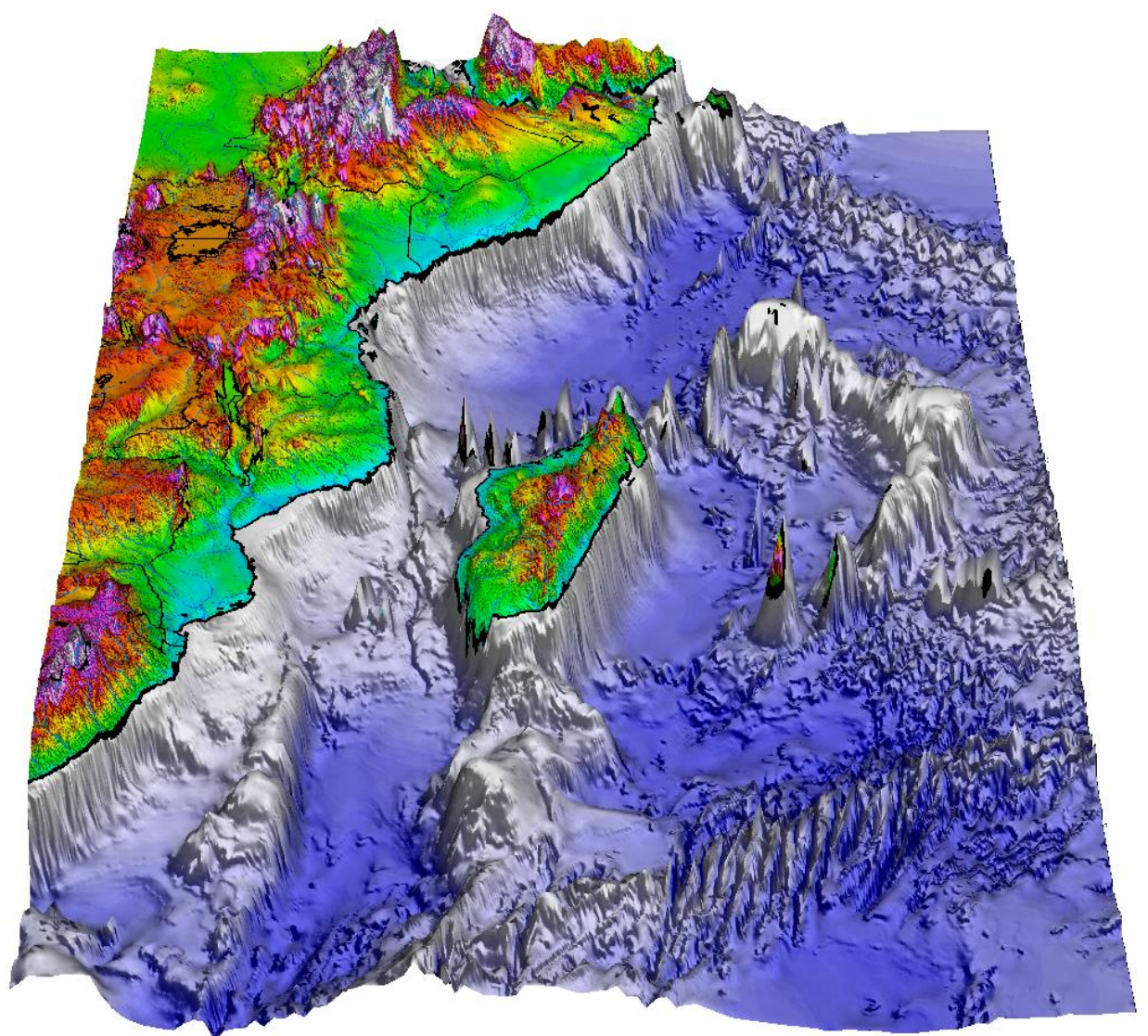


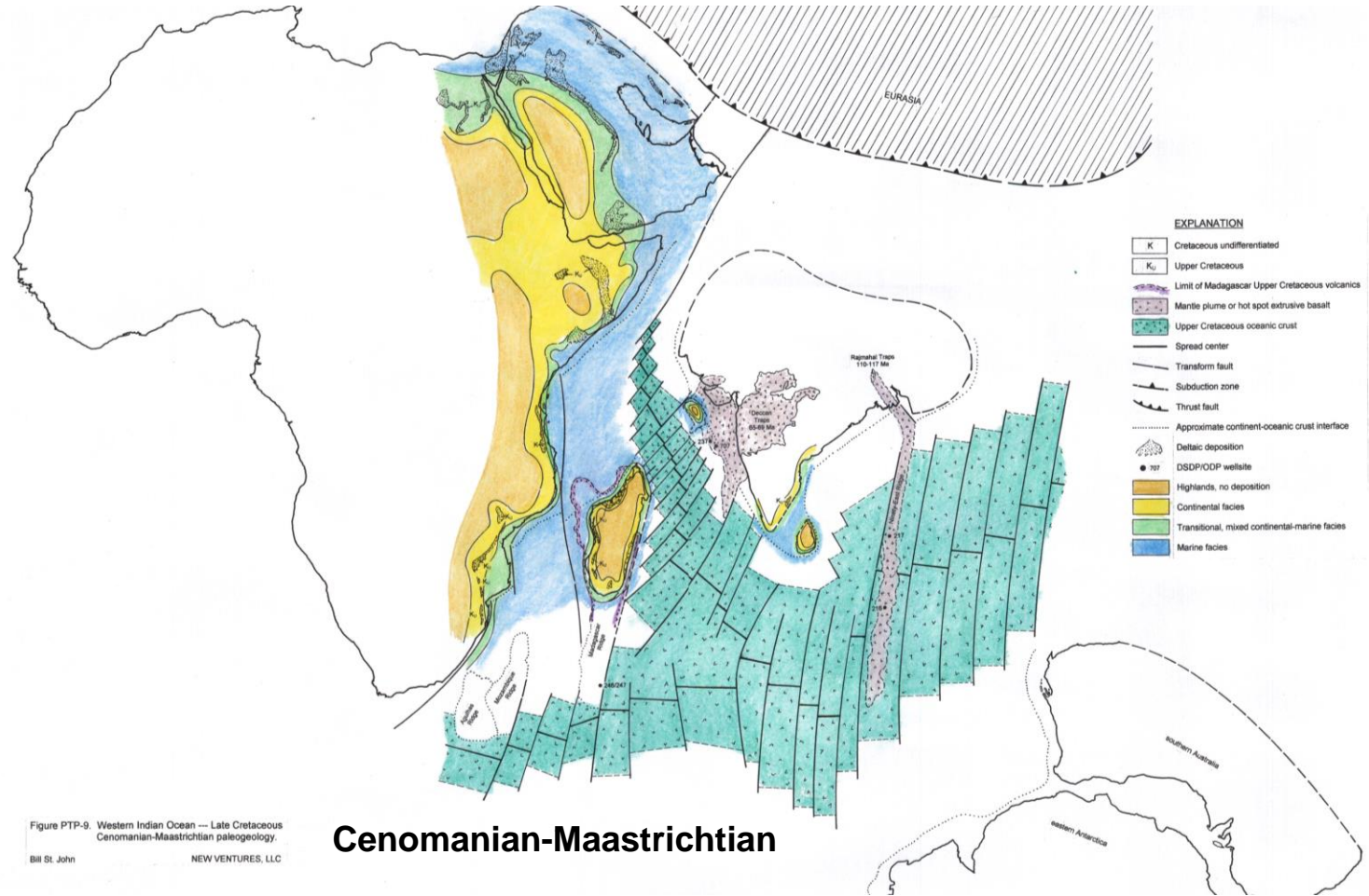
Where is the oil in East Africa, and can it match the gas success story in the region?

Gabor Tari
Group Chief Geologist
OMV

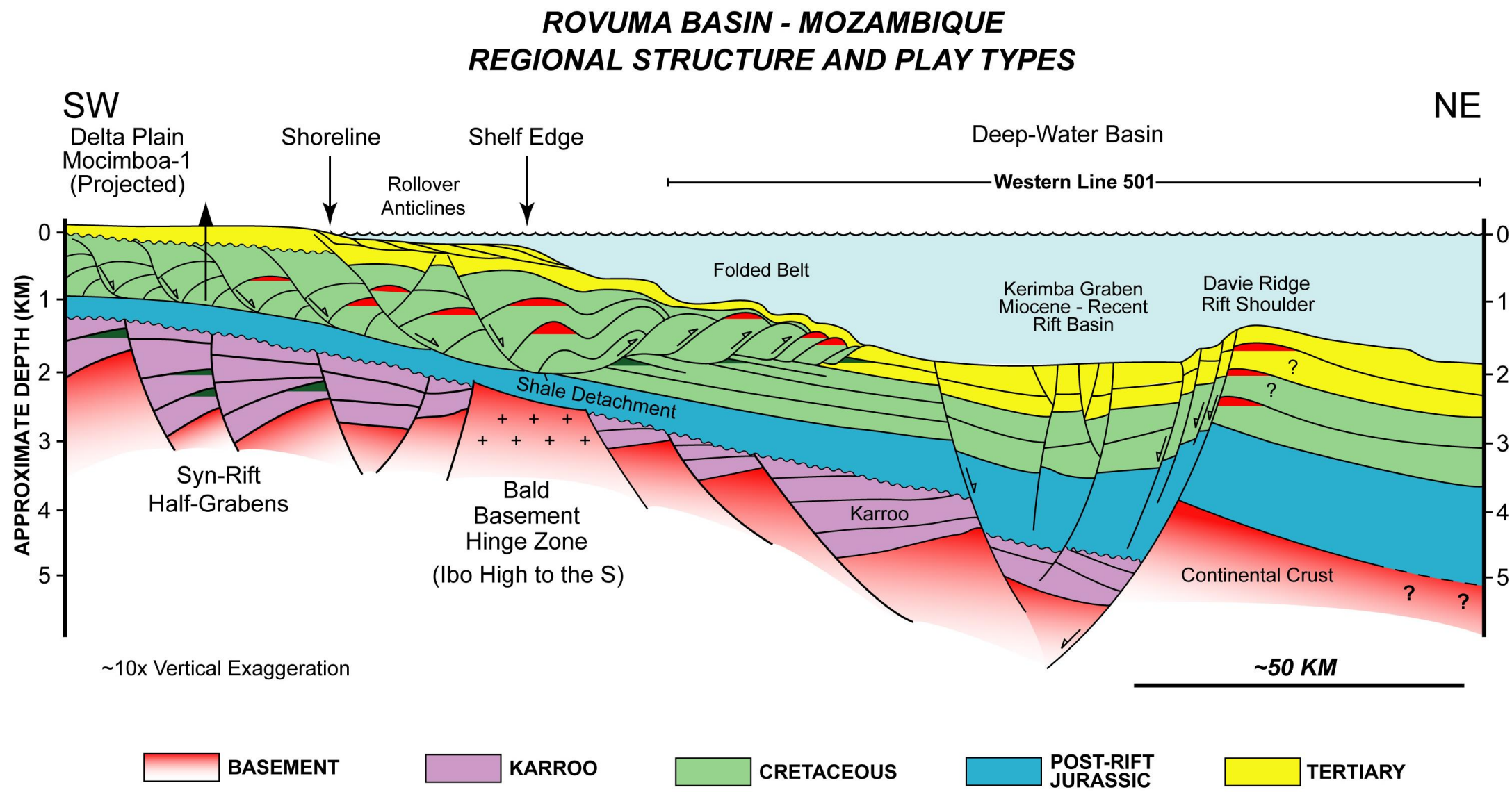


OMV Upstream

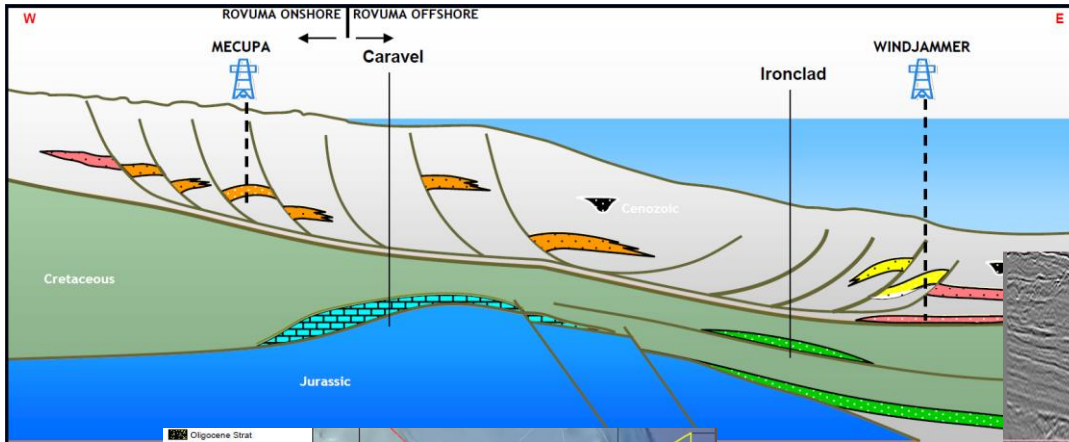
Bill St. John (1932-2015)



