AAPG Annual Convention & Exhibition 2015
with SEPM (Society for Sedimentary Geology)
31st May- 3rd June, Denver, Colorado

New Opportunities in Challenging Time

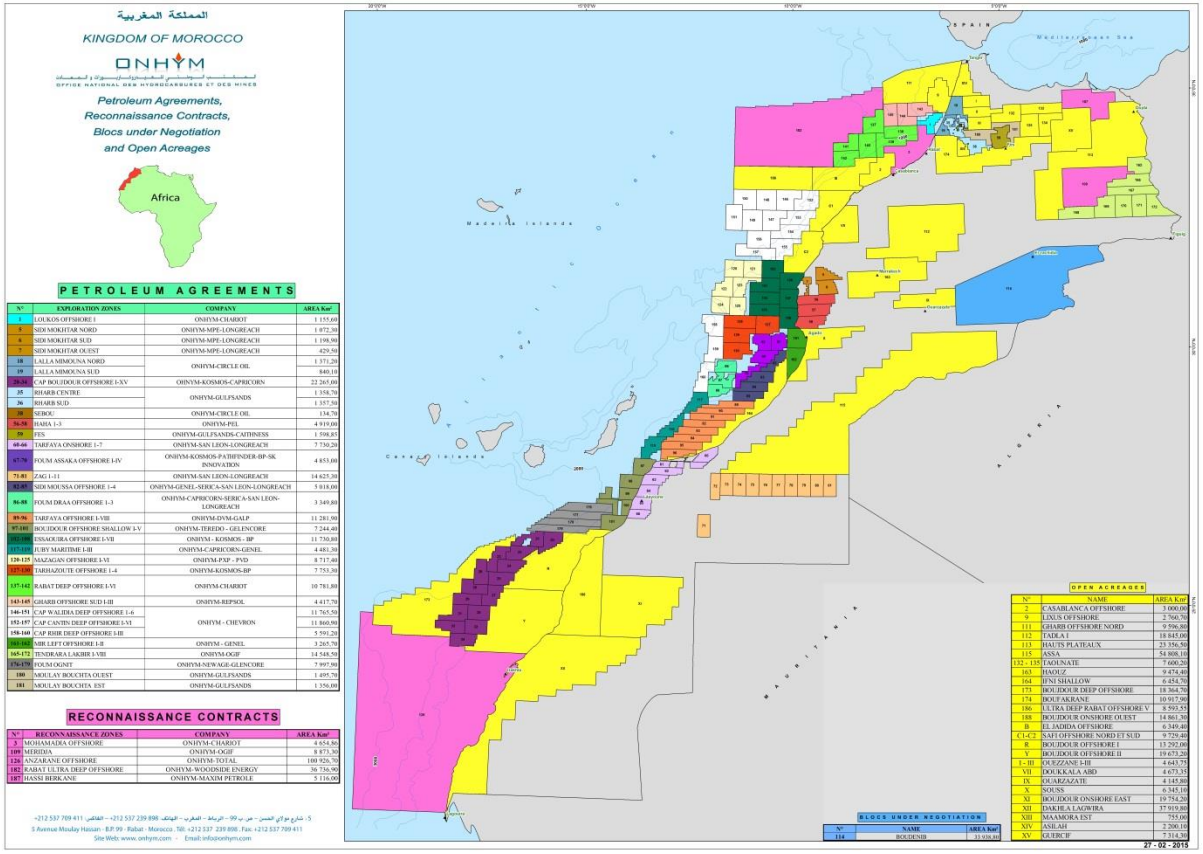
Presented by K. GUERNOUCHE

ONHYM

KEY ASPECTS OF MOROCCO

- A good business environment
- An appropriate institutional framework
- A competitive and fair contract
- A prolific geology
- Encouraging indications of working petroleum systems

EXPLORATION STATUS



Onshore & Offshore

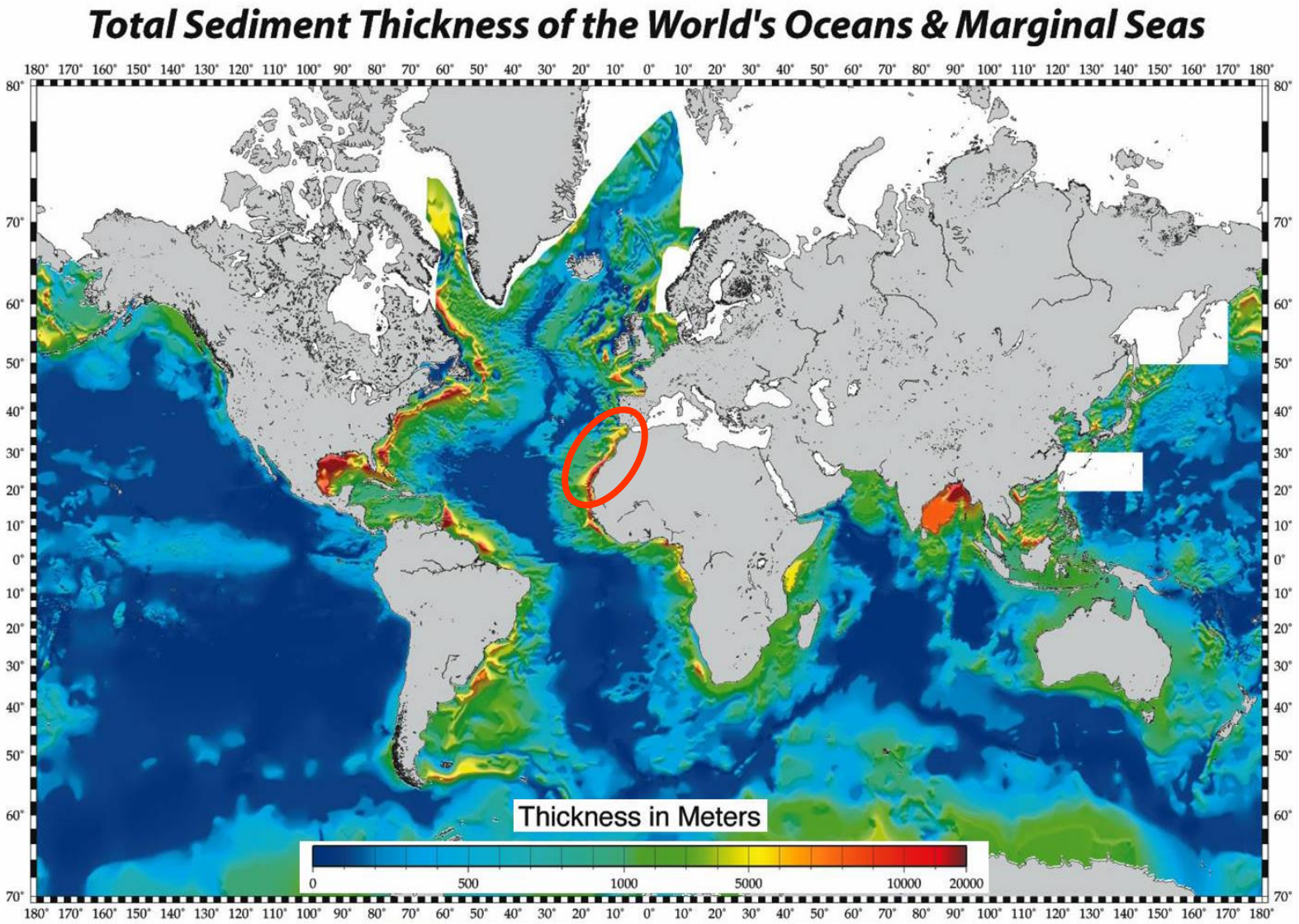
- **33** Petroleum Agreements
- **5** Reconnaissance licences
- **1** block under negotiation

Seismic & Wells Database

- **231 418 Km** of 2D seismic
- **45 797 Km²** of 3D seismic
- **324** Exploration wells

(42 in Offshore)

MOROCCAN SEDIMENTARY BASINS

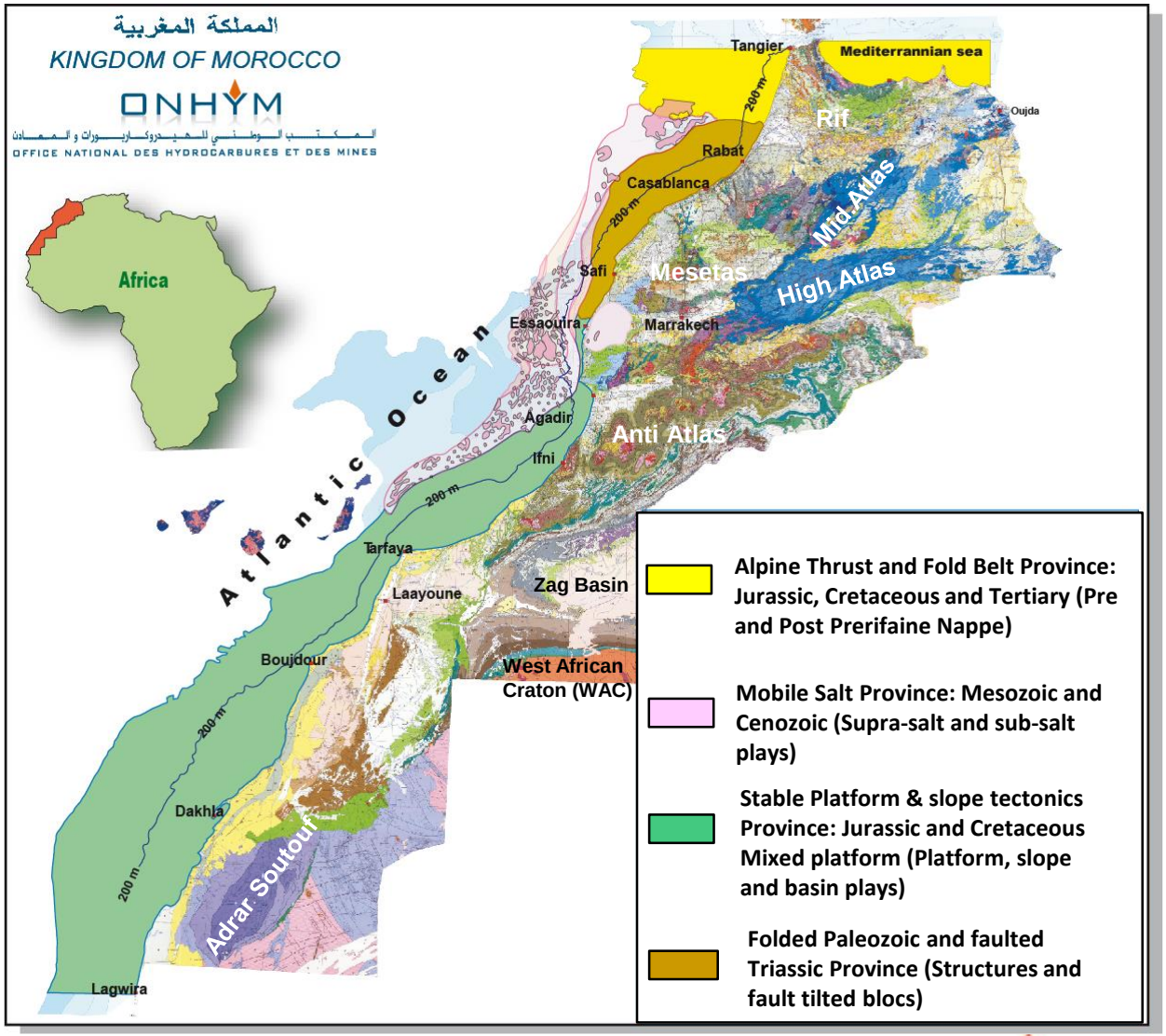


By the National Geophysical Data Center (NGDC)

