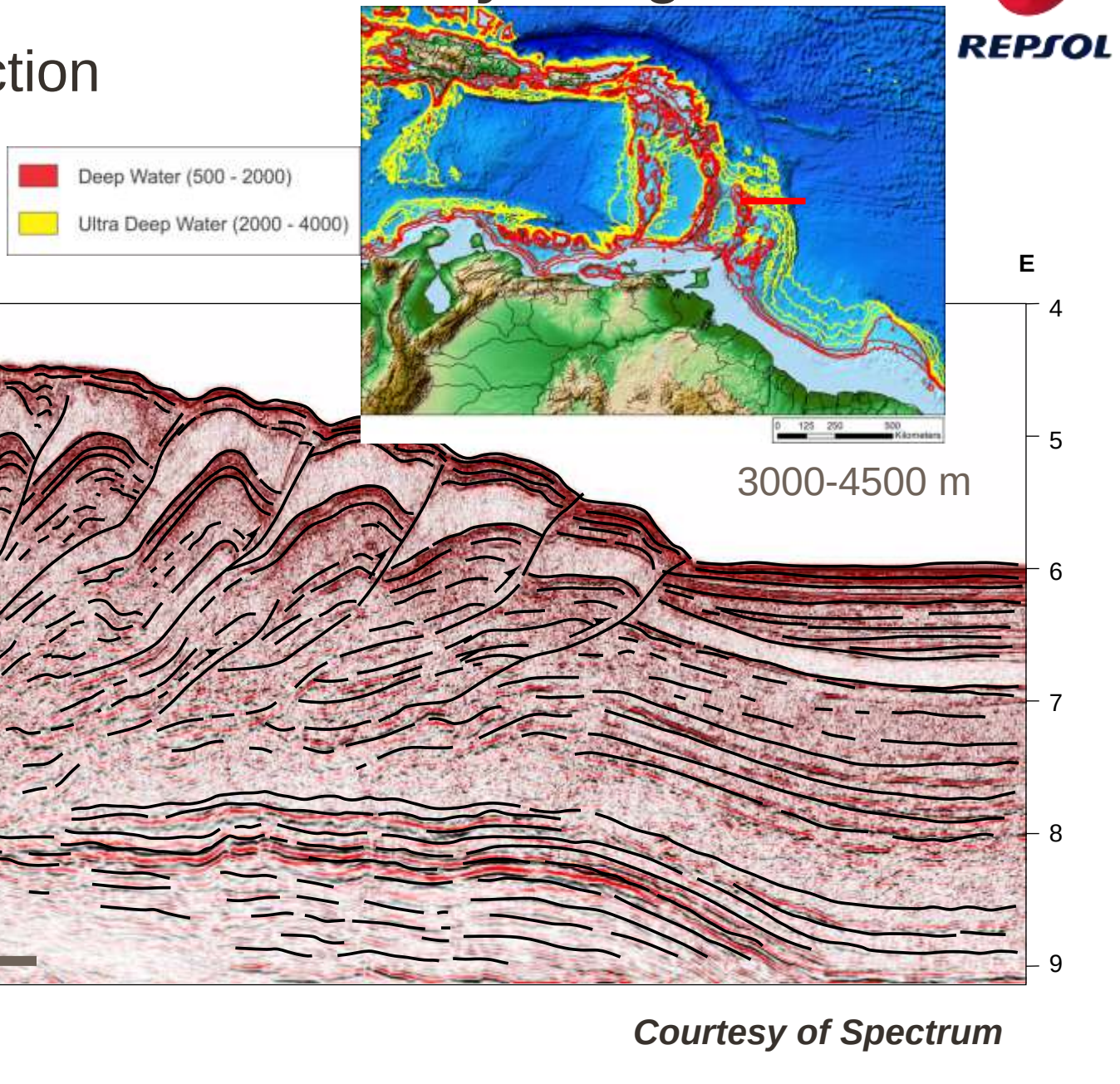
Sinu Accretionary Prism, Northern Colombia





Barbados Accretionary Wedge

PSTM Section



Courtesy of Spectrum

Challenges of Deepwater Plays :

- Deepwater Source Rocks
- Deepwater Carbonate Reservoirs
- Deepwater Erosion

Source Rocks in Deepwater Plays

REPSOL

Shallow water SR subsided into Deepwater

Lacustrine to Shallow marine

Restricted environment

Kerogen Type I

Onshore and Exploration wells

Example :
Bucomazi Shale, Cabinda (Angola)
Neocomian-Lower Aptian
TOC > 20 %, 46 Tn HC/m²

Bracken 1994

SR originally deposited in Deepwater

Deepwater "Black Shales"

