The African Conjugate Basins of the Equatorial Atlantic Margins - What Are We Missing?*

Peter Mullin[1], Stephen Leslie[2], and Francis Inniss[2]

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Abstract

Exploration along the Equatorial Atlantic Margins, outside of the Niger Delta, has promised much but too frequently failed to deliver. Modest sized fields on the shelf and onshore tar belts have proven working petroleum systems, which can be demonstrated to be present in deeper water. However, deep-water exploration has too often resulted in sub-commercial discoveries. The Benin (Dahomey) Embayment is a typical example, but it must be noted that the number of deep-water wells is extremely limited, and there have been a few successful commercial fields (Aje, Ogo). The main exception along the Equatorial Margin is the Tano Basin, where early deepwater exploration success spurred a recent concerted exploration drilling campaign by both majors and large independents, that is now paying off with substantial production levels. A further exploration phase in acreage surrounding the main commercial fields is about to get under way in the Tano Basin. Future exploration in the area should seek to apply learnings from the Tano Basin into neighboring basins, on both margins, where success has been much more limited. Conversely, our understanding of the conjugate and neighboring basins can provide new insights into the geology and plays of the Tano basin as exploration moves into this new phase. In this paper, we will review the petroleum systems of two sets of conjugates: the Benin Embayment and the Ceara Basin, and the Tano Basin and the Barreirinhas Basin. We will highlight aspects that appear to have positive impact in the Tano basin, and review which of the conjugates might have similar play characteristics. We will note certain peculiarities in the current understanding of the petroleum systems of these basins, often the result of viewing each basin in isolation without realizing that key data may already be evident in a conjugate basin. In particular, we will review the detailed stratigraphy of each basin to address some key questions: - The differing timing of opening in the basins straddling the Romanche Fracture Zone. - There is salt in the Ceara Basin, proven in the shelf and potentially thickening into deeper water. Why would it not be present in the conjugates? Could the presalt plays extend into the Equatorial margins? How would salt potentially influence the tectonics of these basins? - The Aptian is present and a key source rock in the Ceara Basin. Why is it not recognized in the Benin Embayment? - Carbonates within the ‘transition’ provide a play, albeit not yet very successful, in Brazil: is this play being overlooked on the African margin? - What precisely is the trapping mechanism in the Jubilee field, and where might it be replicated? While it will be difficult to provide definitive answers to these questions, we hope that the presentation of the limited available data

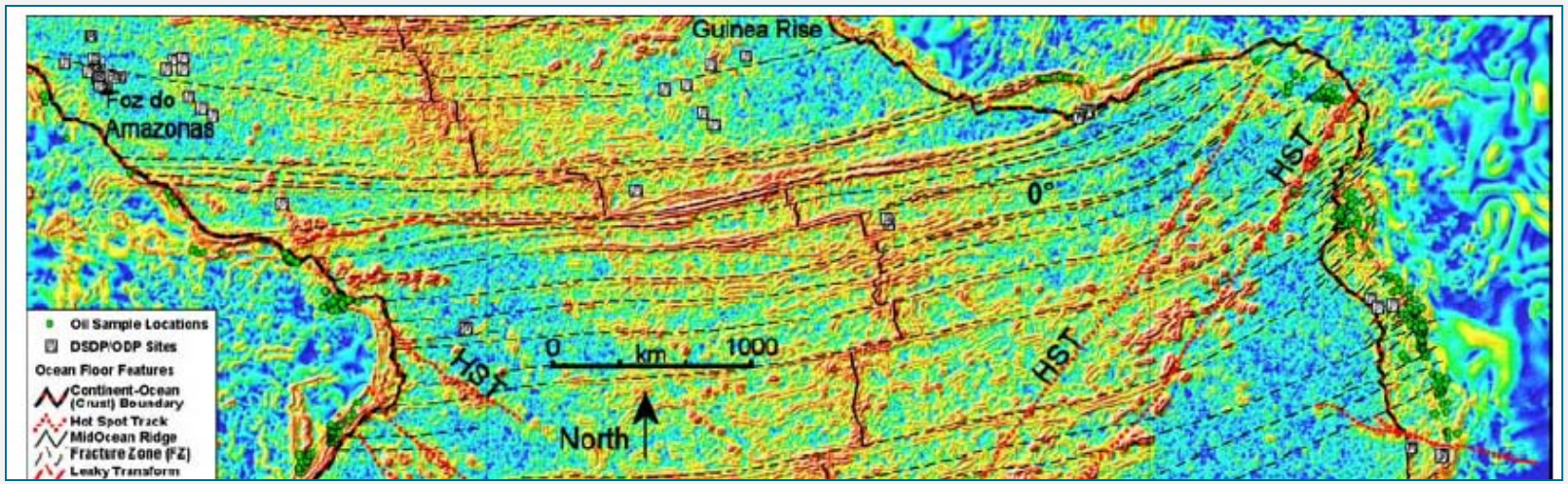
will stimulate a more critical phase of exploration thinking and play analysis. Explorationists are all too aware that it may take years and multiple exploration campaigns before a basin may realise its true potential.

Selected References

Dailly, P., T. Henderson, K. Kanschat, P. Lowry, and S. Sills, 2017, The Jubilee field, Ghana: Opening the late Cretaceous play in the West African transform margin: in R.K. Merrill and C.A. Sternbach, eds., Giant fields of the decade 2000–2010: AAPG Memoir 113, p. 257–272.

Erlich, R., and F. Inniss, 2014, Exploration for Cretaceous Deep-Water Reservoirs in the Circum-Caribbean Region: Historical Review and Expectations for the Future: AAPG Search and Discovery Article #30353, Web Accessed October 28, 2018, http://www.searchanddiscovery.com/documents/2014/30353erlich/ndx_erlich.pdf

The African Conjugate Basins of the Equatorial Atlantic Margins – what are we missing?



Peter Mullin (WTD International)

Stephen Leslie and Francis Inniss (EcoAtlantic Ghana)

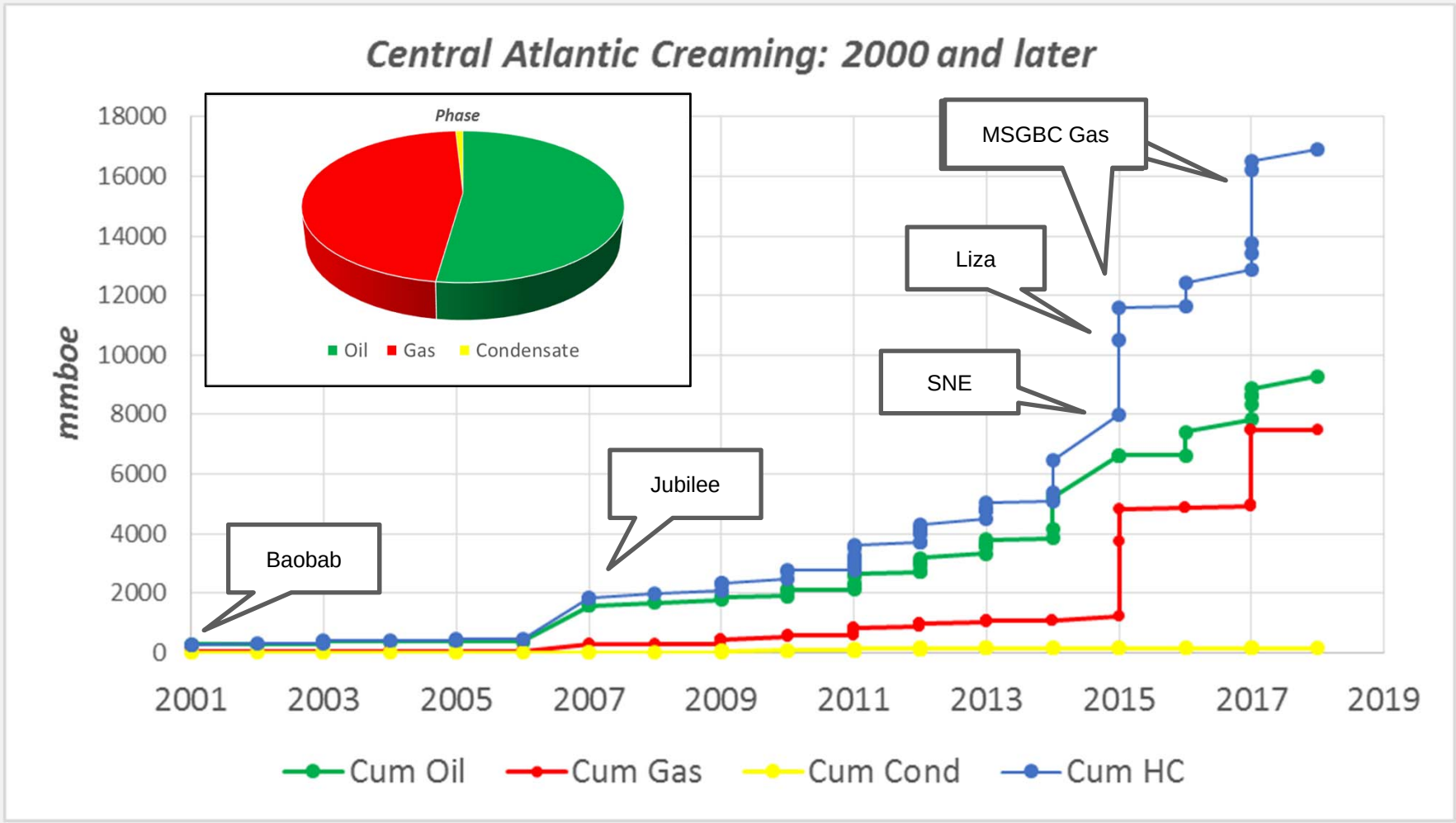
May 2018

Agenda

- Exploration results on the Equatorial Margin
  - Good discovery rate, but very limited commercial success
- Key Learnings from the Tano Basin
  - Why is Jubilee the ‘King’ field?
- Petroleum System Contrasts across the Conjugate Margins
  - Asymmetry and diachroneity …
  - Salt in the Ceara .. Why not on the other margin?
- Thoughts and Conclusions

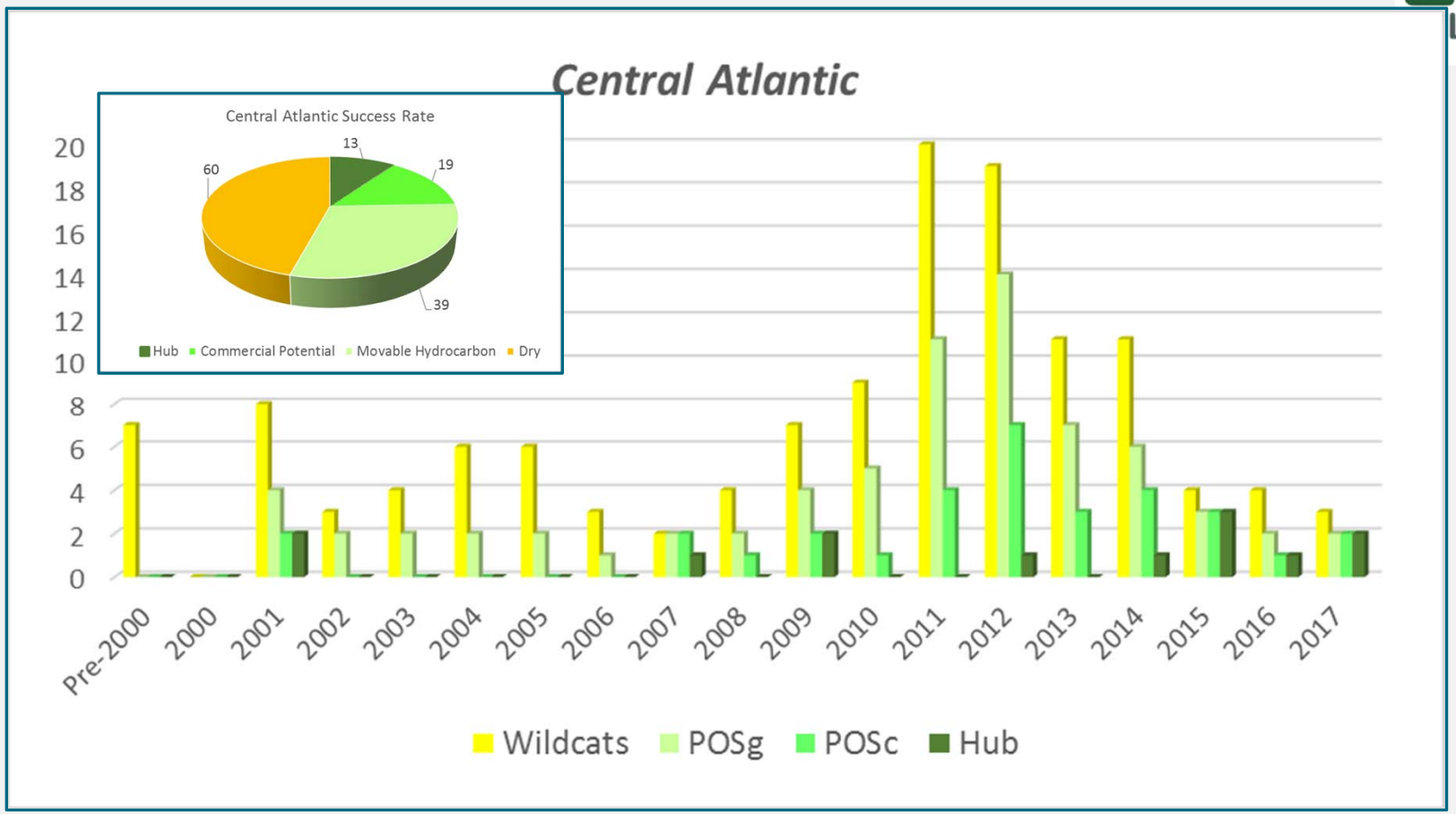
The Central Atlantic Conjugate Basins

The Central Atlantic: Discovered Volumes



Field size data: published sources/scouting (as of end 2018)

