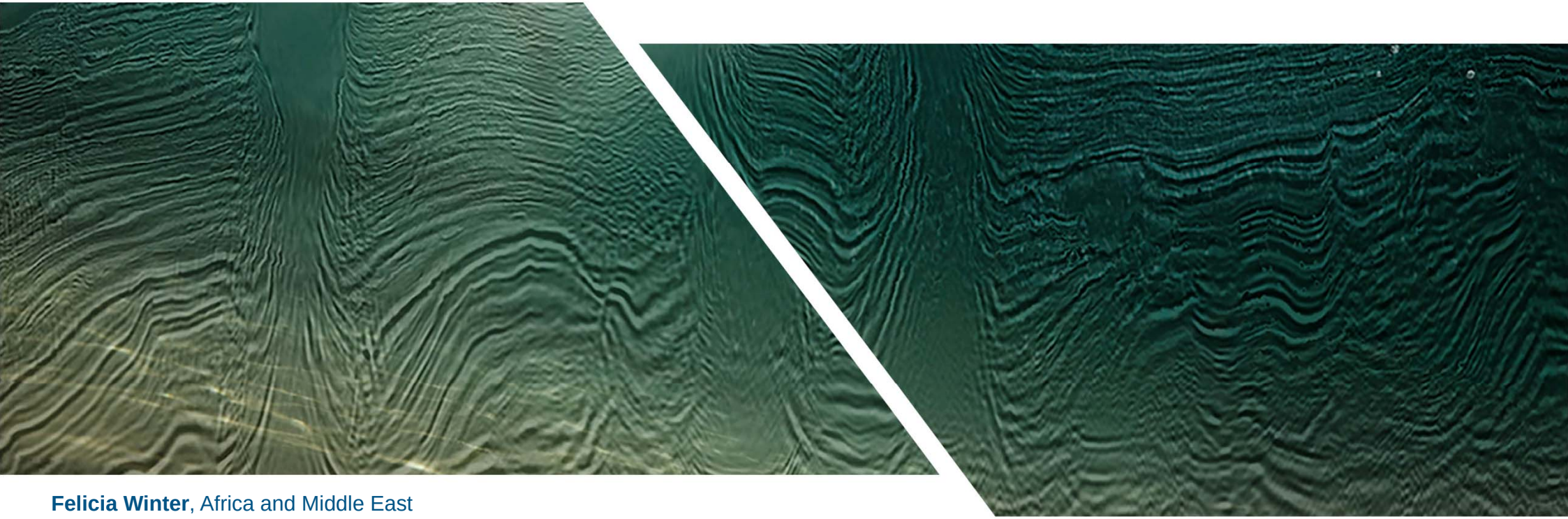
Somaliland
Untested Plays Revealed by TGS Data

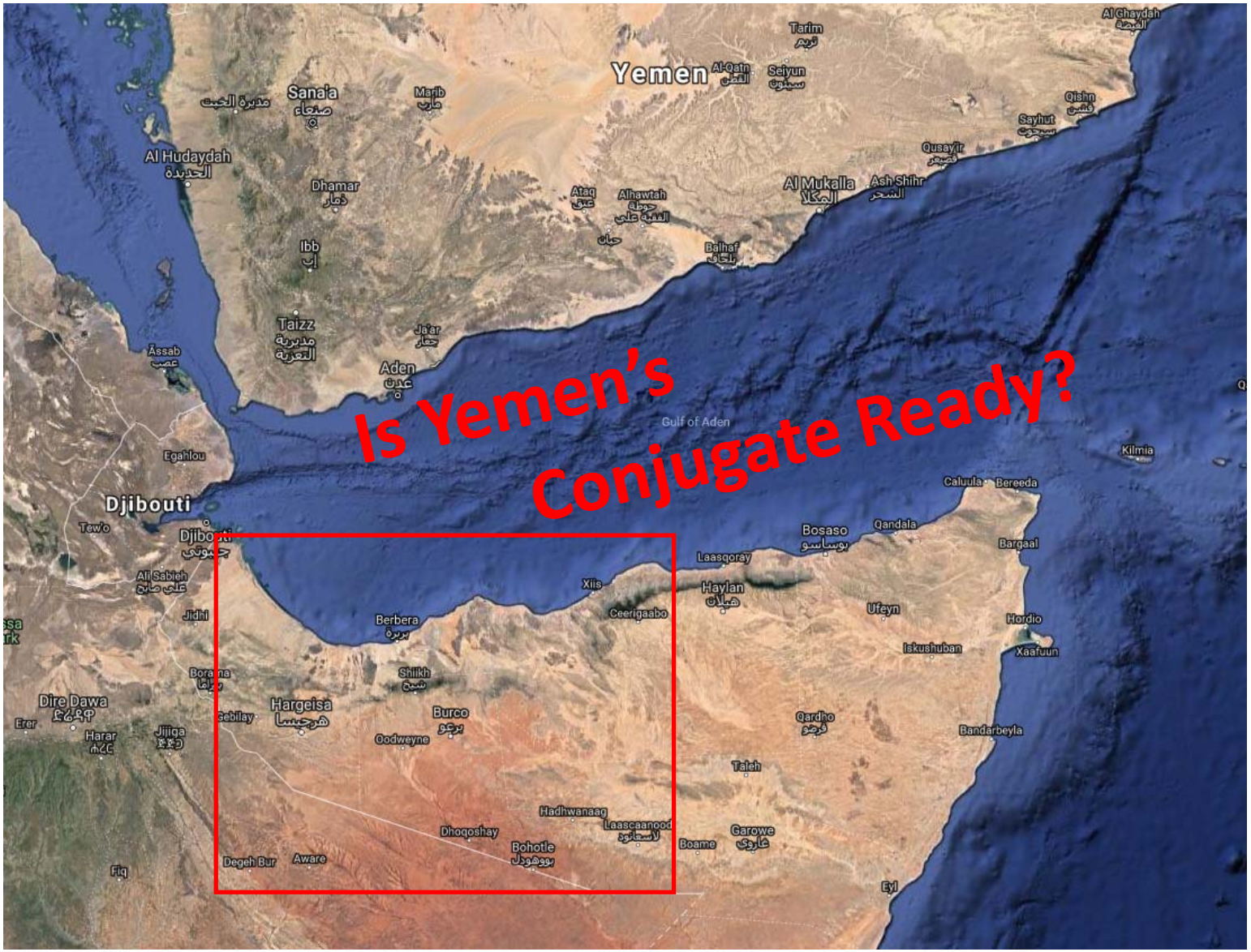


Felicia Winter, Africa and Middle East
Roberta Masotti, Geological Products and Services

Finding Petroleum, Finding Oil and Gas in Sub Saharan Africa, 25 June 2018

LEGAL NOTICE

Study Area

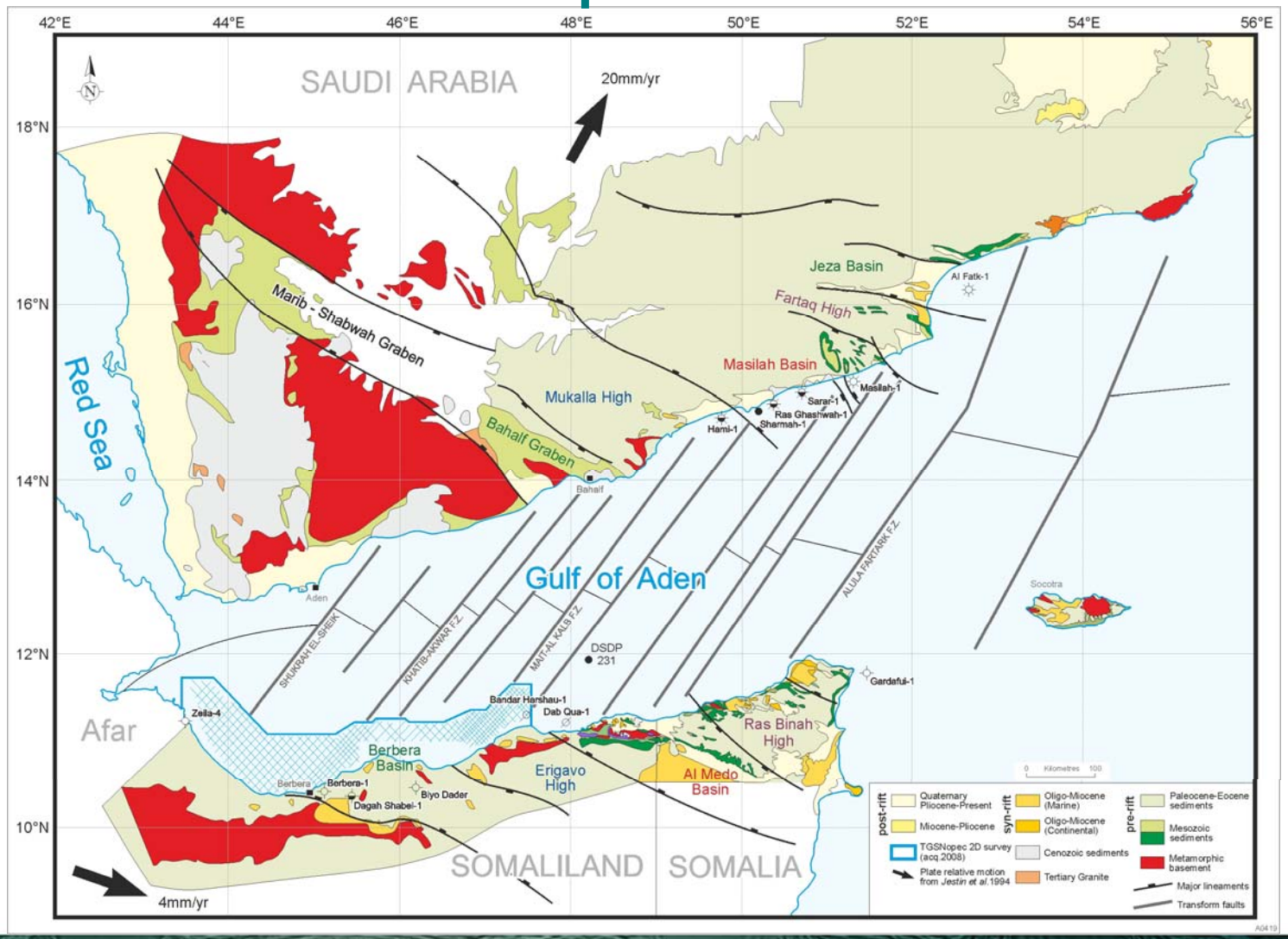


Somaliland. Untested Plays Revealed by TGS Data - Content

1. Where are we?
2. Why re-enter Somaliland?
3. Structural Framework.
4. Building Blocks of the Petroleum System.
5. Offshore - What does that mean for the Prospectivity?
   → Insights based on TGS 2D regional Seismic
6. Onshore Airborne Magnetics - Implications for the onshore Potential.
7. Summary.

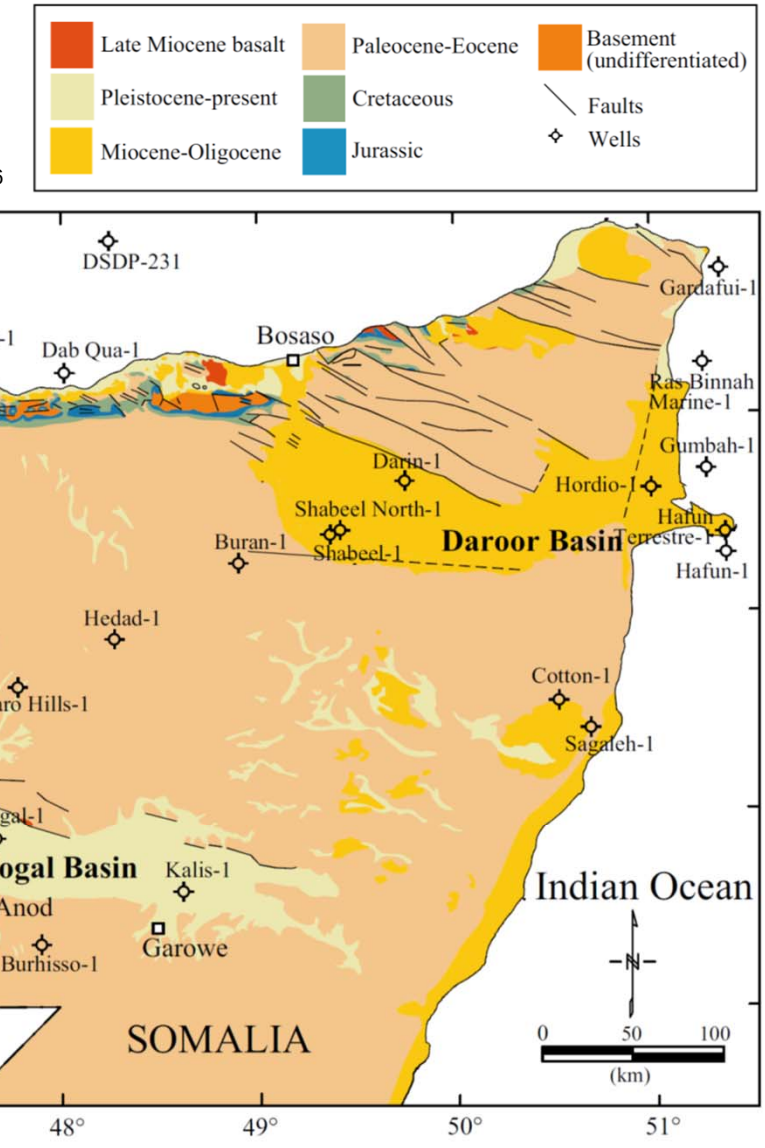

Where are we? (1/7)