Pelagic, Outer Neritic environment

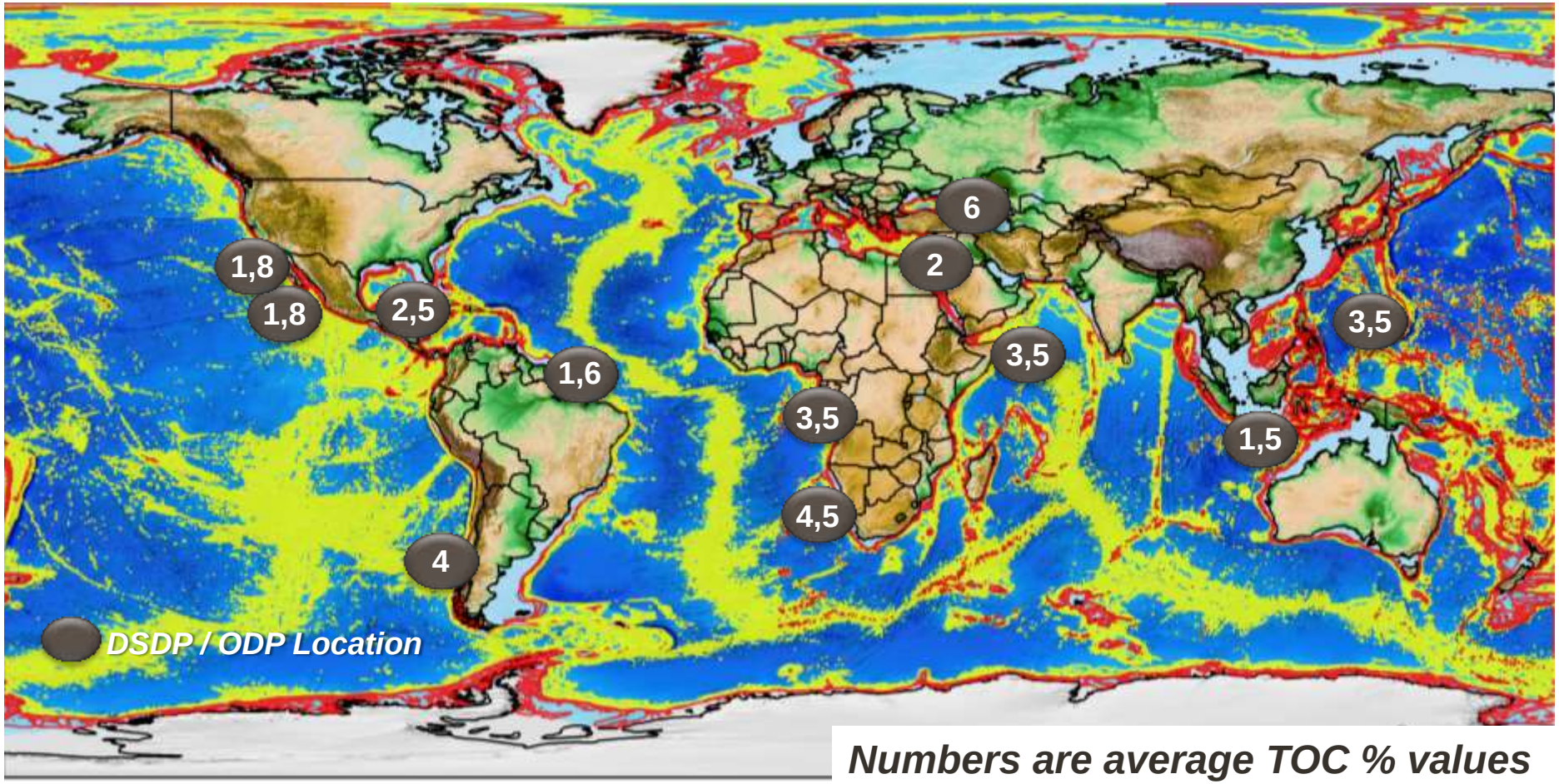
Kerogen type II

Scientific & Exploration wells

DSDP/ODP/IODP
357 hits on Petroleum
57 hits on Butane
44 hits on Bitumen

Hovland et al. 2005

Pliocene to Recent Deepwater Source Rocks encountered by DSDP/ODP wells



Numbers are average TOC % values

Stow et al. (2001)

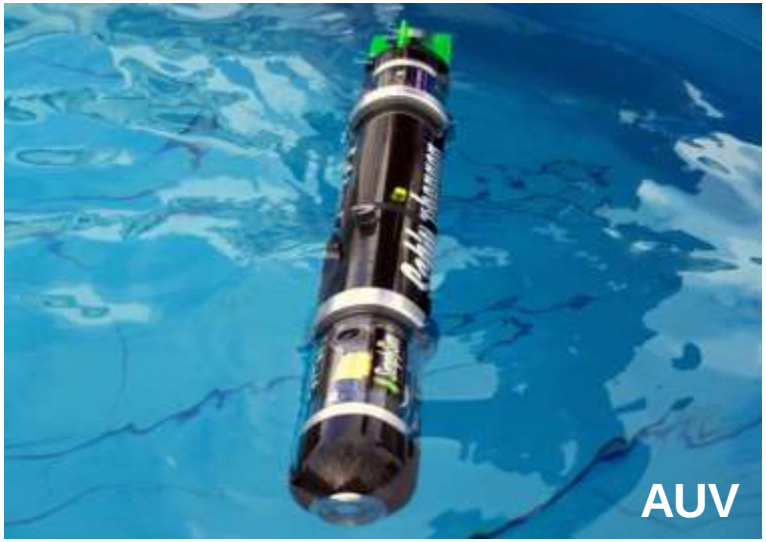
Deepwater Carbonates in Shallow water or Onshore Fields