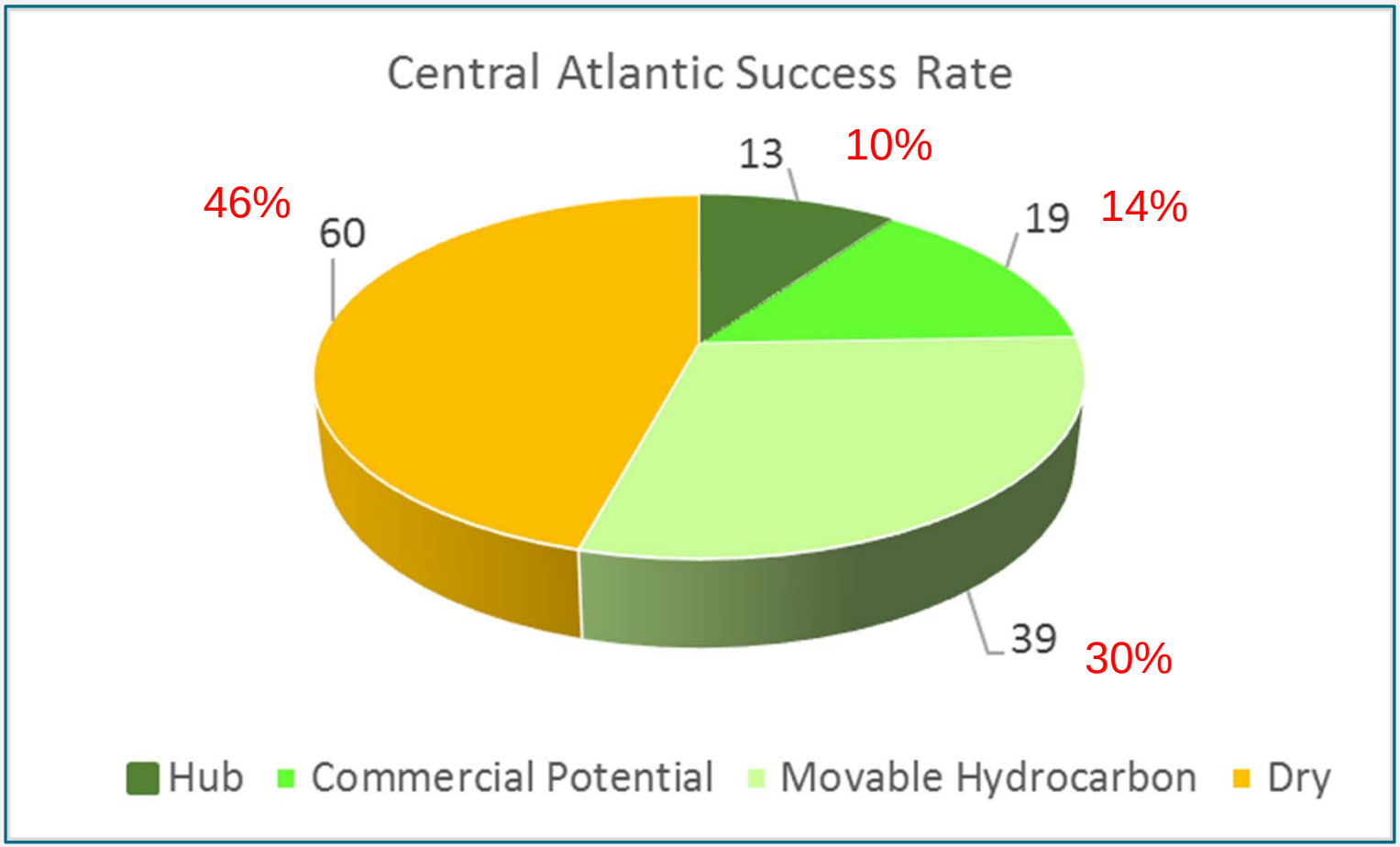
Central Atlantic Success Rate



POSg: Movable hydrocarbons
POSc: Potentially commercial hydrocarbons, including satellites/clusters (100 mmboe+)
HUB: Standalone development potential

Field size/success data: published sources/scouting: Well data courtesy Drillinginfo. Data as of end 2017.

Central Atlantic Success Rate (Pie)



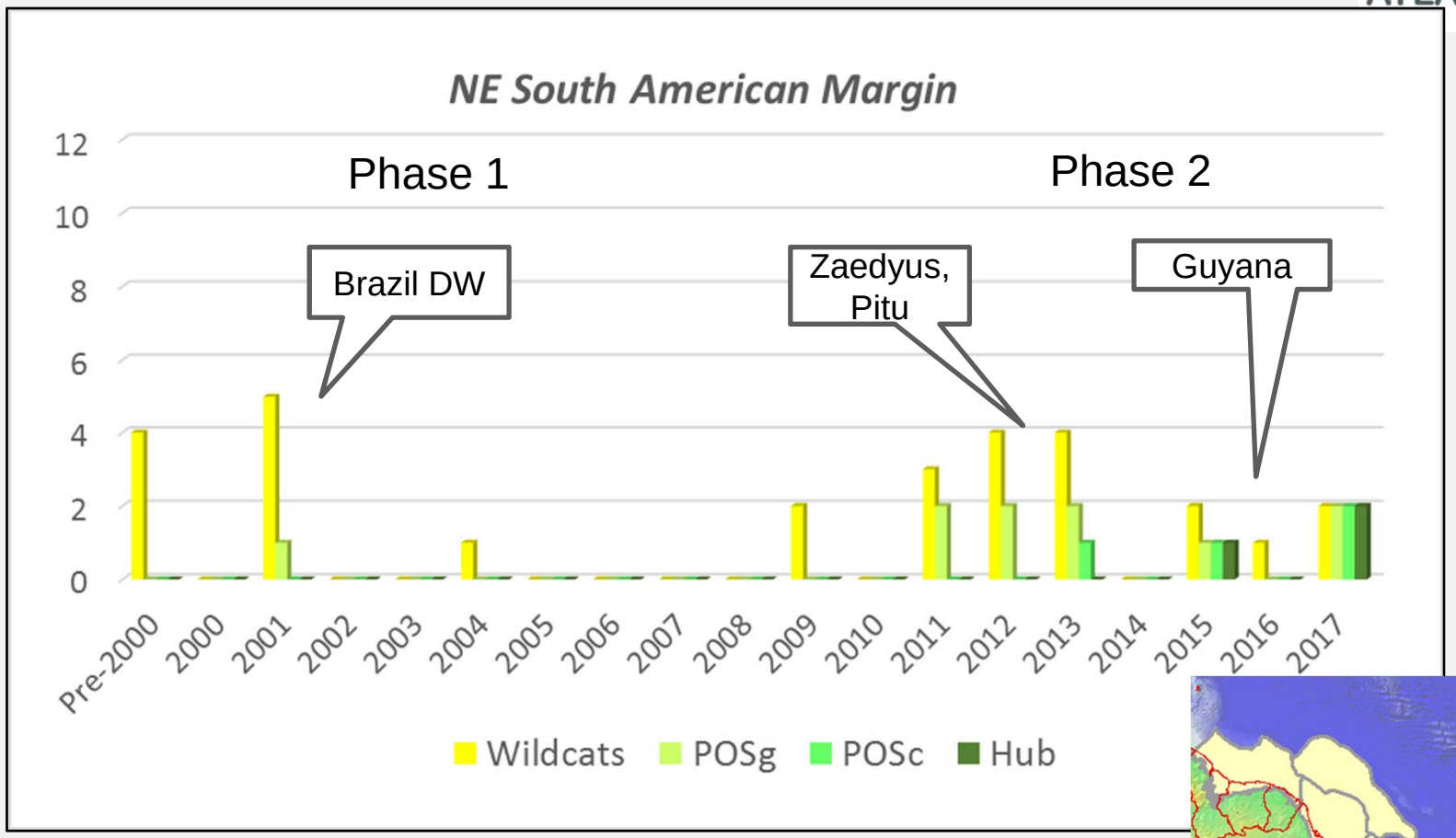
Field size/success data: published sources/scouting: Well data courtesy Drillinginfo. Data as of late 2017.

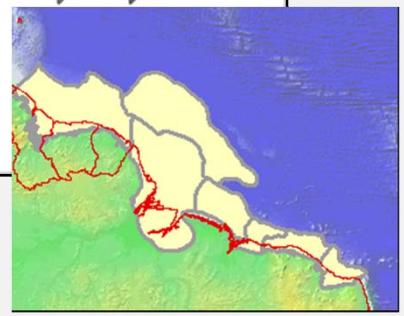
A high success rate ..

- These basins have a high success rate in terms of POSg (55%), considerably greater than global average in emerging basins (25-30%).
  - *despite* having stratigraphic trapping as the dominant trap style.

- This may reflect:
  - A regionally present source rock of good rock quality (Ap-Tu);
  - Present-day optimal maturity in many locations: over-charge and potential re-fill of leaky traps;
  - Cratonic uplift of the Africa margin, in particular – good reservoir potential;
  - Deep marine setting - preservation of adequate seals;
  - Lack of major late tectonism

South America Margin Success Rate



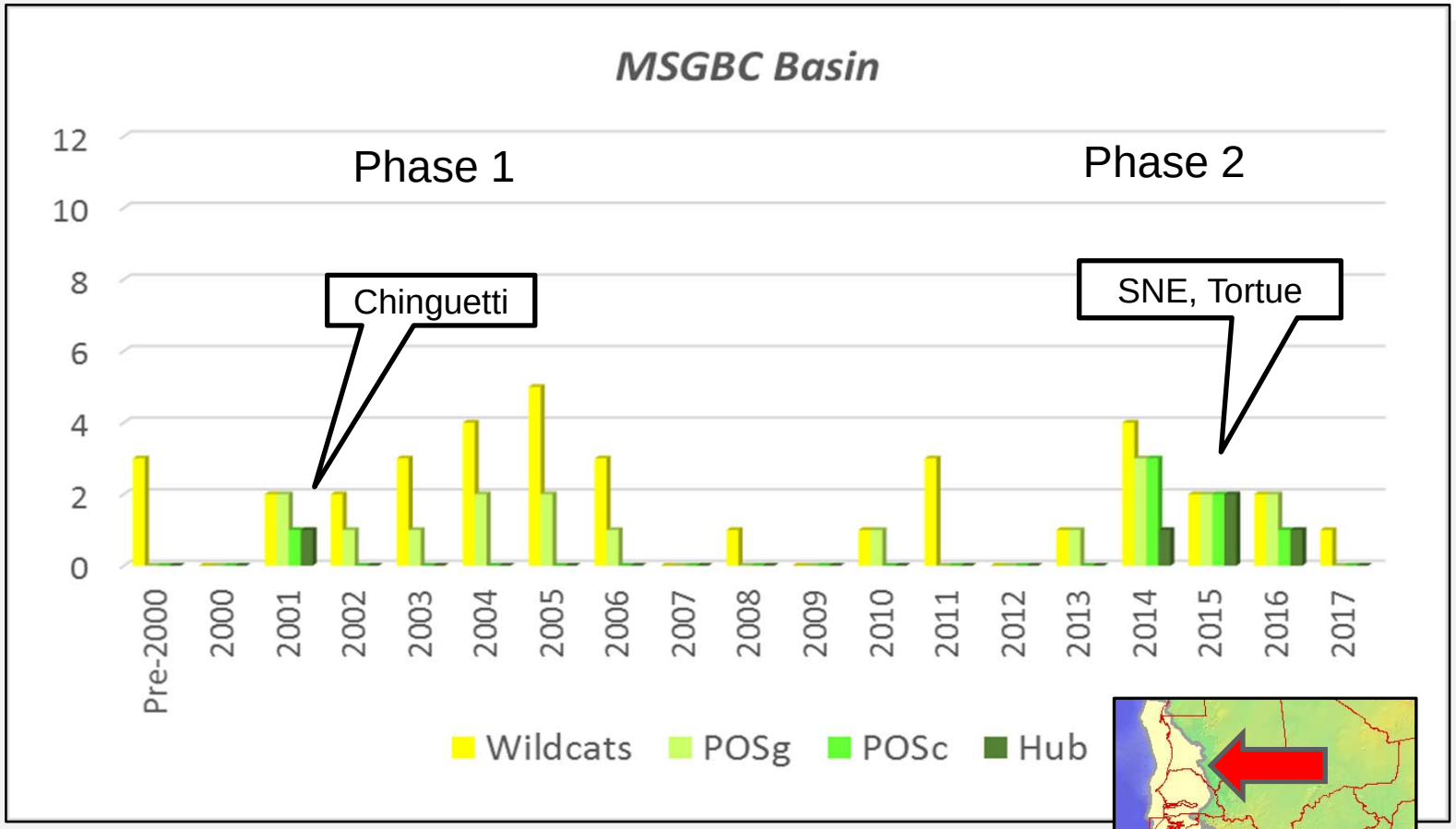


POSg: 46%

POSc: Pecem (Ceara) has >100mmbbl volume potential, but is not standalone

Field size/success data: published sources/scouting: Well data courtesy Drillinginfo. Data as of late 2017.