Geological And Structural Map Of The Gulf Of Aden



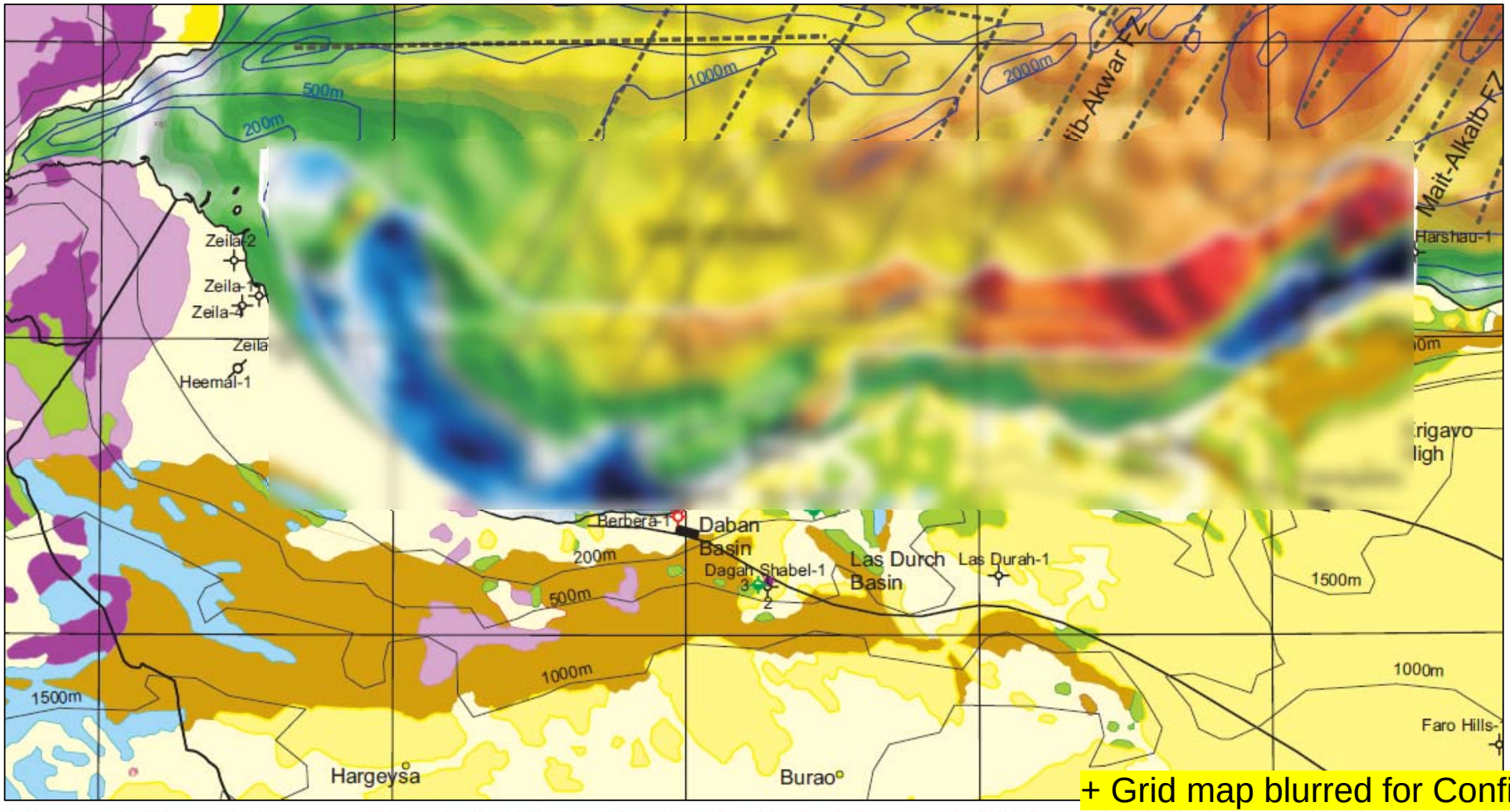
Modified from D'Acremont 2005, and Cochran, 1981; plate relative motion from Jestin et al 1994.

Onshore Geology



Onshore Geology – Offshore Gravity

Bouguer Anomaly offshore compared to Geology onshore (EFA project, Ed Purdy)

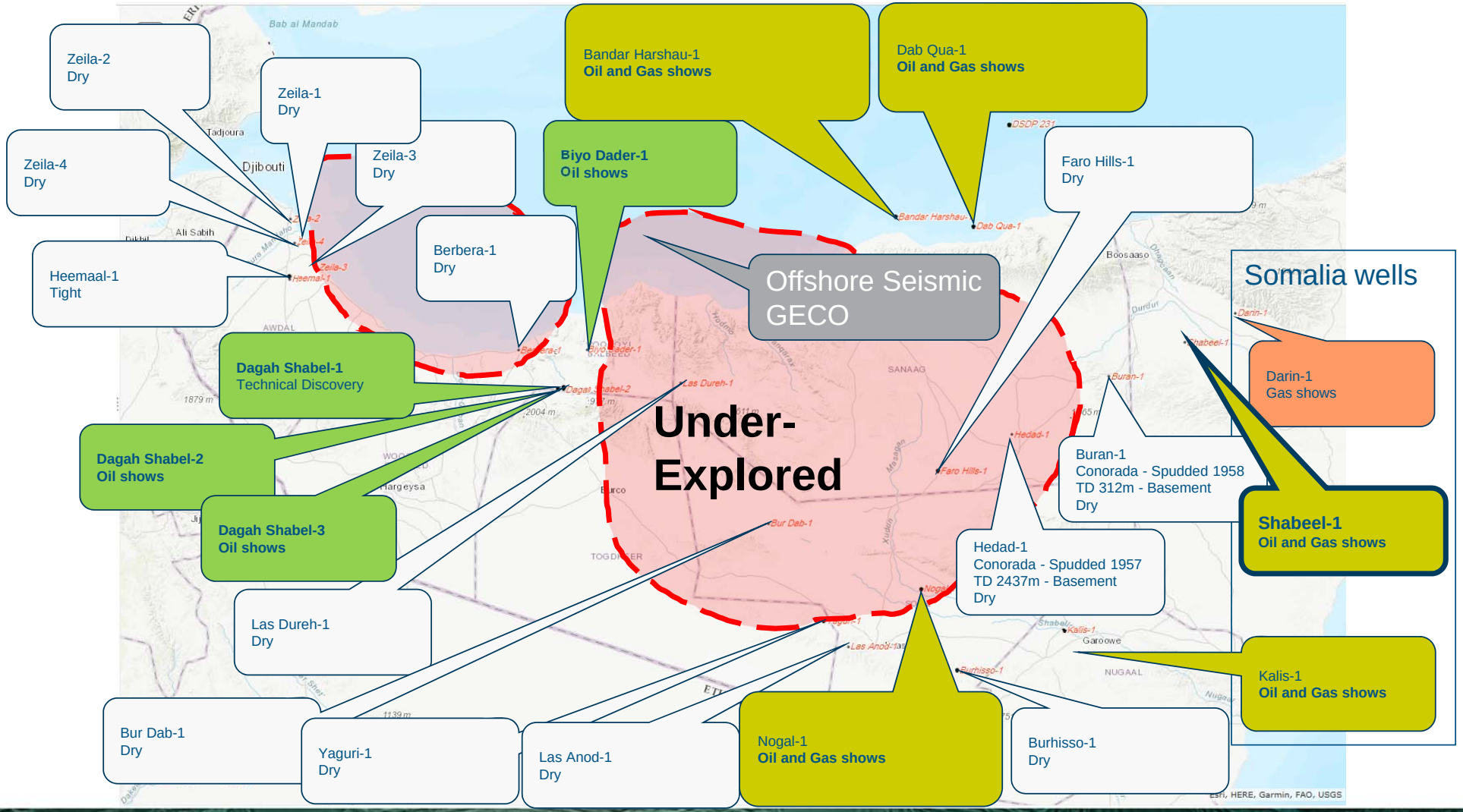


+ Grid map blurred for Confidentiality reasons+


Why re-enter Somaliland? (2/7)

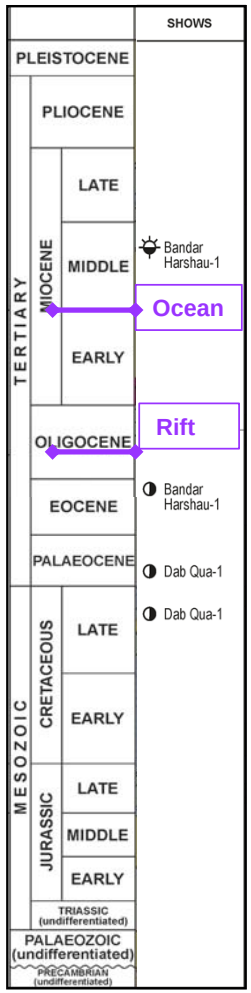
Exploration History

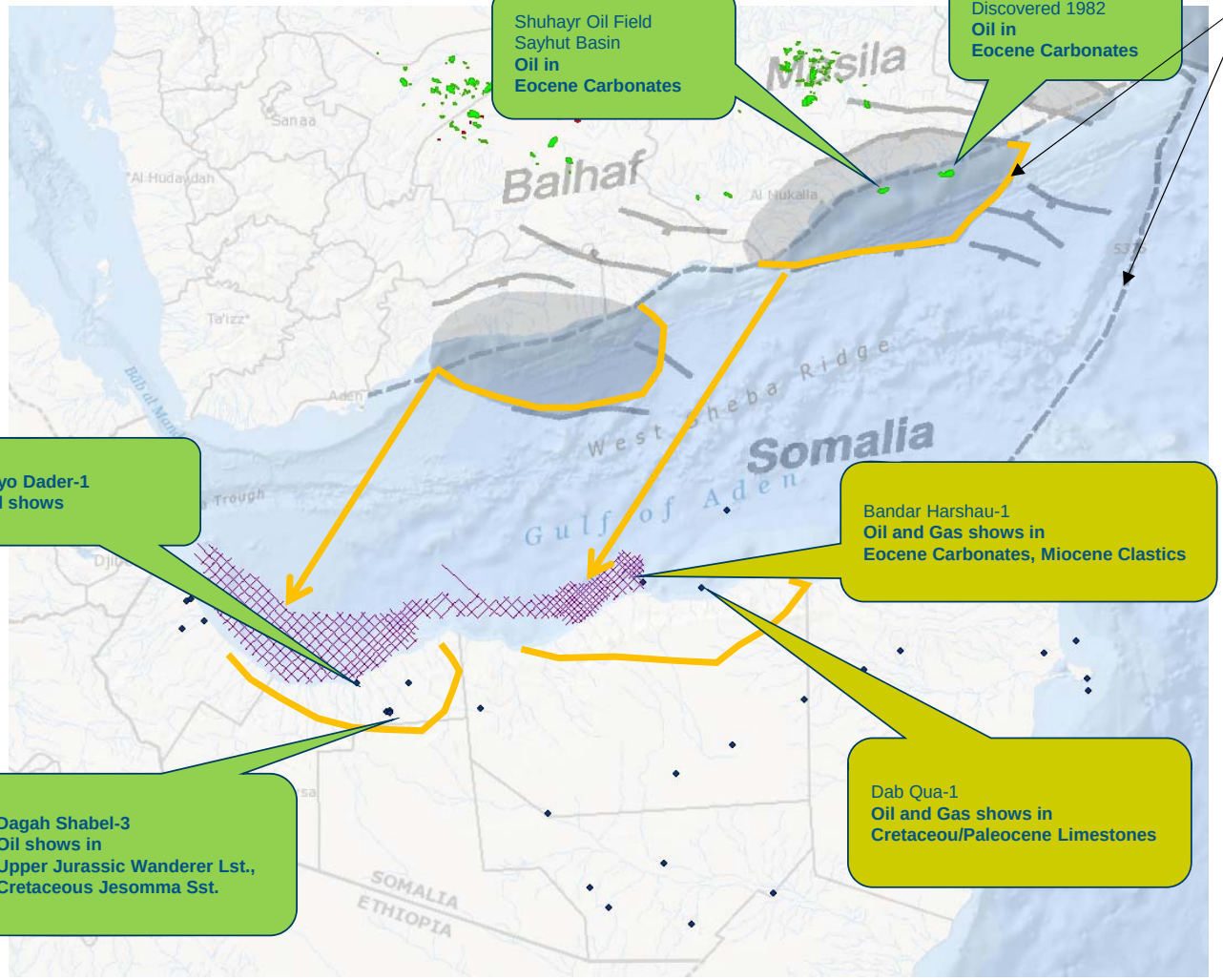
Several exploration plays with world class potential remain to be tested.

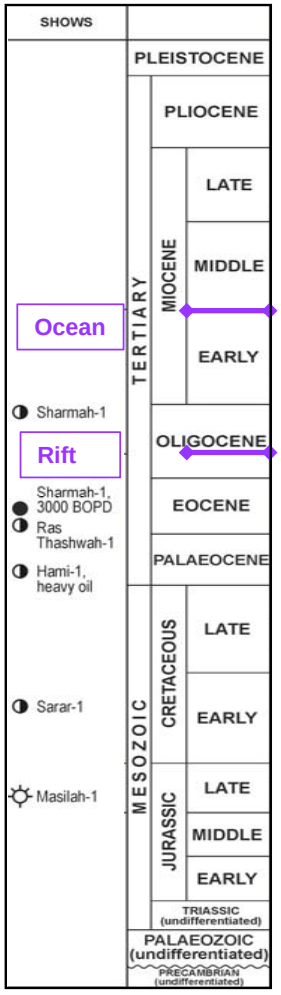


- 2018
- 2012
- 2011
- 2010
- 2000s
- 1990s
- 1980s
- 1970s
- 1960s
- 1950s
- 1940s
- 1930s
- 1920s
- 1910

Shows In Somaliland And Conjugate Yemen





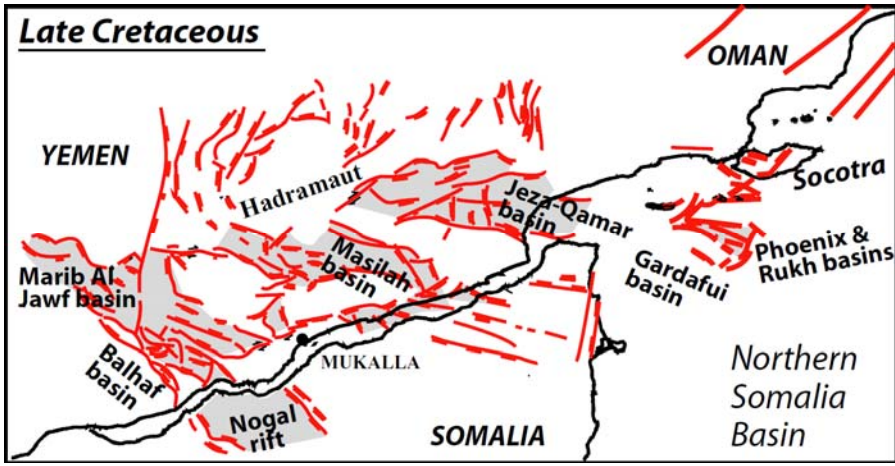


Why Somaliland?