GEOLOGICAL SNAPSHOT : OFFSHORE

Objectives ranging from Paleozoic to Neogene in four main provinces

- **Alpine thrust and fold belt province (Jurassic, Cretaceous and Tertiary)**
- **Northern Shallow Offshore Province (Paleozoic and Triassic)**
- **Mobile salt province (Jurassic, Cretaceous and Tertiary)**
- **Platform and Deep Offshore Province (Jurassic, Cretaceous and Tertiary)**



PALAEOZOIC PETROLEUM SYSTEMS: SILURIAN / ORDOVICIAN-DEVONIAN

Source Rocks

Silurian generated 9% & Upper Devonian-Tournaisian 8% of the world's reserves (North Africa)

Silurian source rock

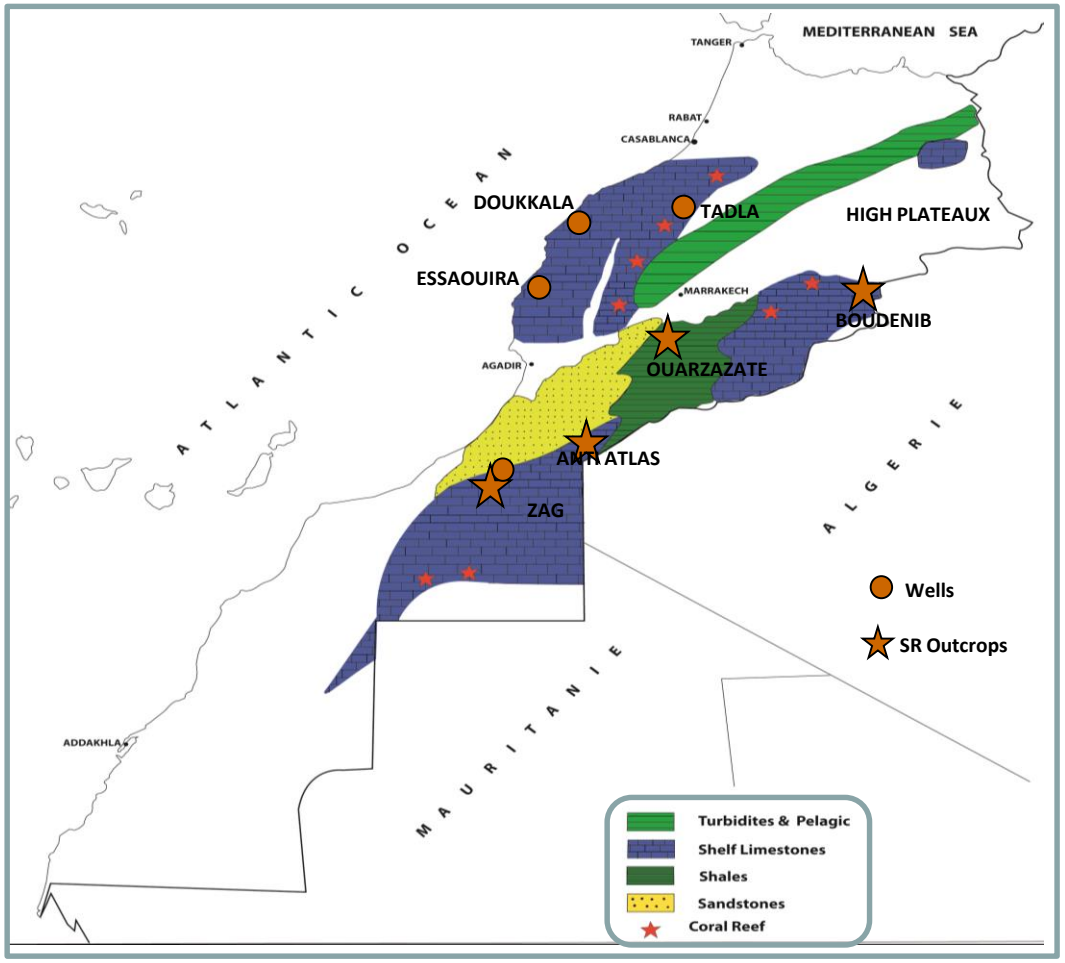
- Oil and Gas shows in Essaouira, Doukkala and Tadla Basins (TOC up to 12.12% in Tadla basin)
- Gas shows in the Zag Basin (TOC up to 1.89% and OD-1 Oil and Gas shows);
- Anti Atlas TOC up to 12.1%

Frasnian source rock (up to 4.5 %TOC)

- Anti Atlas (Erfoud & Bas Draa)

Reservoir Rocks

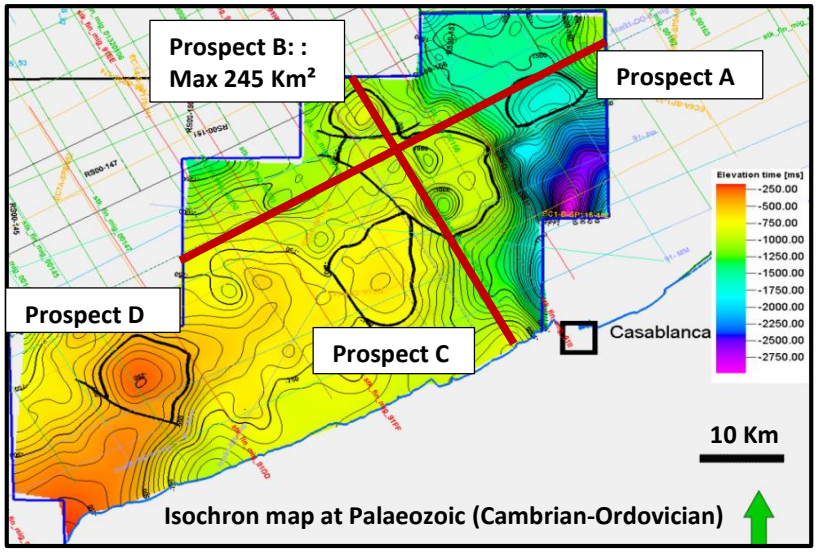
- Cambrian and Ordovician shallow marine sandstones
- Devonian Platform carbonates with Coral and patch reefs
- Upper Devonian and Carboniferous turbidite sandstones

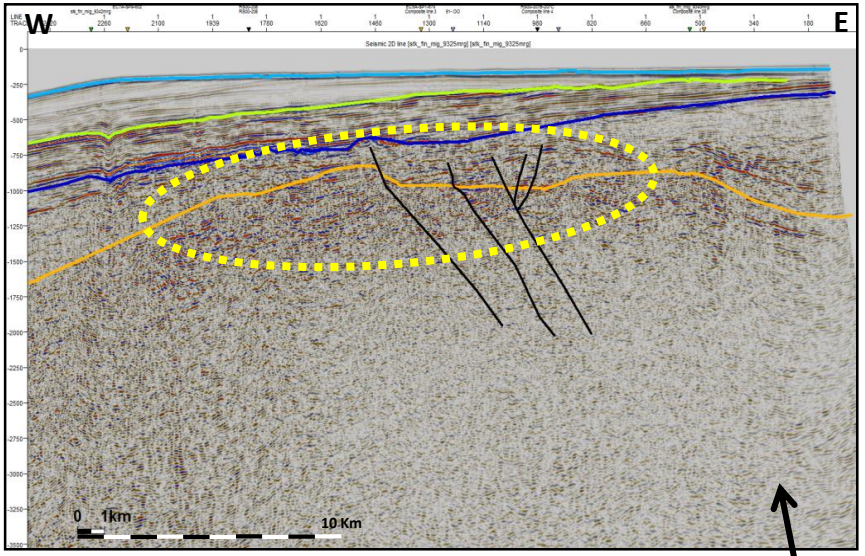


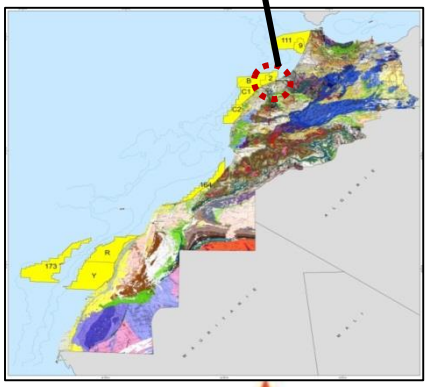
Facies distribution map (Devonian) and hydrocarbon shows at Palaeozoic

PALAEOZOIC PLAY CONCEPTS

Example of Palaeozoic structures (Casablanca Offshore)







1. Source : Silurian black shale
2. Migration: Lateral
3. Reservoir : Cambrian and Ordovician shallow marine sandstones
4. Seal: Triassic shale and evaporites
5. Trap: Faulted structures

ONHYM

PALEOZOIC-TRIASSIC PETROLEUM SYSTEMS: SILURIAN / TRIASSIC

Silurian Source Rocks

- Meskala and Zelten gas and condensate fields in onshore Essaouira basin
- Gas accumulations and shows in the High Plateaux (Tendrara) and Doukkala