MSGBC Success Rate

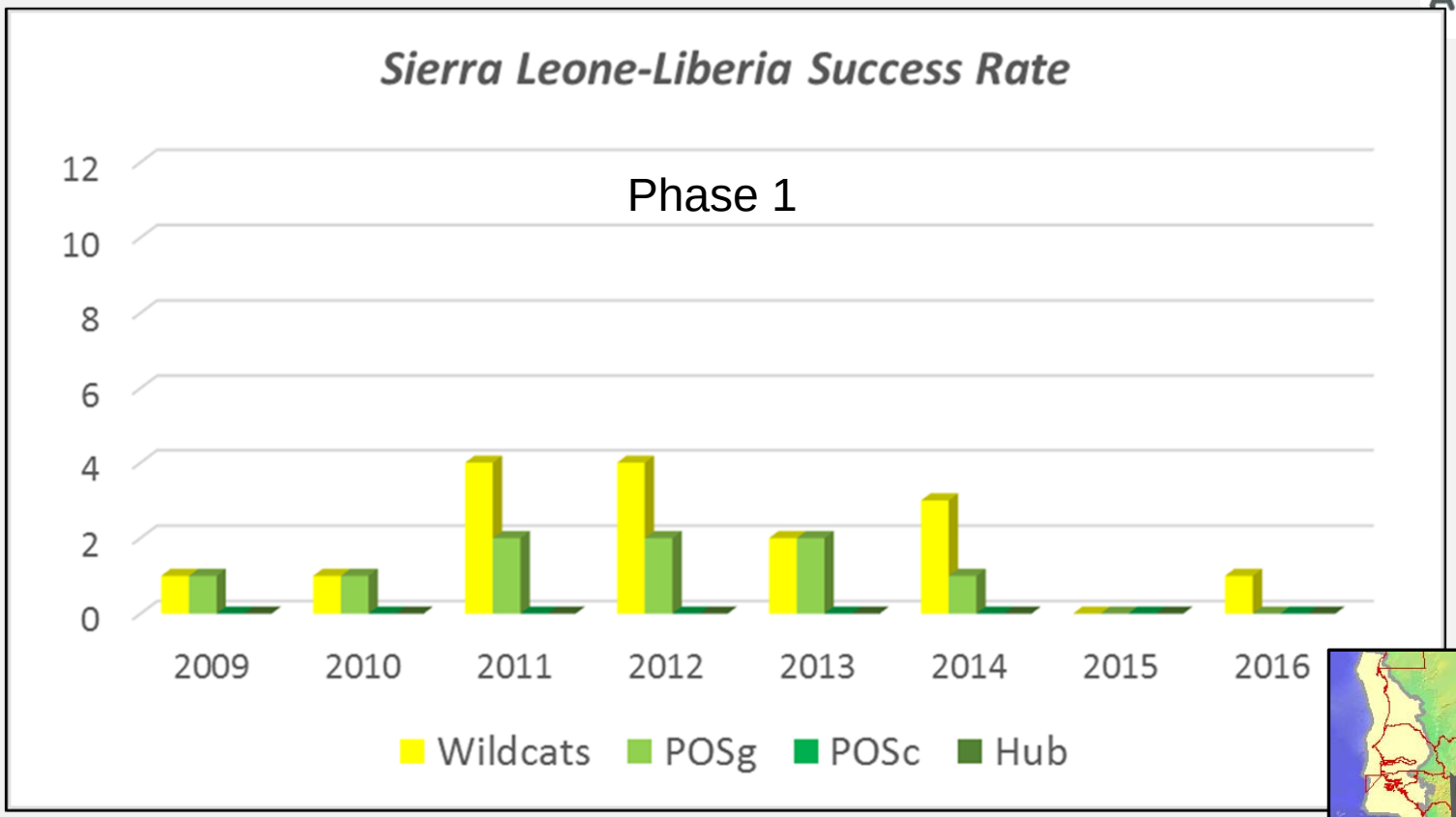


POSg: 46%

Early POSc, HUBs: Chinguetti – but disappointing, prior to Guyana

Field size/success data: published sources/scouting: Well data courtesy Drillinginfo. Data as of late 2017.

Sierra Leone-Liberia Success Rate



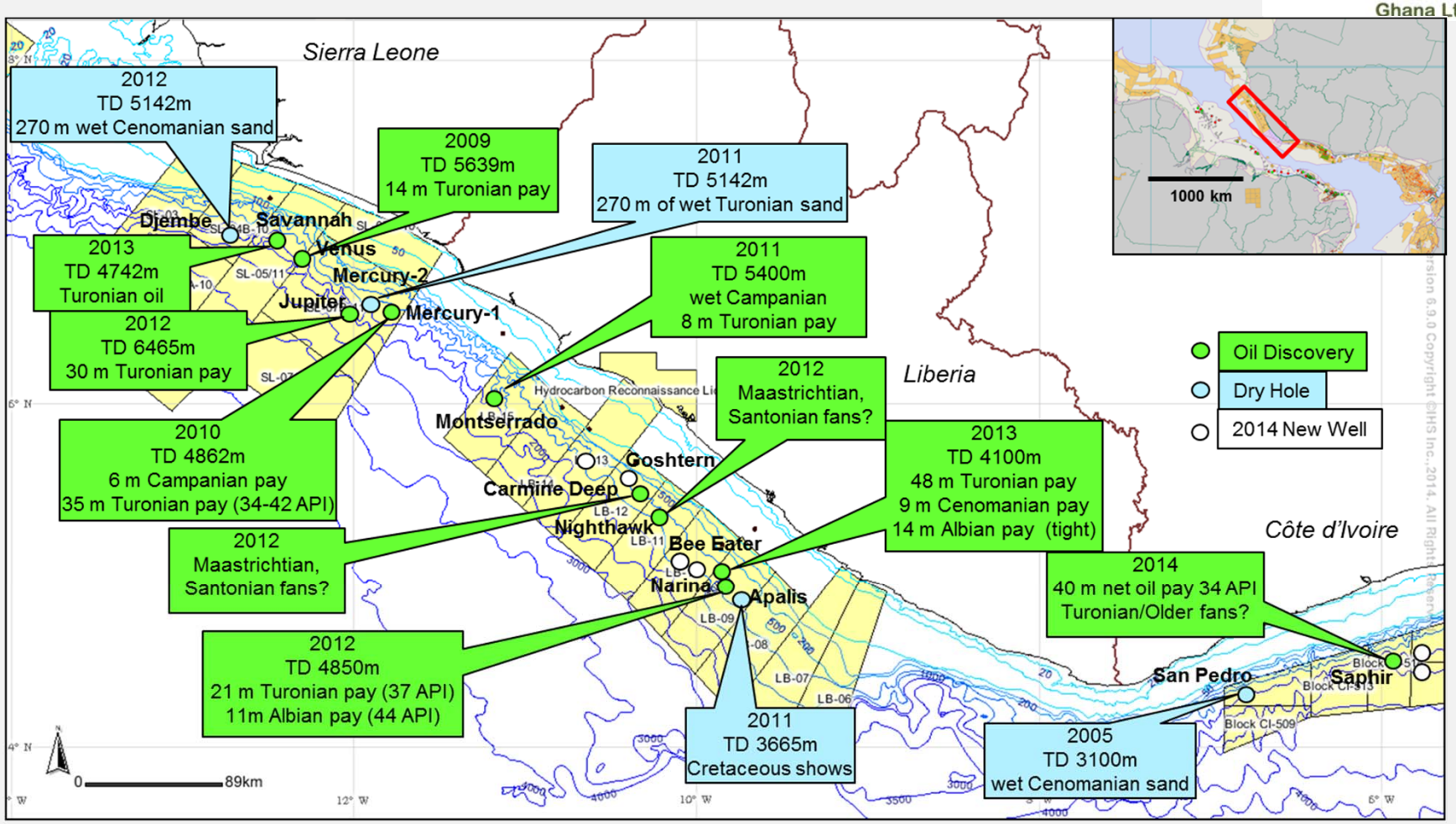
POSg: 56%

Early POSc, HUBs: Zero

Will a second phase of exploration have improved success, taking advantage of the learnings from the first phase?

Field size/success data: published sources/scouting: Well data courtesy Drillinginfo. Data as of end 2016.

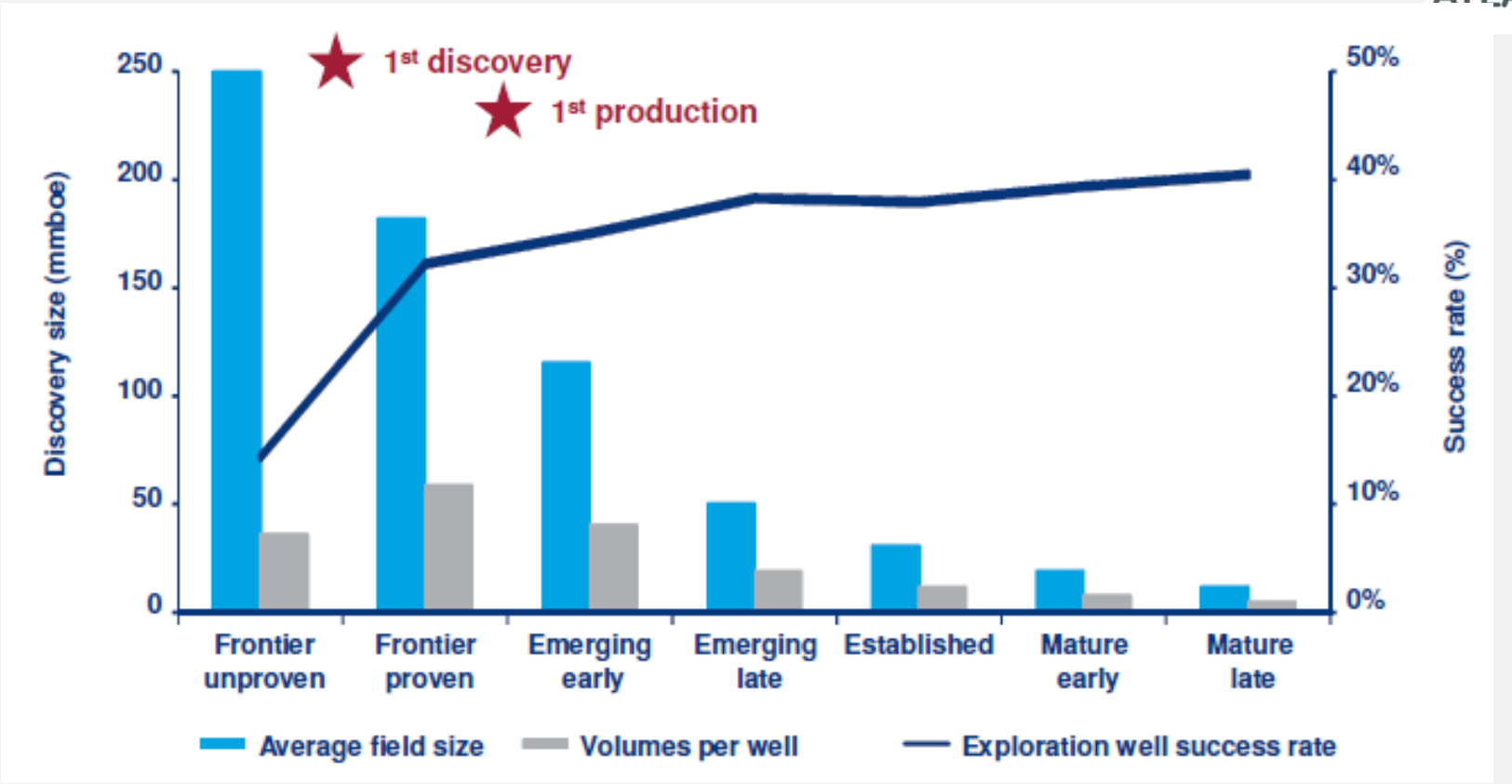
Sierra Leone-Liberia Well Results



Map and Data from IHS, various public sources

Erlich & Inniss (Search & Discovery)

Global Success Rate through Basin History



Phase 1 Phase 2

Source: Wood Mackenzie

After first discovery, play chance increases to 100% ….