1) Yemen, the conjugate margin, is producing hydrocarbons

2) Evidence for hydrocarbons on- and offshore Somaliland
   - Seeps onshore
   - Shows in wells onshore and offshore (gas and oil)
   - Coastal basin structures
   - Structural traps throughout Jurassic, Cretaceous and Tertiary
     (in place for maturation and migration)

3) Let's piece the story together and target more confidently



Mesozoic Basins before opening (modified from Ellis et al.,1996)

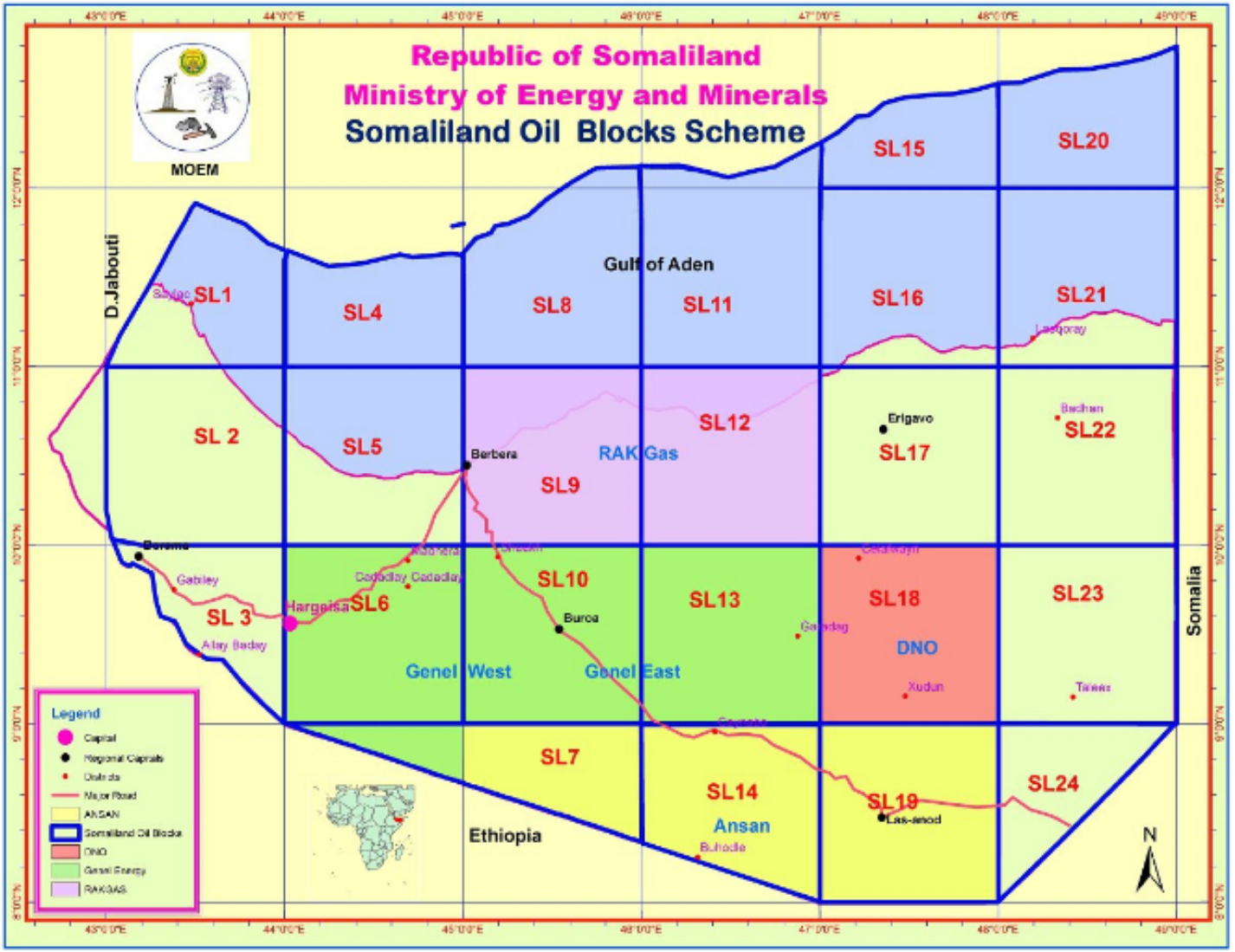
Recent Activity

New government
→ kick start exploration activity offshore

Genel / BGP acquiring the Seismic

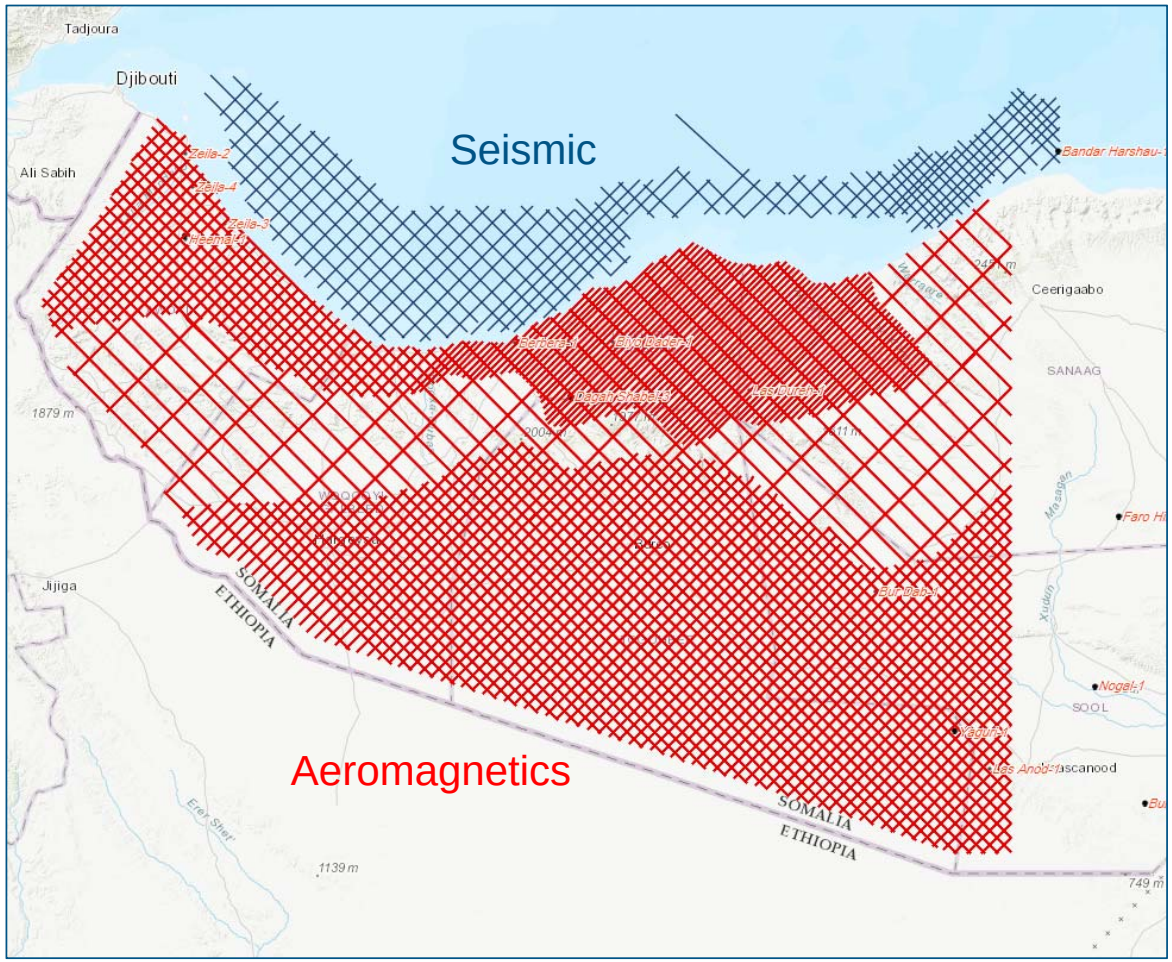
RakGas / BGP planned seismic acquisition (blocks 9 and 12)

Drilling planned (2019) by Genel (Oodweyne block, west)




Structural Framework (3/7)

TGS Data Used For Structural And Prospectivity Interpretation



- 5,323km 2D seismic (6-10km spacing, coverage: 21,500km², 6km streamer, 10s record length)
- 2 offshore wells (1 control well: Bandar Harshau-1)

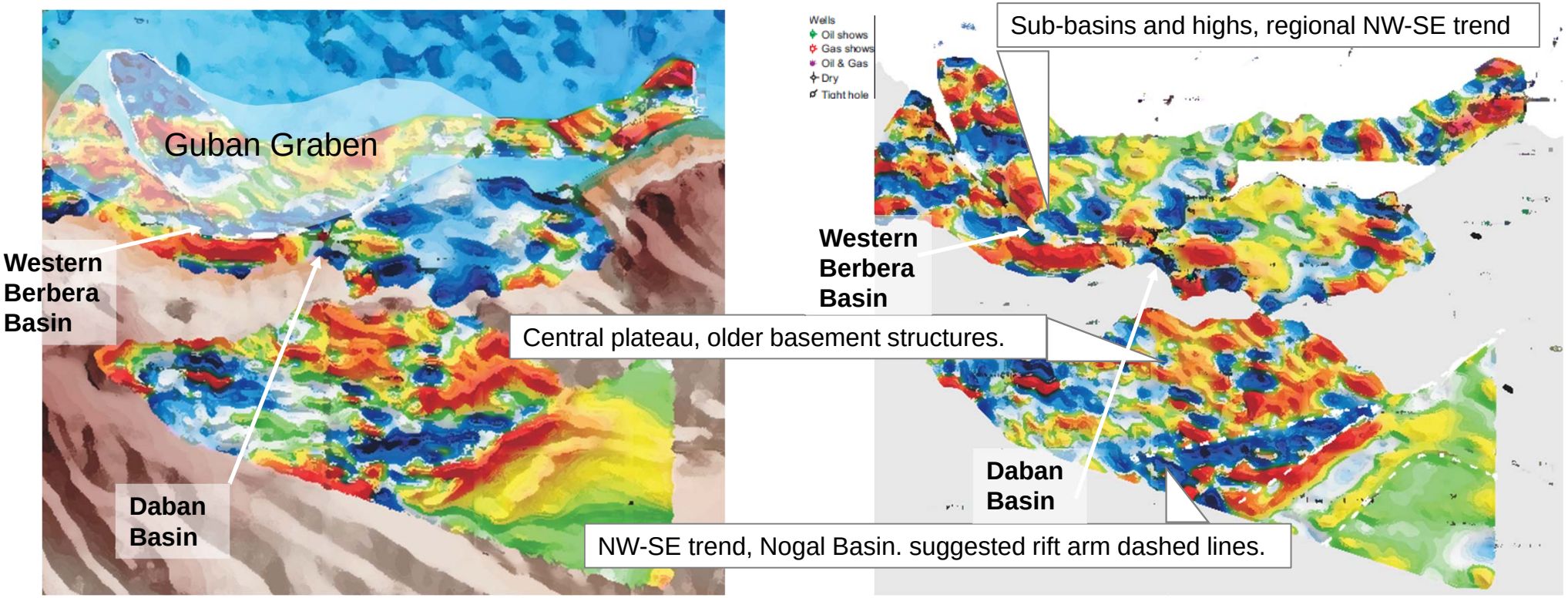
2.5km line spacing
- small scale structures <1.5km width
- depths <0.5km resolvable

25km line spacing
- basement ><5km well resolved

Min. 100km offset (NW)
- maximum depth 17km resolved

TGS Offshore Gravity & Magnetic And Onshore Airborne Magnetics

Magnetic Anomalies Reduced to Pole (RTP)	100 km High-Pass Filtered Magnetic Anomalies (RTP)



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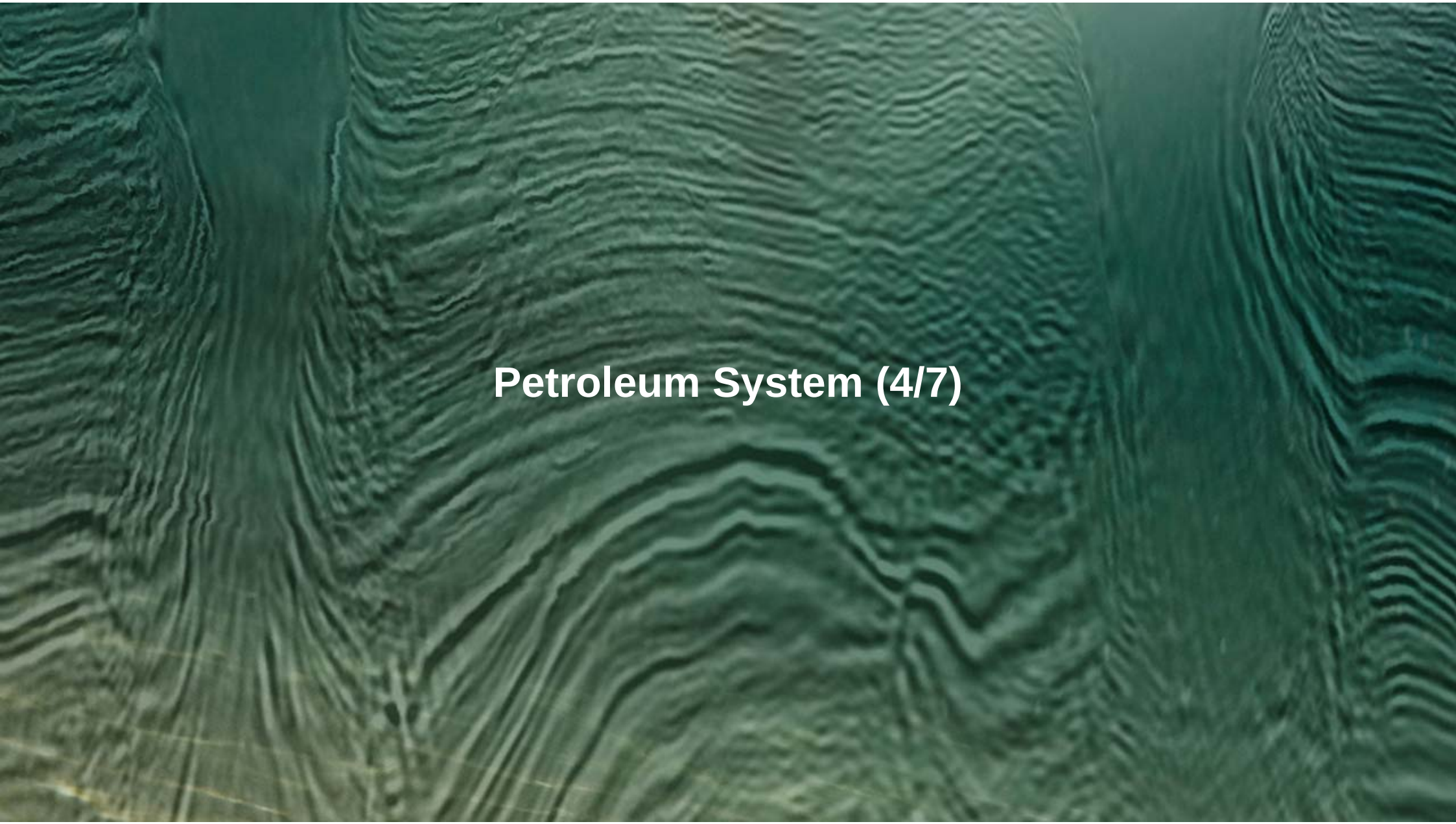