Triassic Reservoir Rocks

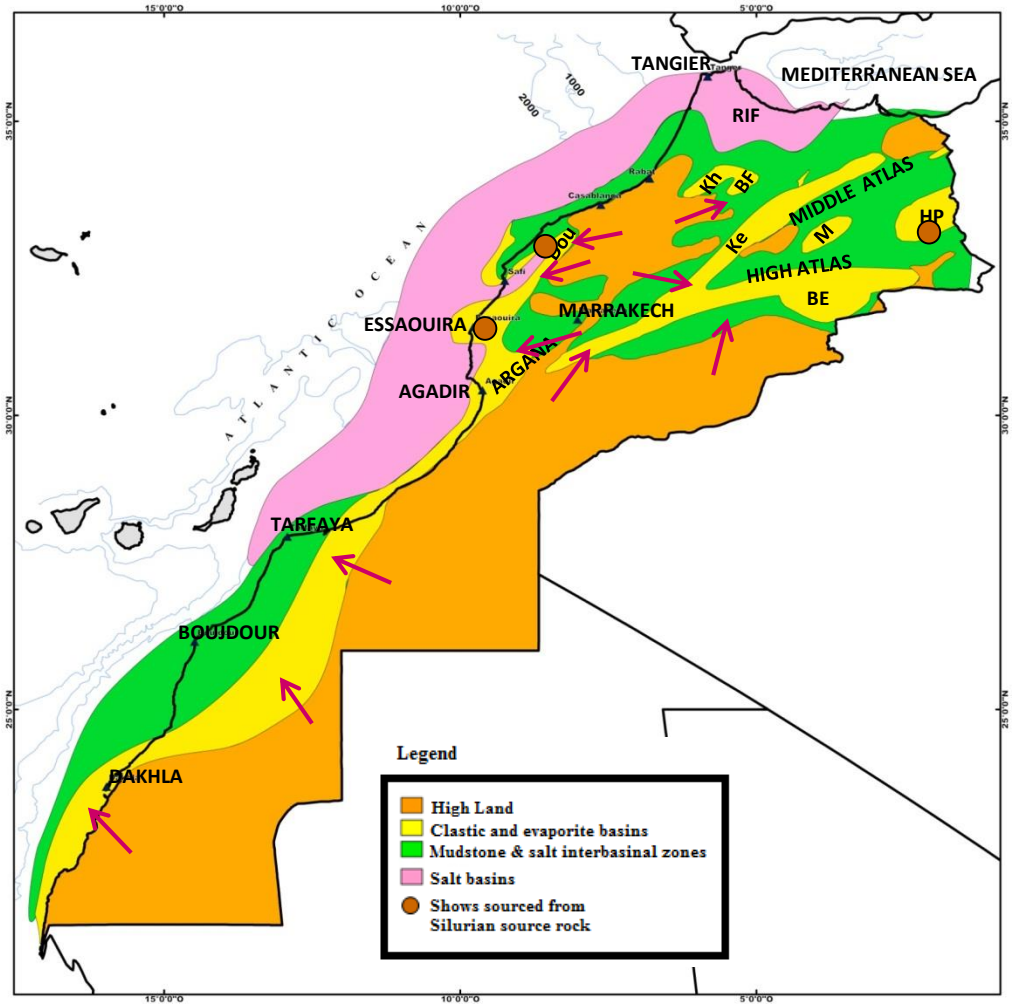
Upper Triassic continental red beds:

Atlantic Rift System (Essaouira & Doukkala)

- Two reservoir intervals with porosity ranging between 10% & 16% and thickness between 10 & 200 m, covalent of the Argana valley outcropping T4 and T6 fluvial sandstone formations

Tethys Rift System (High plateaux & Missour)

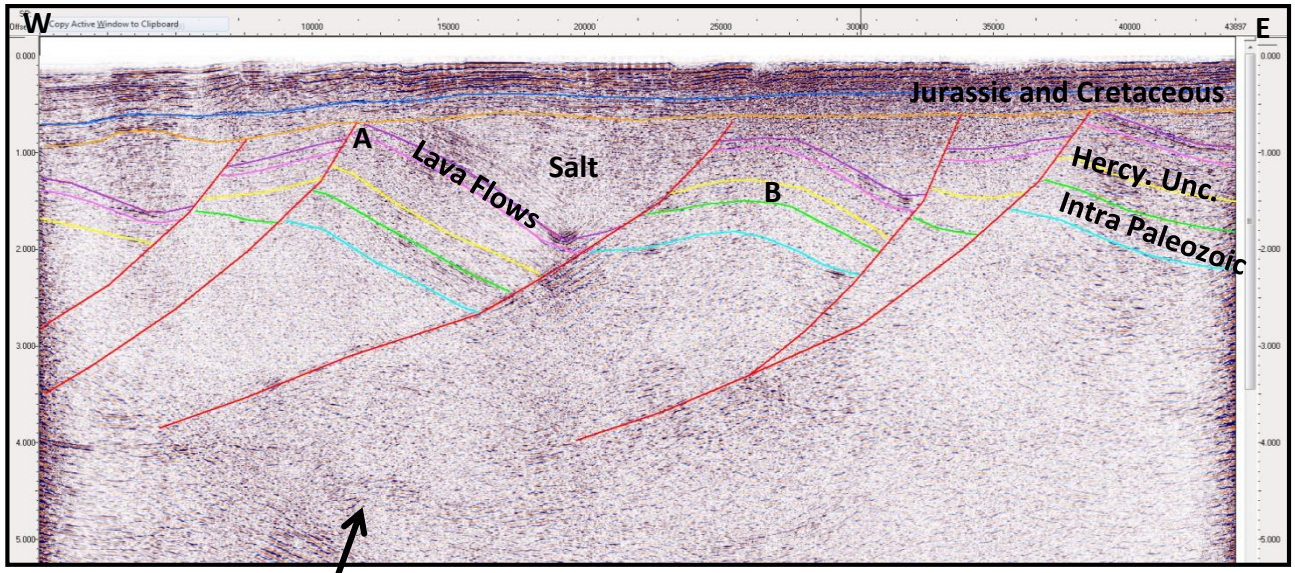
- Two fluvial sandstone reservoir intervals with porosity from 6 to 11% and net pay between 3 and 20m

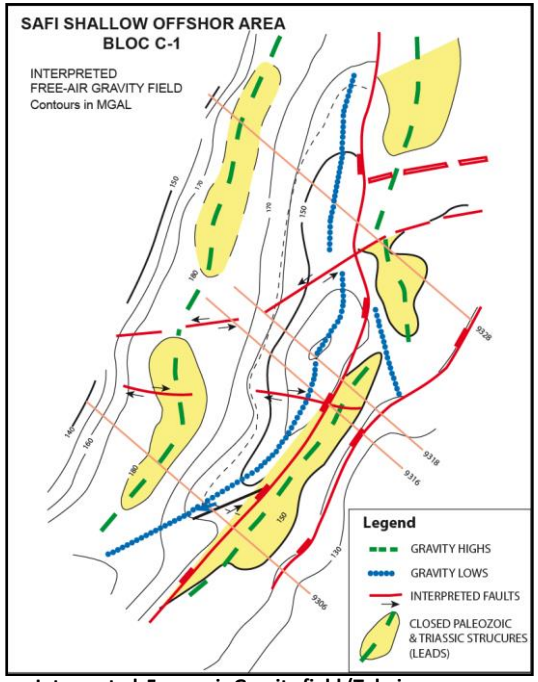


Facies distribution map and Hydrocarbon shows at Upper Triassic

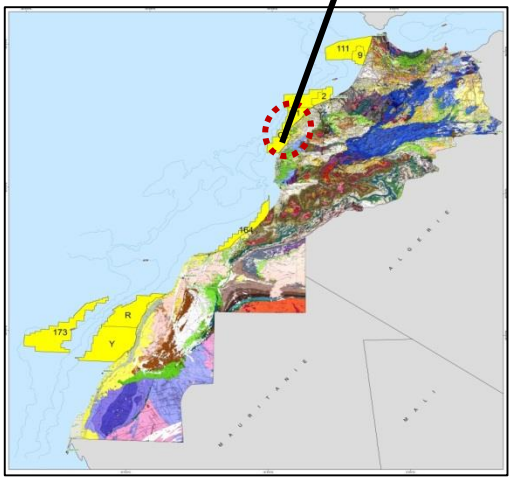
PALAEOZOIC & TRIASSIC PLAY CONCEPTS

Example of Triassic and Paleozoic structures (Safi Shallow Offshore)





Interpreted Free – air Gravity field (Teknica resource development LTD, 1987)