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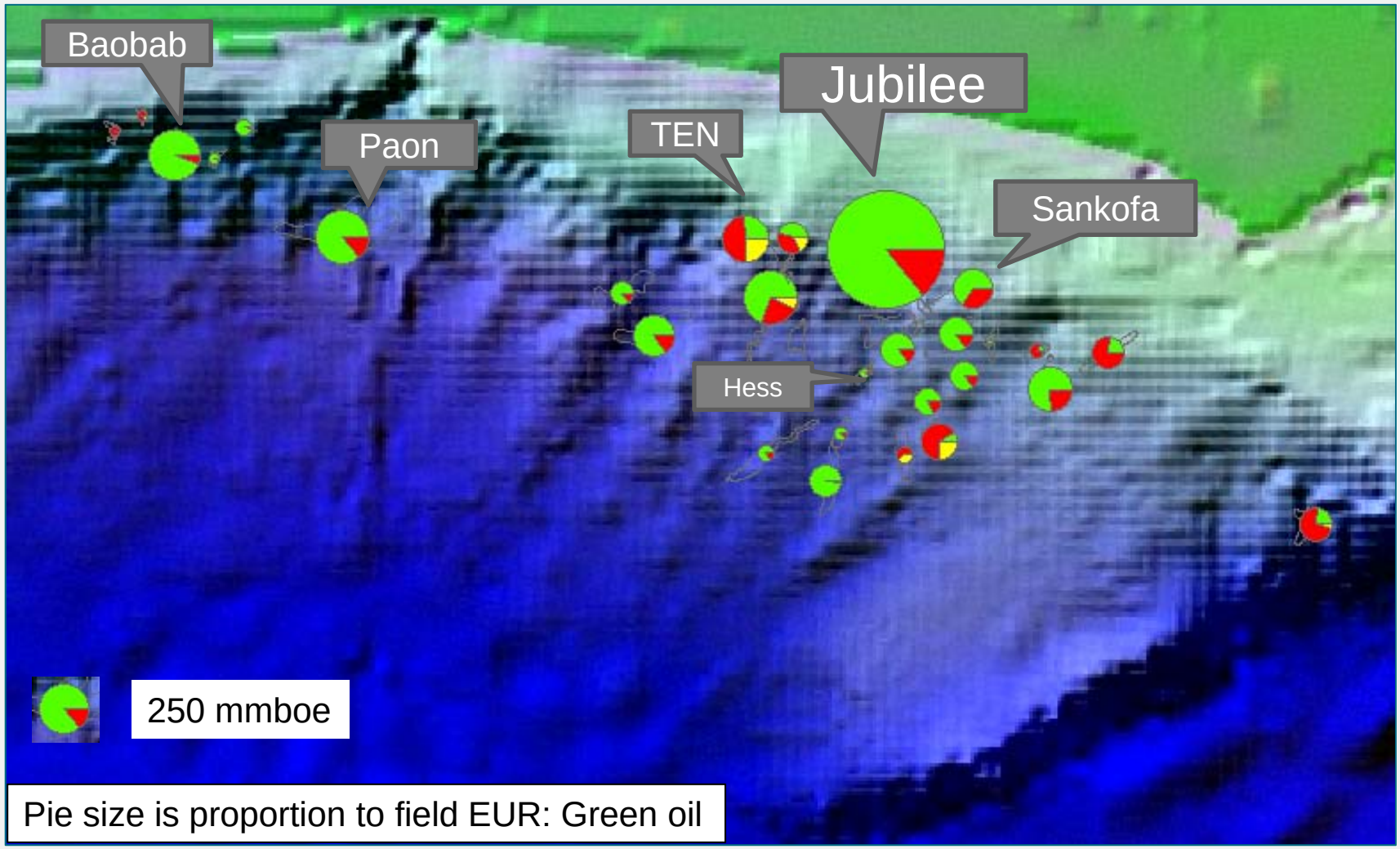
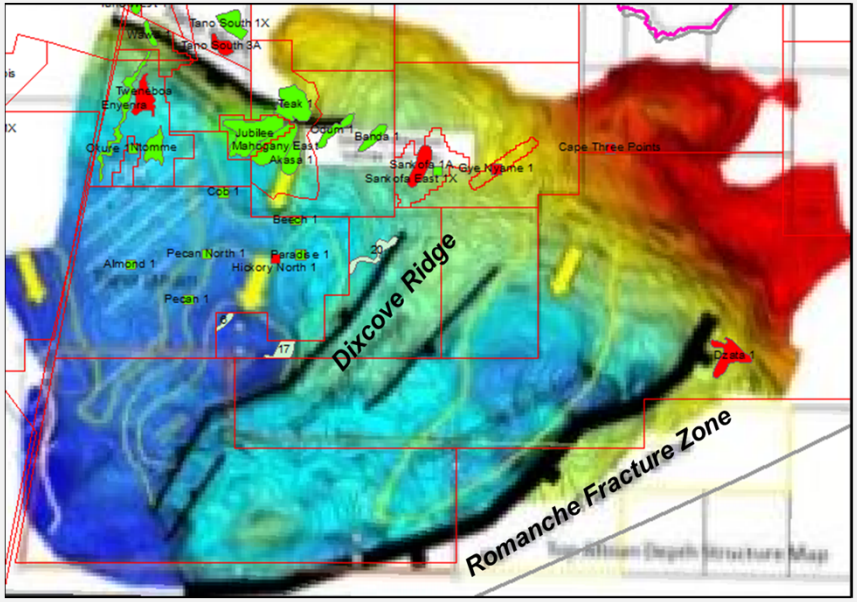
Tano Basin Fields

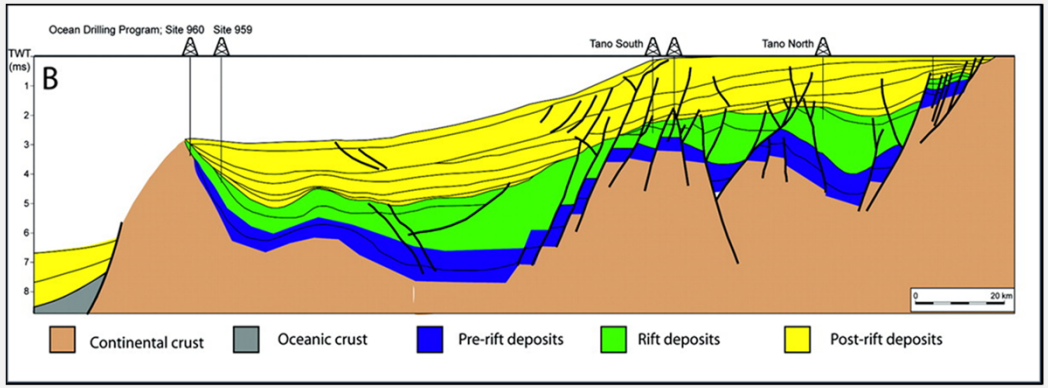


Tano Basin: Why Special?

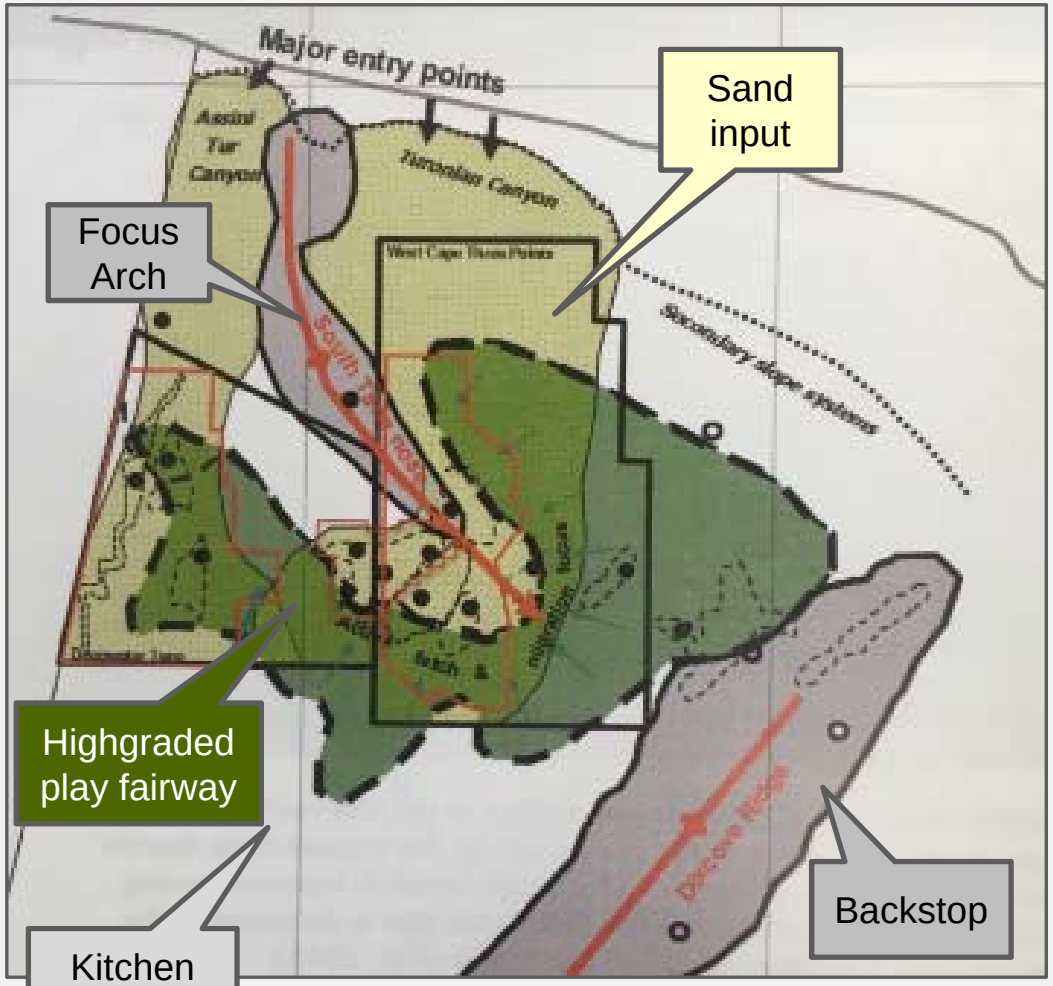
- A long-term isolated pull-apart (last to open), hence potentially a particularly well developed and rich source rock;
- A significant back-stop at the Romanche Fracture zone, and associated elements (eg Dixcove Ridge), with potential for ponding, effectively an embayment;
- Multiple steps related to basement structure, a focus for sediment drop-out.
- A quartz-prone hinterland, providing potentially optimal reservoir quality;



GNPC: Aryeetey



Why is Jubilee the ‘King’ Field?



Dailly, 2017

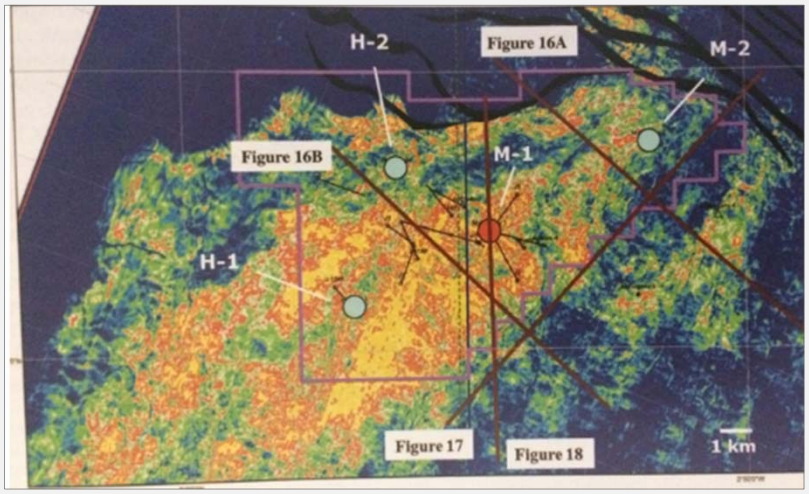
Regional setting:

- Turonian sands drop out over the Tano Arch.
- The Dixcove Ridge diverts and enhances ponding of reservoir sands
- Mature oil-prone source rock provides large hydrocarbon volumes that are
- focused on the Tano Arch *and recharge*.

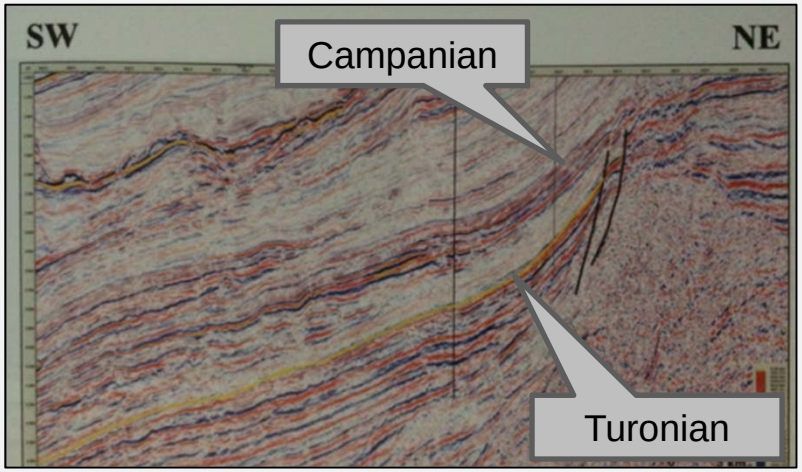
Trapping and seal:

- Next slide

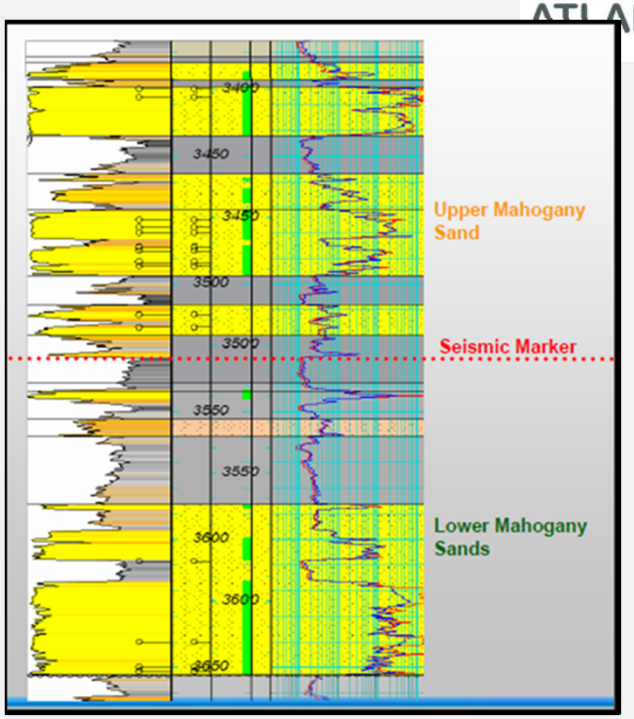
Jubilee Detail



Dailly



Dailly, 2017



- Trap: pinchout in the most critical northern direction is enhanced by basin-margin faulting.
- Top seal is preserved: younger Campanian channel systems do not breach the main accumulations