Petroleum System (4/7)

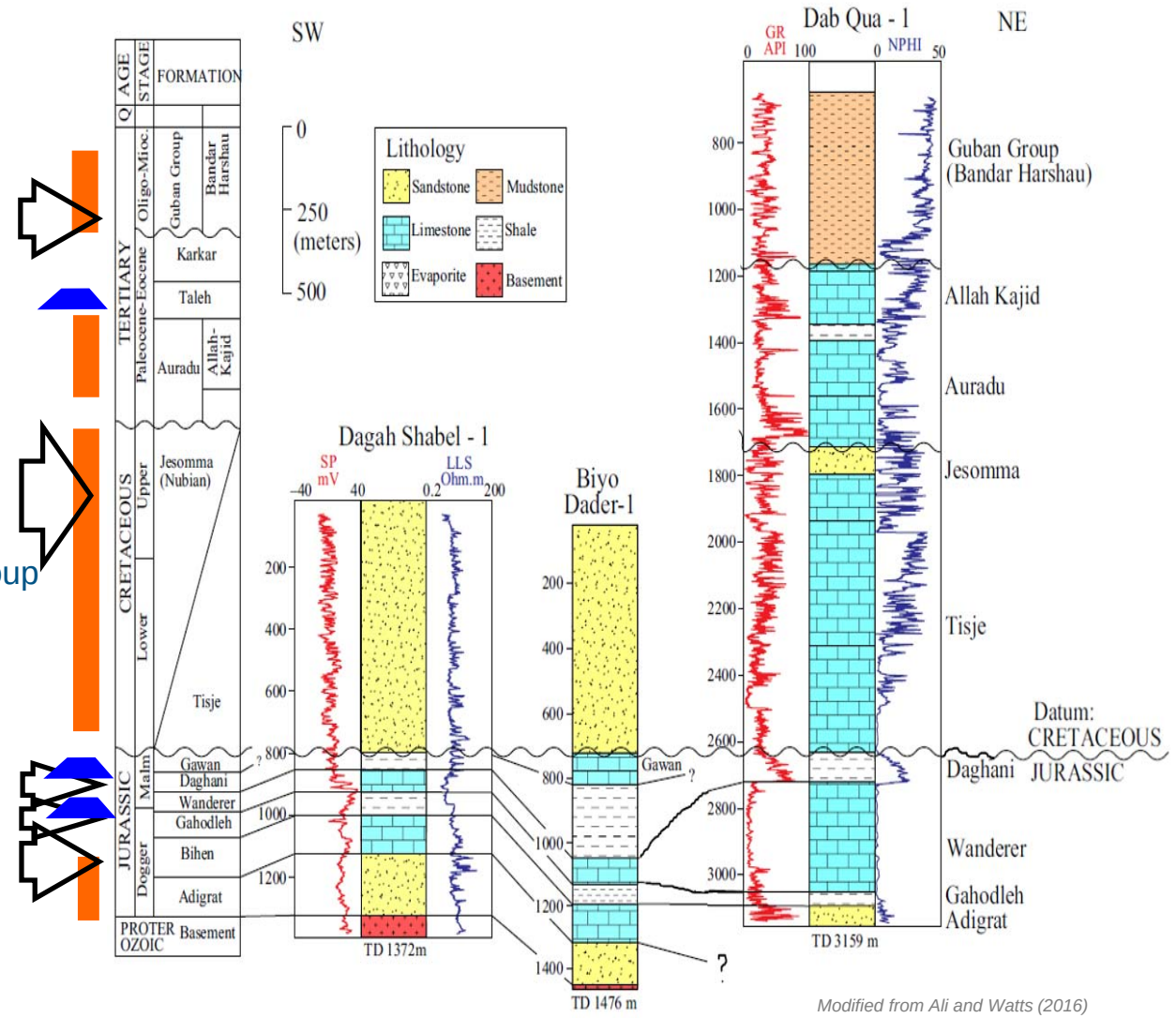
Petroleum Systems

Tertiary Petroleum System:

- S
  - Eocene
  - Miocene
- R
  - Miocene Bandar Harshau Group: clastics, carbonates
- Eocene Taleh anhydrite
- Interbedded shales and mudstones

Mesozoic Petroleum System:

- S
  - Jurassic Bihen, Gahodleh, Daghani Group
  - Cretaceous Jesomma shale
- R
  - Jurassic Adigrat
  - Cretaceous Jesomma/Tisje
  - Paleocene Aurado Formations
  - Miocene Bandar Harshau Group: clastics, carbonates
- Eocene Taleh anhydrite
- Interbedded shales and mudstones



Modified from Ali and Watts (2016)

Trap Types Related To Late Jurassic and Oligo-Miocene Rifting

Structural Traps :

- tilted fault blocks and drag folds
- flower structures (strike-slip movements)
- horsts and grabens

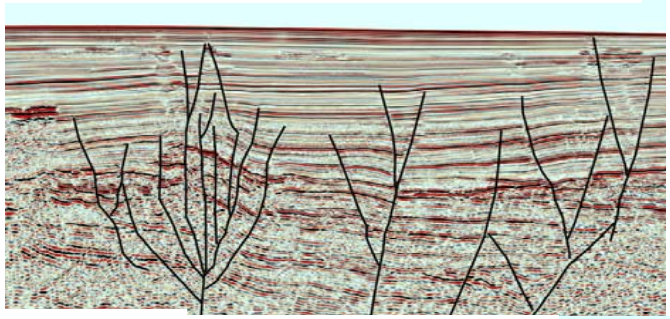
Stratigraphic Traps:

- syn-rift infill clastics with updip-pinchout
- ponded turbidites
- post-rift slope and basin floor fan
- carbonates buildups

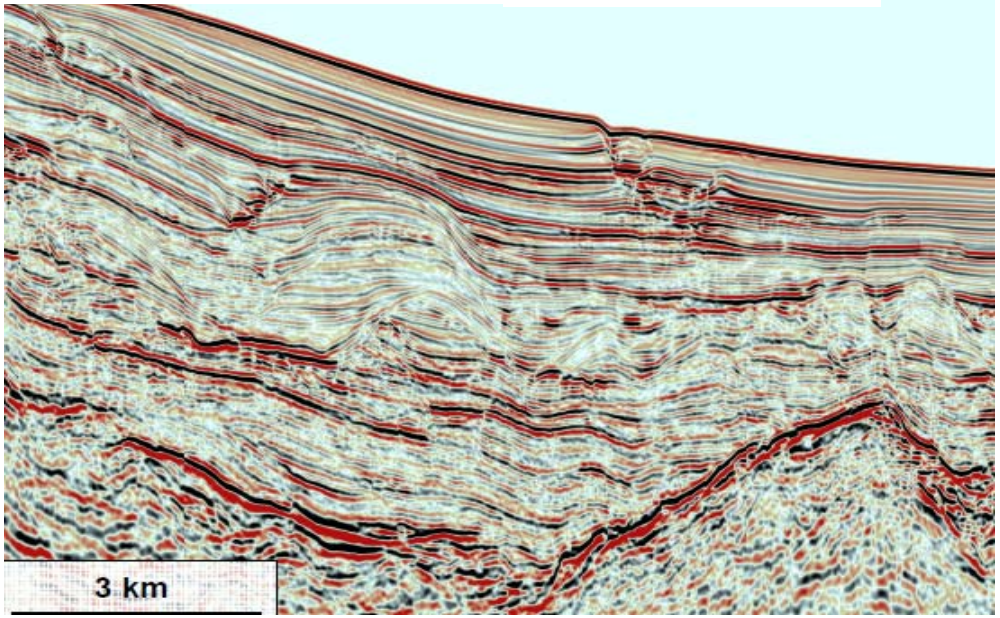
Combination traps:

- Syn- & post-transform transpressional anticlines

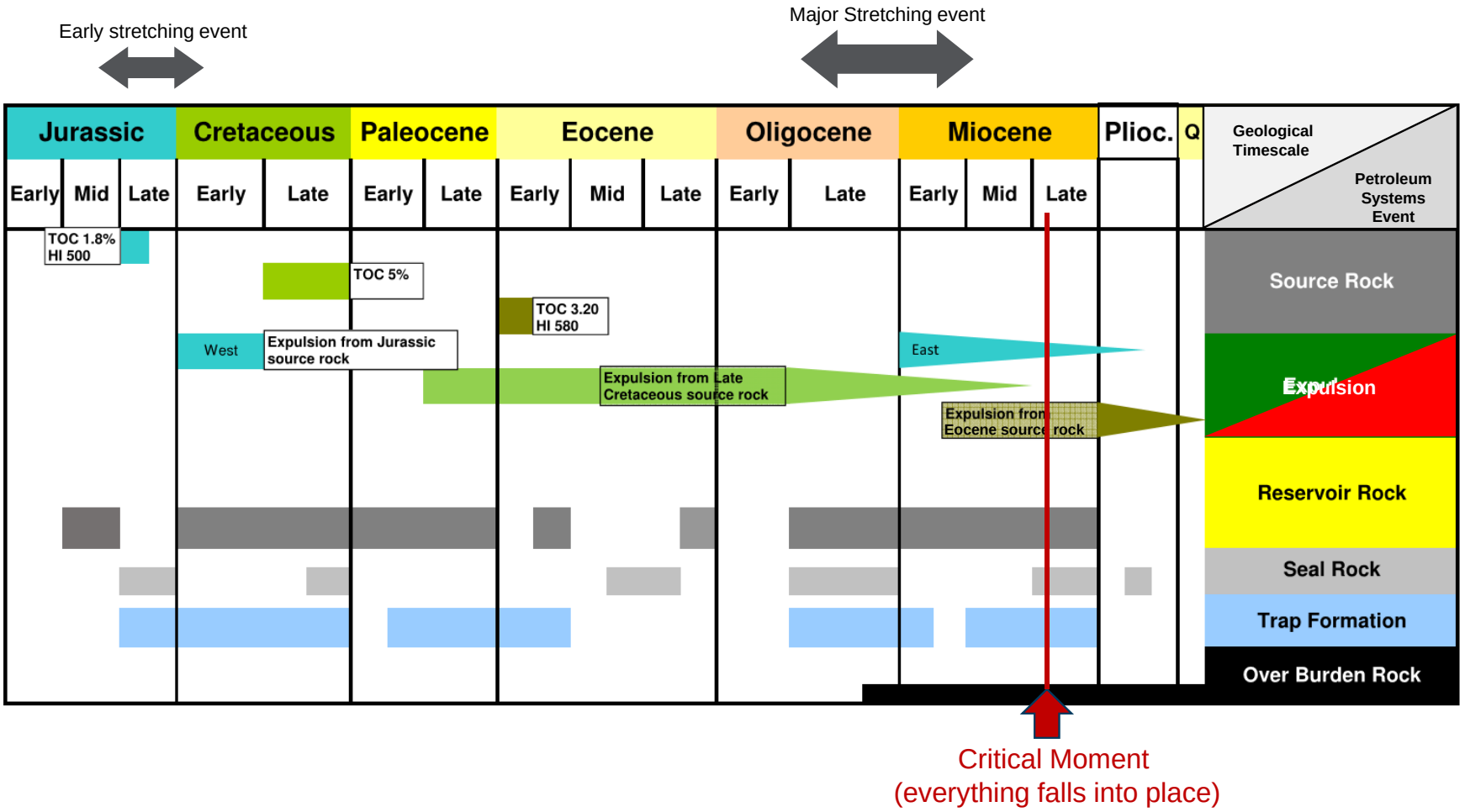
Example of flower Structure in the western offshore Somaliland.



Neogene stratigraphic play example(channels, onlaps, etc).