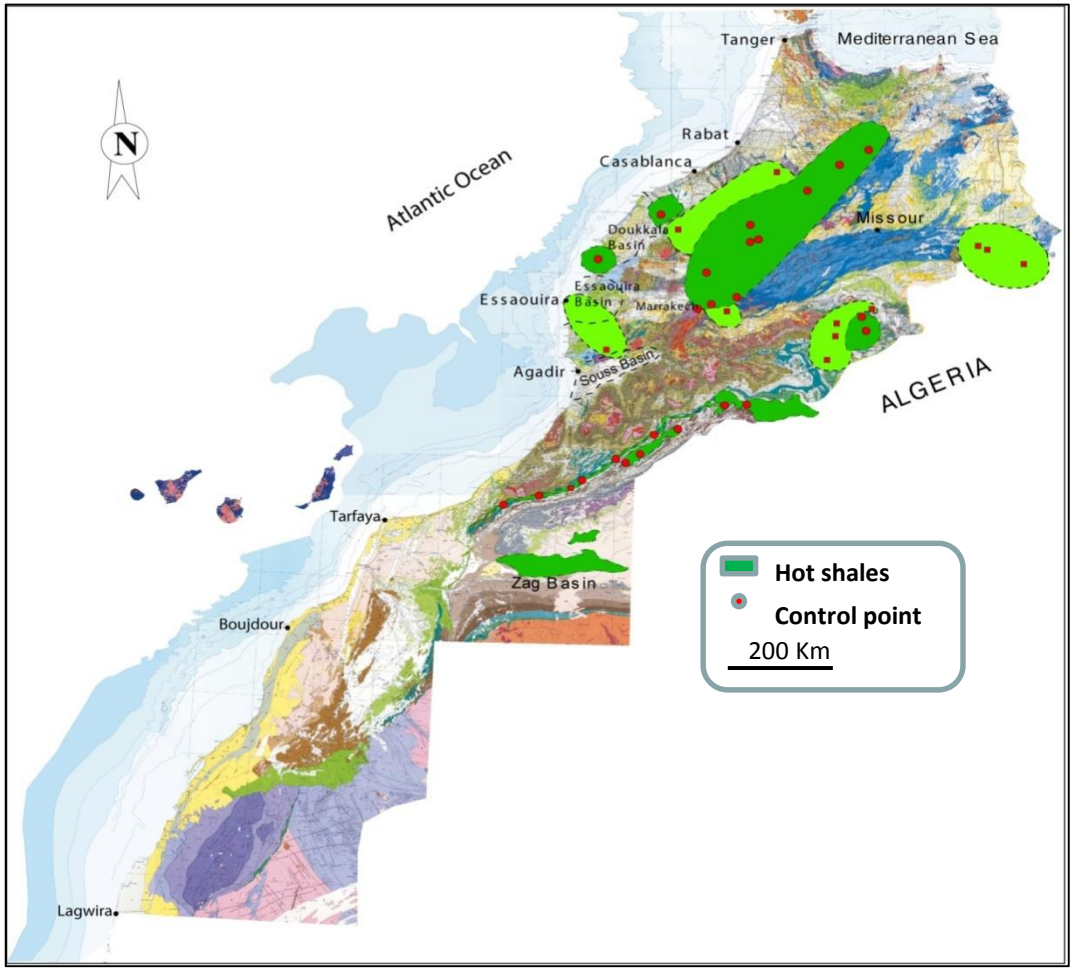


Traps	Source Rocks	Reservoir Rocks	Analogs
A: Rift Fault tilted blocs	Silurian black shale	Triassic sandstone	Meskala gas and condensate field
B: Hercynian Structures		- Middle Devonian limestone - Cambrian-Ordovician Sandstone	Meskala mega show (MKL-104)

PALAEOZOIC PETROLEUM SYSTEMS: **SILURIAN**

Shale gas potential

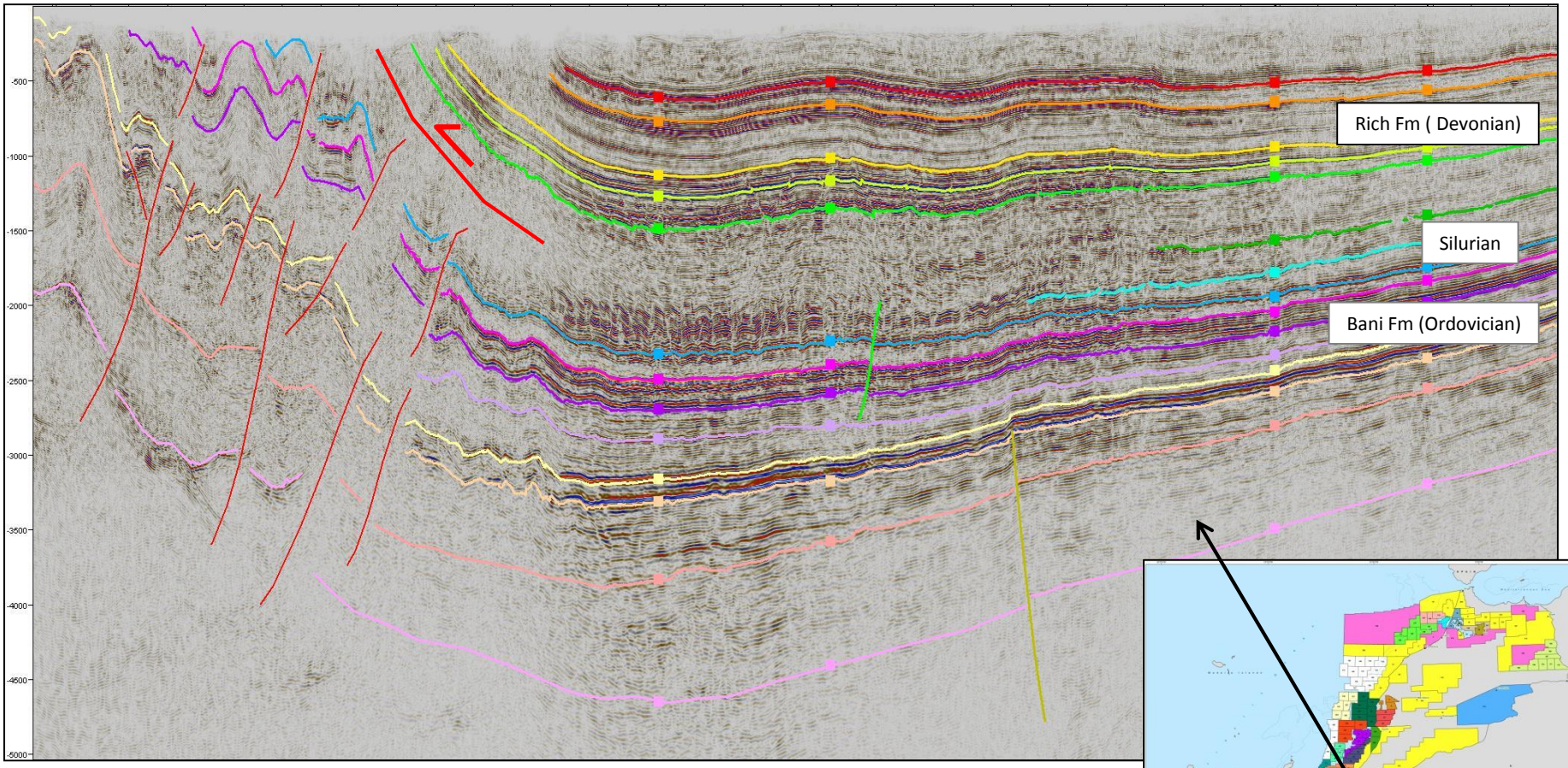
- **Silurian organic rich SRs identified at surface and wells have sourced producing gas and condensate fields and currently targeted for shale gas;**
- **First geological and geochemical appraisal of the Paleozoic depositional systems by Anadarko and Repsol ;**
- **Core drills results provide greater confidence in the presence, thickness, richness, maturation and lithological composition of basal Silurian hot shale, indicating a working shale gas play.**

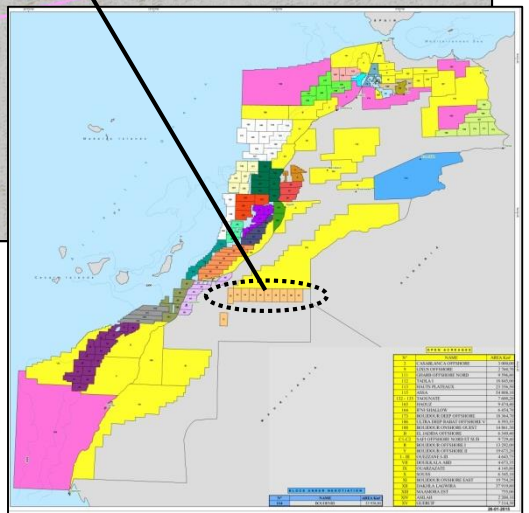


Source Rock distribution map at Palaeozoic (Silurian)

PALAEOZOIC PLAY CONCEPTS

Example of Paleozoic structures (Zag Basin)





JURASSIC PETROLEUM SYSTEMS: TOARCIAN-CALLOVIAN/ JURASSIC

Source Rocks

Toarcian & Callovian (related to Tethys incursion)

- Sidi Fili & Sidi Rhalem oil fields: TOC up to 5.5%
- Rif and Middle Atlas oil seeps (TOC up to 3.4%)
- Essaouira basin (wells with oil shows)
- Souss basin (EGA-1 TOC up to 2.74%)
- Offshore wells: FD-1 wet gas shows and MO-8 Light oil

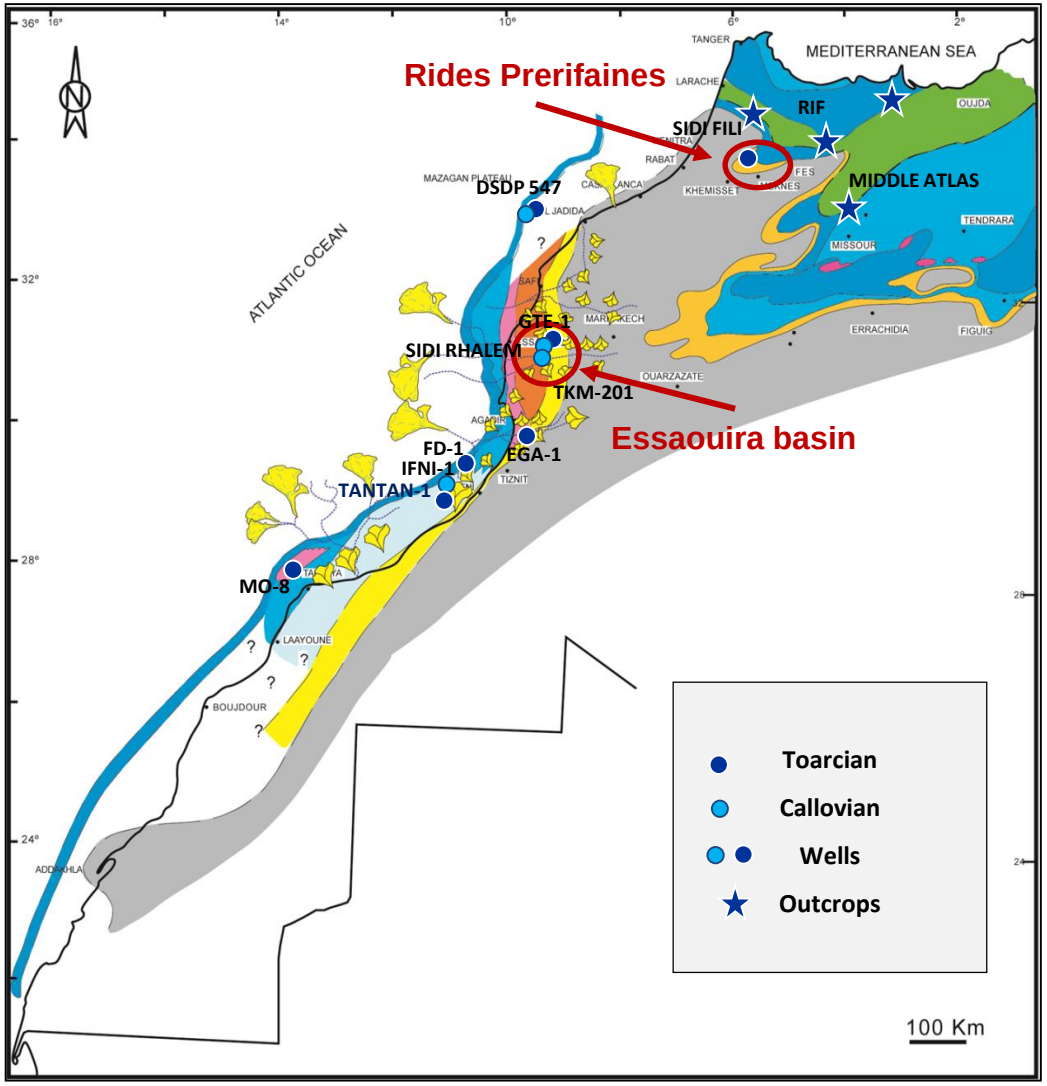
Reservoir Rocks

Jurassic Platform Carbonates

- Karsted platform carbonates in Agadir and Tarfaya offshore segments
- Prograding oolite sand shoals or reefs and aggrading reef buildups in the offshore.