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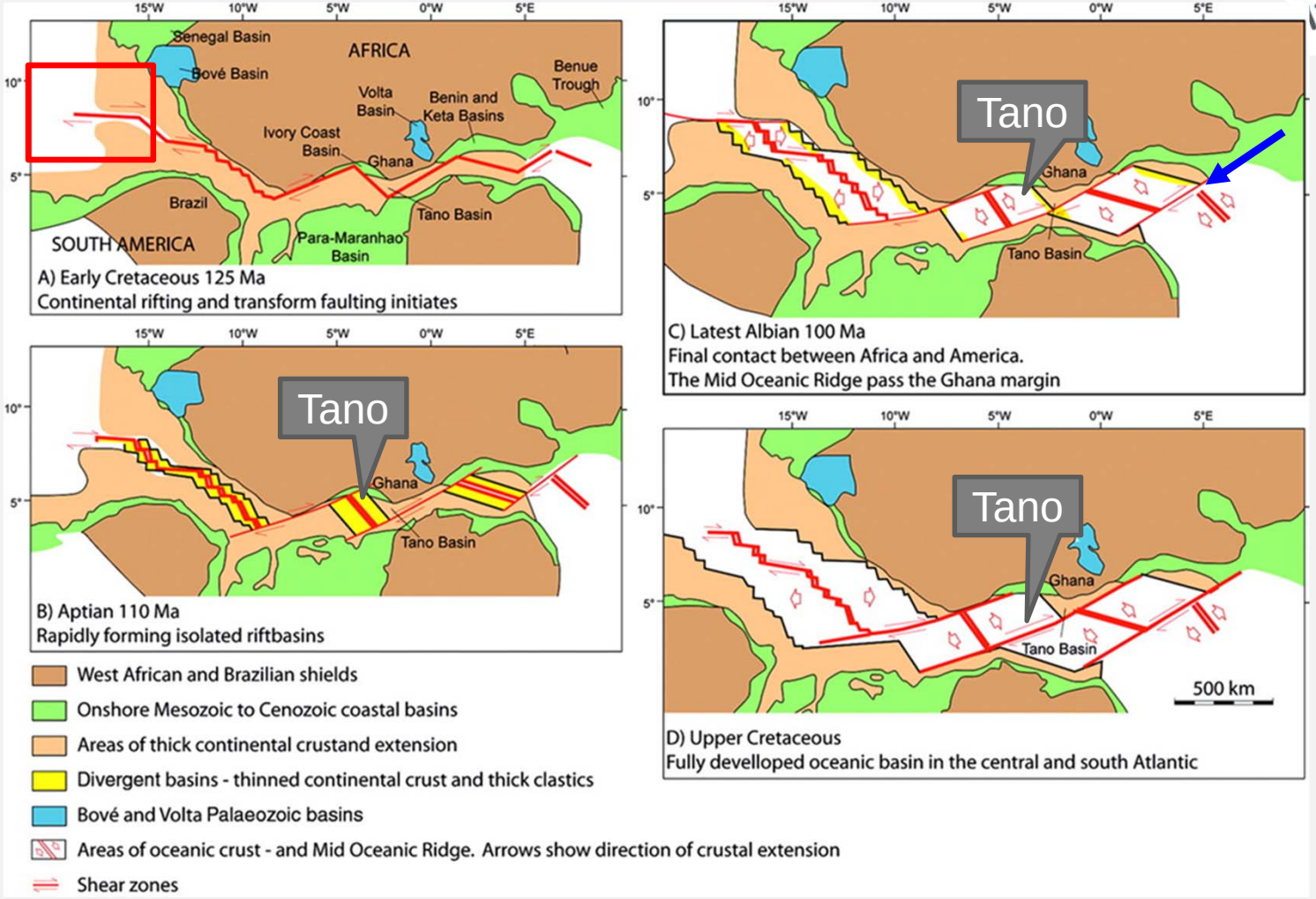
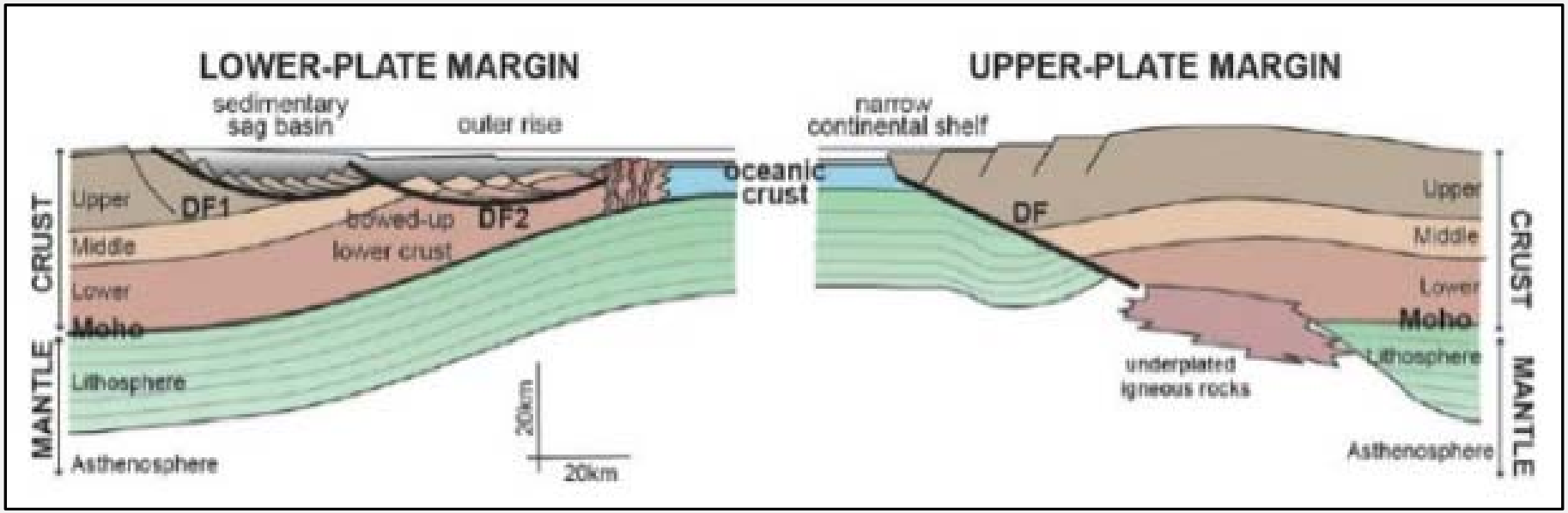
Tano Basin: Paleostructural Setting



Two issues: (1) asymmetry, (2) diachroneity

Asymmetric Rifting ….

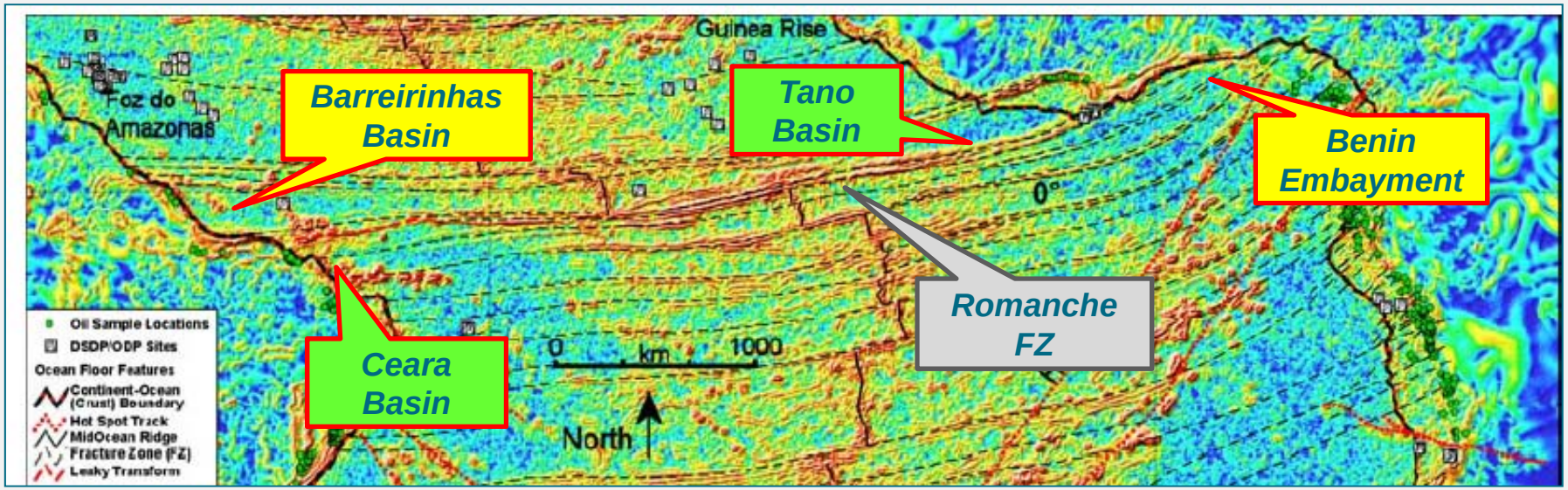


Mann/Davison

Highly extended
Potential for giant salt basins
Broad prospective section
Gravity driven structures
Shelf sediment capture

Narrow shelf
Narrow play fairways
Coarse clastics make it off the shelf

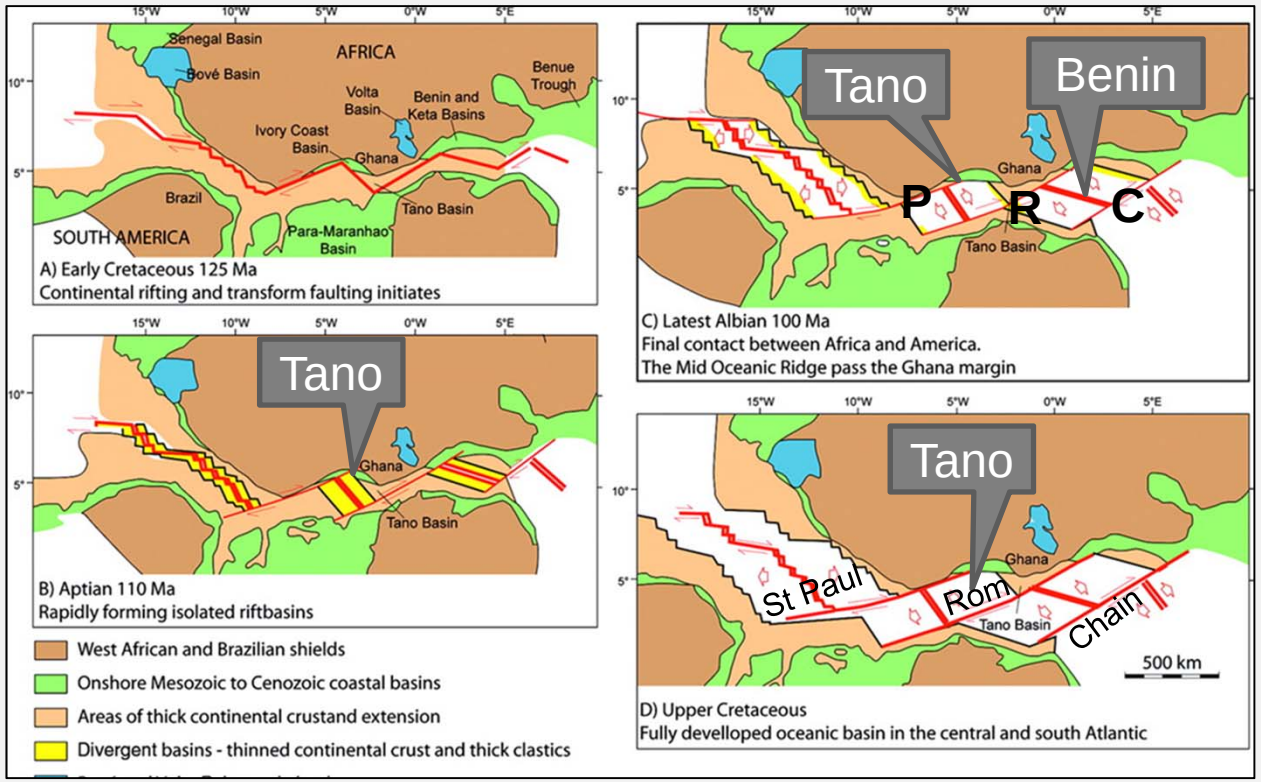
.. on the Equatorial Margin



Lower Plate: Tano Basin, Ceara Basin

Upper Plate: Barreirinhas, Benin Embayment

Diachroneity



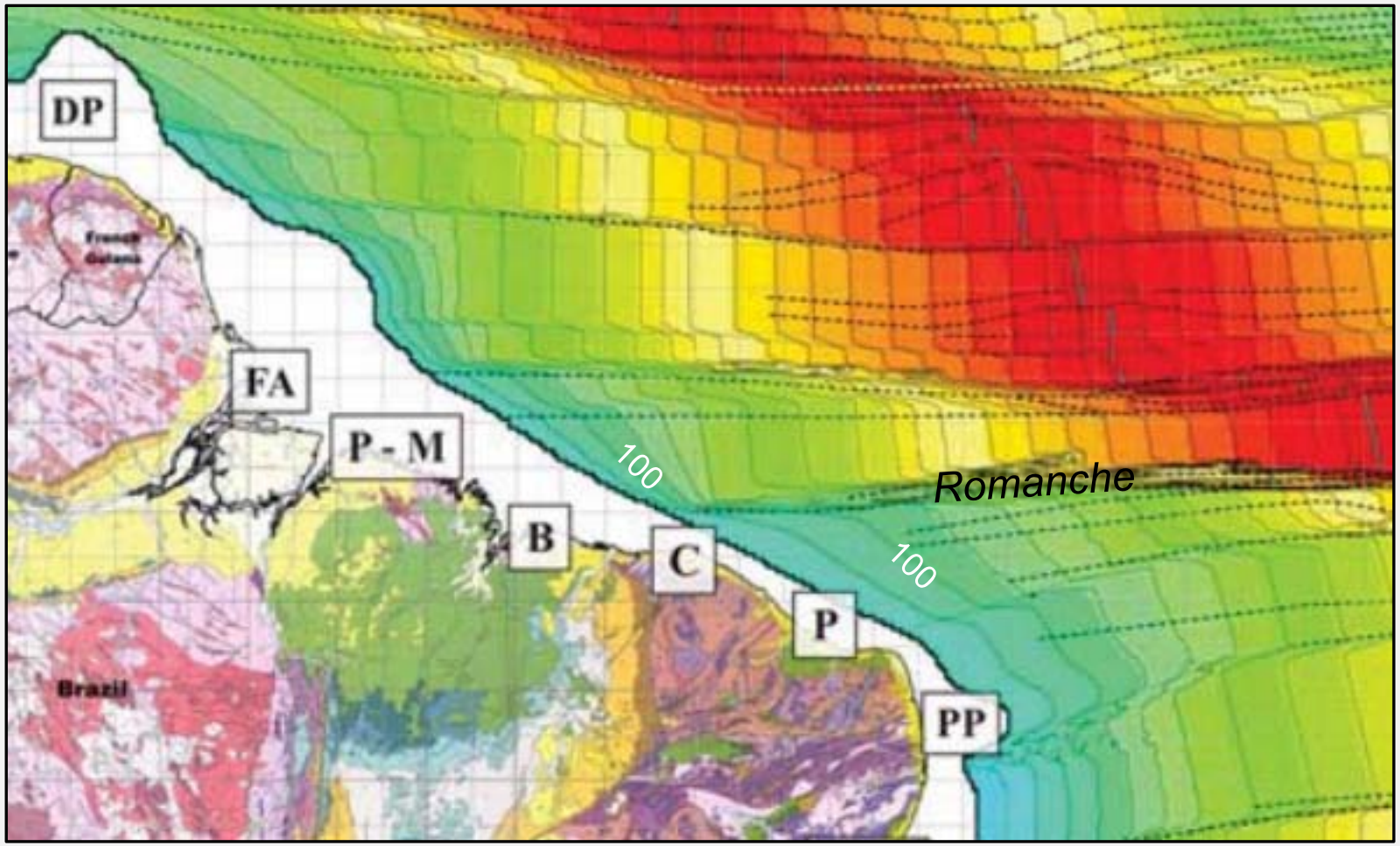
Timing of Separation
Chain: 105my
Romanche 100my
St Paul: 95 my