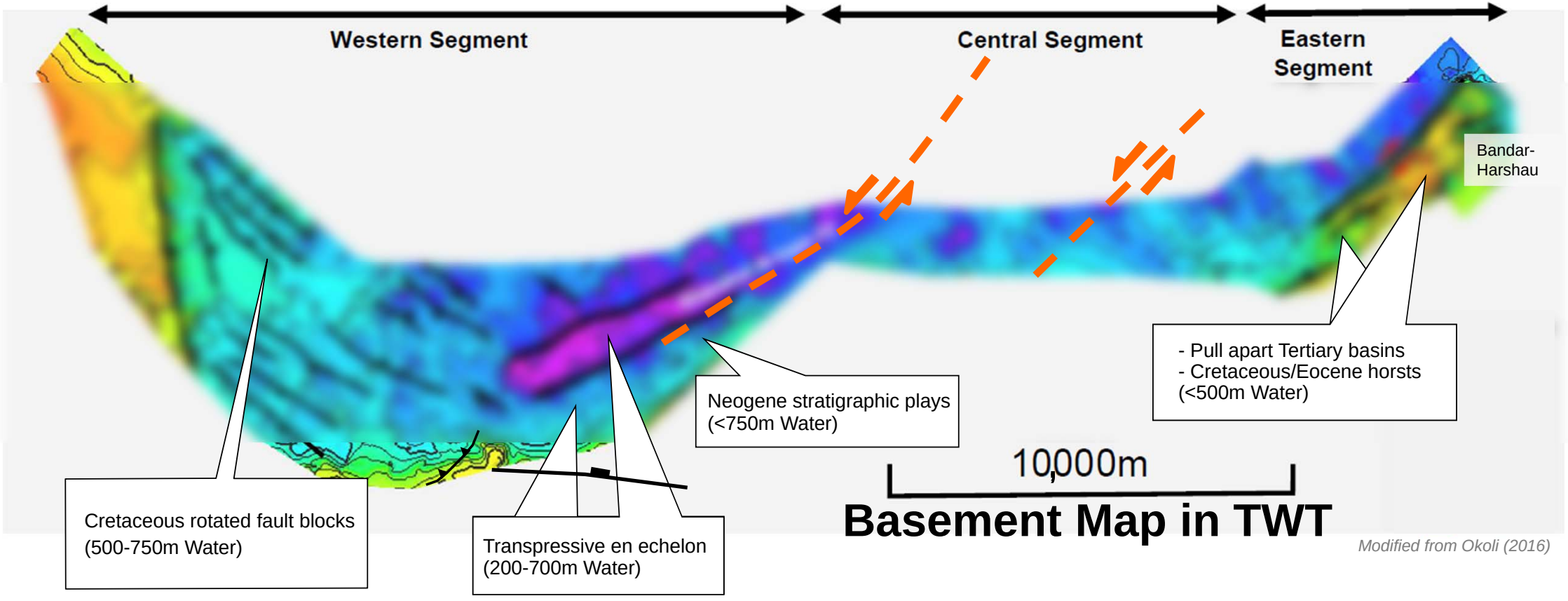
Petroleum System Events Chart




Offshore - Prospectivity (5/7)

Structural And Play Summary Offshore

Sub basins delineated and controlled by converging fault systems (on Basement map, TWT)

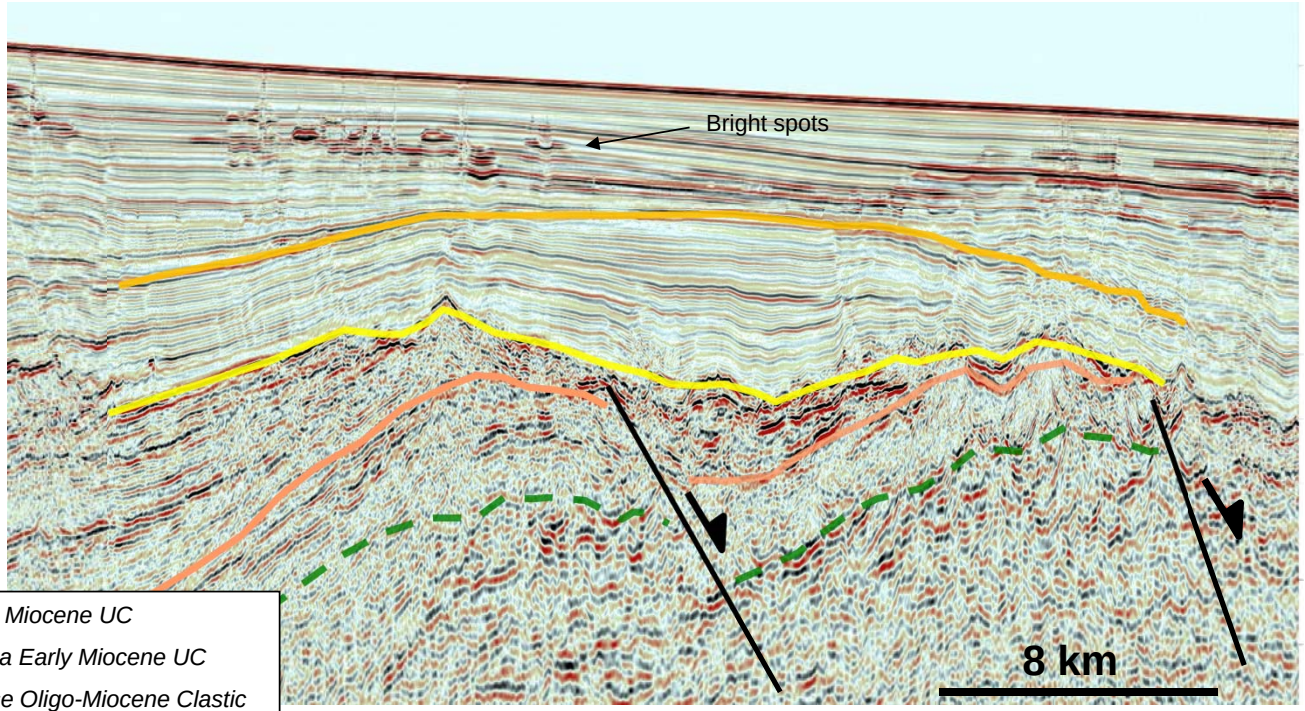


Modified from Okoli (2016)

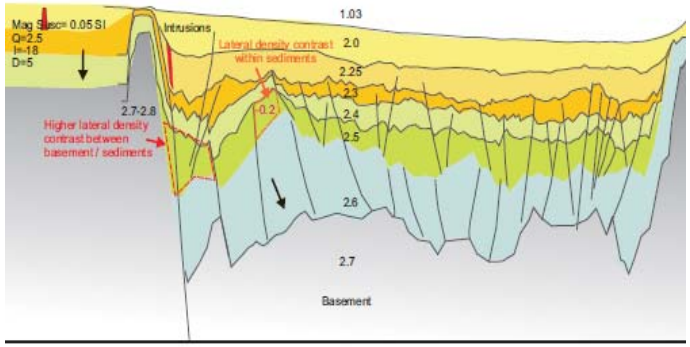
+ Grid map blurred for Confidentiality reasons+

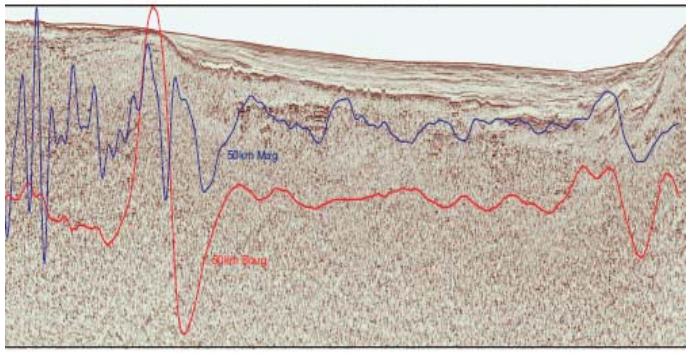
Potential Plays (Gravity Syn-rift Model For Underlying Crust)

- Tertiary slope fans
- Cretaceous rotated fault blocks



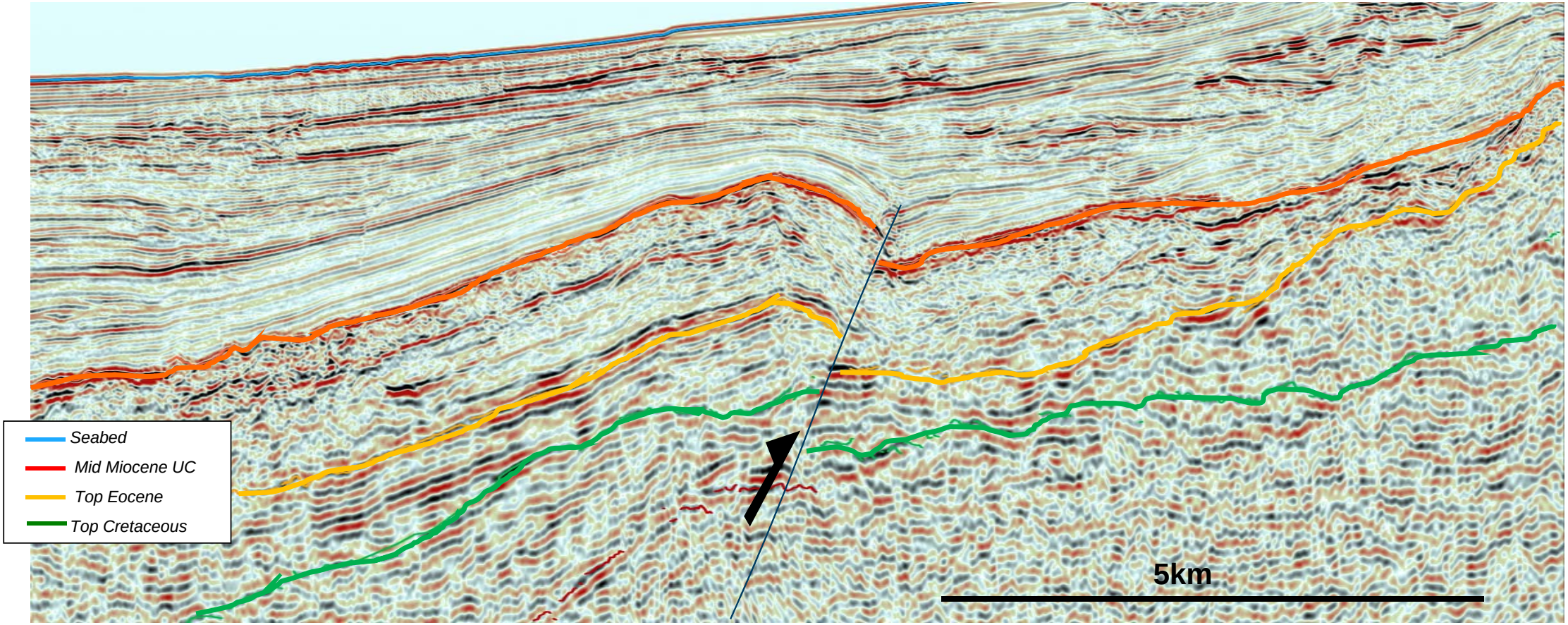
Transitional crust and sediment fill





Play Example Roll Over Anticline

Transpressive structures

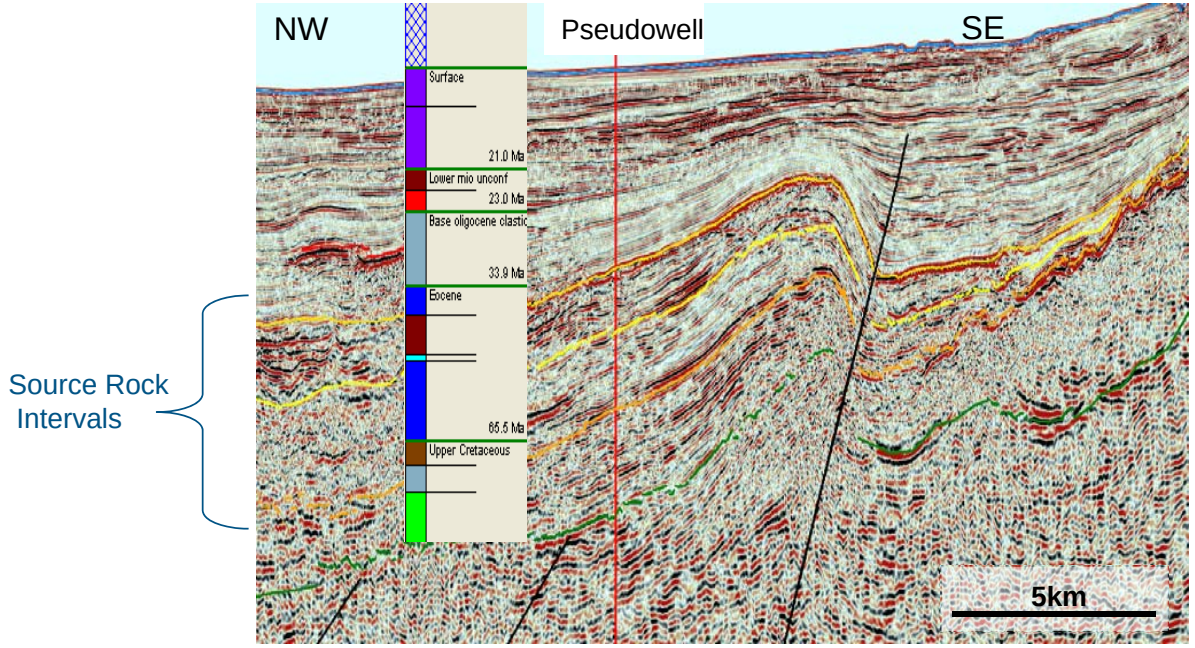


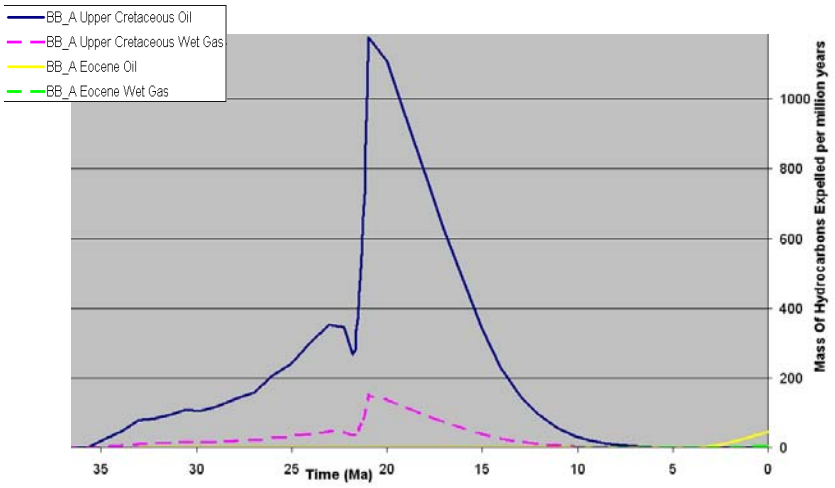
Source Rock Evaluation (Near Rollover Anticline Trap) – Pseudowell Offshore

Good temperature calibration with the crustal stretching model (Calibration well Bandar Harshau-1). Vitrinite calibration done with Dab Qua-1.