Middle and Lower Jurassic Sandstones

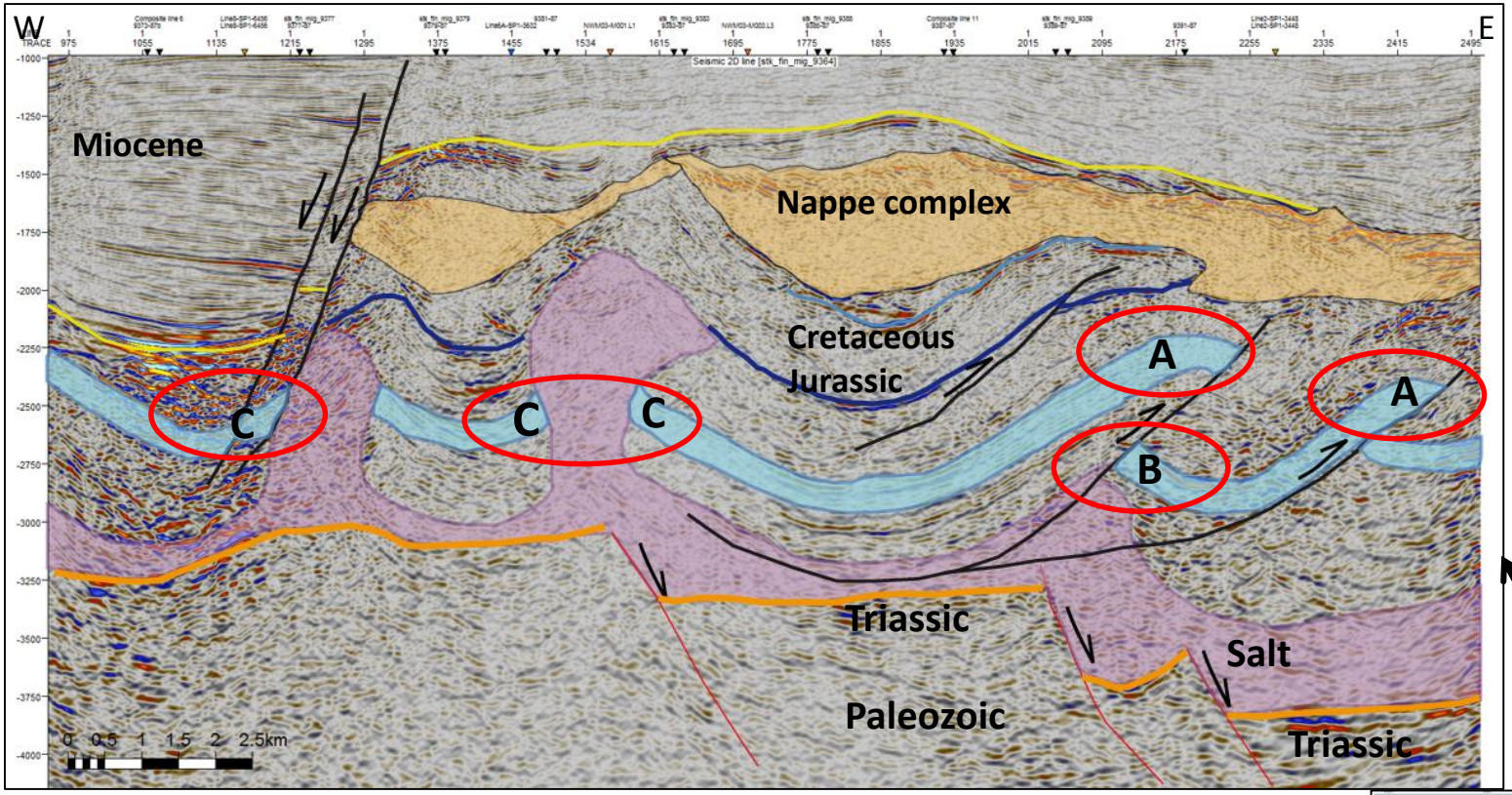
- Zerhoune (Haricha oil field) in the Rif, Guettioua in the Atlas and Amskroud & Amsitene sandstones in Essaouira basin (Upper Bathonian)
- Silicoclastics bypassed the carbonate platform at several locations and developed turbidite complexes (two major and permanent entries)



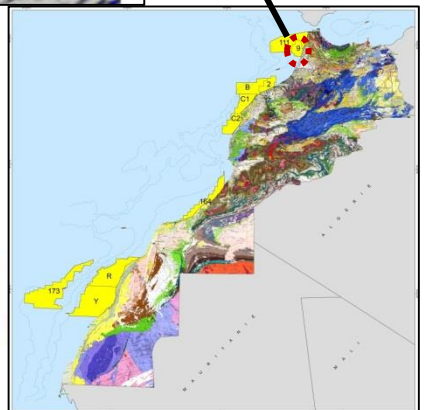
Conceptual paleogeography and hydrocarbon shows during Lower & Middle Jurassic

JURASSIC PLAY CONCEPTS

Example of Salt related traps (Gharb Offshore)

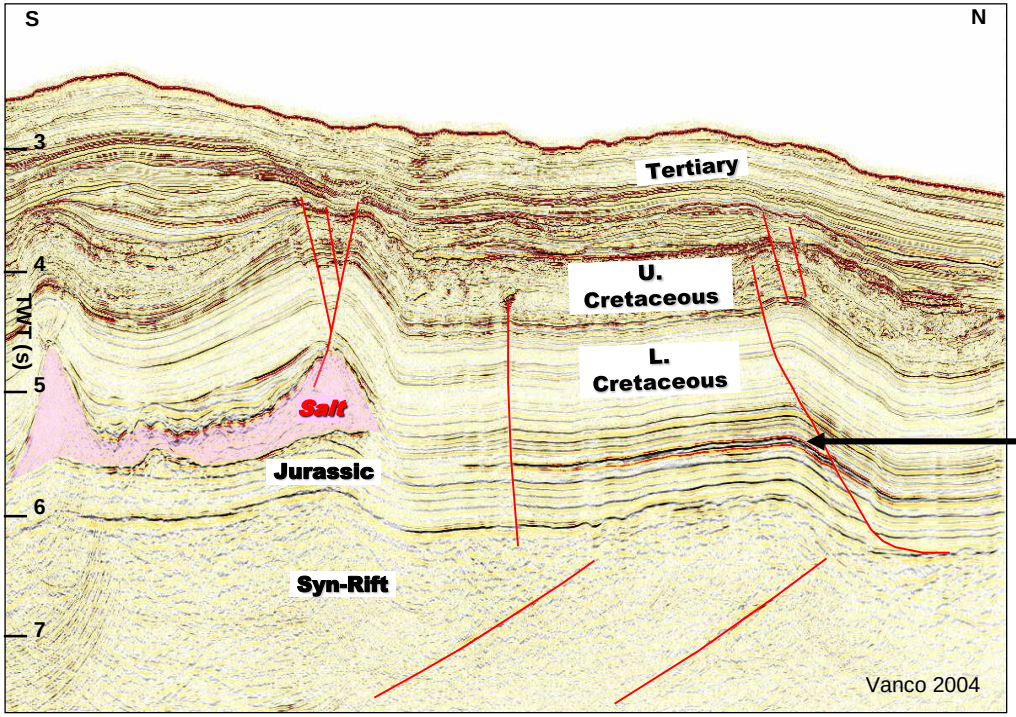


Traps	Source Rocks	Reservoir Rocks	Analogs
A: Over hang anticlines	Toarcian Organic rich shale	- Domerian oolitic limestone - Bajocian Sandstones	Tselfat and Bou Draa oil fields in the onshore Rides Prerifaines
B: Sub thrust			
C: Salt wall related			