ION

Geoexpro

- Detailed work indicates that in the Ceara/Benin basins breakup was late Aptian, while it was late Albian in the Barreirinhas/Tano Basins. *(Ref: eg Jovani et al.)*
- The Romanche FZ acted as an accommodation zone between the two.
- Diachronous opening and marine invasion might profoundly impact key play elements such as source rock in terms both of age and of quality.

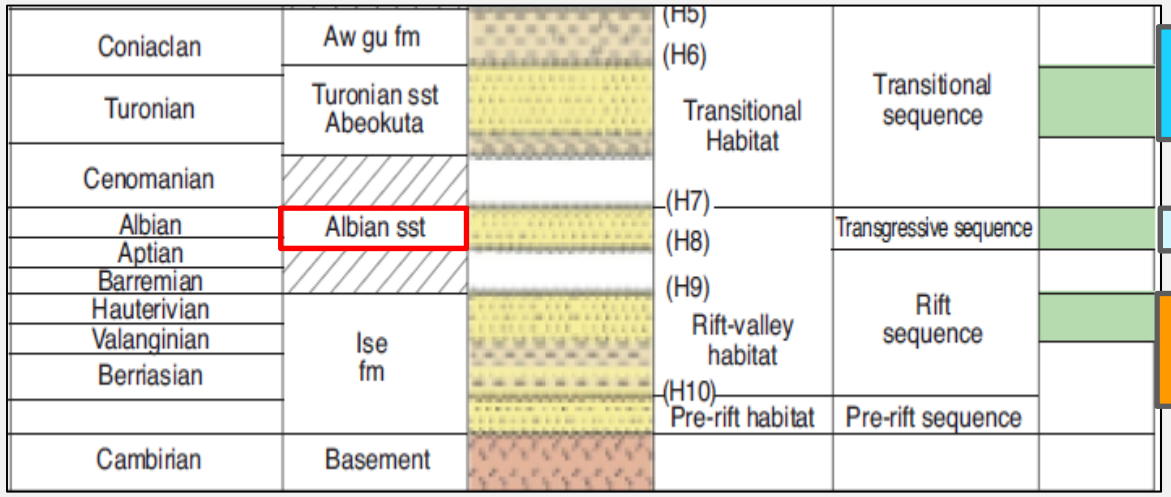
Timing of Opening

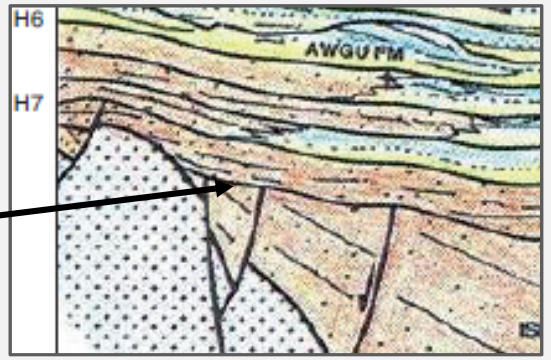


Nemcok

Timing of Opening: Benin-Ceara

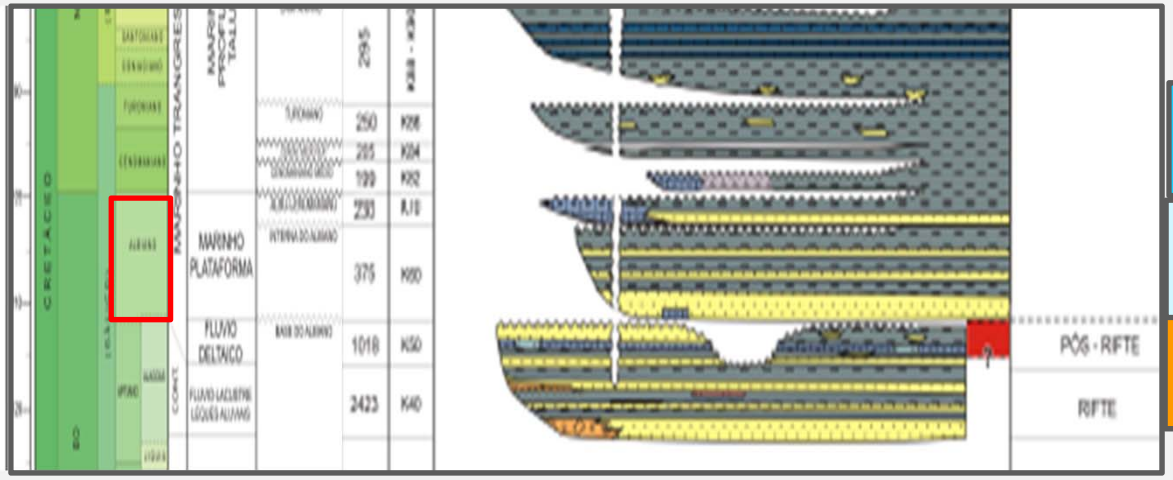
Benin

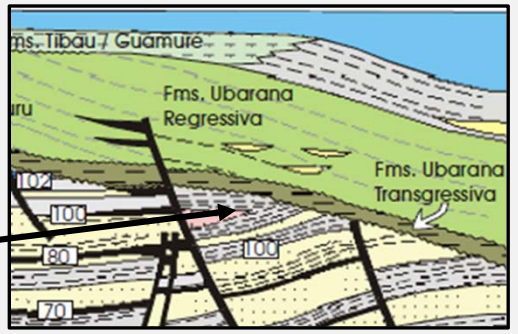




Kaki et al

Ceara



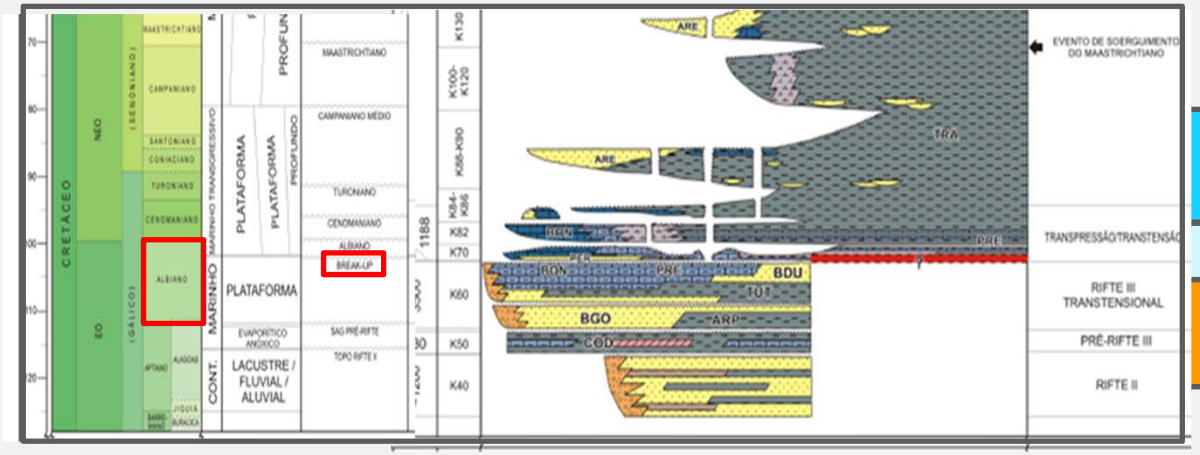


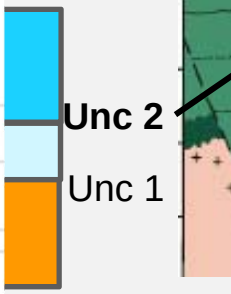
ANP

The breakup unconformity is Unc 1, late Aptian, in both basins

Timing of Opening: Tano-Barreirinhas

Barreirinhas





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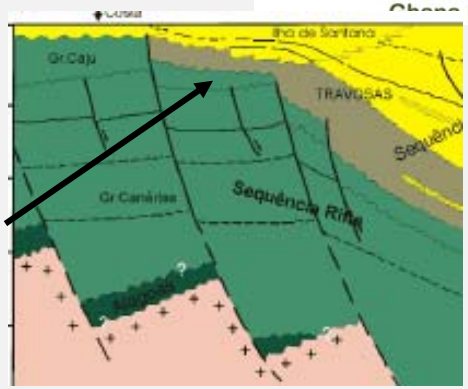
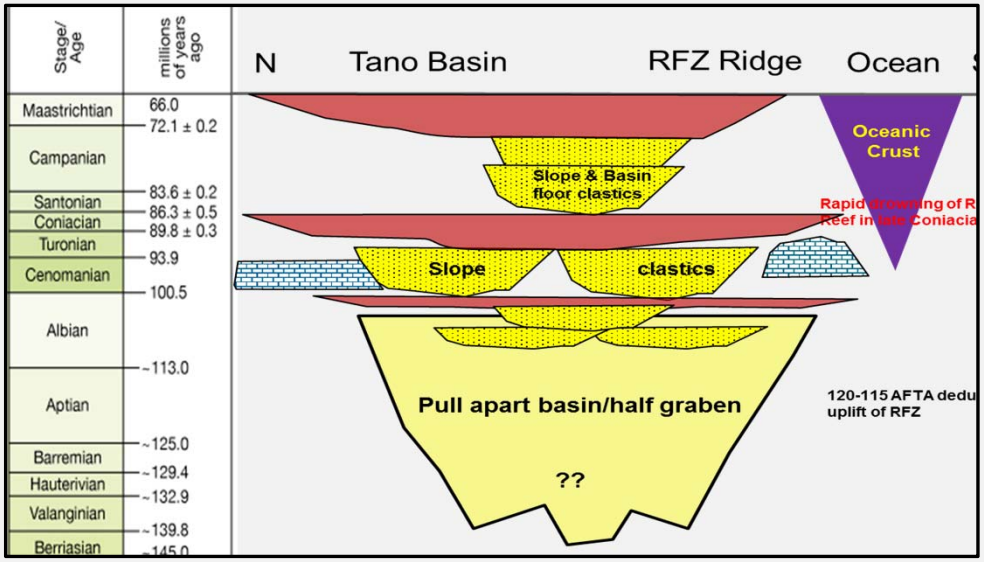
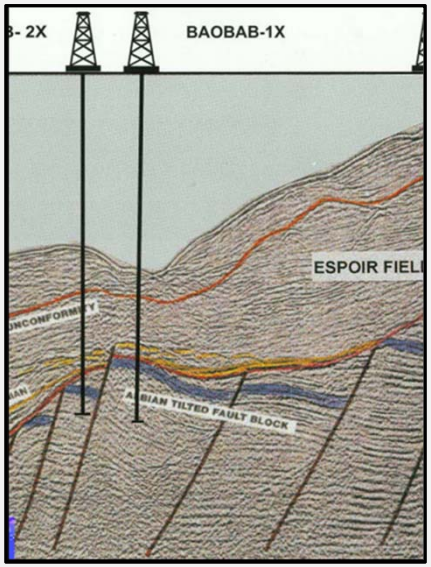