Modelled Source Rocks (Upr. Cretaceous, Lwr. Tertiary) are currently in the Oil window, and started expelling Mid Miocene.

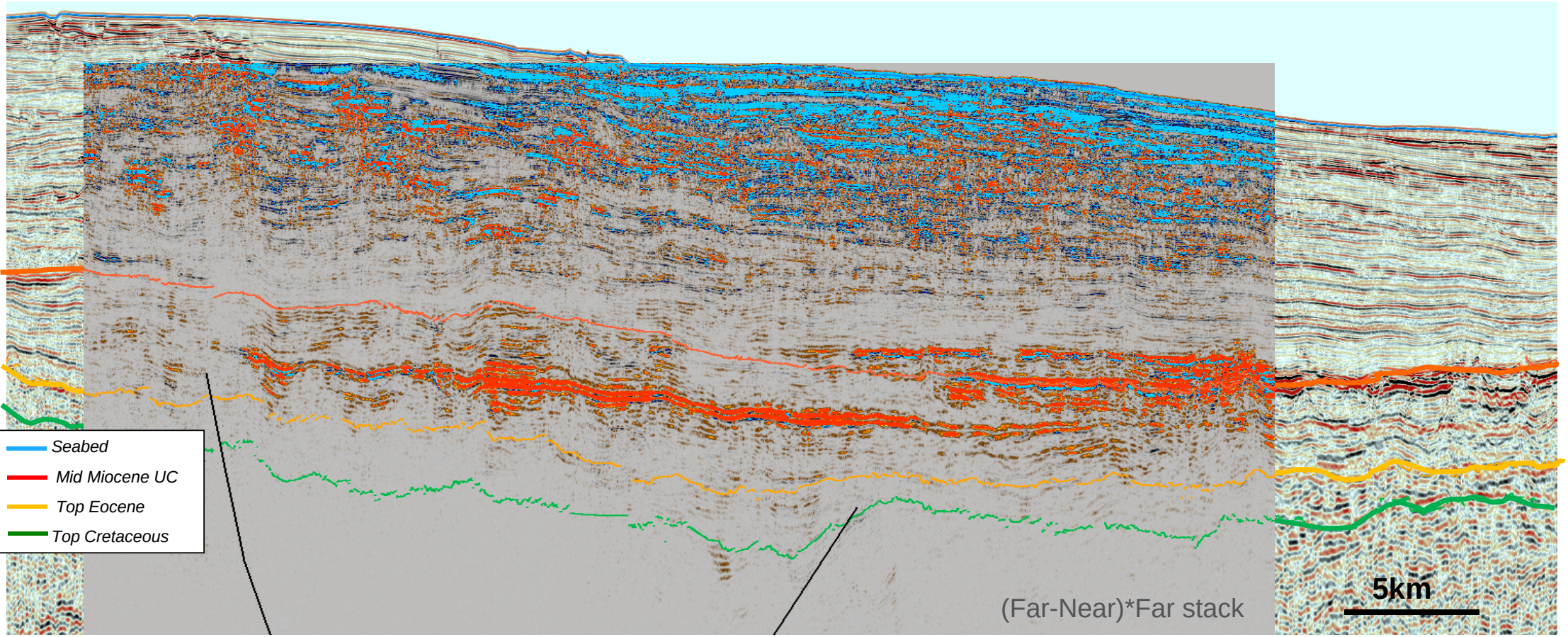
Maximum heat at present day (for Basement/Syn-rift levels), reaching 270°C.





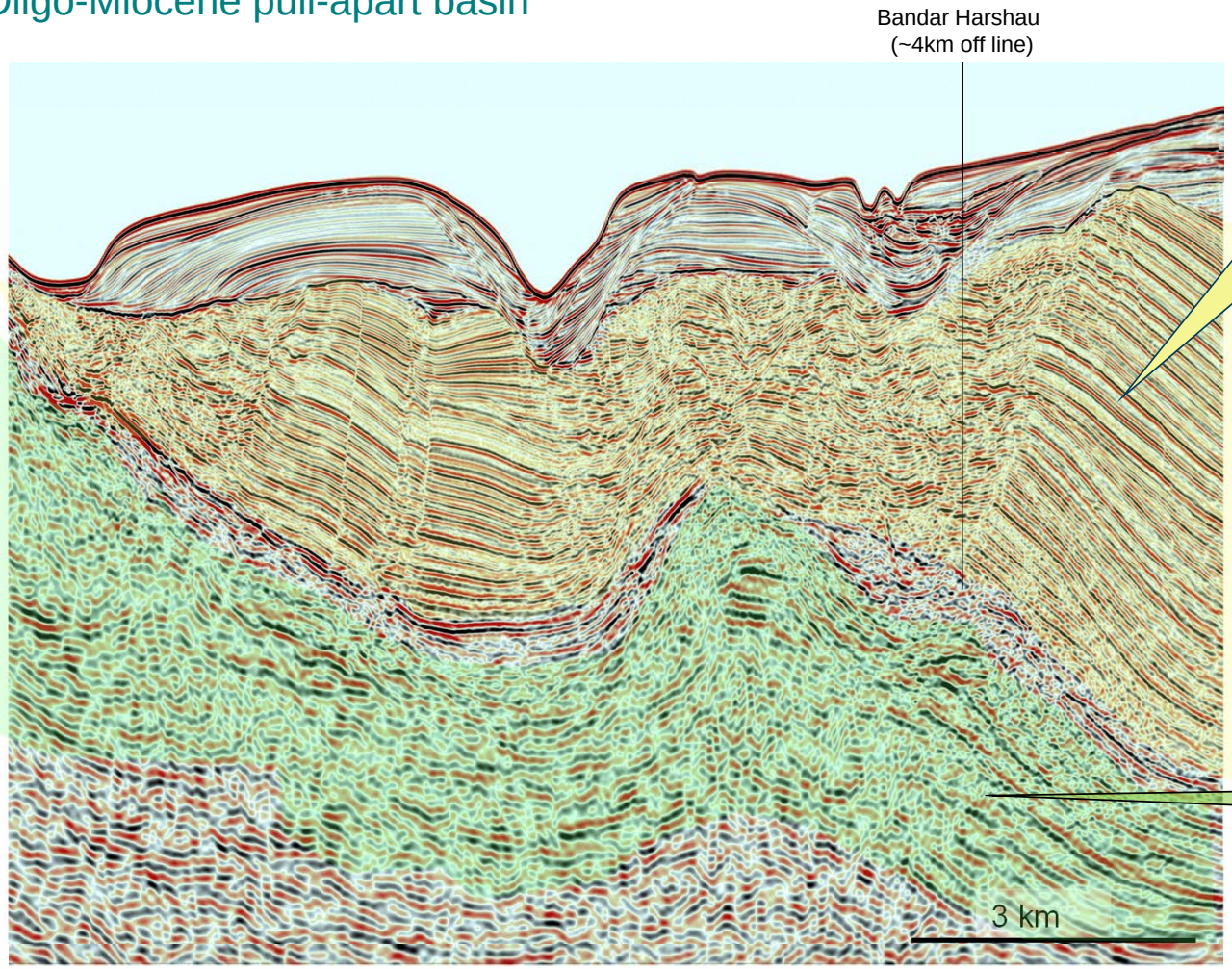
Play Example Oblique Strike - AVO Anomaly

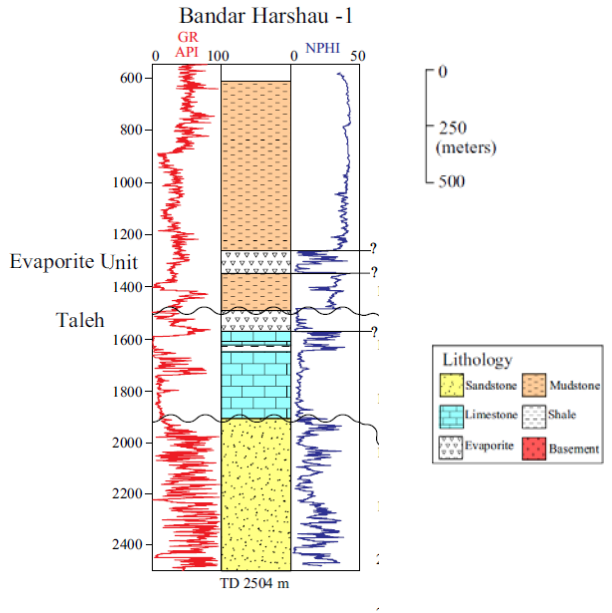
Slope fan class II/III AVO in Oligo-Miocene syn-rift (up to ~200km^2)



Bandar Harshau Basin (Eastern) Example

Oligo-Miocene pull-apart basin






Onshore – Potential (6/7)

Aeromagnetics Onshore – Geological Domains Of Interest

1. High amplitude, high frequency pattern.

   W-E trending densely clustered small scale features, most likely shallow.

   → **Possibly Miocene Volcanism over Rift Basins**

2. Low amplitude, low frequency pattern.

   NW-SE trending continuous regional features.

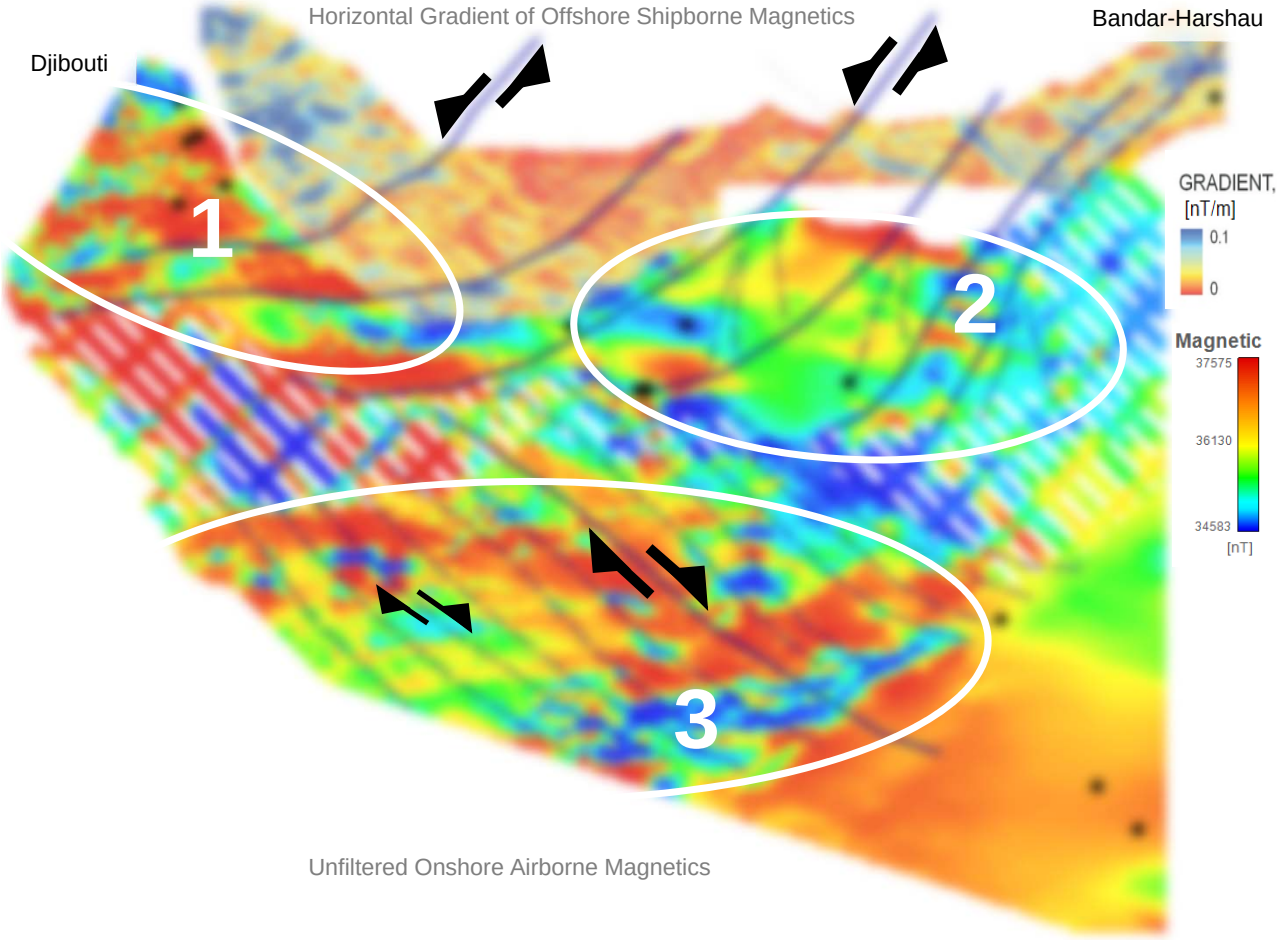
   → **Possible Halfgraben as offshore E and NE**

3. Variable amplitude, high and medium frequencies

   W-E trending superimposed small and large scale features.