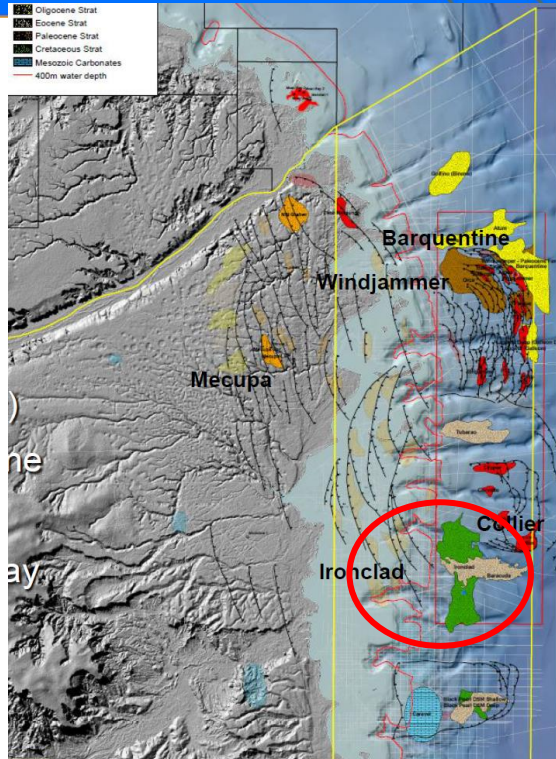
“Positive thinking” in 2005, prior to the Anadarko/ENI gas discoveries



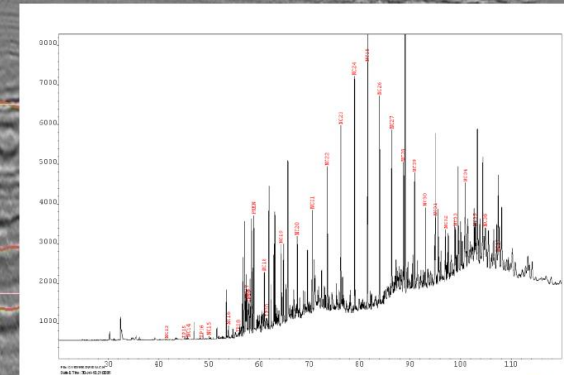
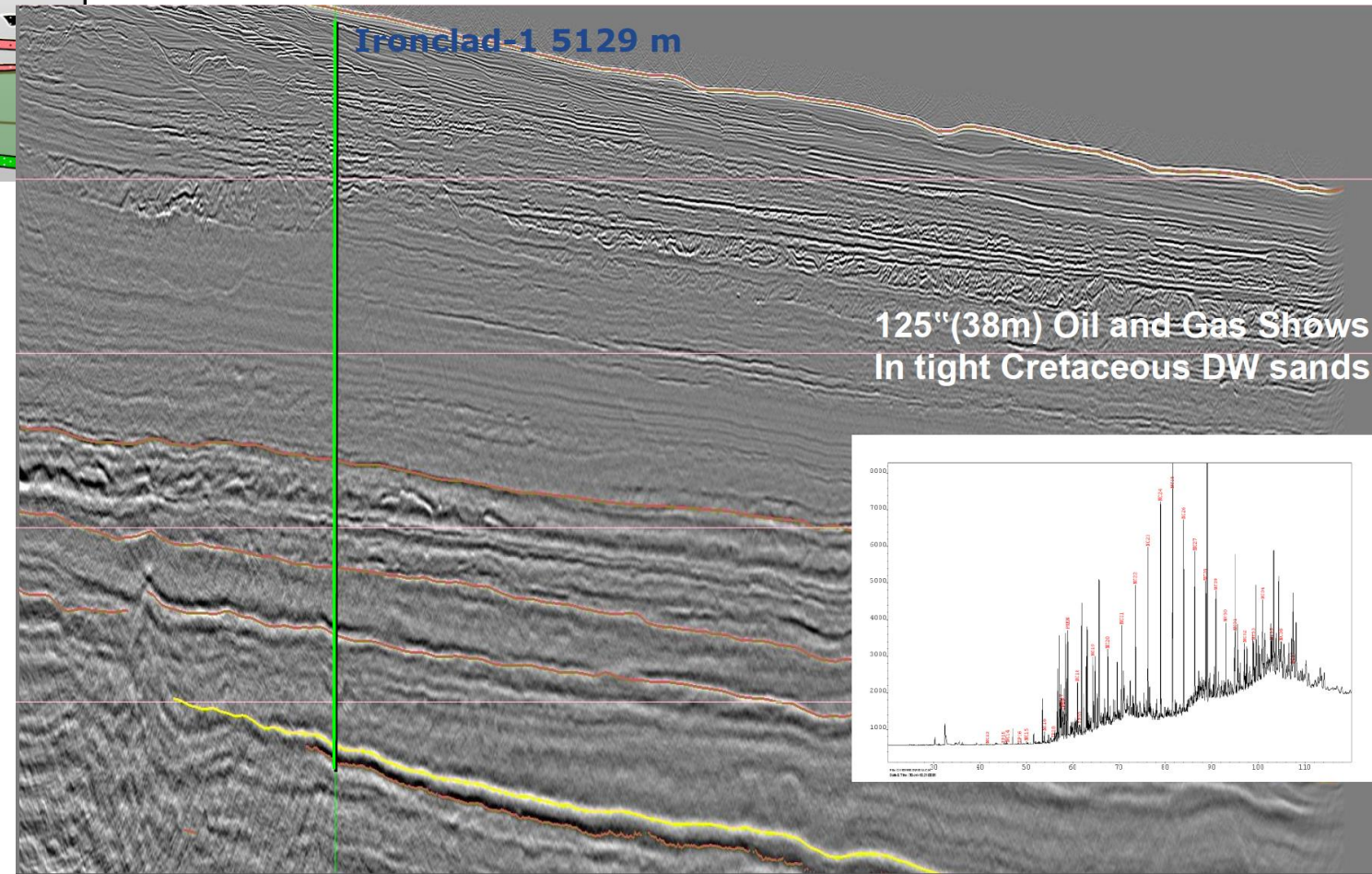
Ironclad oil, from Cretaceous side-core, Rovuma Basin, Mozambique



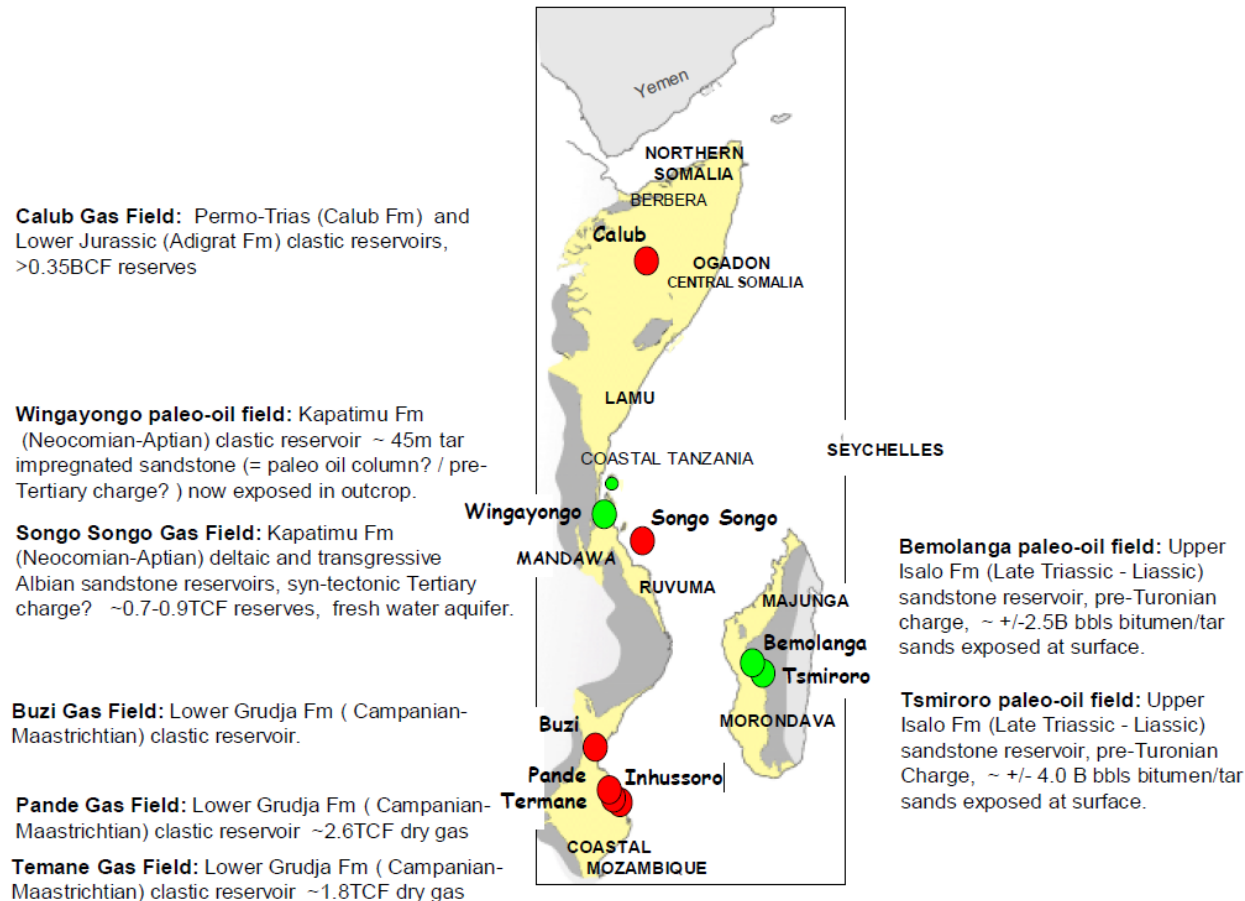
The rising GC baseline is typical for low maturity / biodegraded oils
The n-alkane envelope points towards low maturity HCs
The n-alkane maximum is at C25, biodegradation should not affect first higher HCs
As the pristane/phytane ratio is not resolved the source rock type remains uncertain



(Law, 2011)



Oil families in East African coastal basins... is it a complete list?