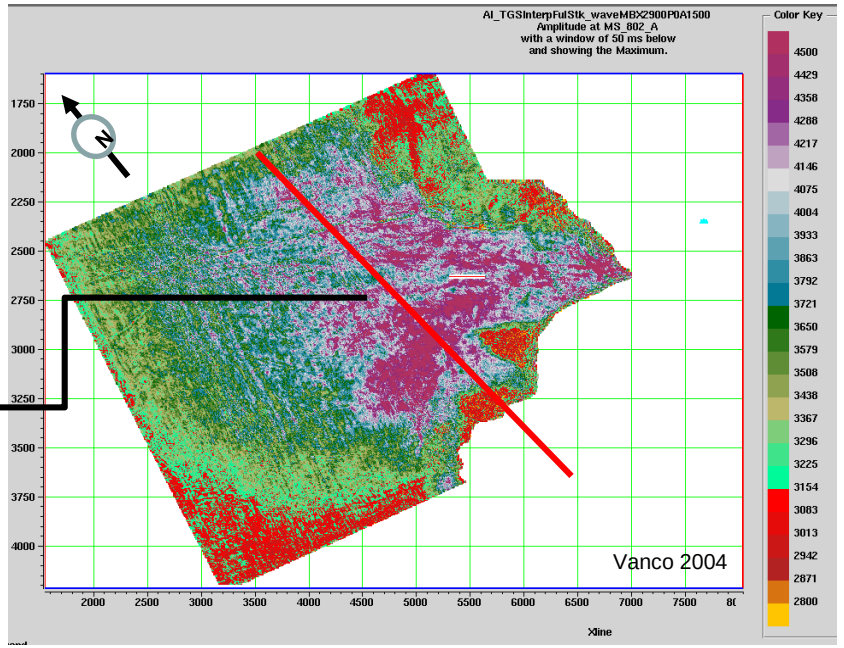


JURASSIC PLAY CONCEPTS

Deep Offshore Atlantic Domain



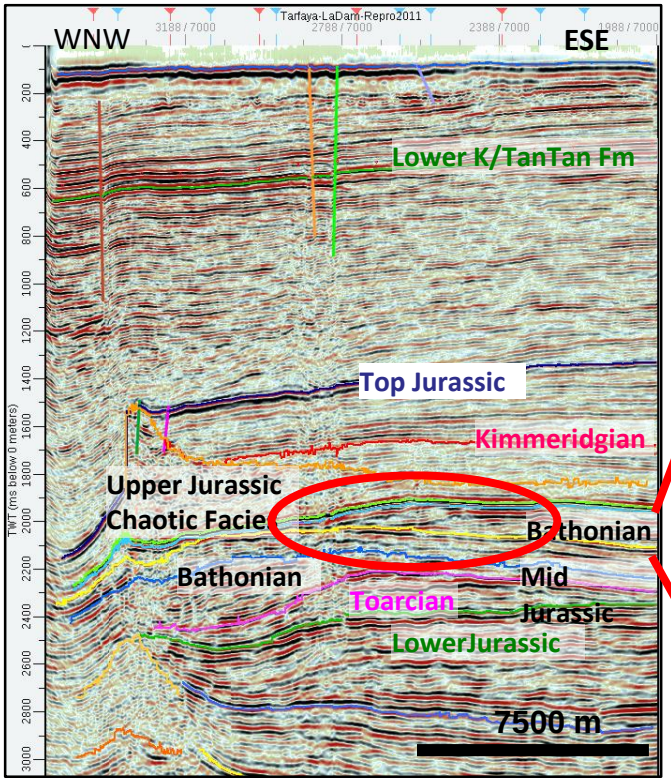
Maximum Impedance Extraction map

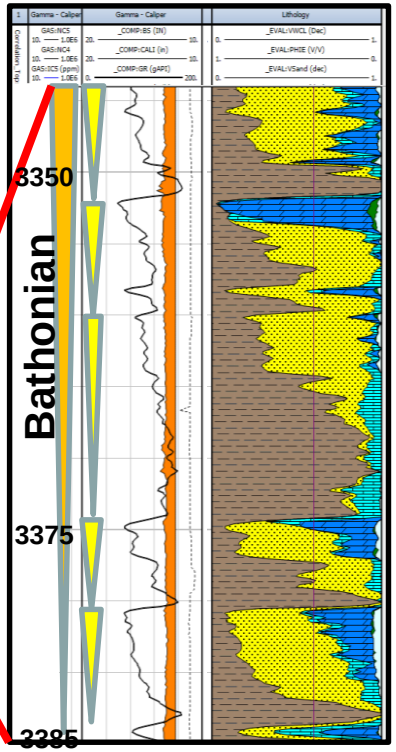


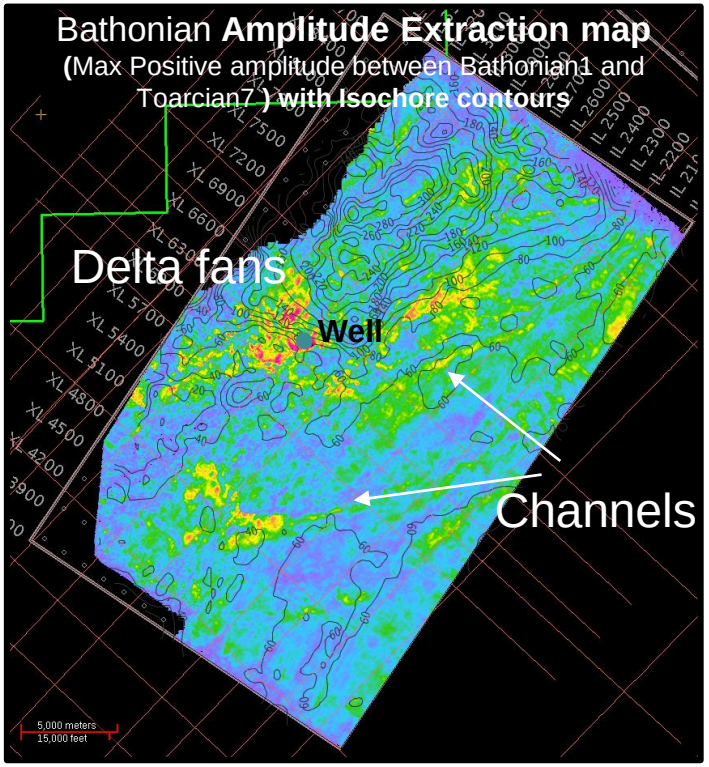
West of the Essaouira onshore area, the map of the Maxium Impedance extraction (50 ms below the intra Jurassic bright horizon) draw a fan shape, which corresponds very likely to a Mid-Jurassic turbidite complex.

JURASSIC PLAY CONCEPTS

Shallow Offshore Atlantic Domain







Seismic data and well logs indicate prograding delta and the amplitude extraction map, at the Bathonian interval, corroborate the interpretation and show feeder channels, trending NE-SW, and Deltas fan shapes.

ONHYM

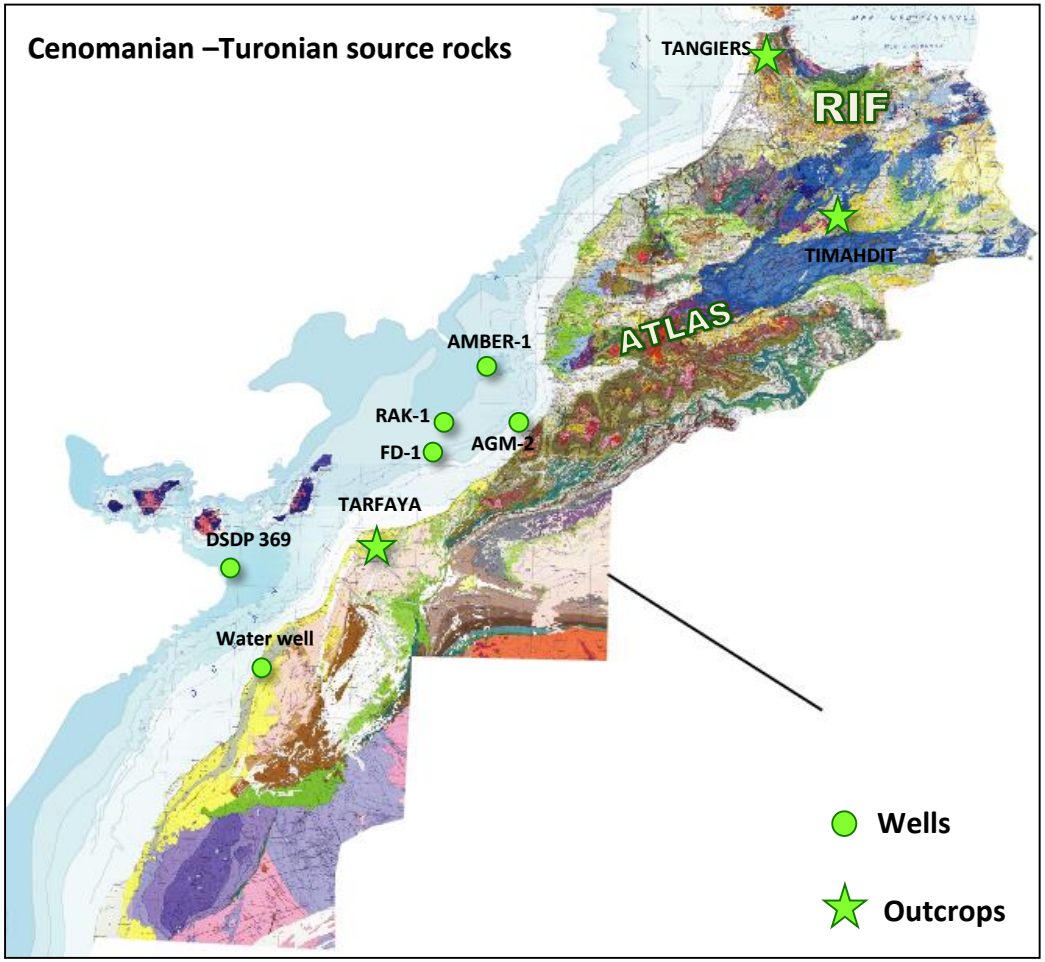
UPPER CRETACEOUS PETROLEUM SYSTEMS: CENOMANO-TURONIAN / CONIACIAN-TURONIAN

Cenomanian-Turonian Source Rocks

- Tarfaya and Timahdit oil shale quarries, with a TOC of 2-19%
- AGM-2 3.5% TOC, 574 HI
- Amber-1 well 26 m thick section Turonian interval 12.5% to 15.9% TOC
- RAK-1 well encountered organic rich laminea
- FD-1 well: good oil potential

Turonian-Coniacian Reservoir Rocks

- Low Stand System Track turbidite sandstones, e.g. Turbidite fans in Agadir and Boujdour-Dakhla Offshore segments)