Breakup: 102 my

Tano

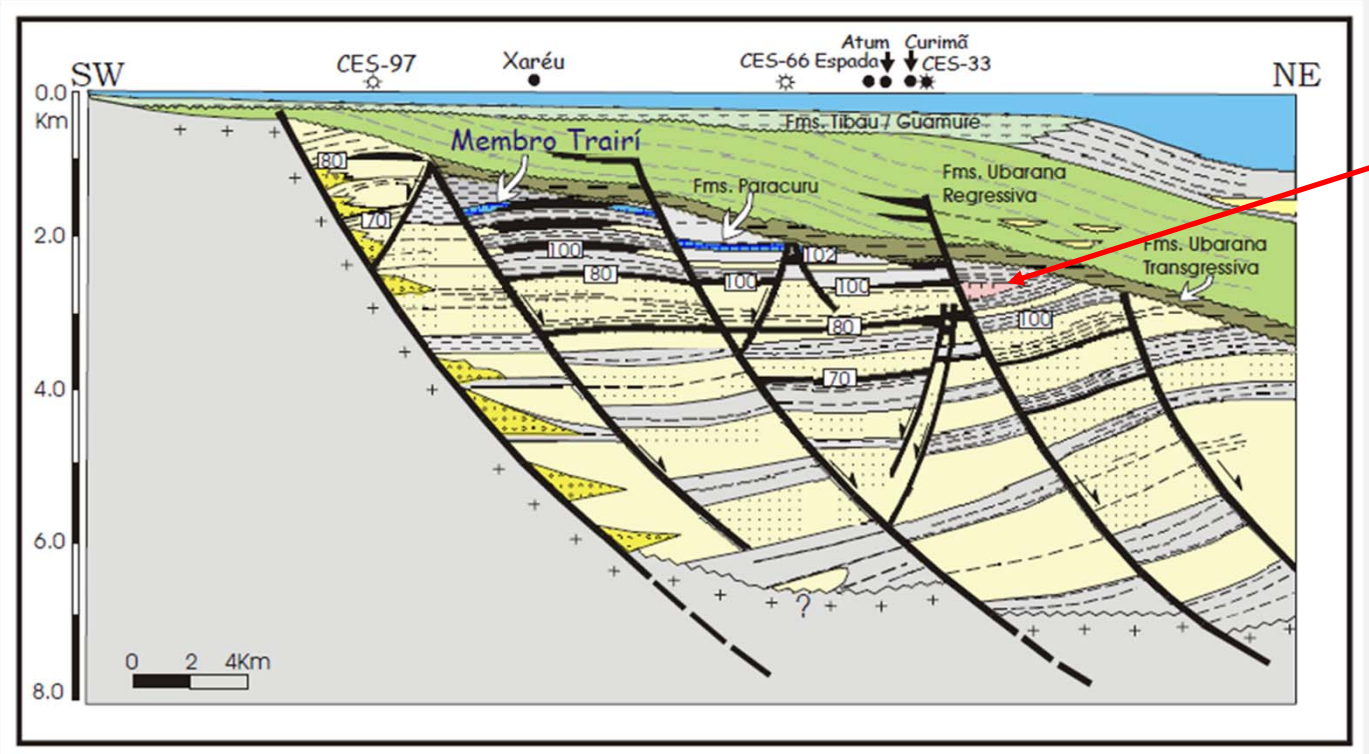


EcoAtlantic Ghana



The breakup unconformity is Unc 2, late Albian, in both basins

Does salt extend into the Conjugate Margin?



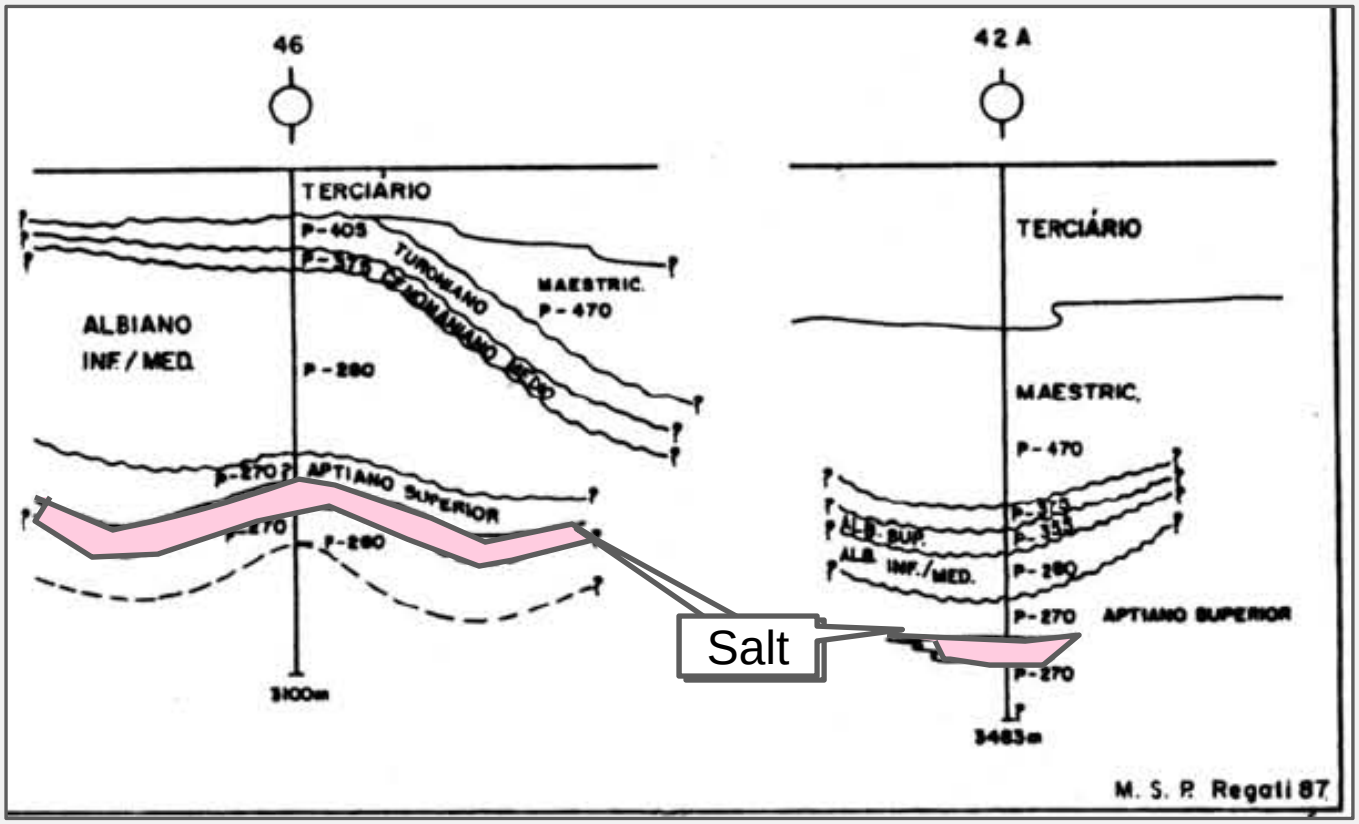
Shelfal salt

Conde et al

In Brazilian South Atlantic Margin, salt originally deposited within the transitional sag facies has been key in trap development in the drift sequence, and to seal development for underlying sag carbonates.

Could it be present in the conjugate margins also??

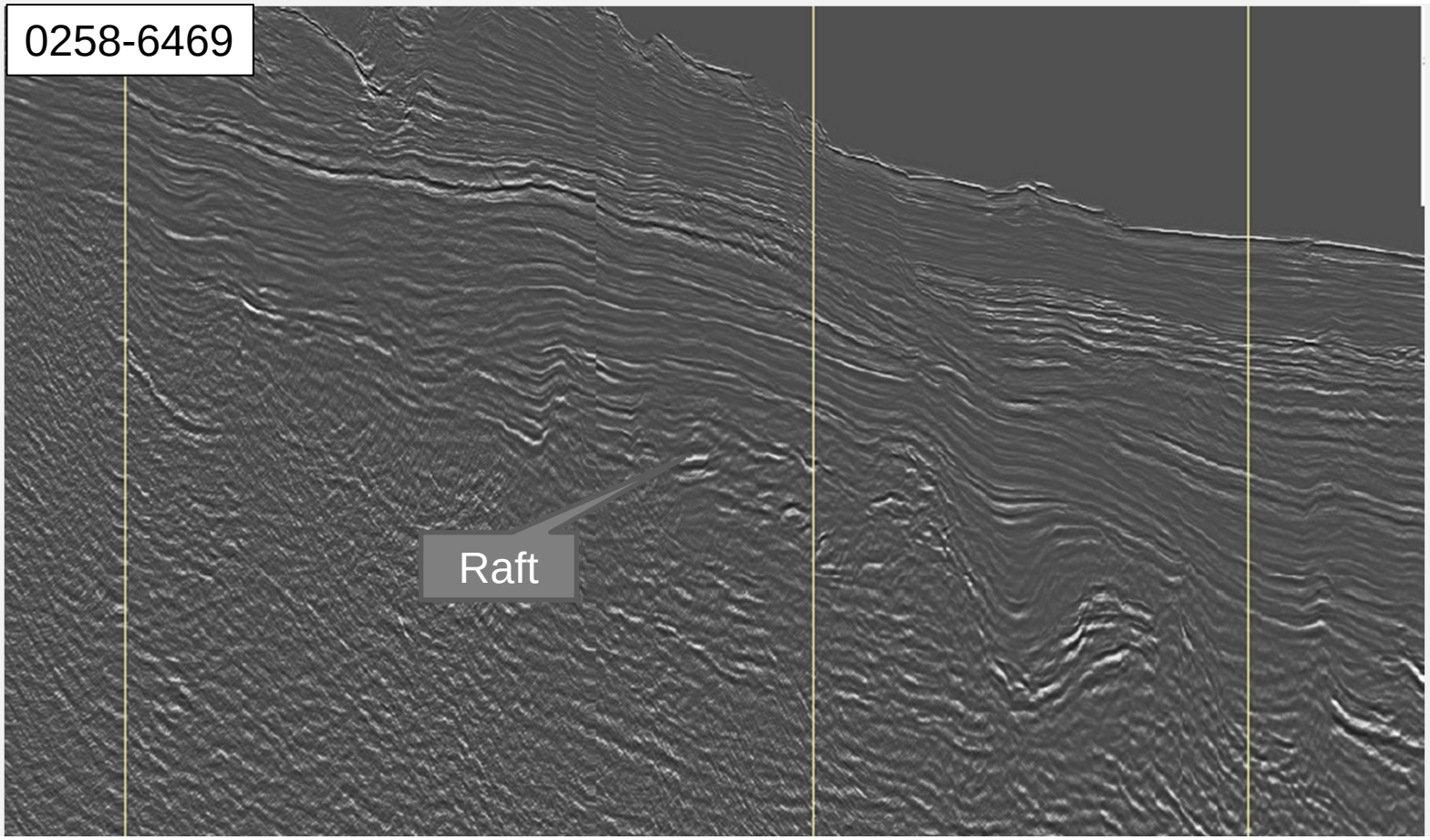
Ceara Basin Shelf: Salt



In a shelf setting, 2 wells encountered evaporiates: CES-46 penetrated 200 meters of halite. On the shelf, these evaporitic sequences appear limited in areal extent, perhaps eroded in the outboard, so did not generate typical halokinetic features.

However, why would the salt basin not extent into the deeper basin where one could reasonably expect thicker and more extensive salt deposition?

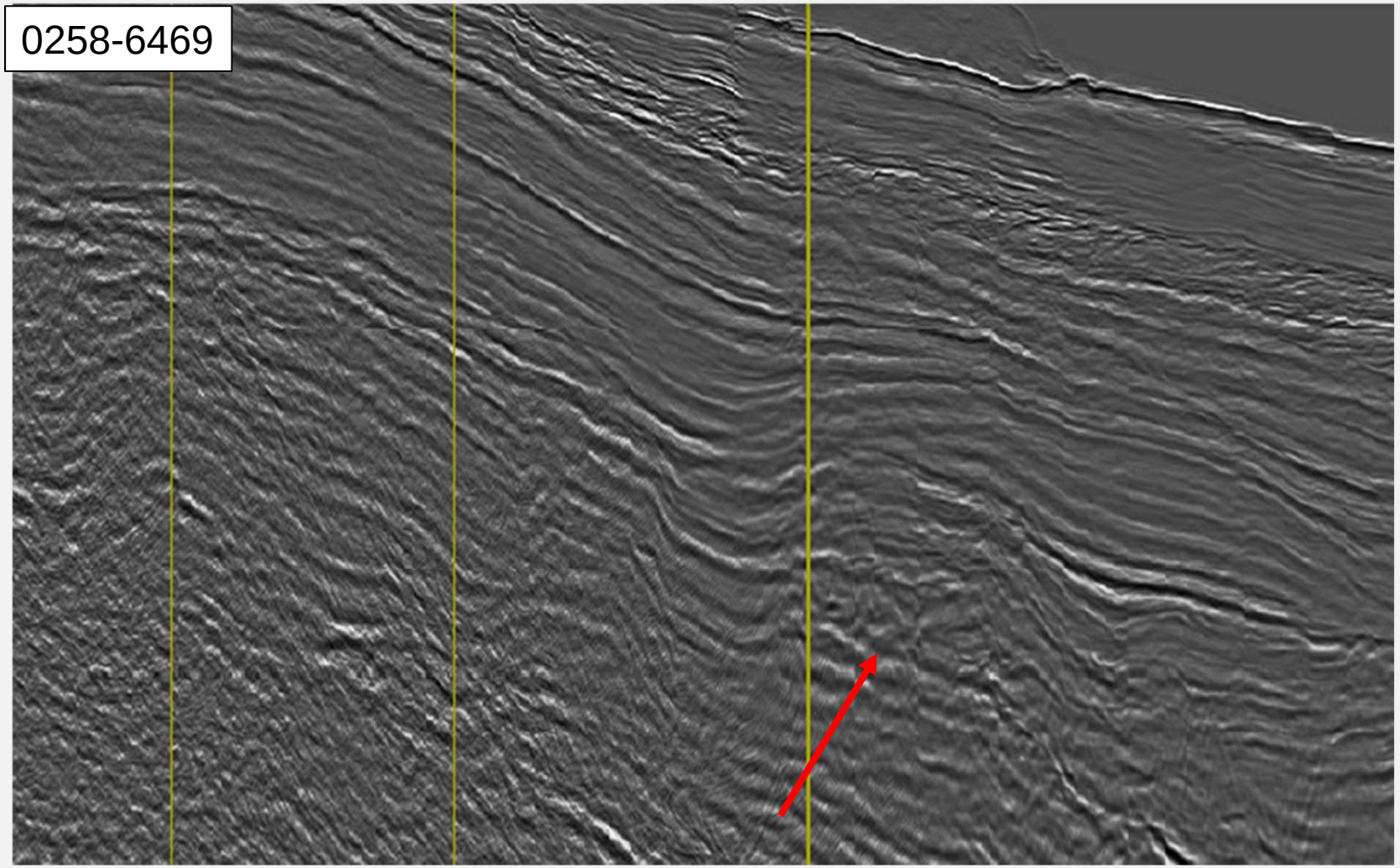
Ceara DW: A Salt-induced Raft?