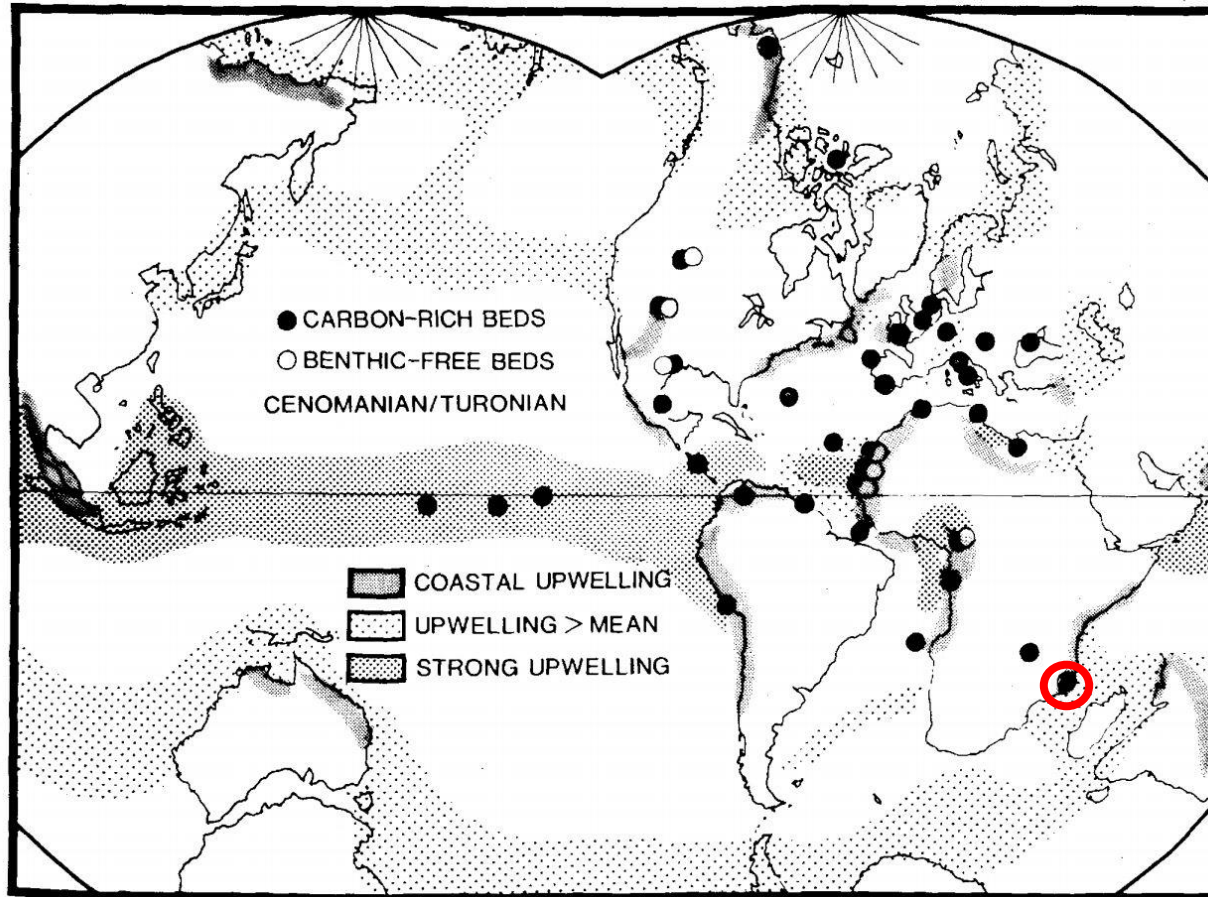
Tentative Oil Families ~ East African Coastal Basins

Late Cretaceous/Tertiary	●	Syn-rift lacustrine source facies offshore Yemen, ?Cariole (Somalia), NE Seychelles, Cambay (NW India)
Upper Jurassic Late Kimmeridgian - Tithonian	● Lam ● Mabdi	Syn-rift restricted clastic source facies, Marib-Jawf (Lam) Saar (Madbi) and Berbera (Daghani) Grabens, Yemen and Northern Somalia
Oxfordian-Early Kimmeridgian	● Uarandab	Marine shelf clastic source facies (Uarandab) Ethiopia/Somalia
Middle Jurassic	● Early post-rift ● ? early post-rift	Distal slope-basin & restricted marine carbonate source facies (Amboni, Mtumbei, Bemaraha), Tanzania coastal, Rovuma and Morondava / Majunga Basins, Madagascar
Lower Jurassic	● Syn-rift ● ? syn-rift	Variable, heterogeneous hypersaline (Mbuo) and restricted marine (Beronono, Andafia) clastic source facies, coastal Tanzania, Mandawa, Rovuma, Majunga/Morondava & Seychelles
Early Triassic-Late Permian	● δC light ● δC heavy ● undetermined	Lacustrine (isotopically light, saline) source facies (Sakamena, Maji ya Chumui, Bokh), northern Morondava, Kenya & Ethiopia Restricted marine /lagoonal source facies (Sakamena, Maji ya Chumui, ?Stigo), Majunga/Morondava, coastal Tanzania, ?coastal Mozambique.
Lower Cambrian - Upper Pre-Cambrian	● Q oils ● North Huqf ● South Huqf	Restricted (post salt) carbonate source facies (Early Cambrian Dhahaban), central Oman Siliceous and carbonate intra-salt (Ara Gp/Al Shomou) and pre-salt (Buah, Shuram) source facies south and north-central Oman and ?dolomites facies (?Bilara), Punjab/ Bikaner-Nagar Basin, Pakistan & India

(Boote and Matchette-Downes, 2009)

“The Cretaceous and Tertiary interval along the entire East African sea-board appears to lack any significant regional source.”

Oceanic Anoxic Event 2 (Cenomanian-Turonian) in East Africa



Arthur et al. (1987)

The Domo Formation

The name derives from the first occurrence, discovered while drilling the Domo-1 coastal well from 1,452 to 2,853 m.

The entire Domo Formation was later subdivided into three members: Lower Domo Shale, Domo Sand, and Upper Domo Shale, and is known only in the subsurface of coastal and offshore wells.

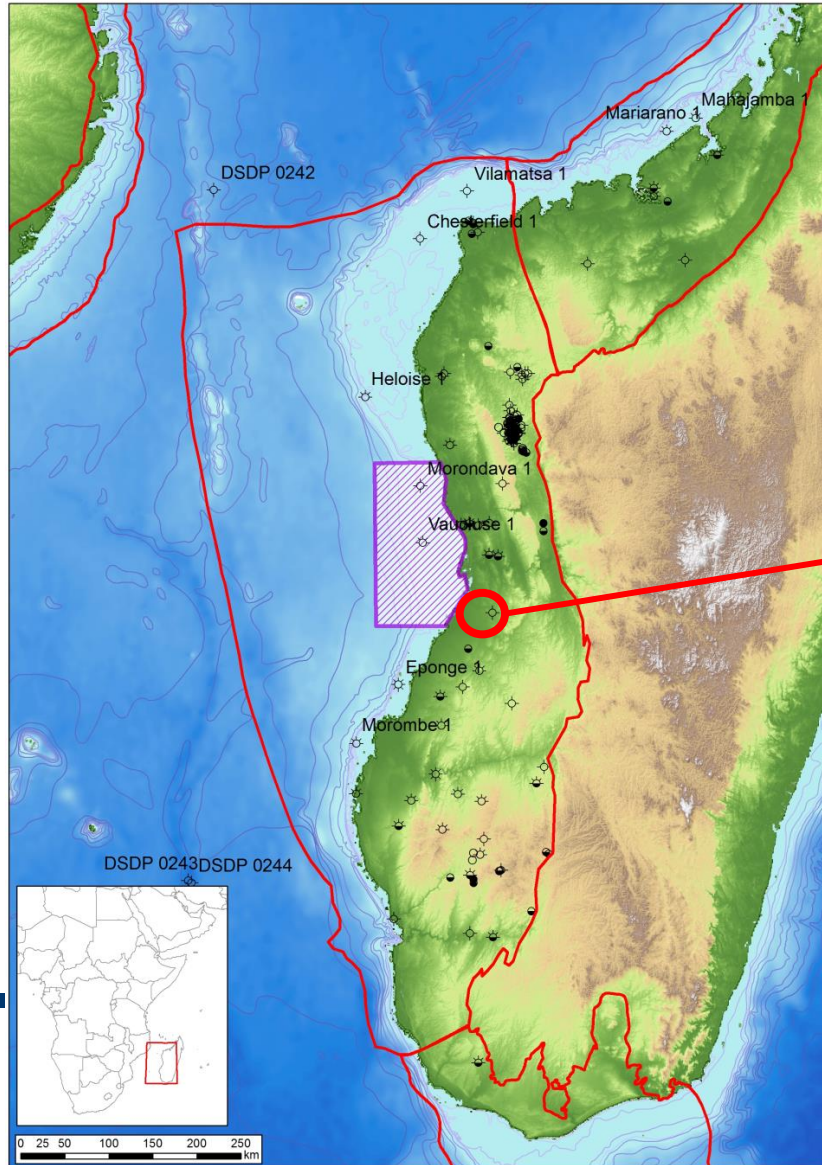
The age of the Domo Formation was shown by microfossils to be Albo-Aptian to Albo-Cenomanian and Turonian to Senonian (Flores, 1971, 1973).

No Domo Formation is known to the north of about 20°S (Sofala-1). The onshore wells Micaune-1 (TD 4,607 m), Nhanquazi-1 (TD 3,348 m) and Nhamura-1 (TD 5,489 m) did not encounter Domo Formation. As shown on Figure 4/6, Domo Formation structural map, this formation is confined to a belt parallel to the present day coast between about 20°S and 25°S. Its eastern edge is uncertain due to lack of control.

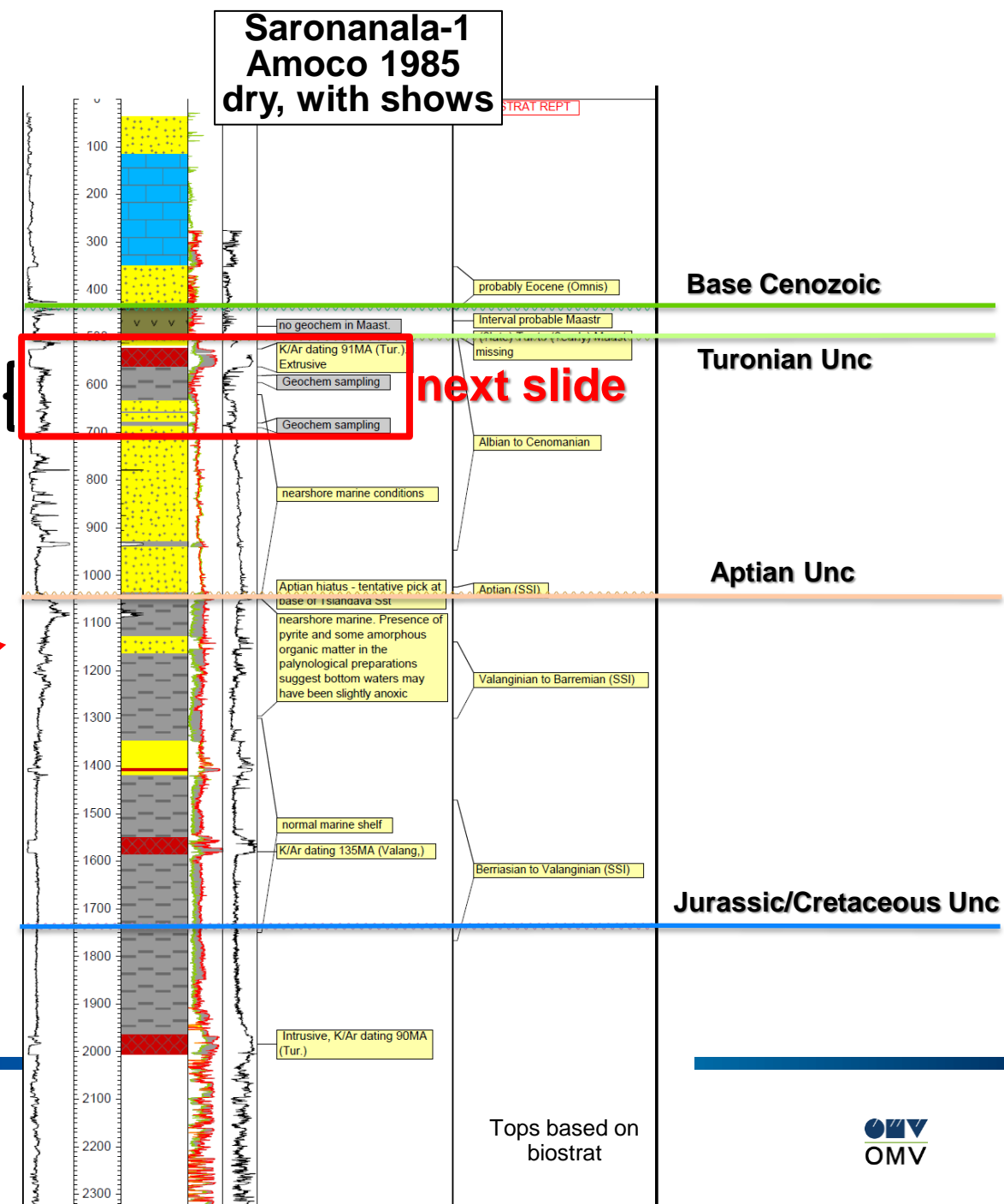
The Lower and Upper Domo Shale units are black to brown shales in euxinic facies apparently deposited in the deepest part of a poorly oxygenated graben of the sea bottom, in a quiet environment below wave action (cf. dwarfed, pyritized fauna and pelagic foraminifera). In fact the Domo Formation as a unit is particularly well developed as a partial fill of the Limpopo, Palmeira and Chidenguele grabens (on seismic interpretation), as well as of the Chissenga Graben from about Beira to the south-southeast. Here the Domo Formation thickness is 1,097 m at Buzi-1; 1,048 m at Divinhe-1; 921 m at Mambone-1, as compared to 1,073 m at Pande-1 and 877 m at