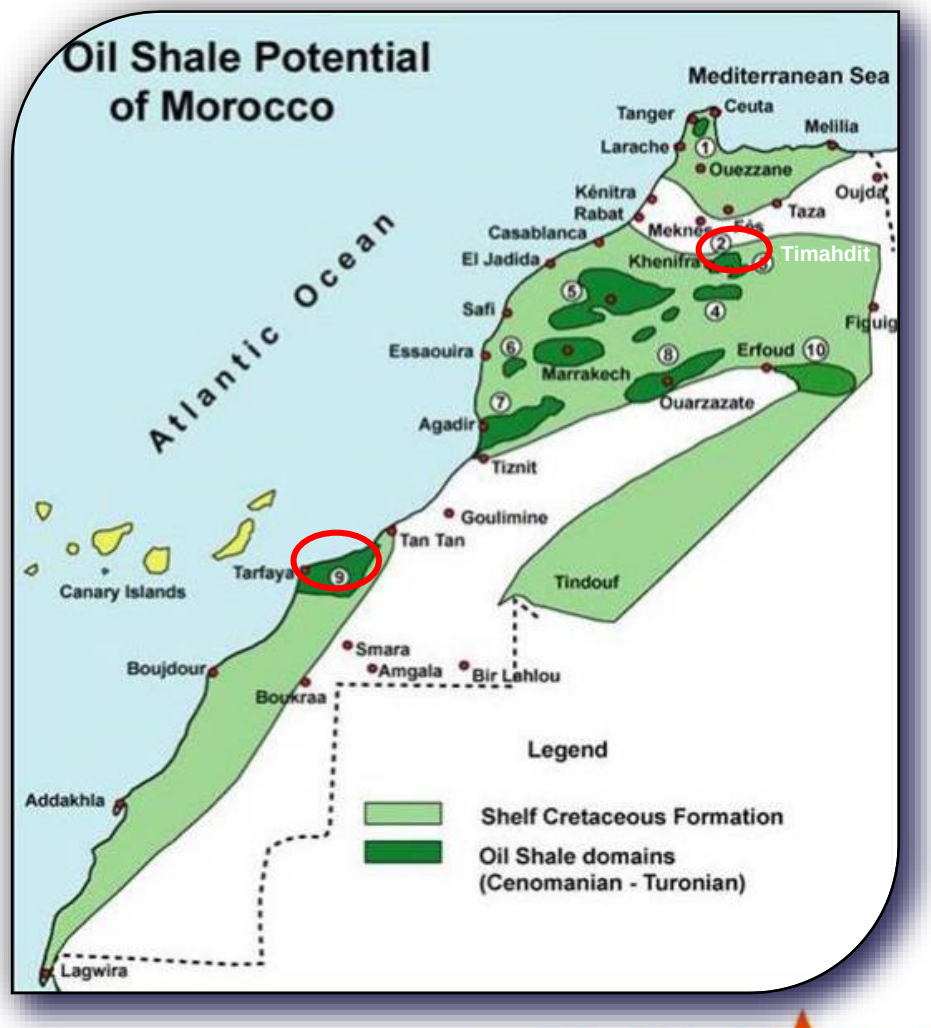


UPPER CRETACEOUS PETROLEUM SYSTEMS

Oil shale potential

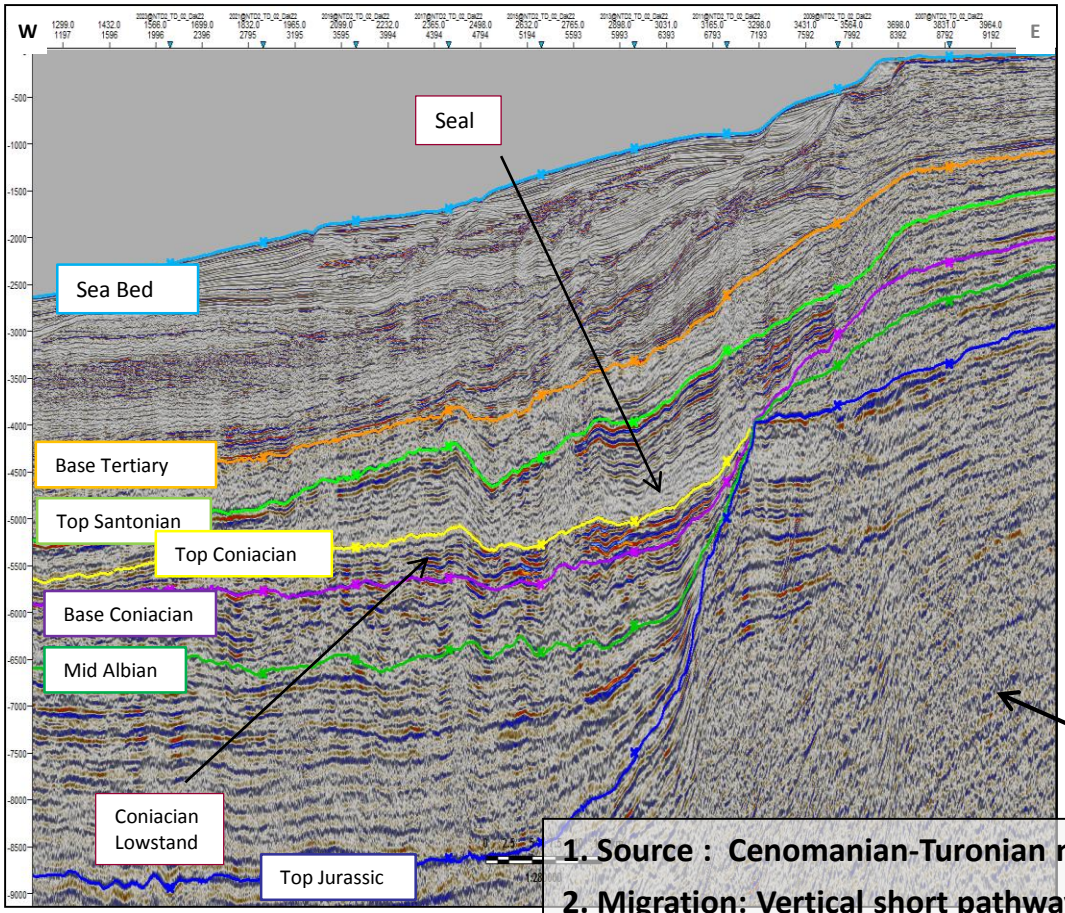
- **Oil shale deposits have been identified at ten localities in Morocco (map), the most important of which are Cenomanian-Turonian in age. The most extensively explored deposits are the Timahdit and the Tarfaya**

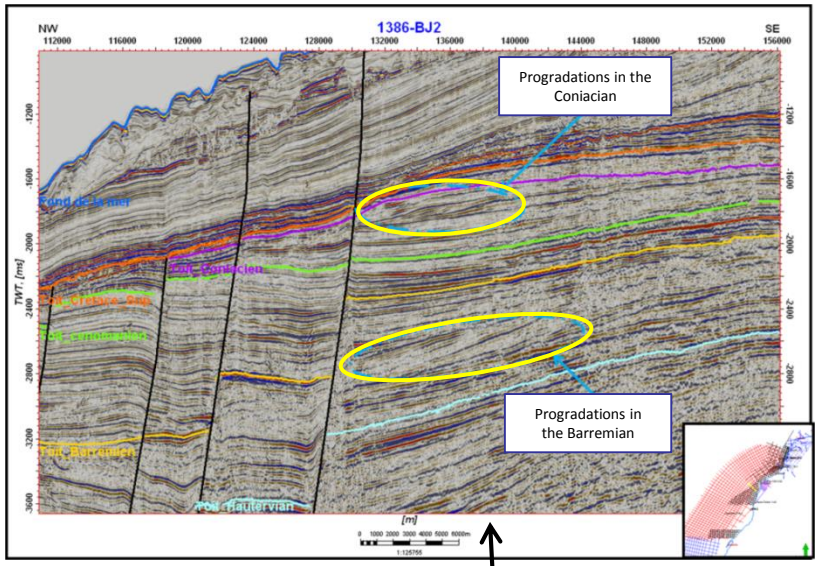
- **Morocco has important oil reserves contained in the oil shales (approximately 50 billion barrels, just in Timahdit & Tarfaya)**

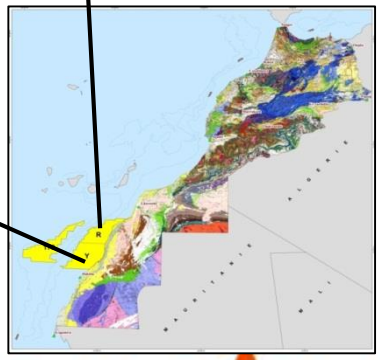


UPPER CRETACEOUS PLAY CONCEPTS

Example of Coniacian turbidite systems (Boujdour& Dakhla Offshore)







1. Source : Cenomanian-Turonian marls
2. Migration: Vertical short pathway
3. Reservoir : Coniacian turbidite sandstones
4. Seal: U. Cretaceous & Tertiary Marls & shale
5. Trap: Stratigraphic (LST)

ONHYM

LOWER CRETACEOUS/JURASSIC PETROLEUM SYSTEMS

Aptian-Albian Source Rocks

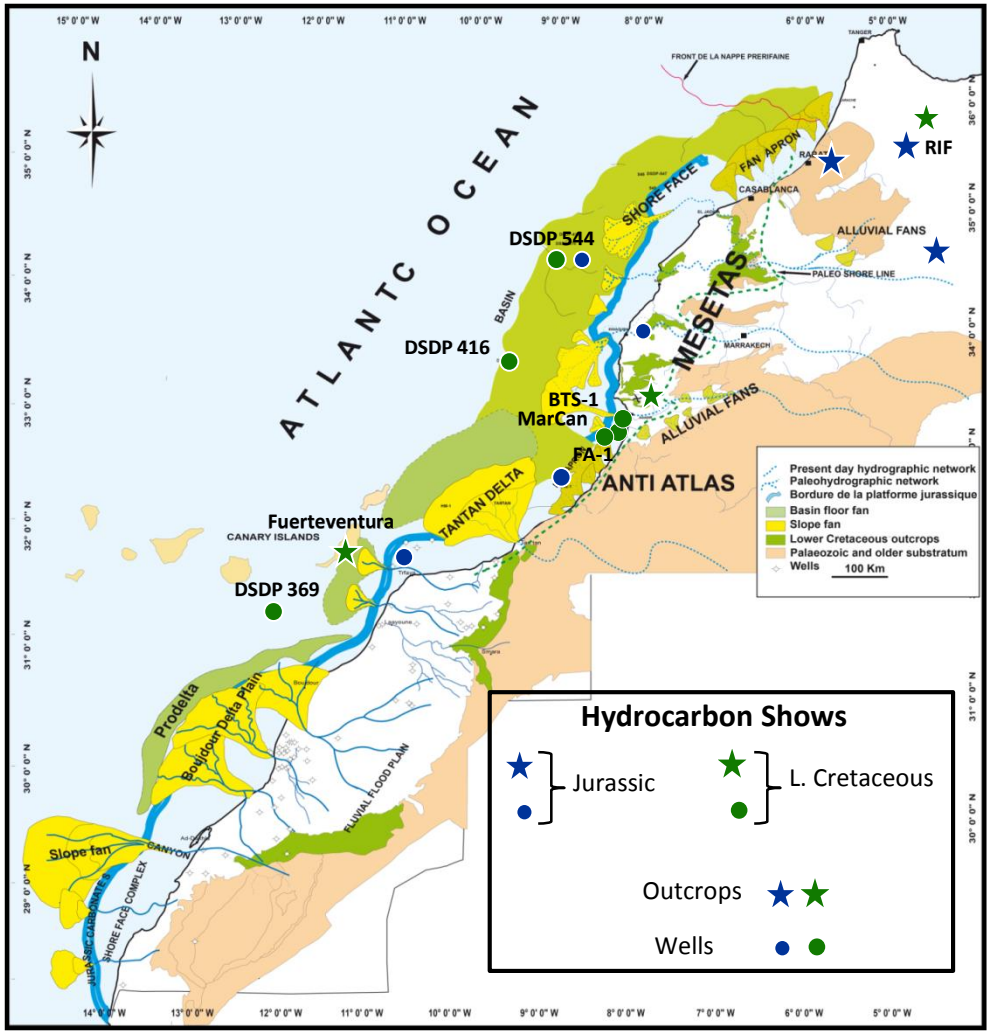
- Locally developed thin “bituminous shale” onshore in the Rif and western High Atlas
- DSDP wells: TOC up to 6.2%
- Offshore wells: TOC from 2 to 4%
- 40 m organic rich black shale crops out in Fuerteventura