   → **Possibly Basins with intra-basinal fault related structures and traps**

   Nogal Rifting WNW-ESE trends (E of survey)



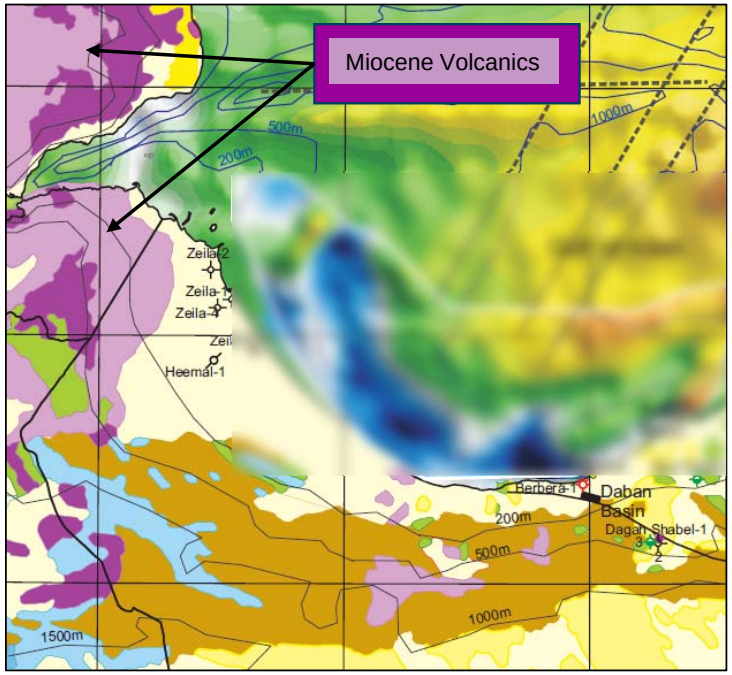
+ Grid map blurred for Confidentiality reasons+

Aeromagnetics Onshore – Domain #1

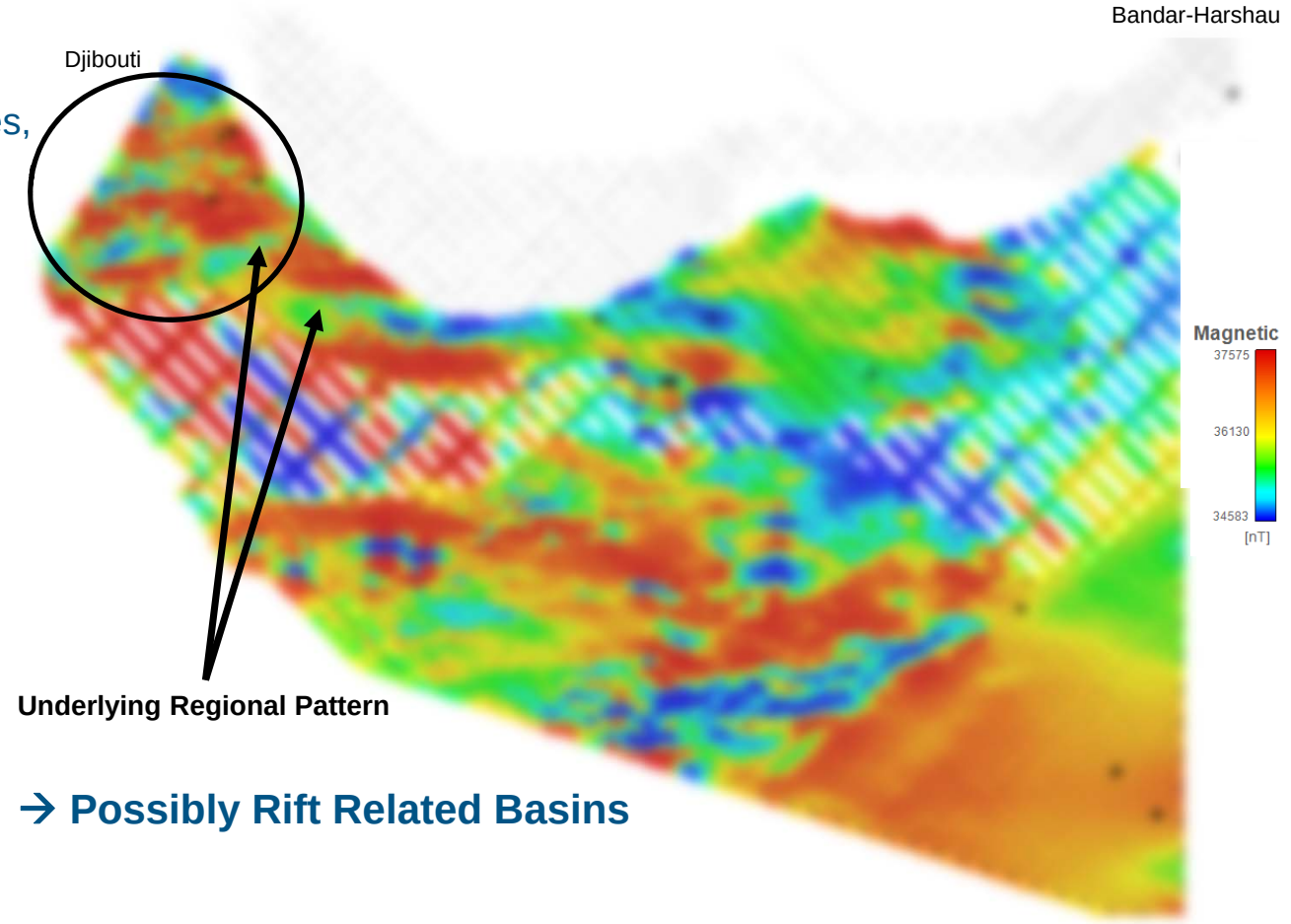
High amplitude, high frequency pattern.

W-E trending densely clustered small scale features, most likely shallow

→ **Possibly related to Miocene Volcanism**



Geology onshore (EFA project, Ed Purdy)

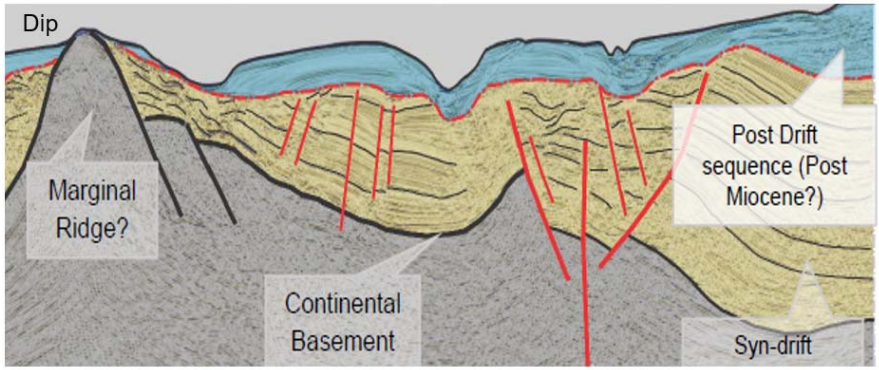


→ **Possibly Rift Related Basins**

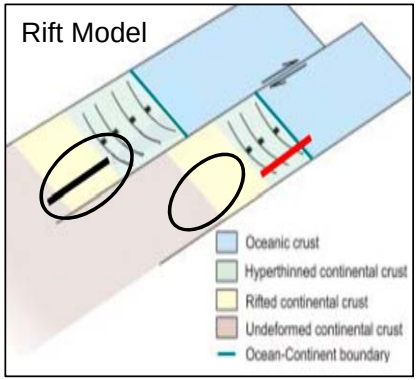
Aeromagnetics Onshore – Domain #2

Low amplitude, low frequency pattern. NW-SE trending features.

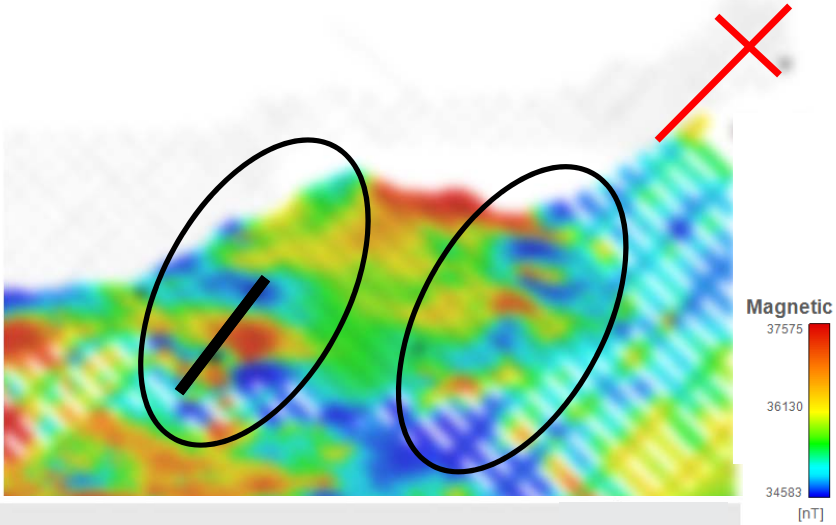
→ **Likely onshore set of halfgraben as in continuation offshore N and NE**



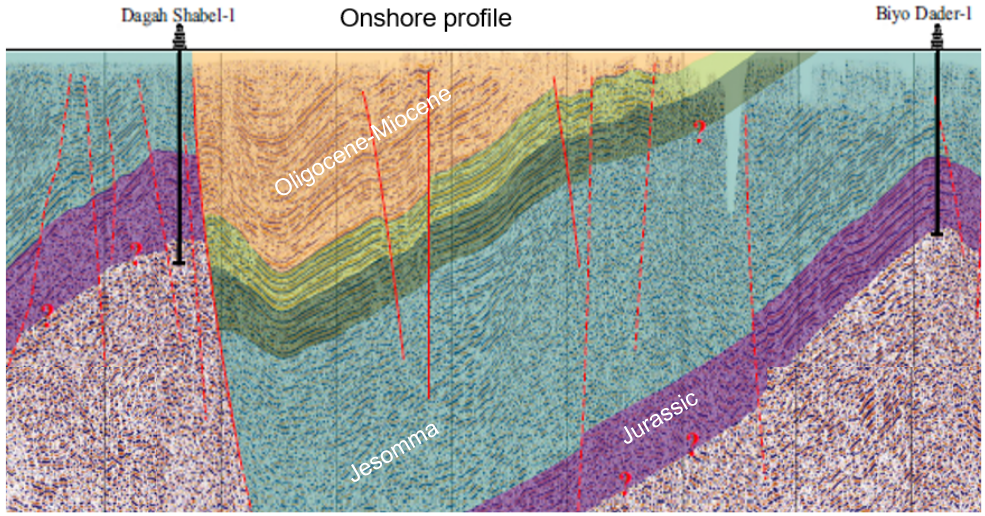
Okoli (2016)

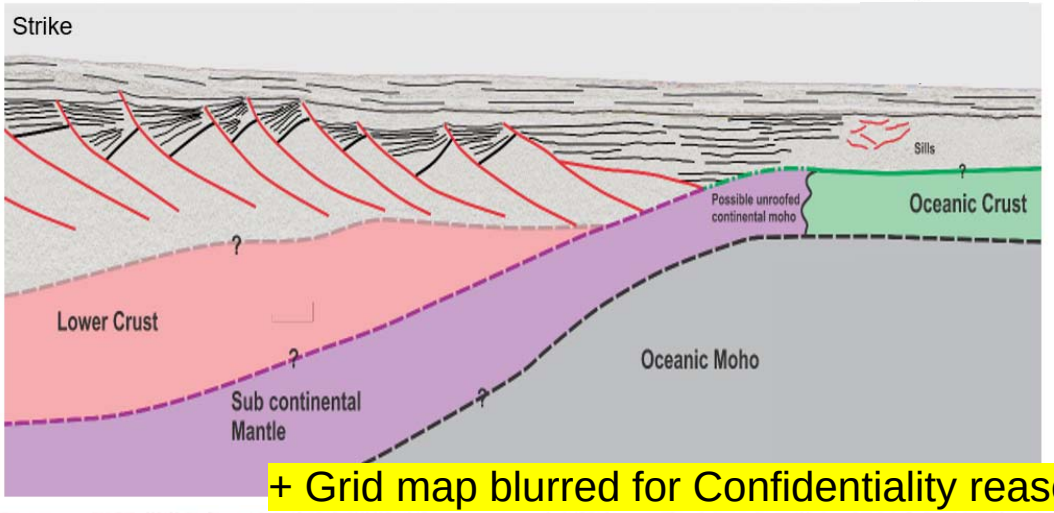


Okoli (2016)



Ali (2016)





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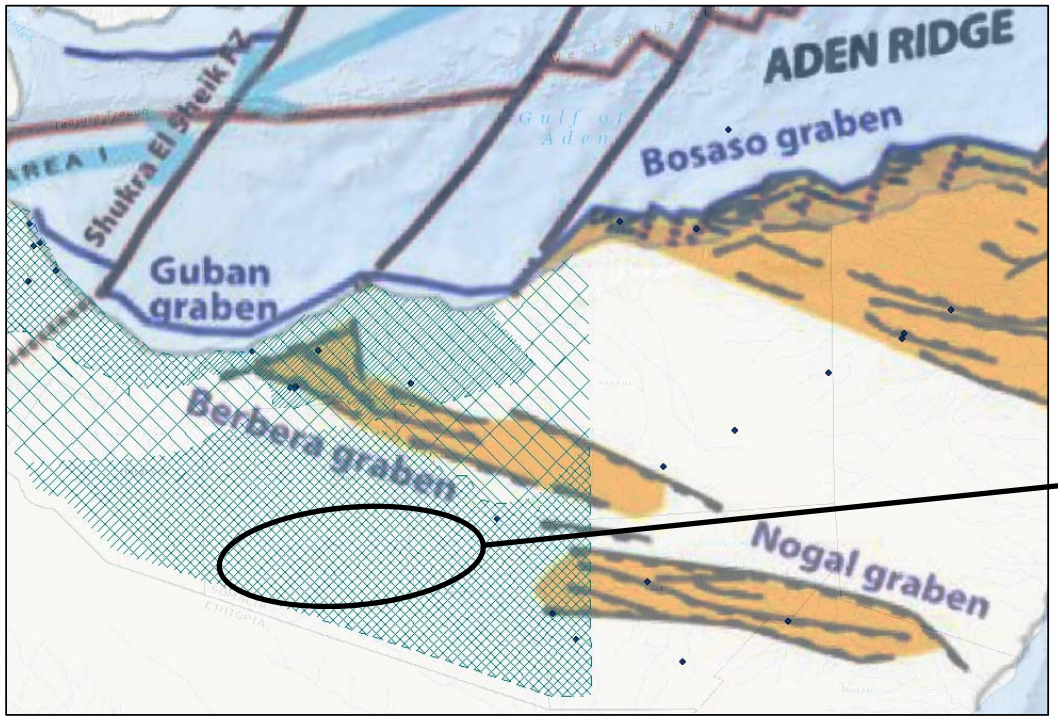
Aeromagnetics Onshore – Domain #3

Variable amplitude, high and medium frequencies.