Flores (1994)

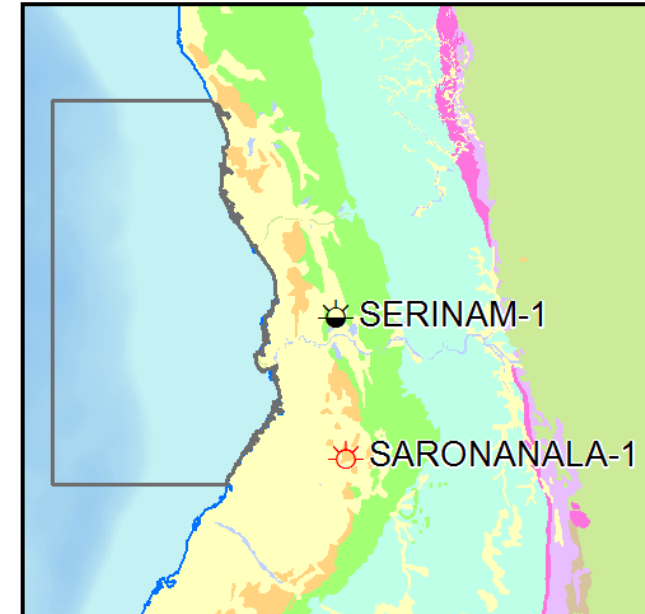
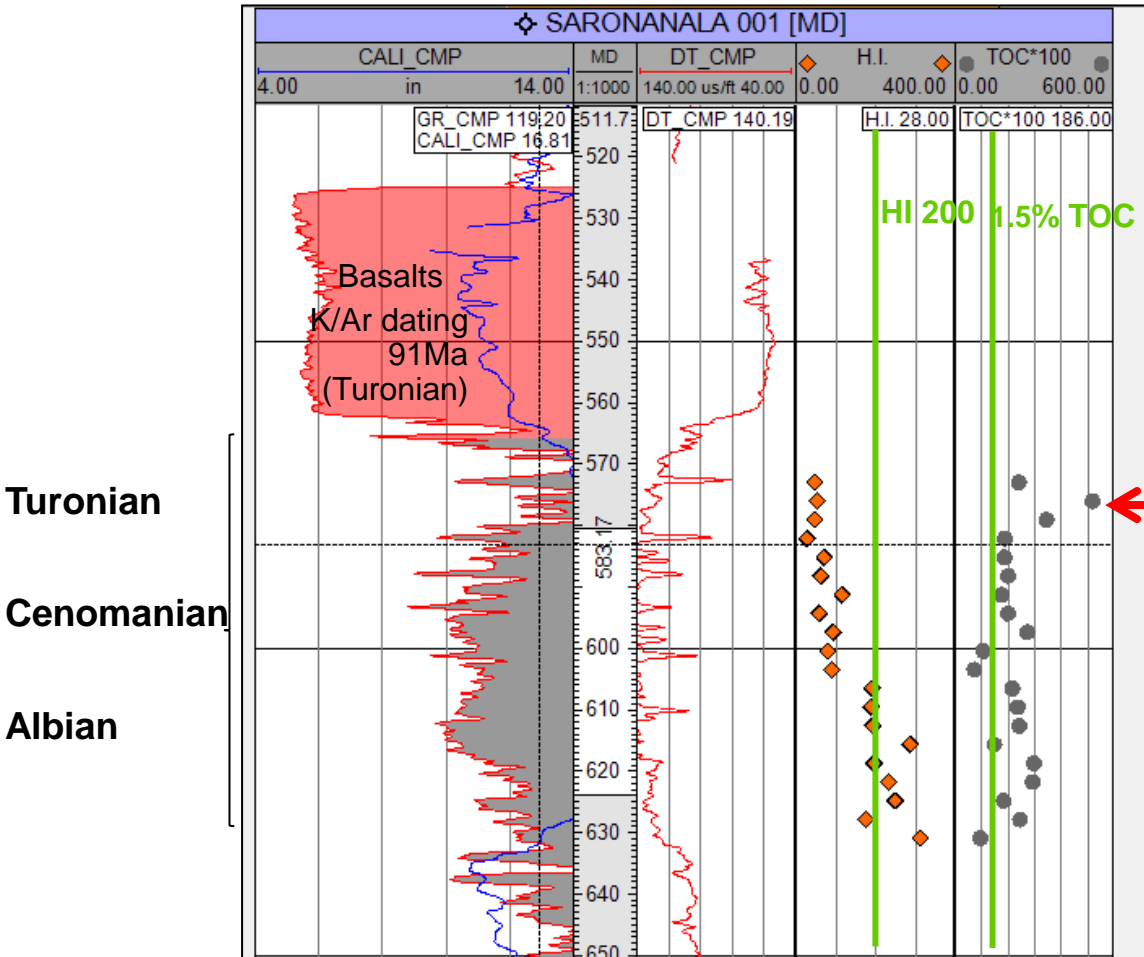
Cretaceous source rock on the paleo-shelf



Geochem sampling from cuttings



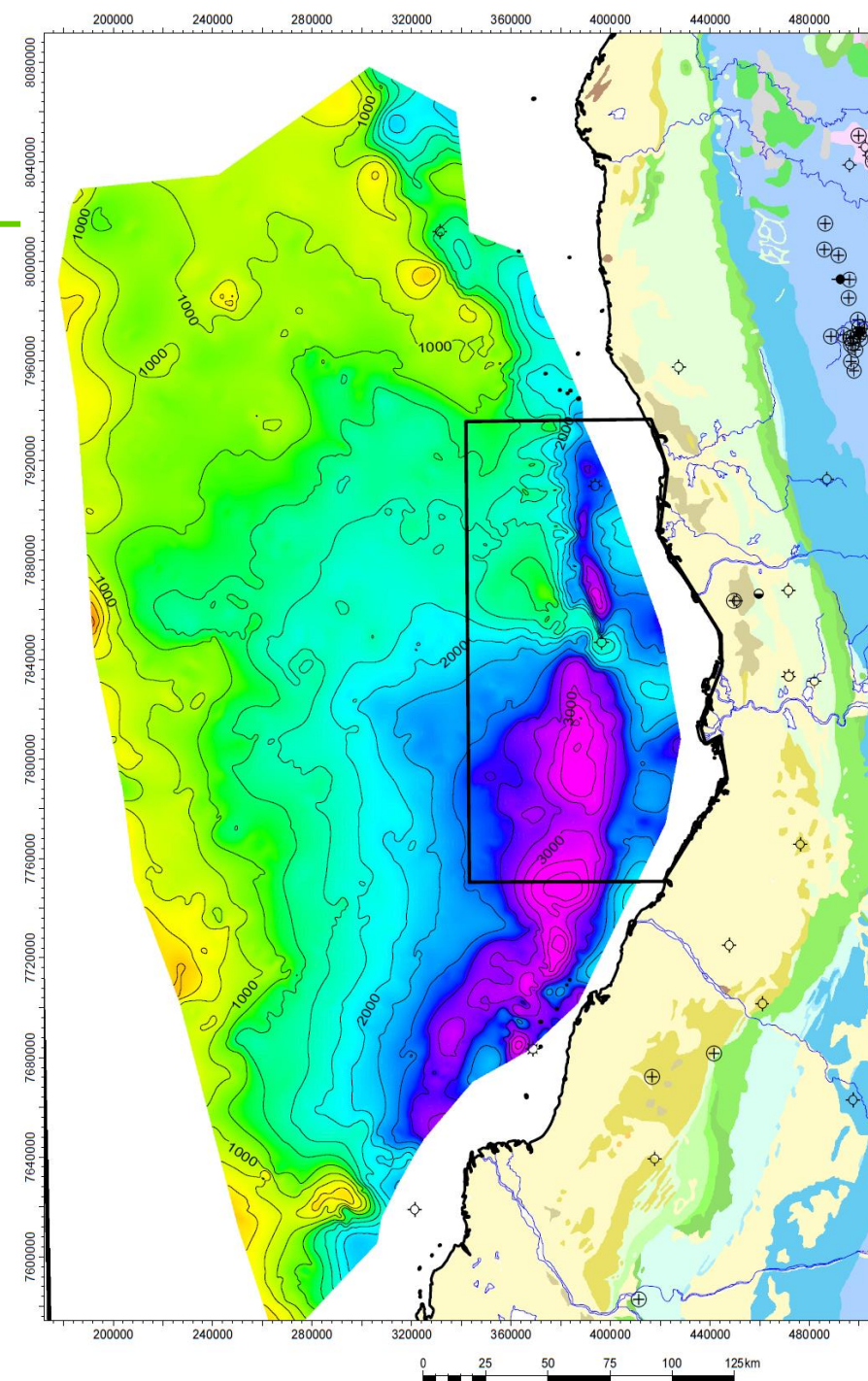
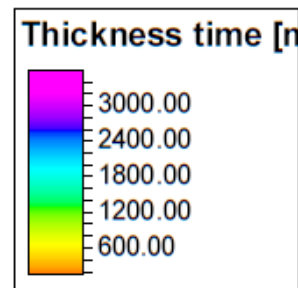
Saronanala-1 well (Amoco, 1985), onshore Morondava Basin TOC & HI values support Cenomanian-Turonian source potential