Oil/Gas Field	Region/Country	Sea Bottom / Reservoir Depth	Reserve Estimates	Facies Type & Age
Cantarell	Campeche, Mexico	WD 40-60 m, 1500 m RD	408.000 bl/d 14 BBO	Slope breccias, calci-turbidites
Ekofisk	North Sea, Norway	60-70 m WD, 3000-3300 m RD	65-75 MBC 1TCF	Chalks, debris flows & turbidites
Tengiz	Caspian Basin, Kazahstan	0 m WD, 4000 m RD	6-13,5 BBO	Boundstone debris
Kirkuk	Kirkuk, Northern Iraq	0 m WD,	10 BBO	Mudstones and Wackstones with Globigerina, radiolarian & tintinnids

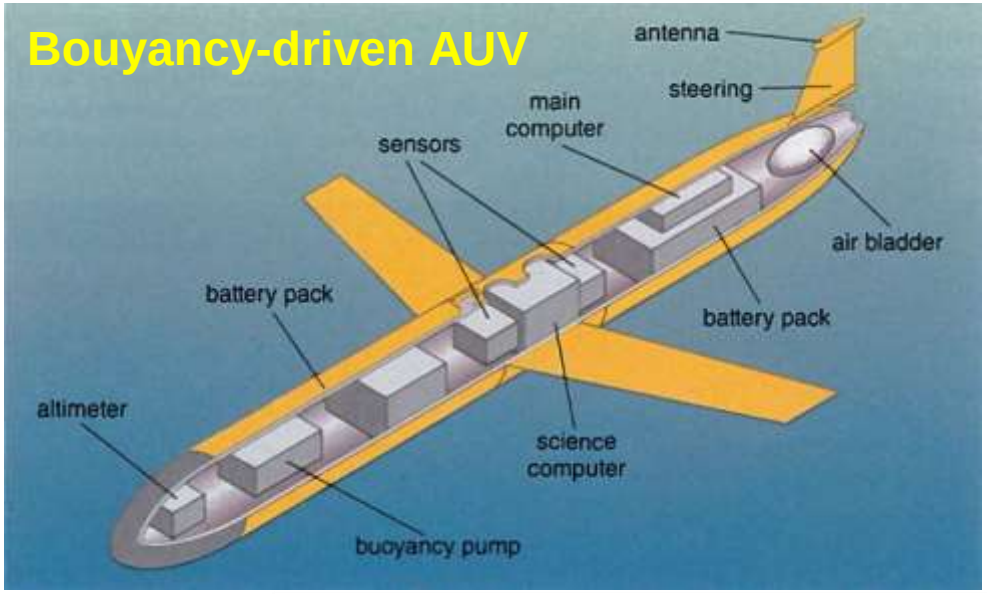
Shallow water Carbonates in Deepwater Fields

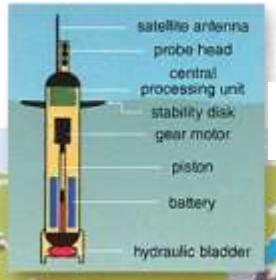
Oil/Gas Field	Region/Country	Sea Bottom / Reservoir Depth	Reserve Estimates	Facies Type
Lula, Iara	Santos Basin, Brazil	2000 m, WD 4000-5000 m RD	30 BBO	Lacustrine Microbialites
Malampaya	Palawan Basin Philippines	840-1200 m WD, 2700-3000 m RD	41 MBC, 3.7 TCF	Red algae & foramminiferal mounds

Automated Underwater Vehicles (AUVs) and Remote Operated Vehicles (ROVs)