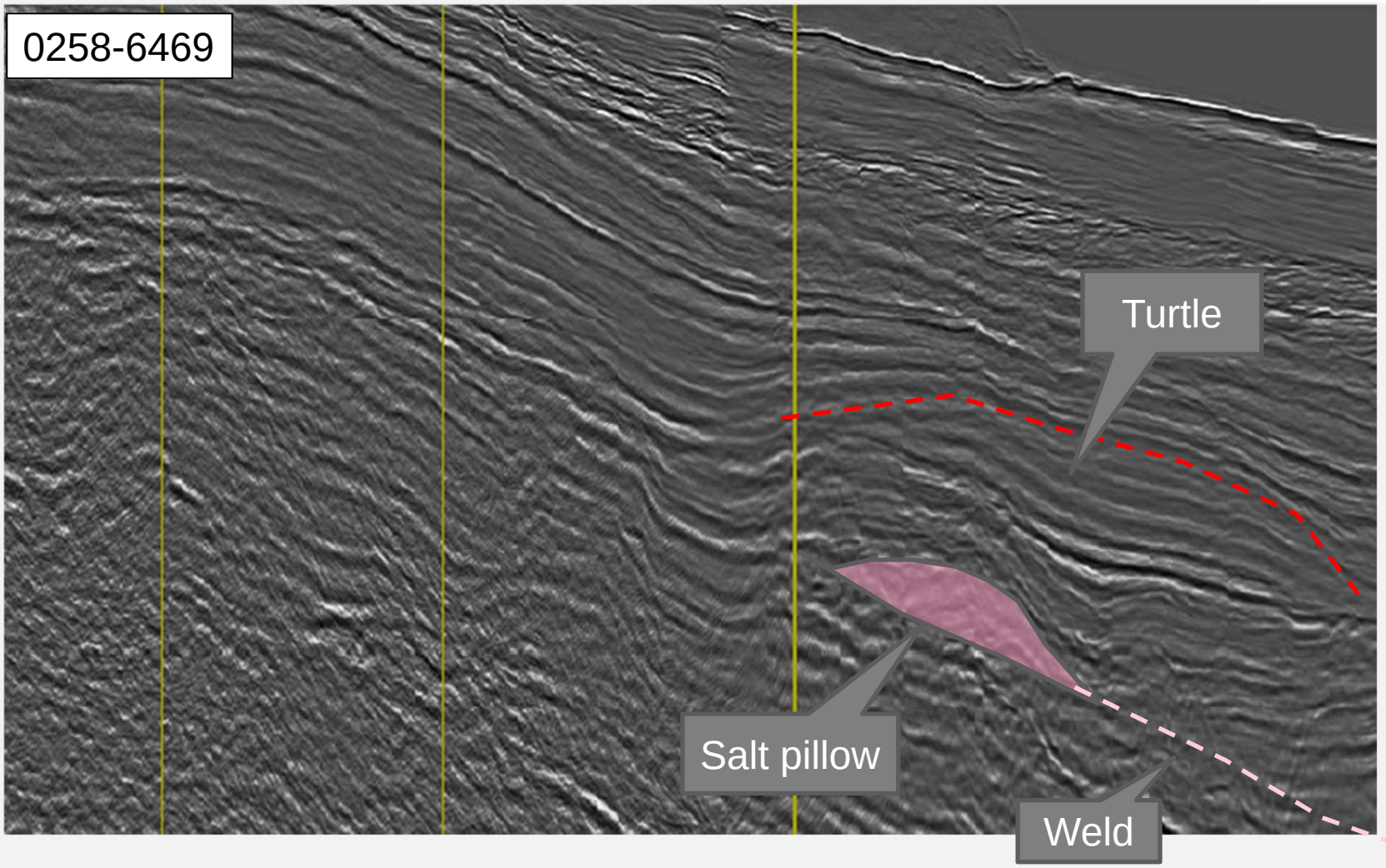
This raft slid on shale or salt

Salt evacuated from the slope might be expected to be expressed as domes and diapirs in the further outboard area.

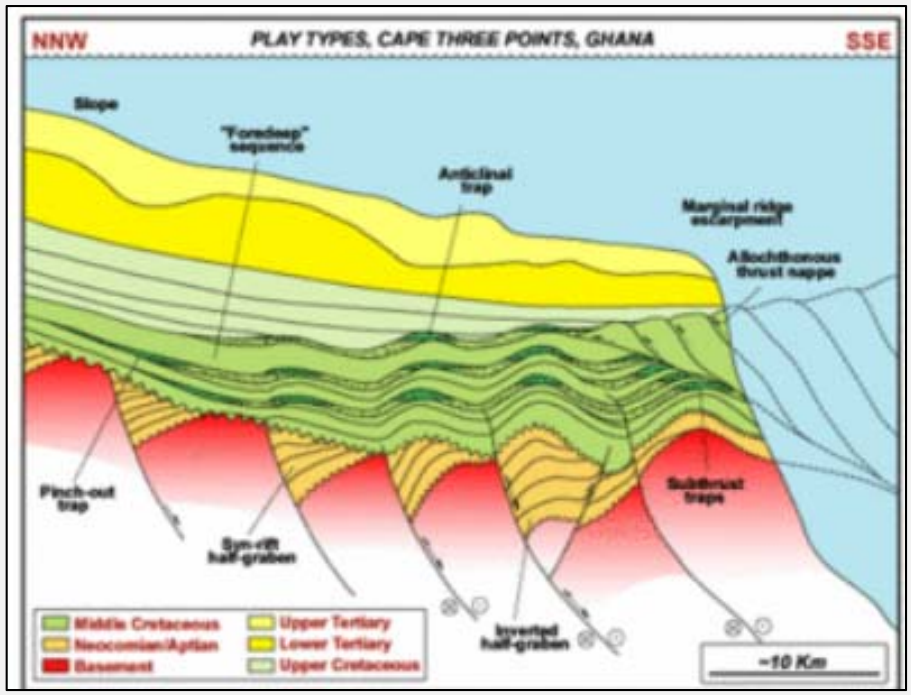
Ceara DW: Seismic Expression

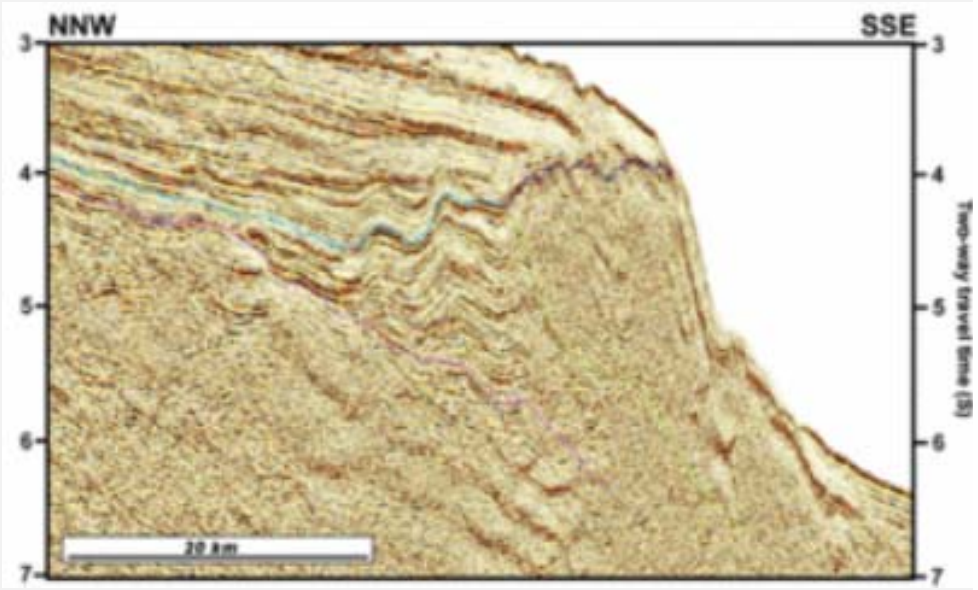


Ceara DW: Seismic Expression



Tano Basin: Romanche ‘Nappe’





Tari et al

The ANP View …

Em associação lateral aos carbonatos Trairi, foram recuperados níveis de sal, predominantemente halita, em dois poços na Bacia do Ceará (1-CES-42A e 1-CES-46). Ocorrem como cristais de granulação grossa, com matéria orgânica e argilominerais incorporados e intercalação de folhelhos ricos em matéria orgânica.

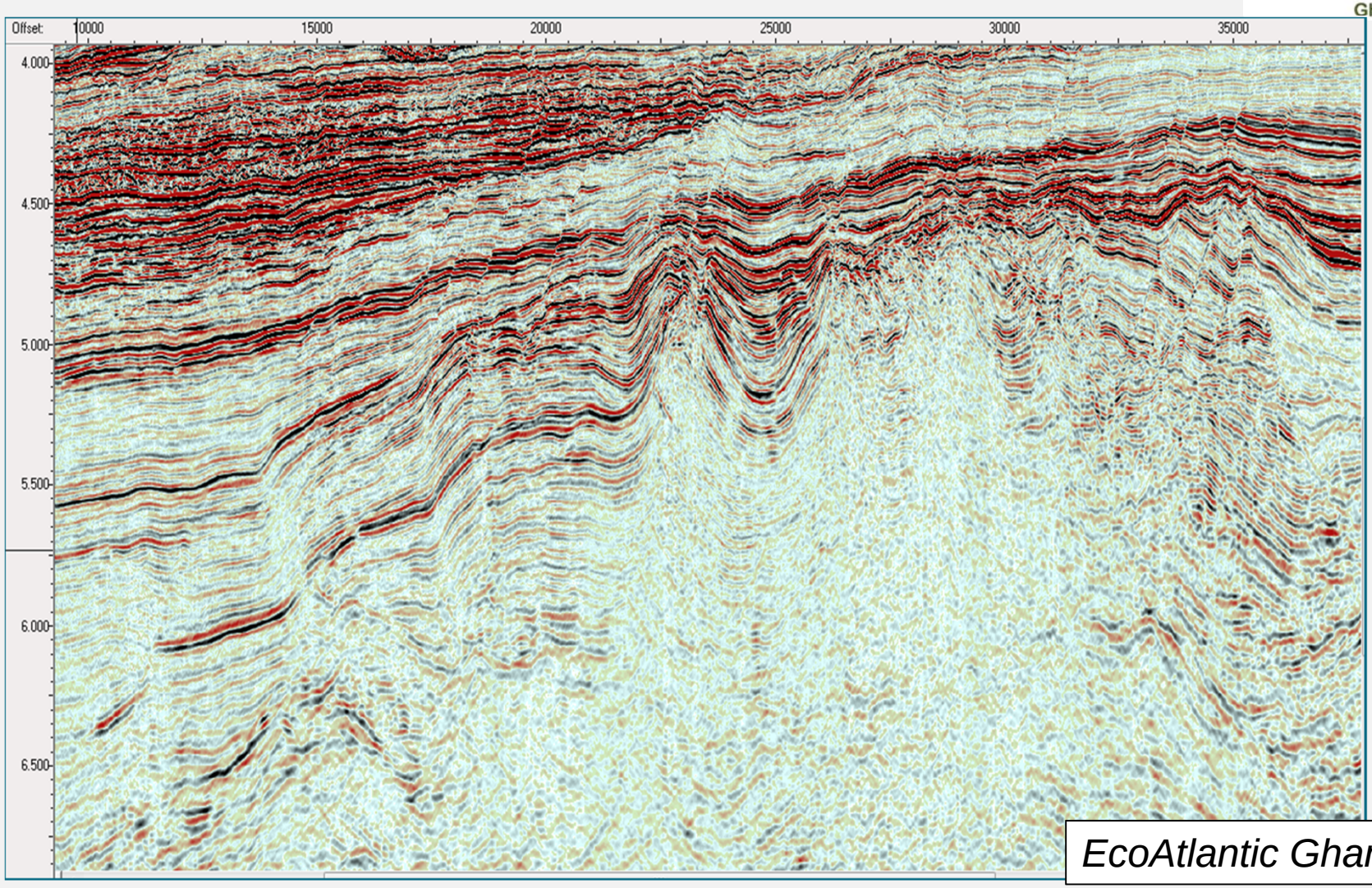
Recentes análises de dados sísmicos na parte mais distal da bacia indicam uma provável presença de evaporitos na área de águas profundas-ultraprofundas da bacia, sugeridas pela presença de feições dômicas.

O ambiente restrito é atestado pela ocorrência da ecozona de dinoflagelados *Subtilisphaera* spp (Regali, 1989; Lana e Roesner, 2002) e pela elevada concentração do biomarcador gamacerano, caracterizando, assim, condições hipersalinas no ambiente deposicional.

Conde et al

'Recent analysis of seismic data in the distal part of the basin indicates the probable presence of evaporites in the DW and UDW portion of the basin, suggested by the presence of domal features'.

Salt in the Tano Basin?



EcoAtlantic Ghana

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  - Salt in the Ceara .. Why not in the Tano?
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Thoughts and Conclusions

- Very high hydrocarbon discovery rate ..
- Commercial success much more elusive ..
- Second phase of exploration builds on the learnings of the first ..
- The Tano Basin has provided the best results in the Equatorial Margin ..
- Is there a true analogue? Asymmetry and diachroneity may make this elusive .. My pick is the Ceara ..
- Does the Ceara shelf salt extend into the deepwater?
- Can there be salt in the deepwater of the African basins?
- ***Let's keep an open mind – no dogma!***

Thank you!

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