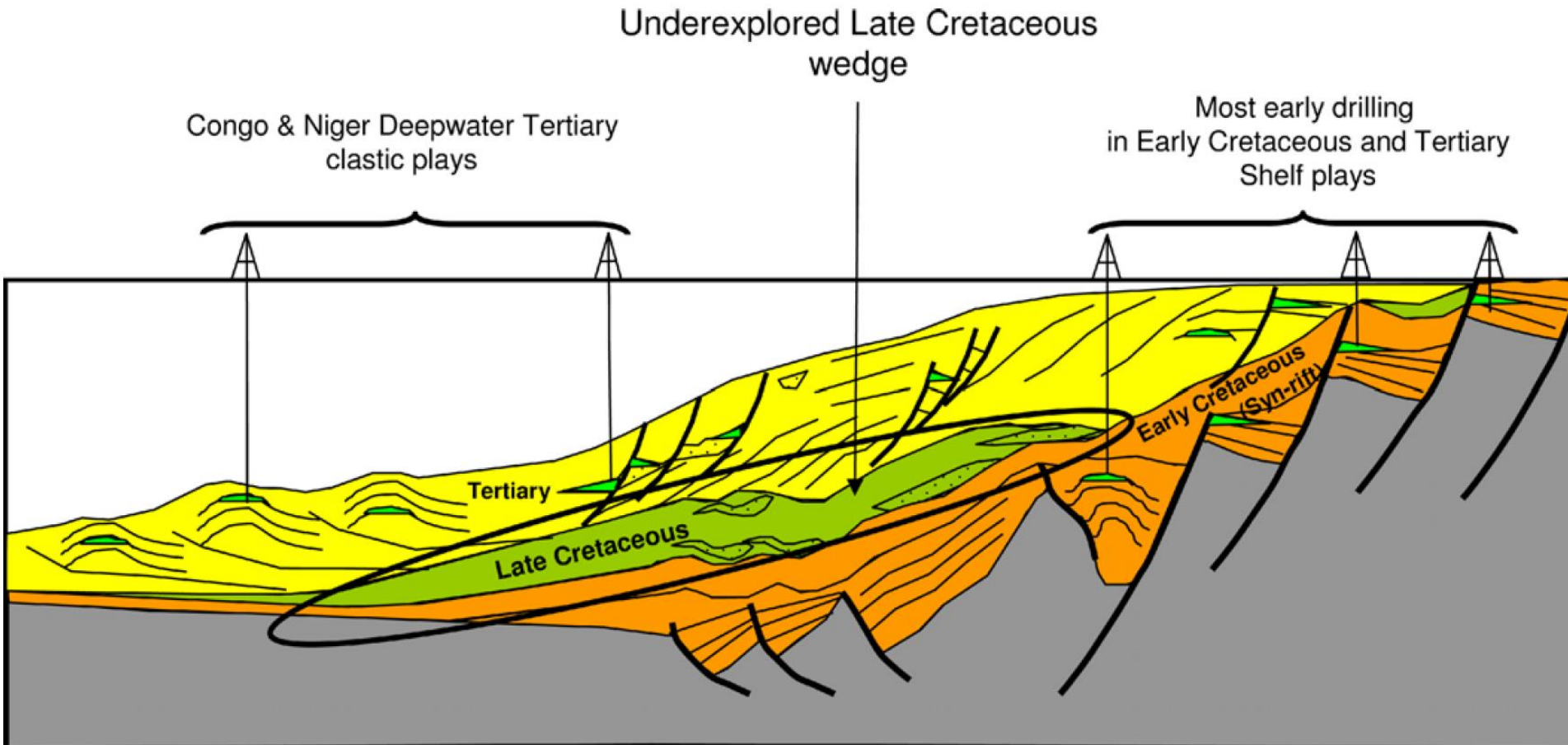
- HI/TOC data from Exlog geochemical post-well report based on cuttings/caving samples. Petra-Chem report on same well noted TOCs up to 7.76% (580-595m MD) and abundant amorphous kerogen supporting oil-prone source potential.
- Exlog report notes that the lower HI values immediately below the basalts may be related to thermal degradation

Isochron of seafloor to top Turonian, offshore Morondava Basin

The preferential influx of Cenozoic to Recent clastics into the central segment of the Morondava embayment created a thick enough sedimentary cover to push the mid-Cretaceous source rocks into the oil window



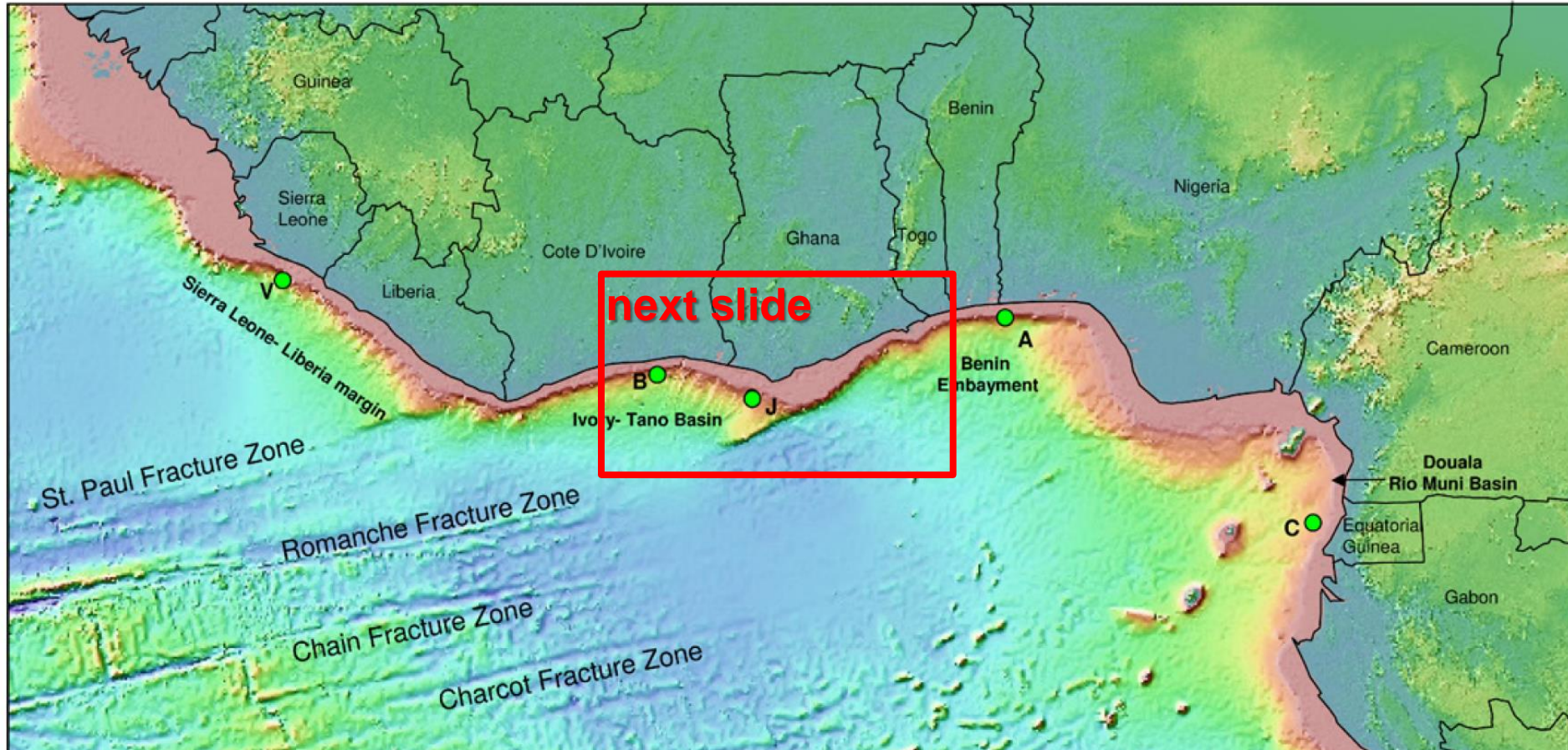
Changing exploration focus in West Africa: focus on the underexplored Late Cretaceous



Schematic cross-section across the West African passive margin showing the evolution of exploration targets from shallow-water structural plays to deep-water Miocene plays of the Niger and Congo clastic systems to a more recent focus on Late Cretaceous structural and stratigraphic plays

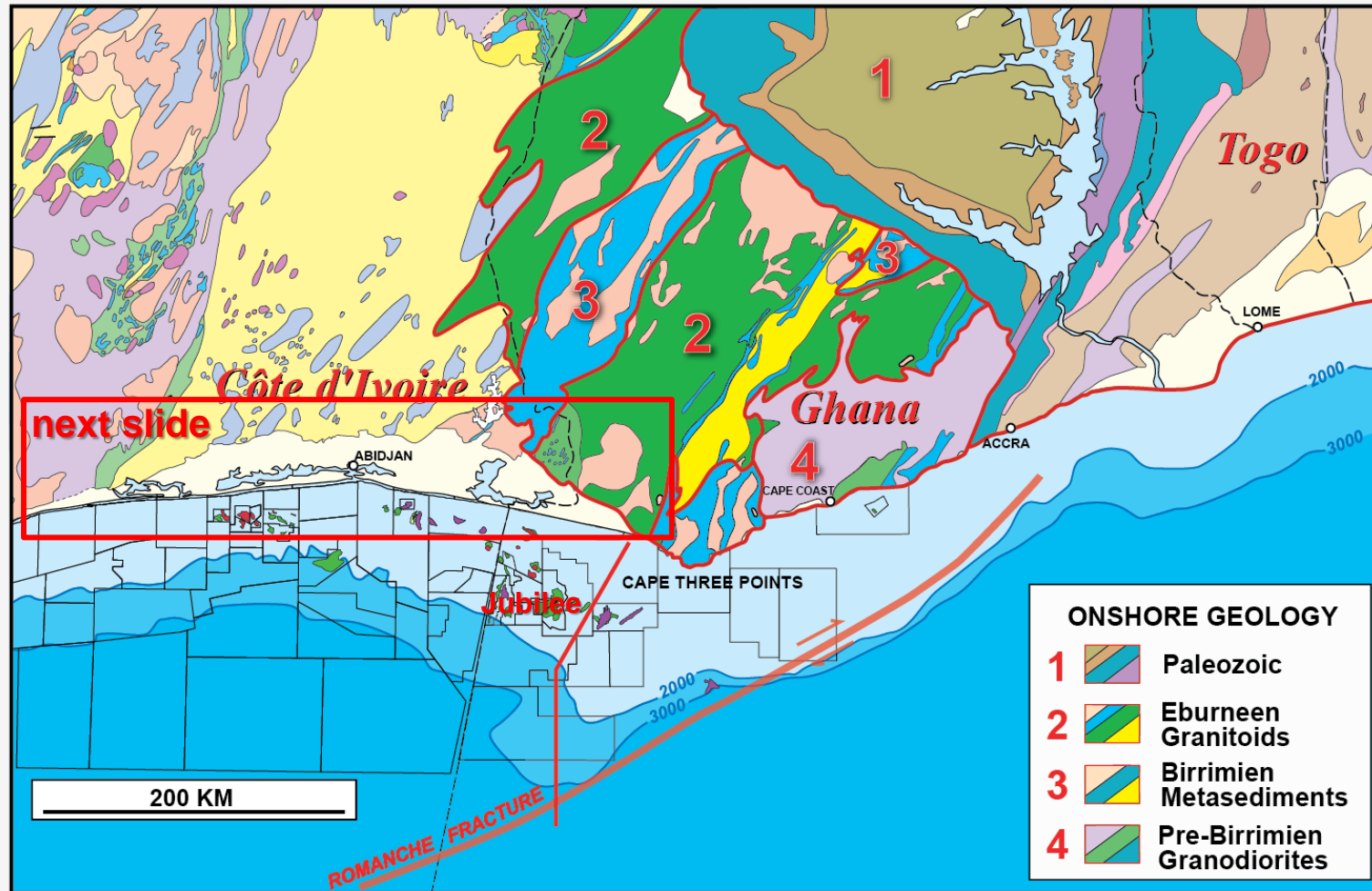
Dailly et al. (2013).