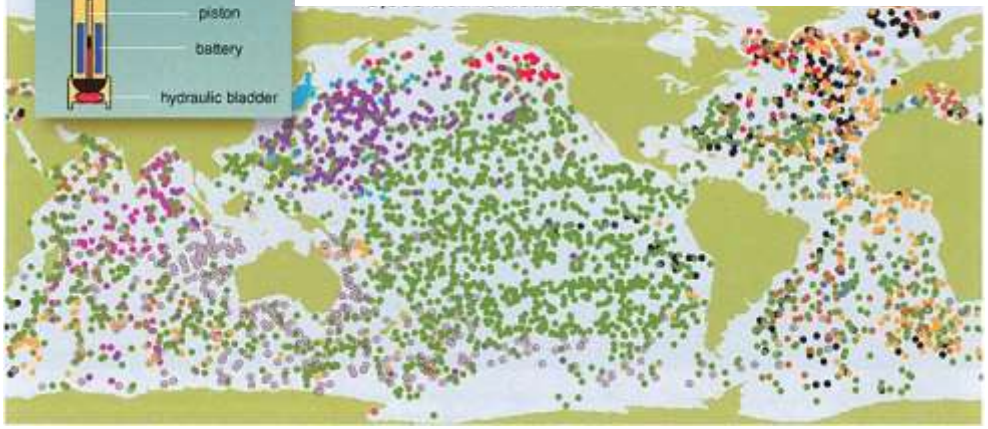


Automated Underwater Vehicles



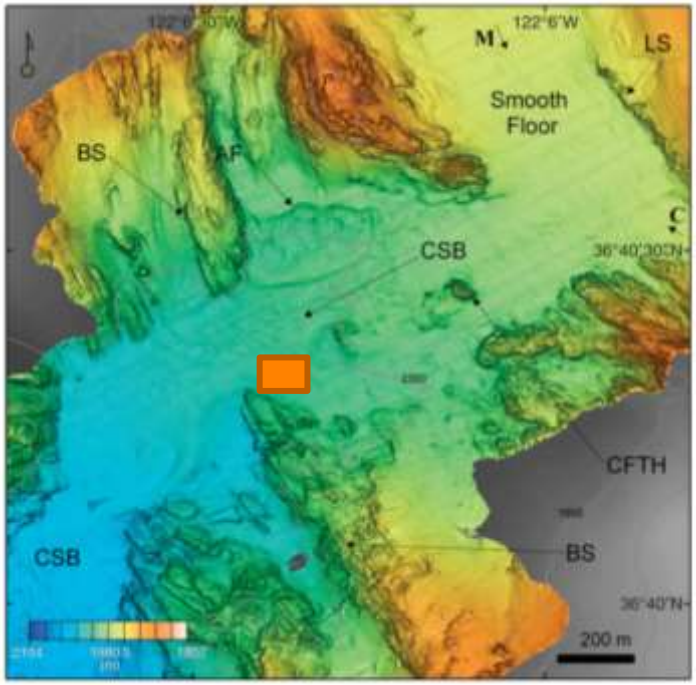


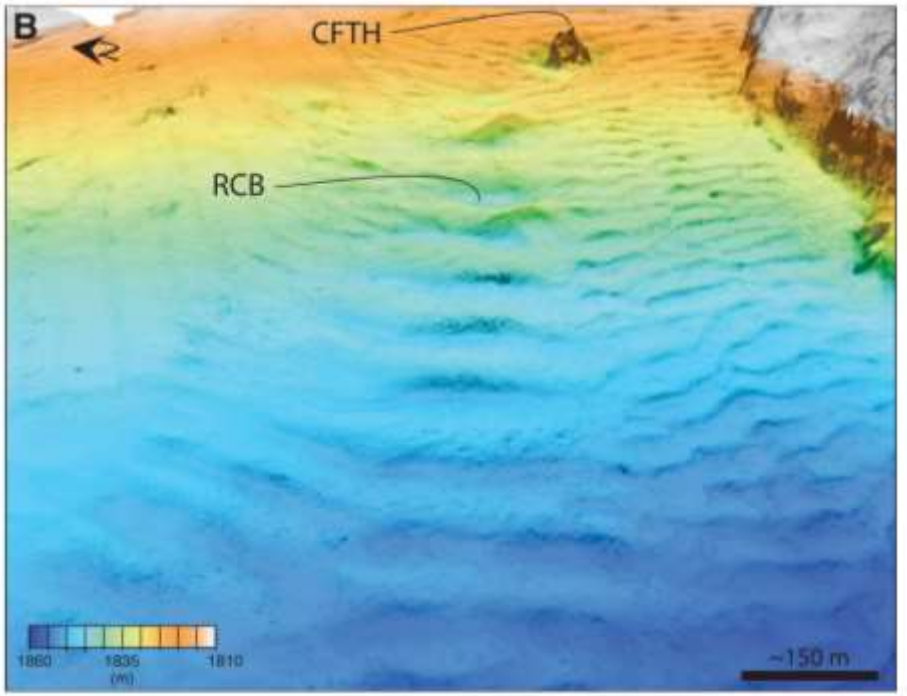
3,568 Active Floats Worldwide

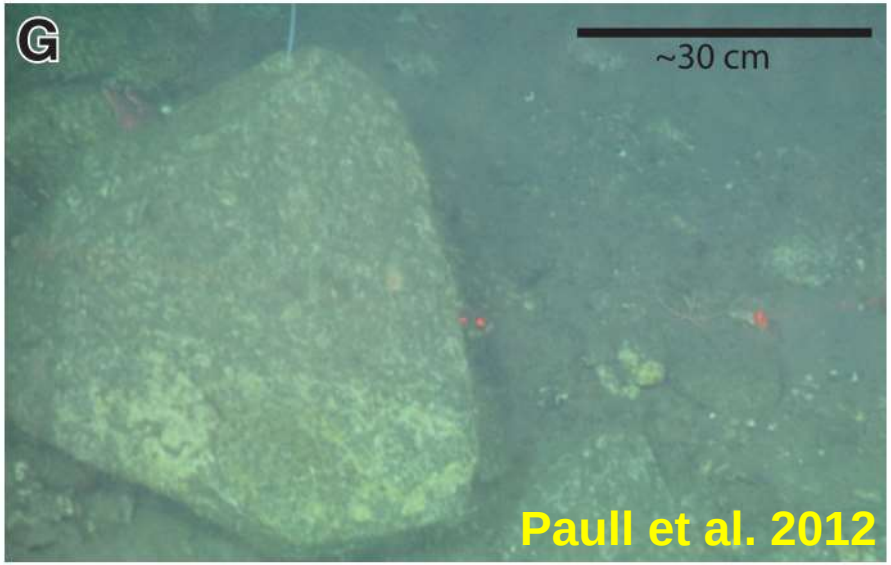