W-E trending superimposed small scale and large scale features.

→ **Deep regional structures, possible Jurassic rift basins (Nogal)**

→ **Offsets by NW-SE strike-slip faulting (Nogal Rifting trend)**



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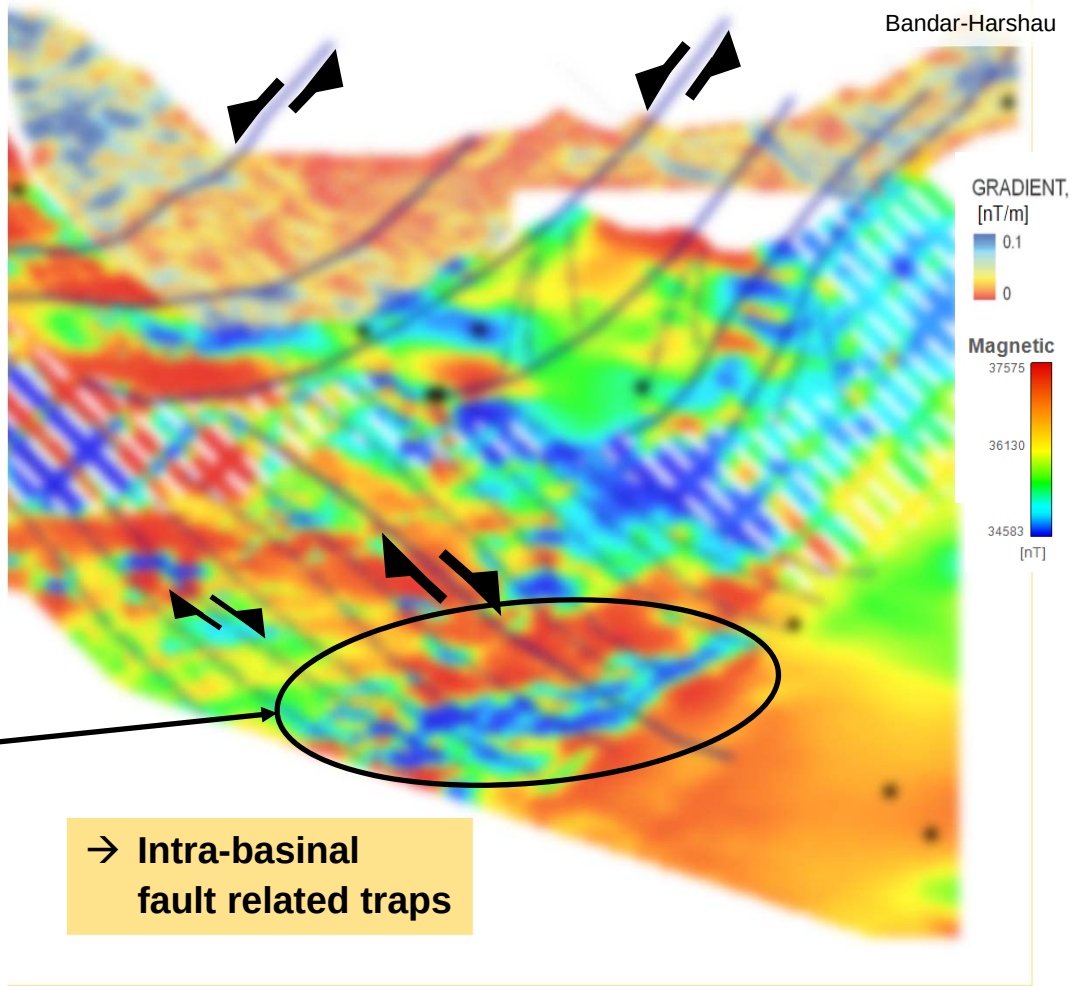


→ **Intra-basinal fault related traps**

+ Grid map blurred for Confidentiality reasons+

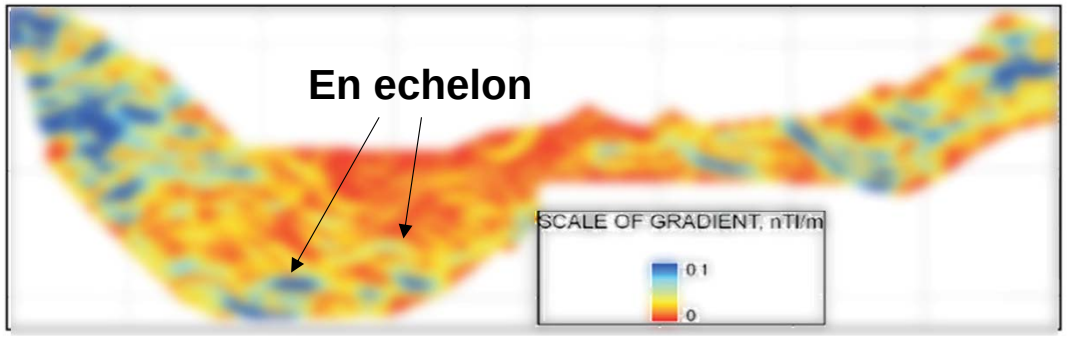
Aeromagnetics Onshore – Domain #3 - Note

Variable amplitude, high and medium frequencies.

W-E trending superimposed small scale and large scale features.

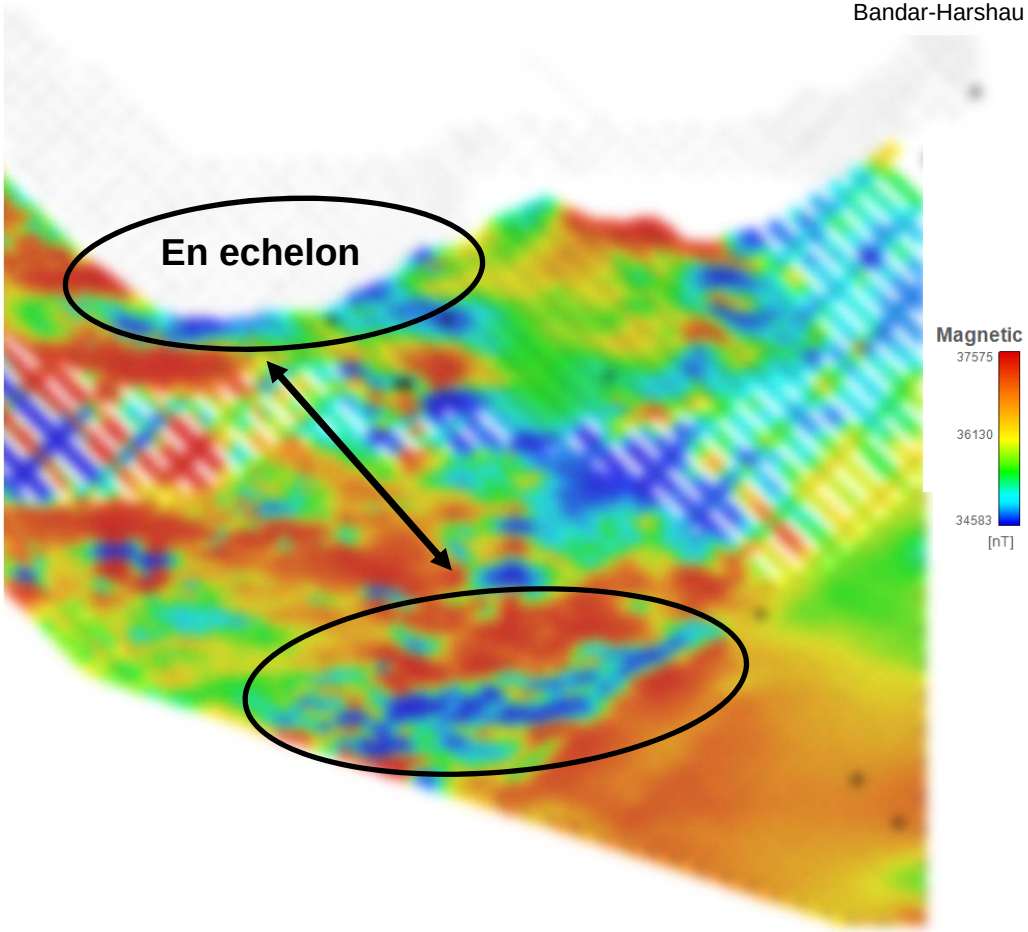
- → Deep regional structures, possible Jurassic rift basins (Nogal)
- → Offsets by NW-SE strike-slip faulting (Nogal Rifting trend)
- → Intra-basinal fault related traps
- ➔ **Note: The deep basin structures onshore seem to follow the same trend as the pull-apart en echelon basins (oblique rifting offshore)**

Horizontal Gradient of Magnetic Anomalies RTE



Transtensional/transpressive En echelon structures in Water Depths of 200-700m

Bandar-Harshau



+ Grid map blurred for Confidentiality reasons+


Summary (7/7)

Somaliland. Untested Plays Revealed by TGS Data - Content

1. Where are we?
2. Why re-enter Somaliland?
3. Structural Framework.
4. Building Blocks of the Petroleum System.
5. Offshore - What does that mean for the Prospectivity?
   → Insights based on TGS 2D regional Seismic
6. Onshore Airborne Magnetics - Implications for the onshore Potential.
7. Summary.

1. Conjugate to Yemen

(producing fields)

2. Hydrocarbon evidence

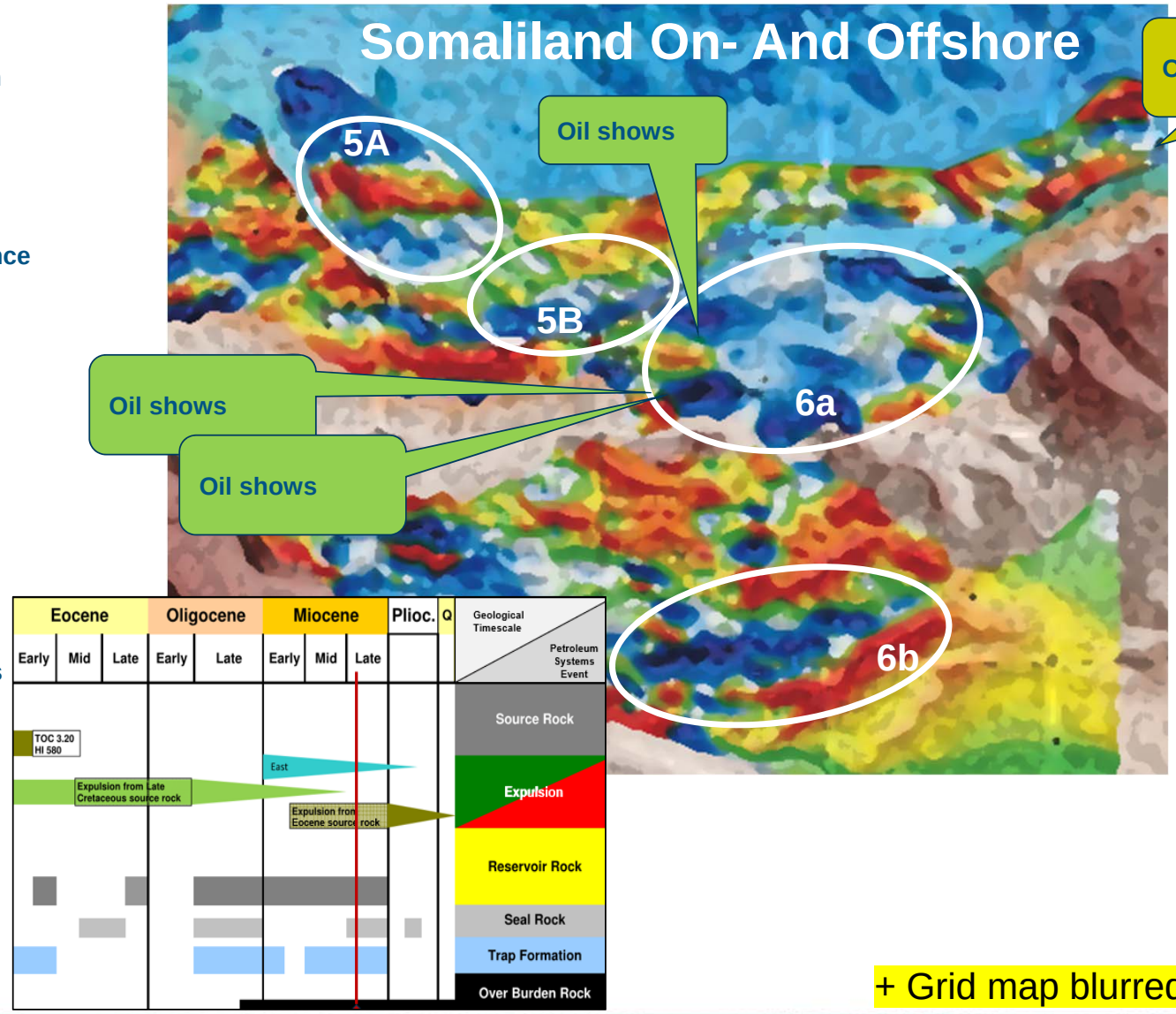
- onshore seeps
- oil/gas shows onshore
- oil/gas shows offshore

3. Rift basin regimes

- Mesozoic rift onshore
- Tertiary rift offshore

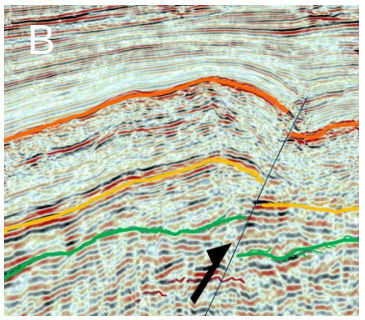
4. Tested source rocks

- Jurassic
- Cretaceous
- Eocene/Miocene



5. Prospectivity offshore showcased

- Rotated fault blocks (A)
- Transgressive structures (B)
- Stratigraphic plays
- Seal and overburden in place
- AVO brightening of slope fans
- Traps in place for expulsion



6. Onshore potential is promising

a) Halfgraben structures
b) Basins with fault related traps

+ Grid map blurred for Confidentiality reasons+

Thank you

Felicia.Winter@tgs.com