Cretaceous discoveries along the West African transform margin



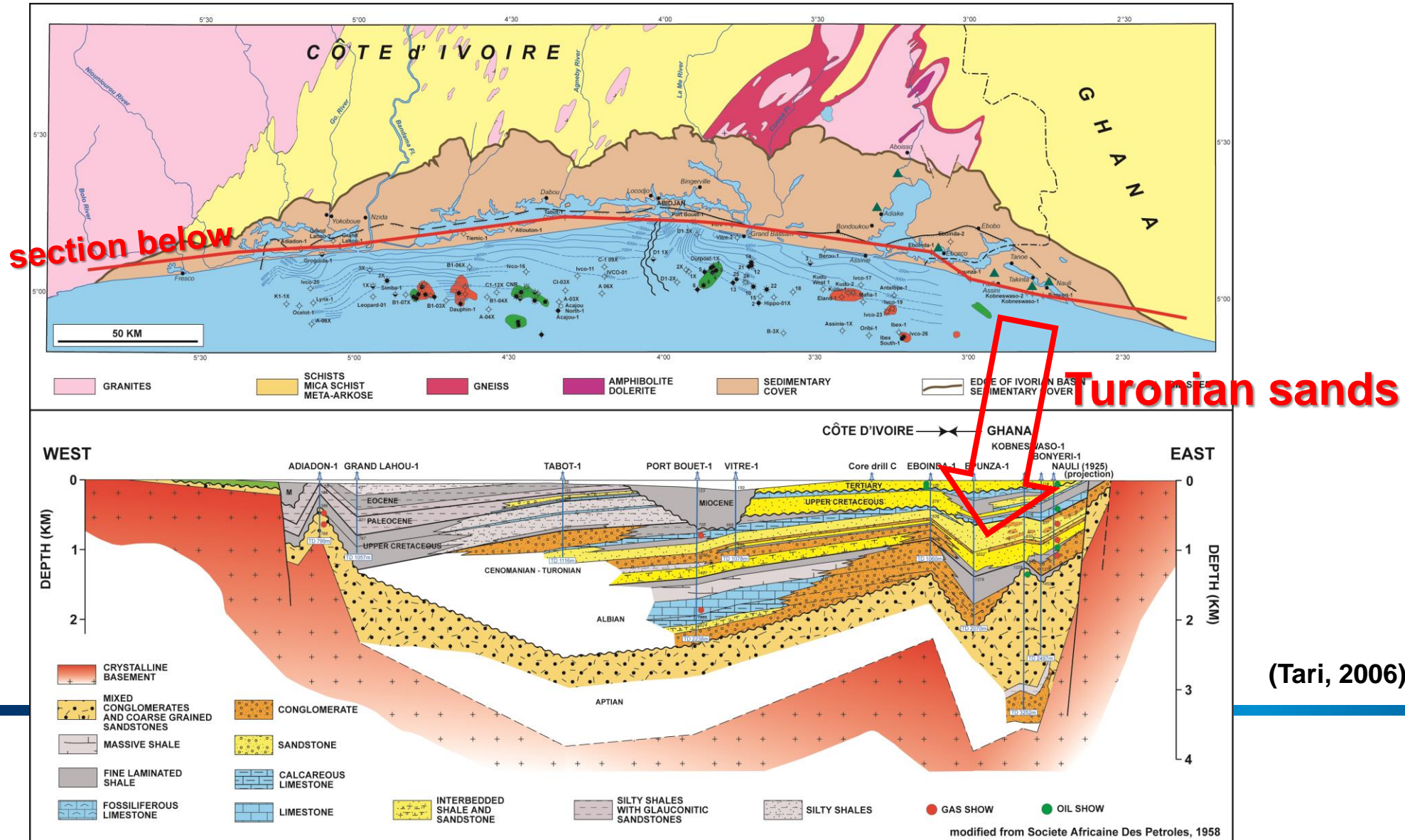
Gravity map of the African transform margin showing the location of major fracture zones and adjacent basins. Areas containing deep-water Late Cretaceous oil and gas discoveries shown in green. C, Ceiba/Okume; A, Aje; J, Jubilee; B, Baobab; V, Venus/Mercury (Dailly et al., 2013).

Côte d'Ivoire/Ghana transform margin as an analogue: focusing of Late Cretaceous sand influx

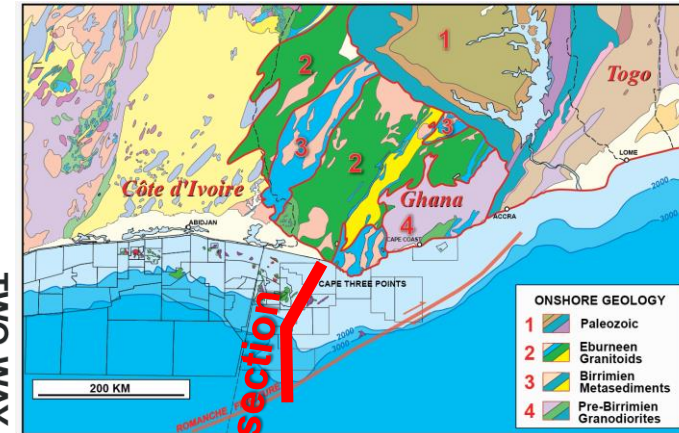
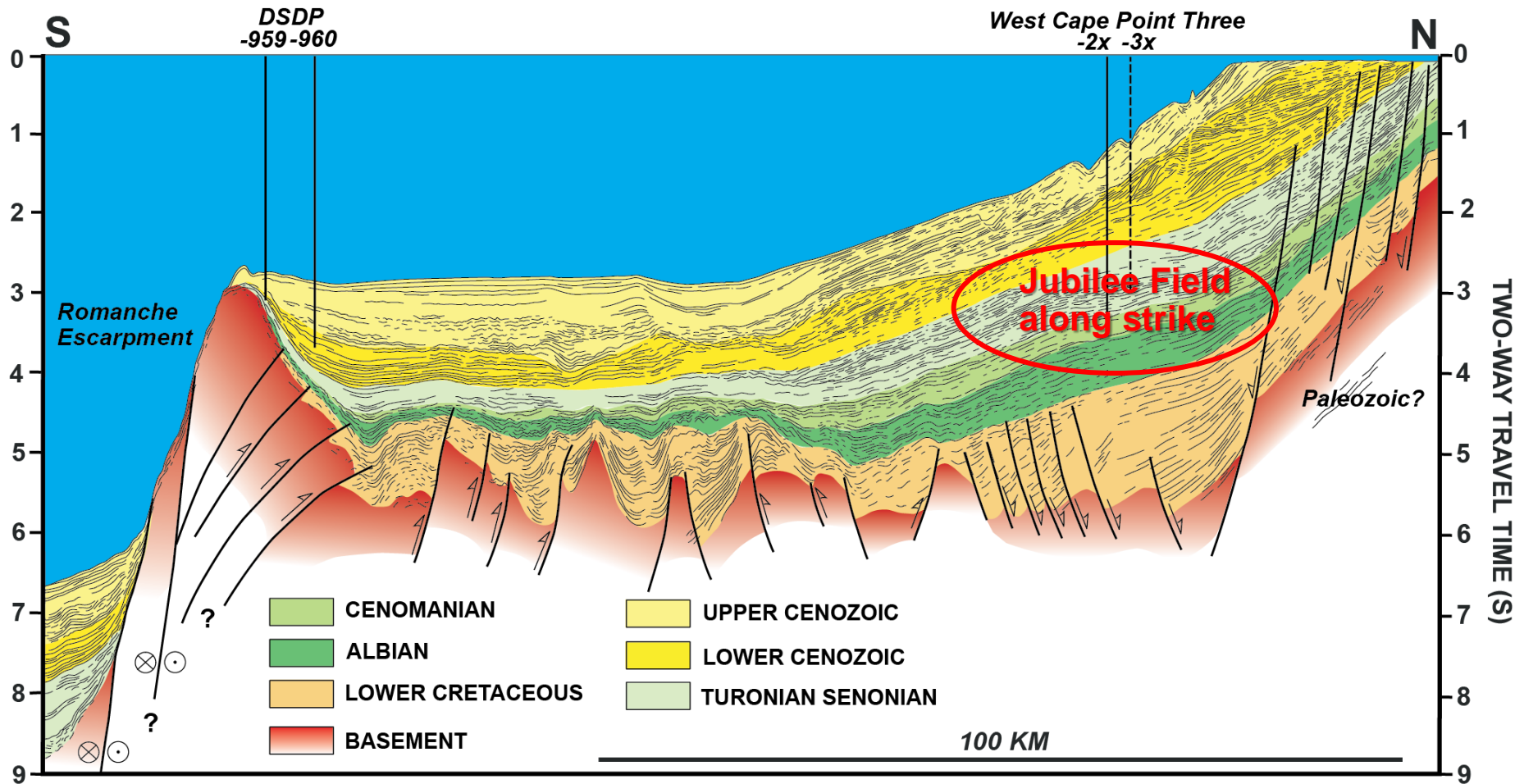


(Tari, 2006)

Côte d'Ivoire/Ghana transform margin as an analogue: pre-Jubilee hints of reservoir influx on the nearby onshore

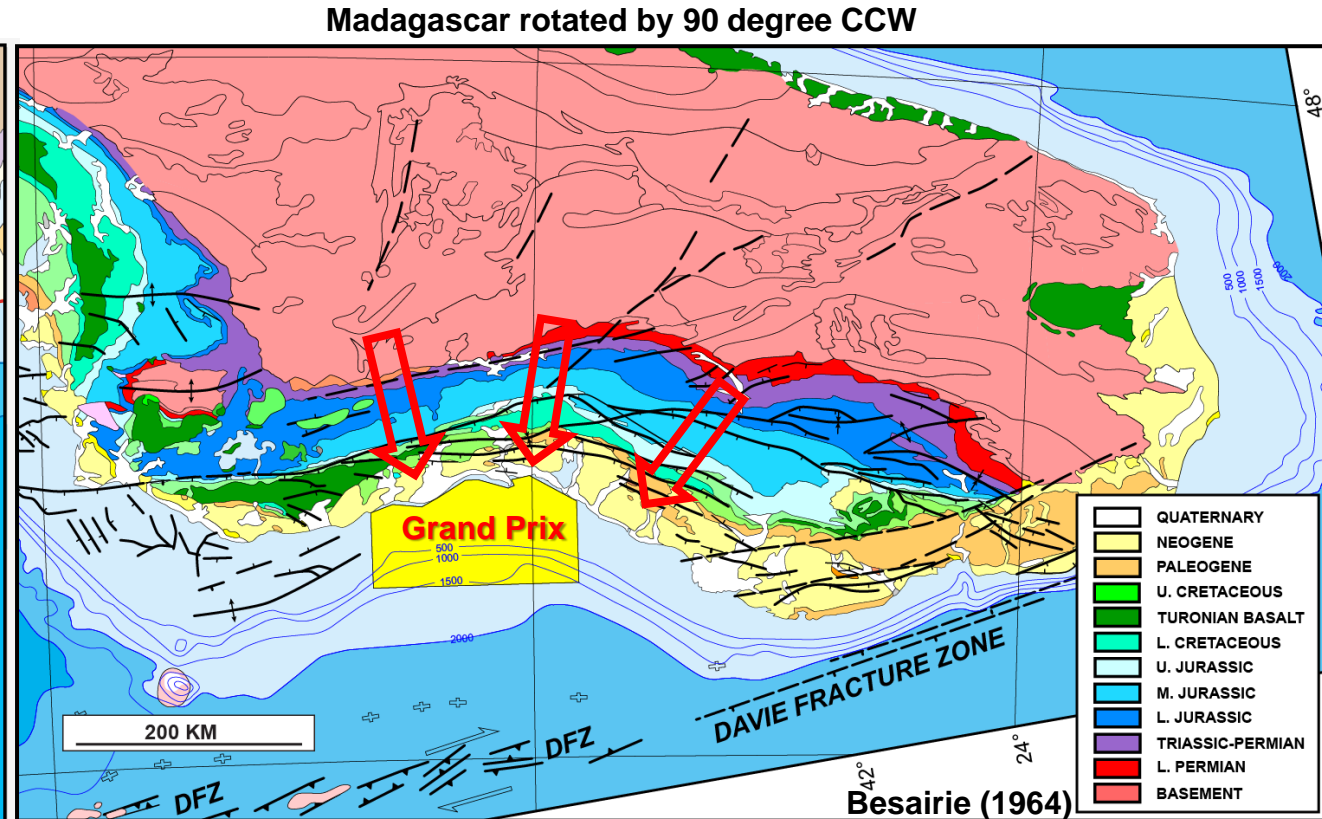
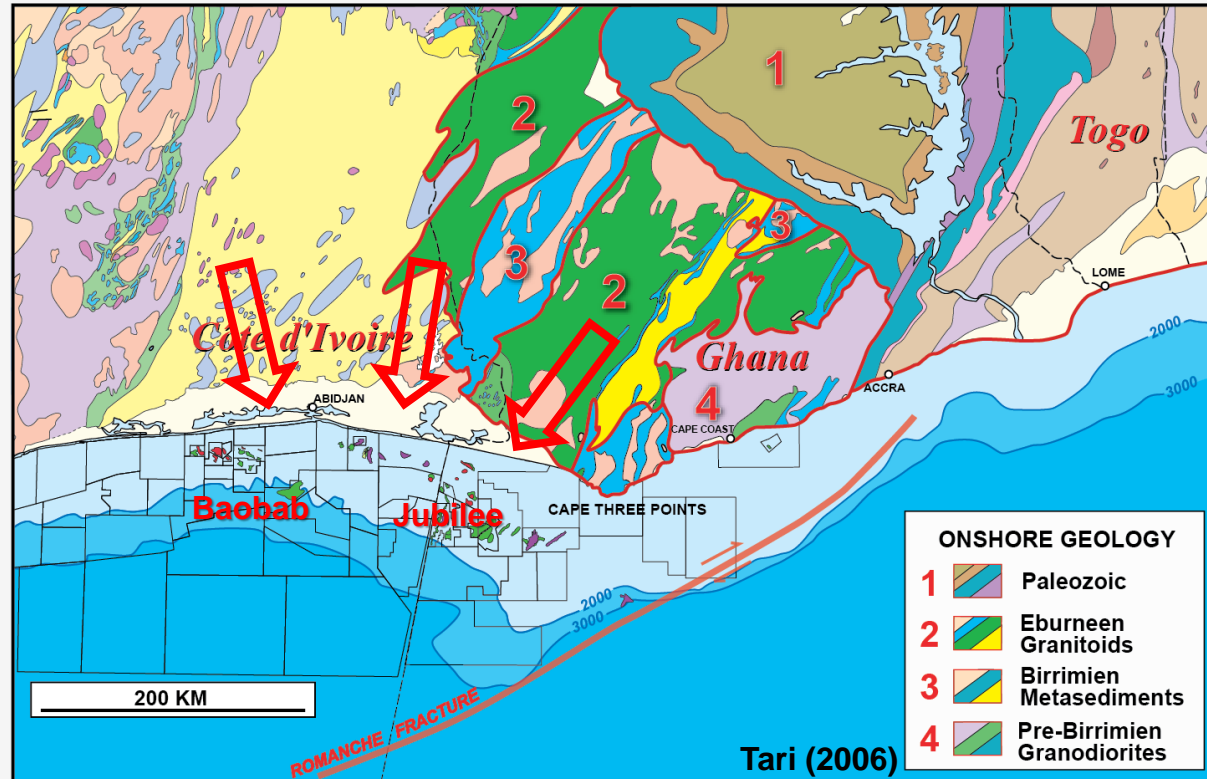