Schofield,Glenn and Moline 2013
American Scientist

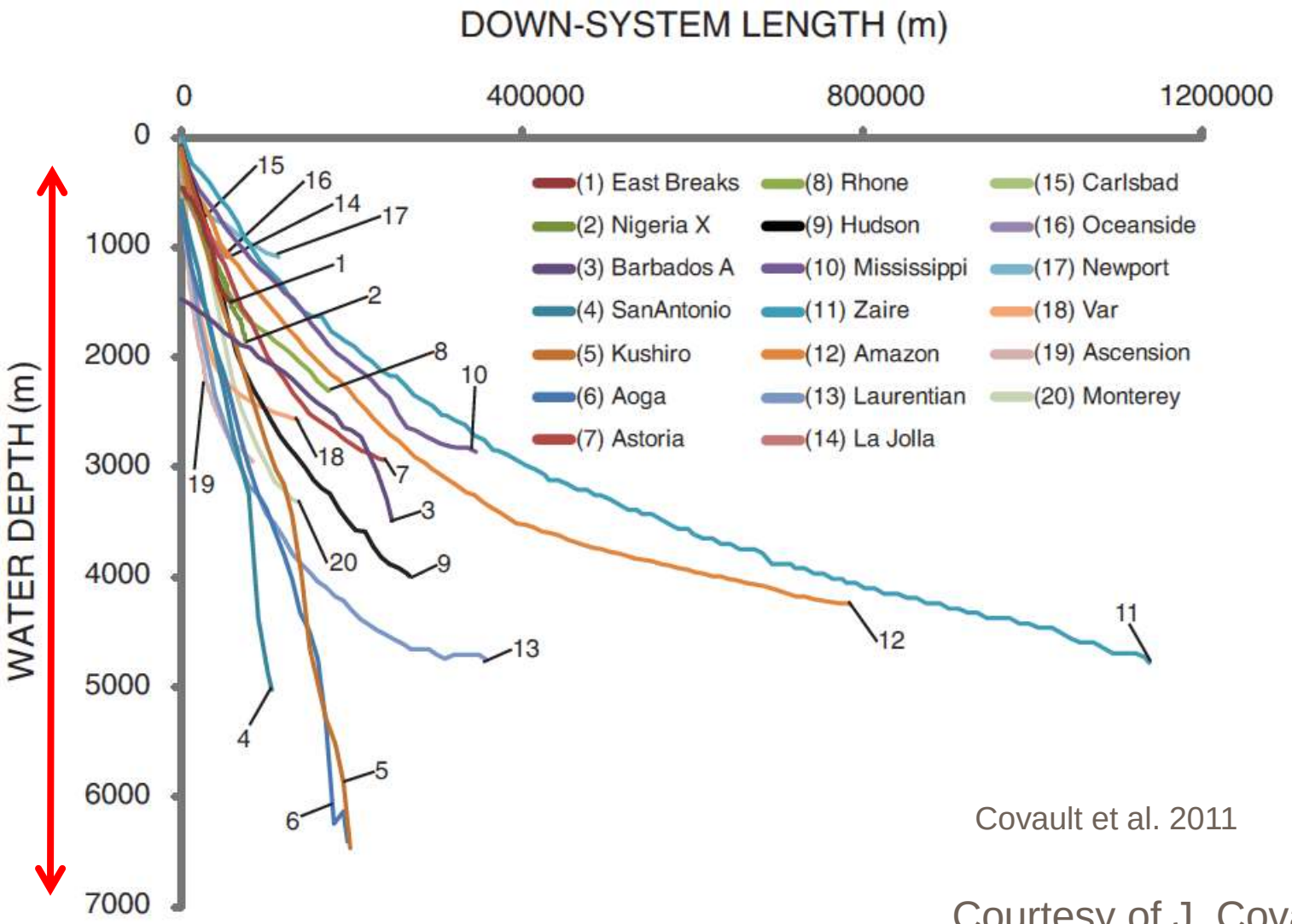
Monterrey Canyon, Offshore California







Canyon and Channel Longitudinal Profiles



Covault et al. 2011

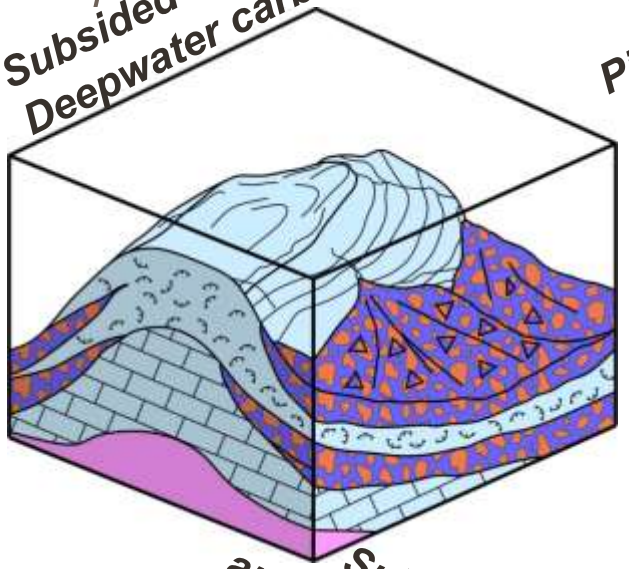
Courtesy of J. Covault

Future Deepwater Plays

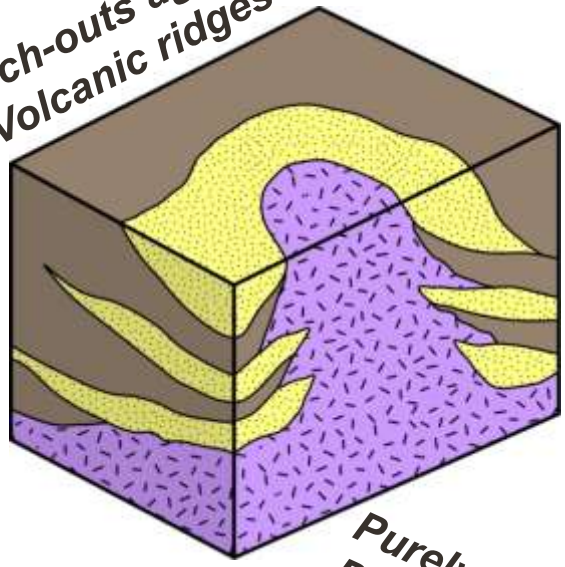
Future Deepwater Plays

REPSOL

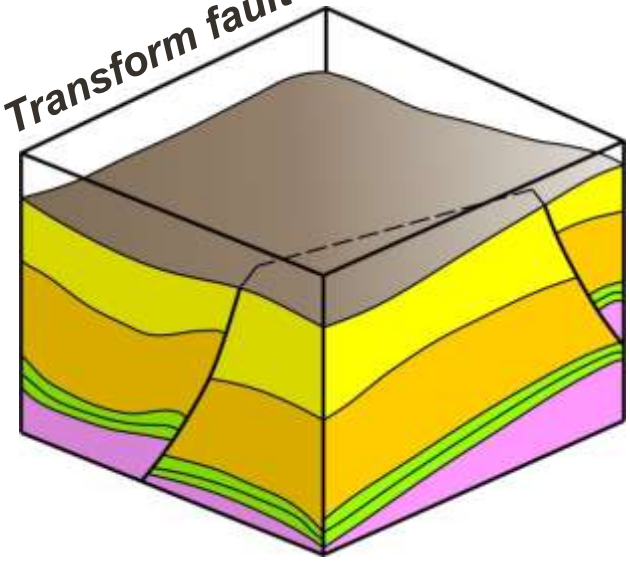
Subsided Bioherms
Deepwater carbonates



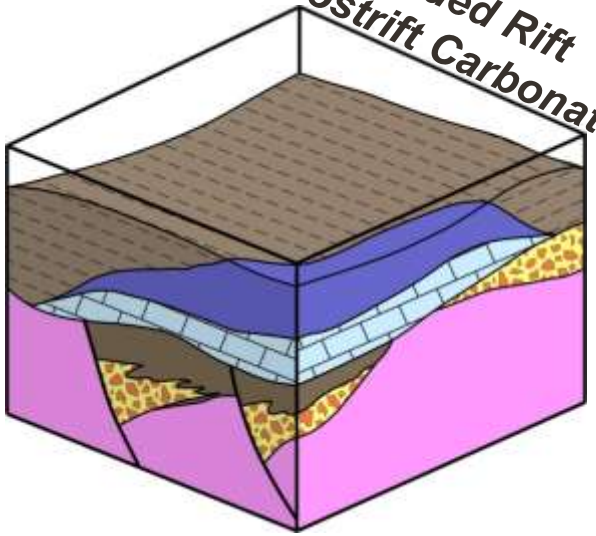
Pinch-outs against