Côte d'Ivoire/Ghana transform margin as an analogue: regional context of the Jubilee Field



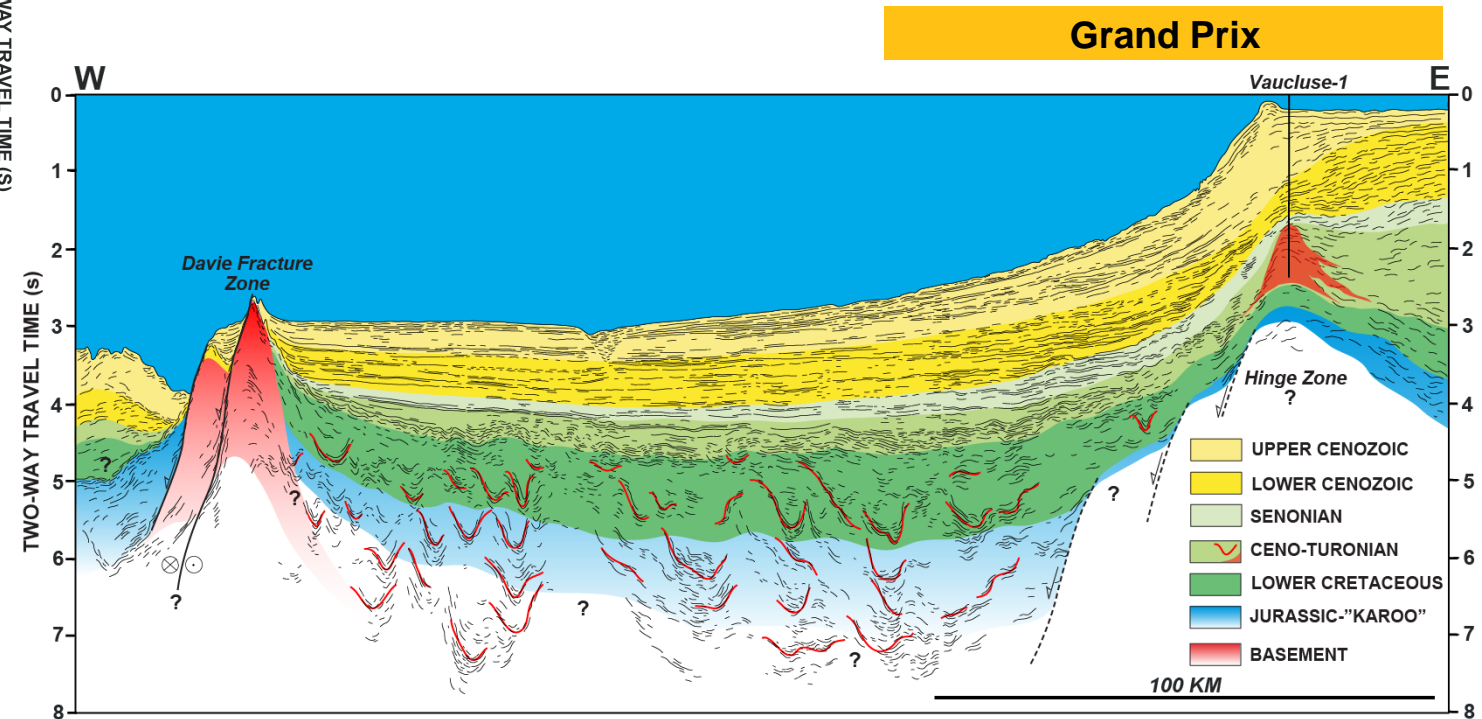
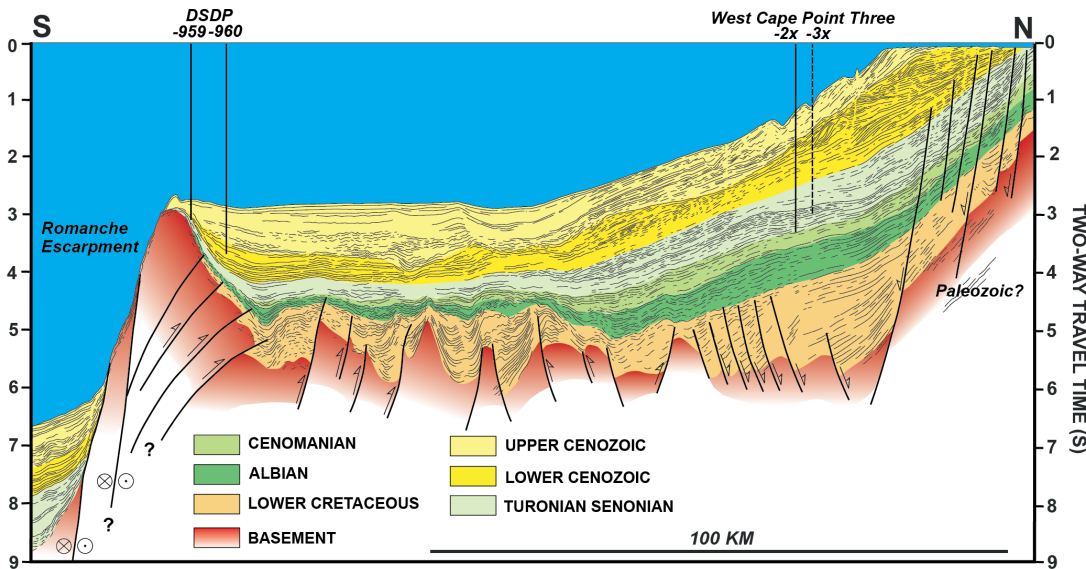
(Tari, 2006)

West Africa Transform versus Morondava Basin

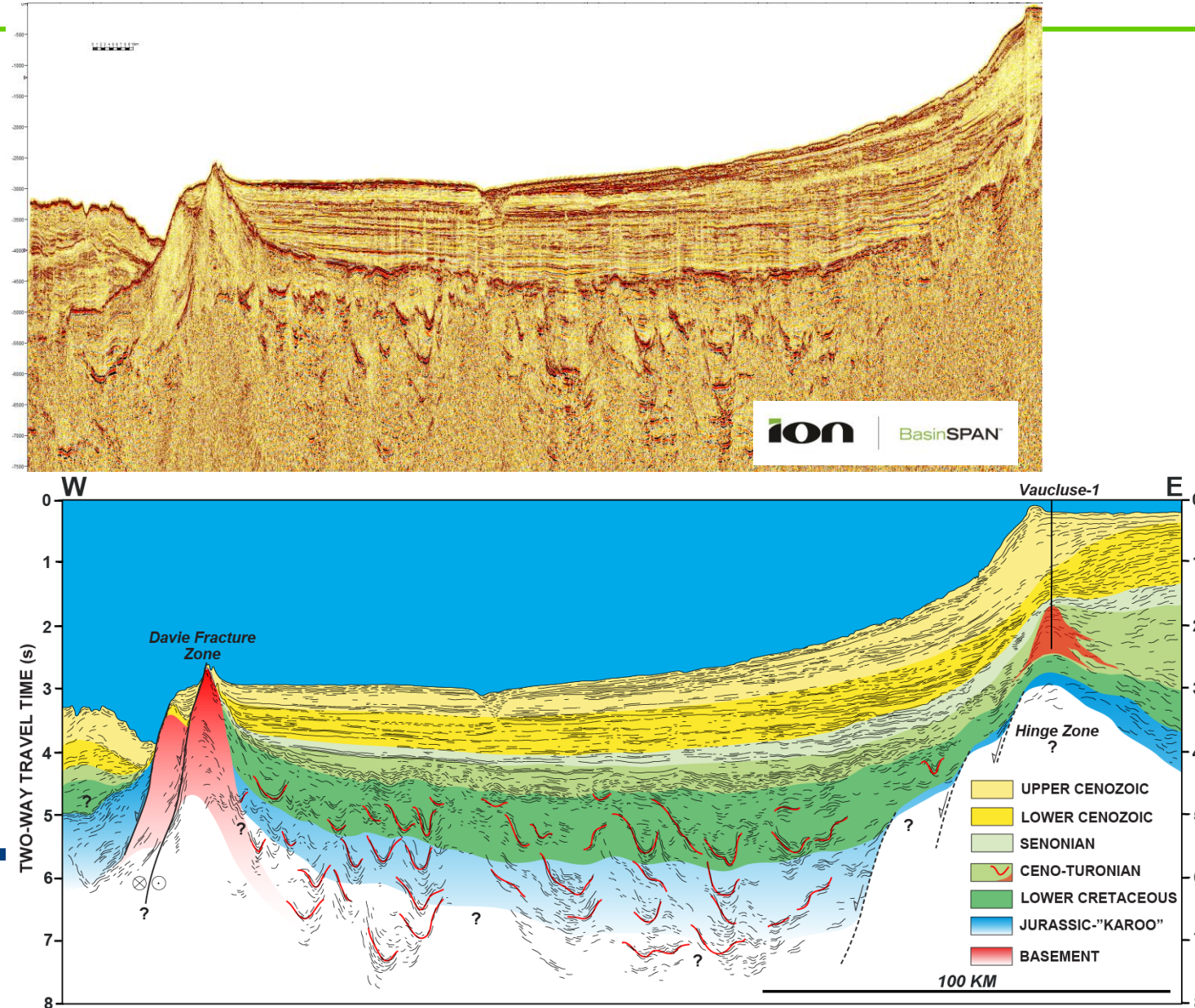


Based on the analogy between the Ivorian-Tano Basin and the Morondava Basin the Grand Prix block appears to be located in a „sweet spot“
a) for reservoir influx into the paleo-deepwater, b) for Cretaceous source rock development and c) Cenozoic hydrocarbon generation