Volcanic ridges



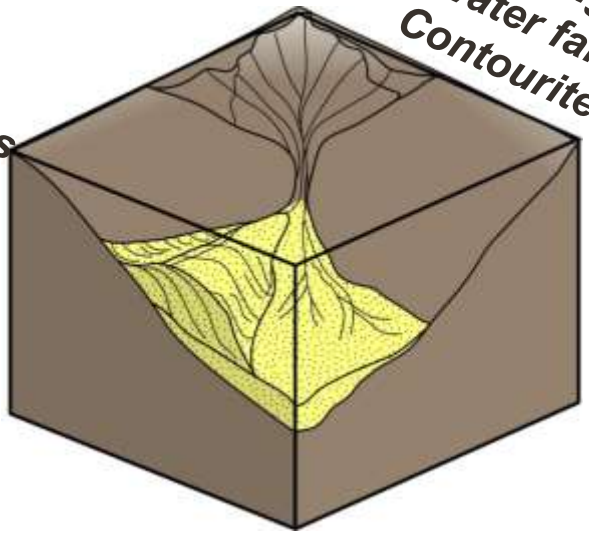
Transform faults



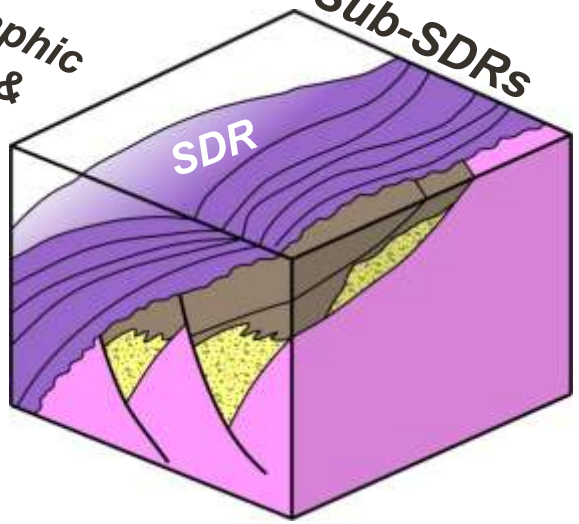
Subsided Rift
and Postrift Carbonates



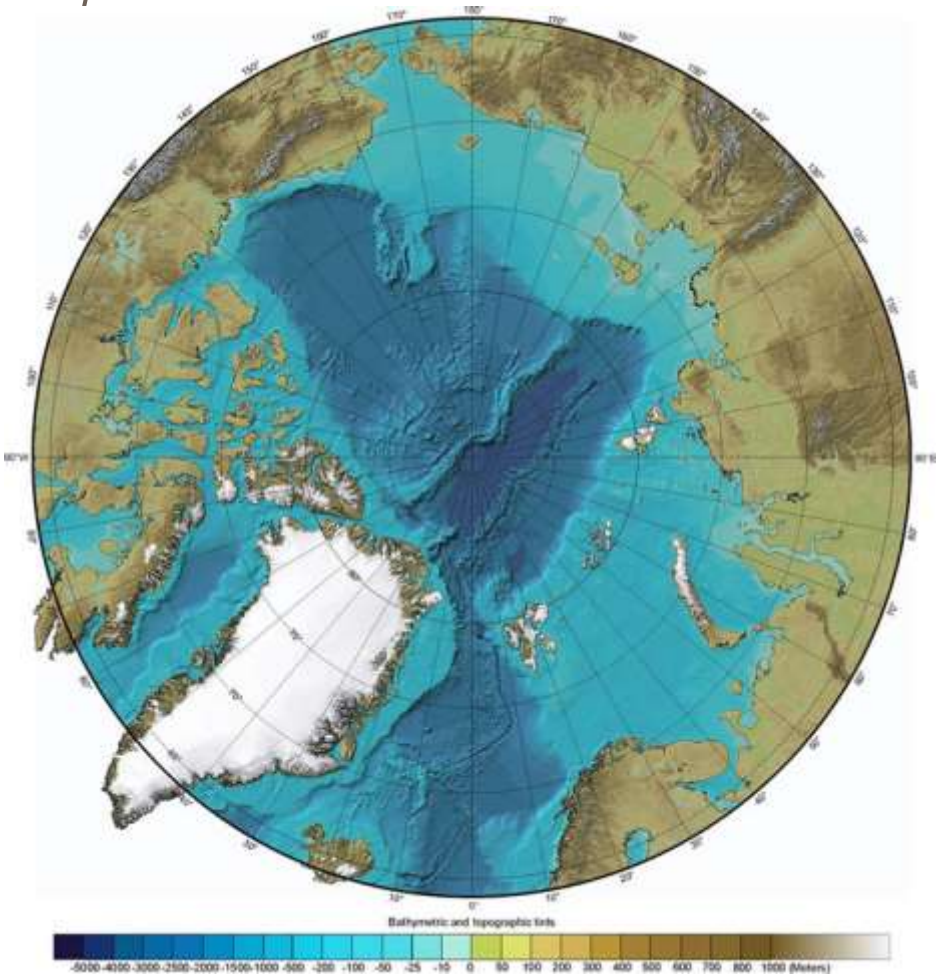
Purely stratigraphic
Deepwater fans &
Contourites



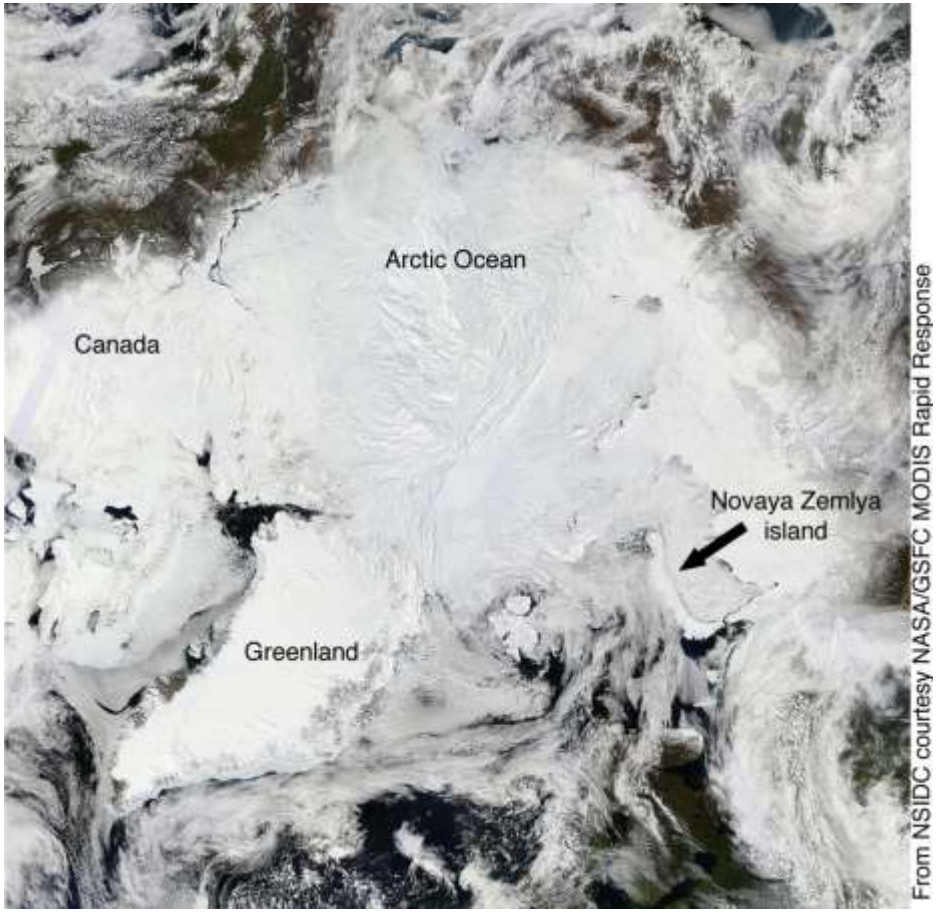
Sub-SDRs



Artic and Antartic Deepwater Exploration ?

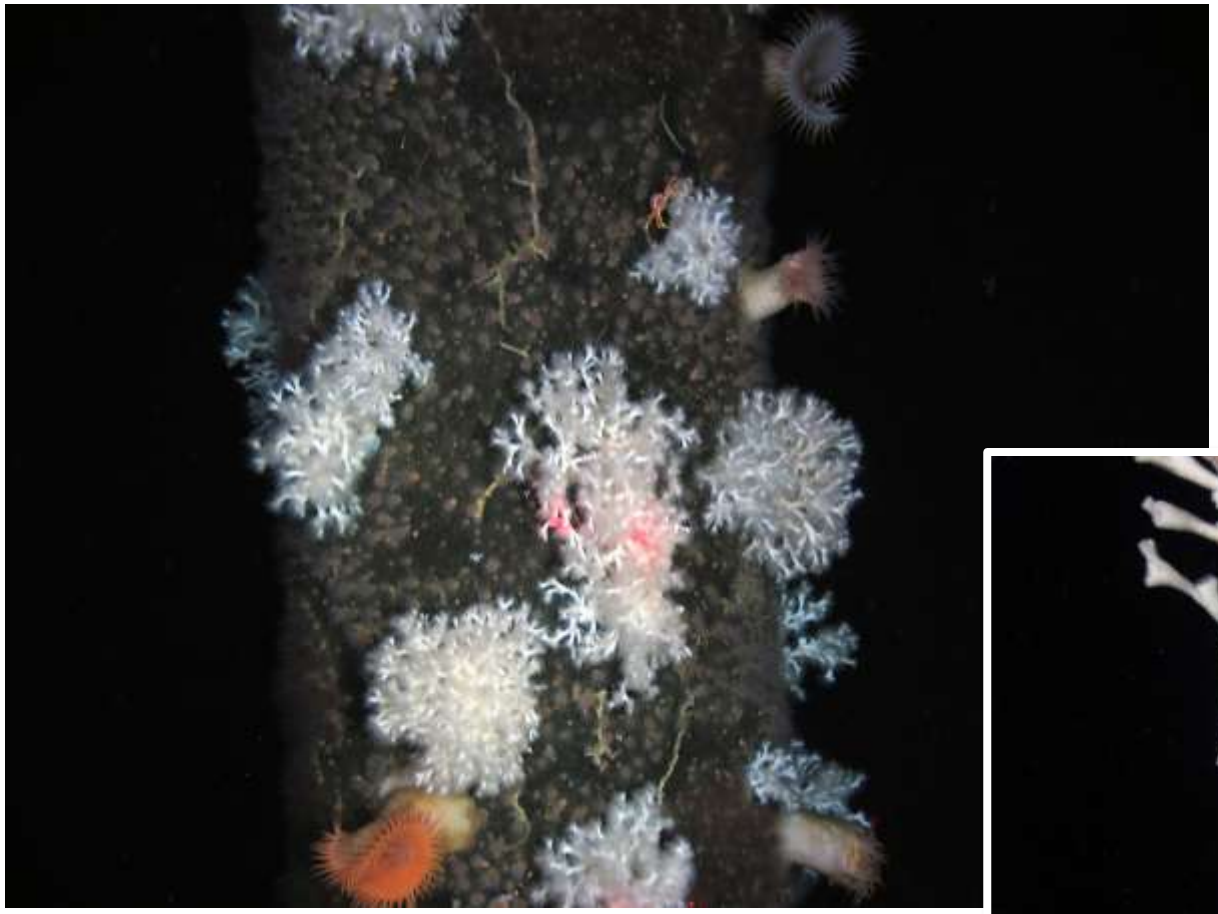


Geology.com



In NSIDC from NASA

Gulf of Mexico Deepwater Corals



995 m below sea level, Zinc Platform

2012 Expedition

Lophelia Corals

Conclusions

1. **Most current Deep water plays Subsalt, Presalt, Folded Belt and Stratigraphic pinch-out plays**

2. **Deep water plays can be subdivided according to their Geodynamic setting.**

3. **Source Rocks are common in Deep water regions, Rich lacustrine or restricted marine SR later subsided or Deep water Black Shales deposited in pelagic or Outer neritic environments as indicated by Exploration but also Scientific wells.**

4. **Knowledge of Deep water erosion has strongly improve thanks to High Quality seismic data, HR bathymetry and to AUV/ROV observations.**

5. **Deep water carbonate plays related to drown/subsided shallow water facies or deep water carbonate facies**

Thank You

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