West Africa Transform versus Morondava Basin transform margin

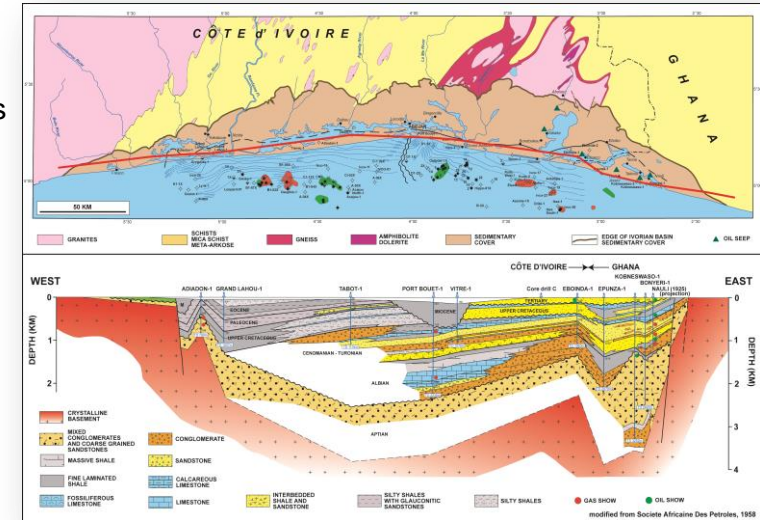
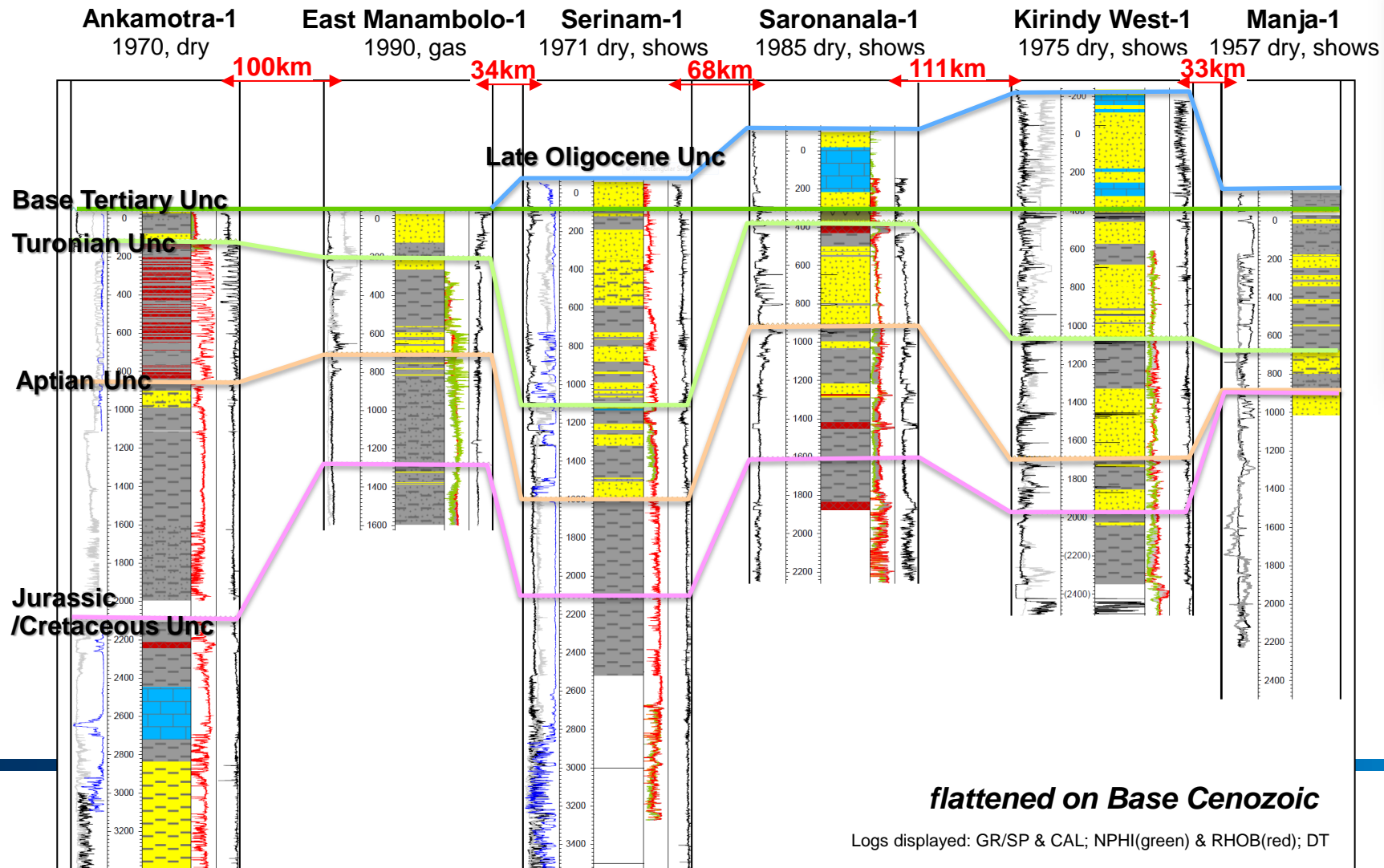


ION seismic across the Morondava Basin transform margin

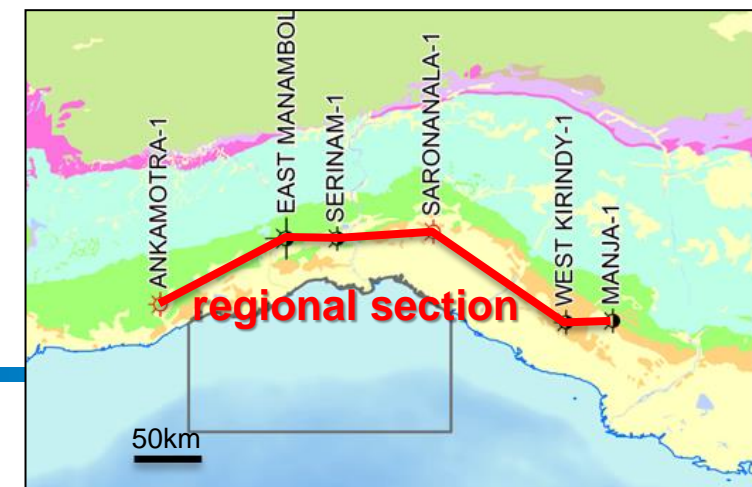


N-S Onshore Morondava well correlation

Sand-rich Late Cretaceous sequence – large sand supply to the basin



Analogy with the Ivorian-Tano Basin



Conclusions

- **Cretaceous source rocks, documented along the coastline, should be present in the paleo-deepwater along the margin, but remain undrilled so far.**
- **The post-Cretaceous sedimentary cover is not thick enough everywhere to trigger hydrocarbon generation**
- **Concave-to-the-basin margin segments focus Cenozoic to Recent sedimentary influx and provide critical overburden thickness**
- **The same basin segments anchored the reservoir influx into the paleo-deepwater creating sweetspots for oil exploration offshore East Africa**
- **Some aspects of the successful petroleum plays in West Africa may be applicable to offshore East Africa, as useful exploration analogues**

Sunbird-1 oil discovery by BG, offshore Lamu Basin, Kenya

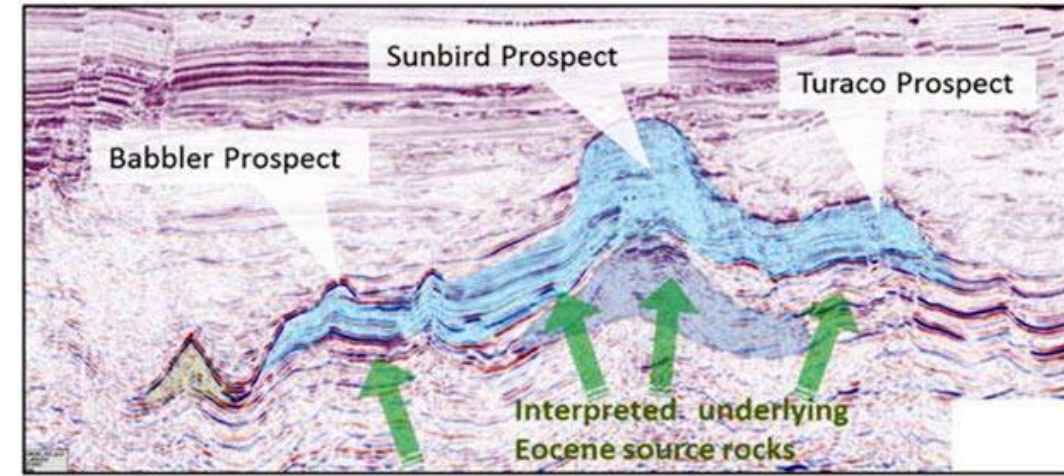
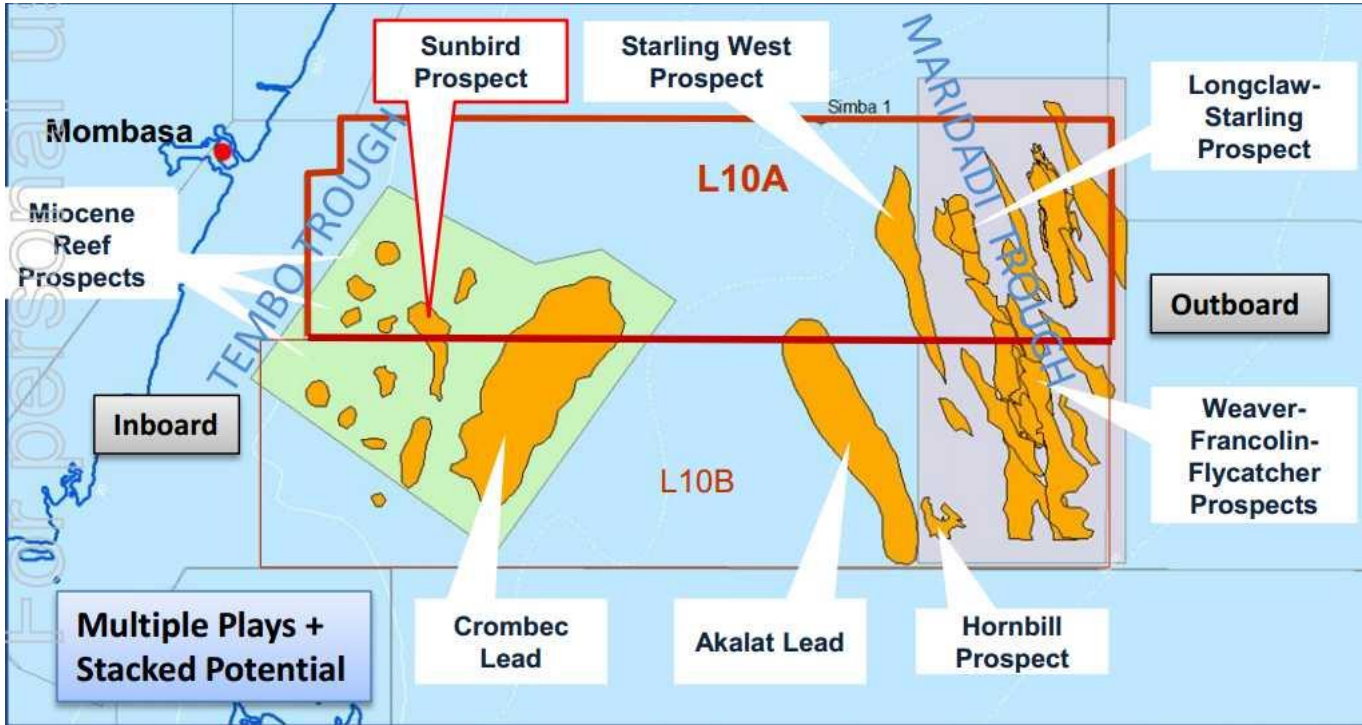


Figure 2: Seismic Cross Section through L10A / L10B Miocene Reef Prospects

“Geochemical analysis of the oil from Sunbird suggested a Late Cretaceous-Tertiary source, arguably a first for this margin”

The gross oil column is assessed to be 14m thick beneath a gross gas column of 29.6m in a reefal limestone reservoir in the Sunbird Miocene Pinnacle Reef in area L10A.

The Sunbird Reef is a Miocene pinnacle reef buried beneath approximately 900m of younger sediment. The top of the Sunbird Miocene Pinnacle Reef was reached at 1,583.7m sub-sea. The water depth is 723m.