Barremian Source Rocks

- DSDP 367 (Senegal): TOC 1.2% - 4.8%

Reservoir Rocks

- Aptian Low Stand System Track (e.g. Assaka prograding wedge in the Agadir-Essaouira Atlantic Segment)
- Lower Hauterivian fluvio-deltaic complex, fan apron and associated turbidites in Agadir to Tangiers offshore segments
- Valanginian-Barremian Fluvio-Deltaic complex and associated deep sea fans in Agadir-Tarfaya and Boujdour-Lagwira offshore segments (sourced from Jurassic source rocks)



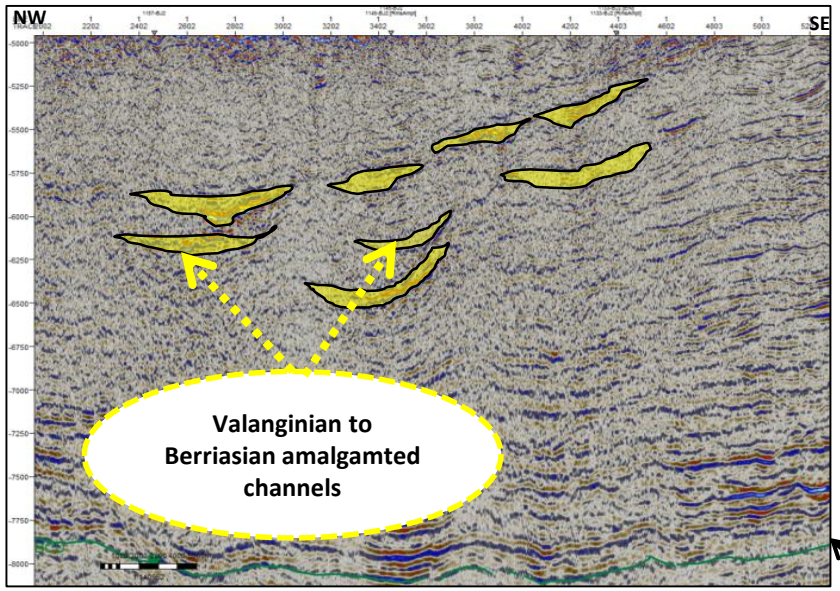
Paleogeography of the Moroccan Atlantic Margin during Lower Cretaceous

ONHYM

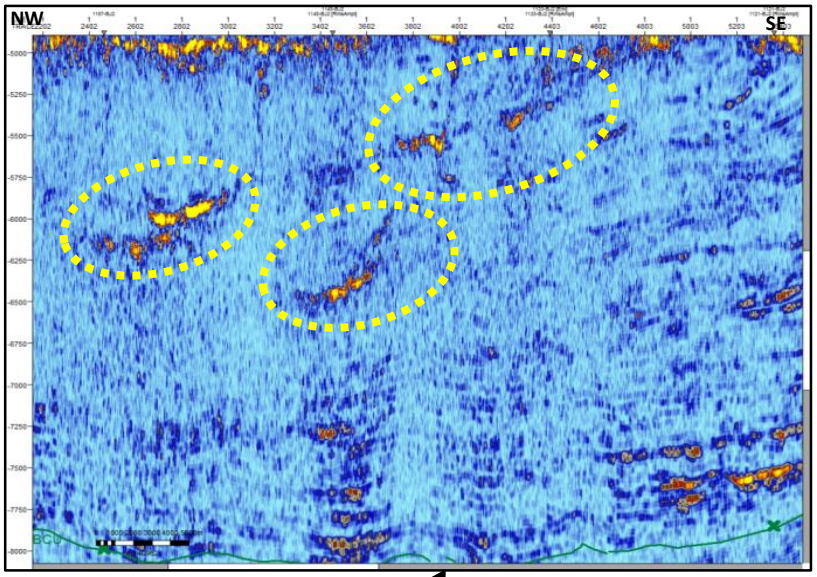
LOWER CRETACEOUS PLAY CONCEPTS

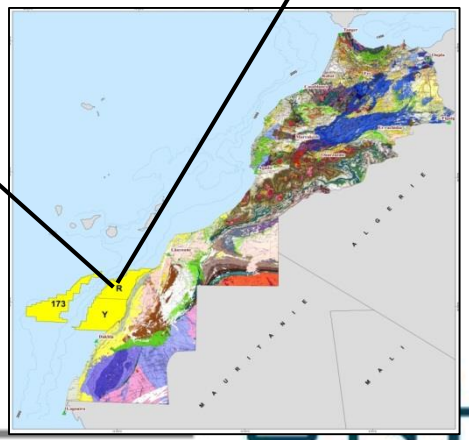
Example of amalgamated channels (Boujdour Offshore)

1422-BJ2



RMS amplitude attribute (1422-BJ2)





1. Source : Jurassic marls & carbonates
2. Migration: Vertical with short pathway
3. Reservoir : Valanginian to Berriasian channel sandstones
4. Seal: Marls & shale (U. Cretaceous & Tertiary)
5. Trap: Stratigraphic (amalgamated channels)

TERTIARY PETROLEUM SYSTEMS: CENOMANO-TURONIAN / OLIGOCENE-MIOCENE

Cenomanian-Turonian Source Rocks

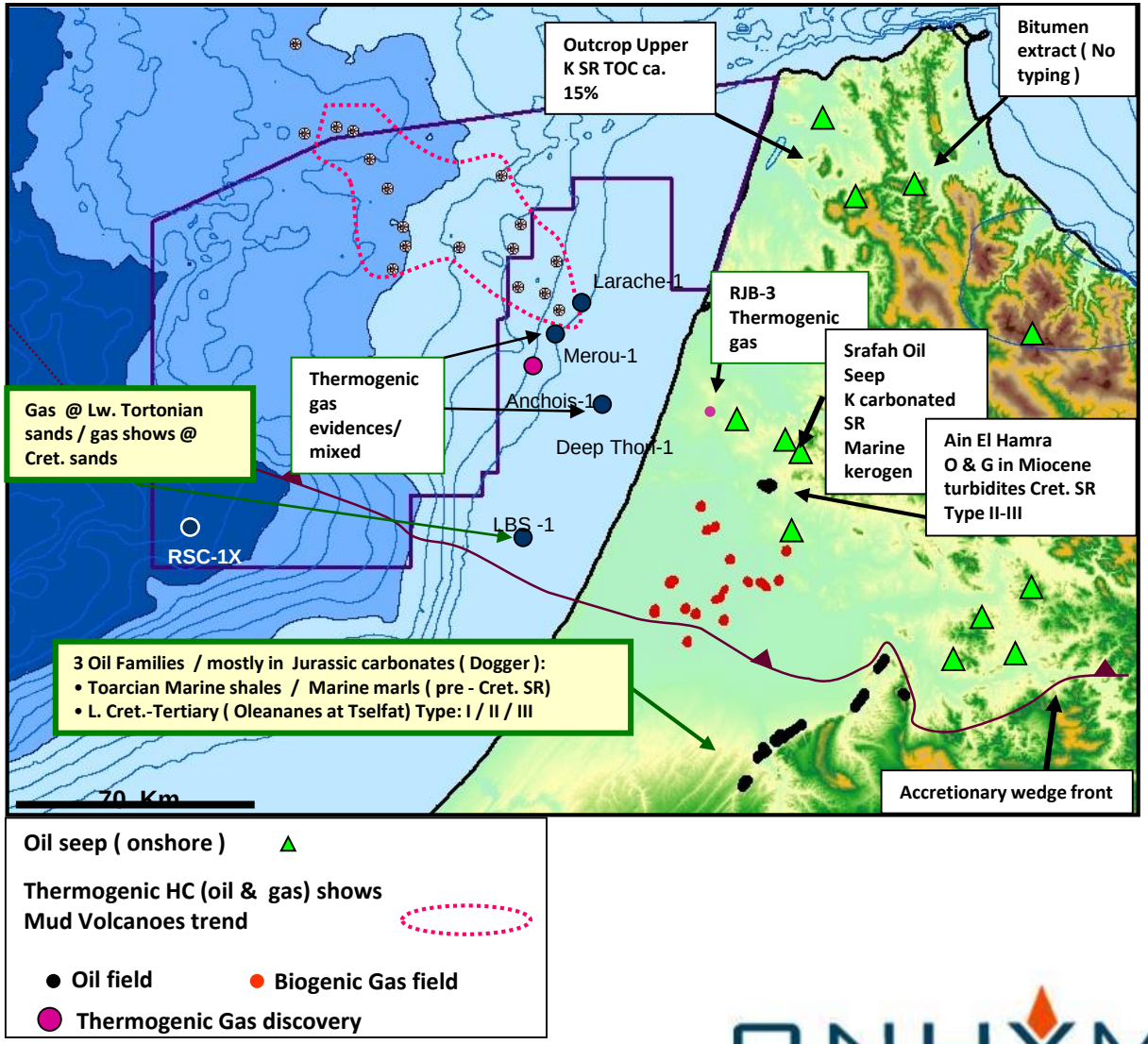
- Oil seeps along the thrust faults, Haricha oil field and Tangiers old quarry

Miocene Source Rocks

- Numerous biogenic and thermogenic gas fields
- Gas discoveries and shows in the Gharb Offshore wells

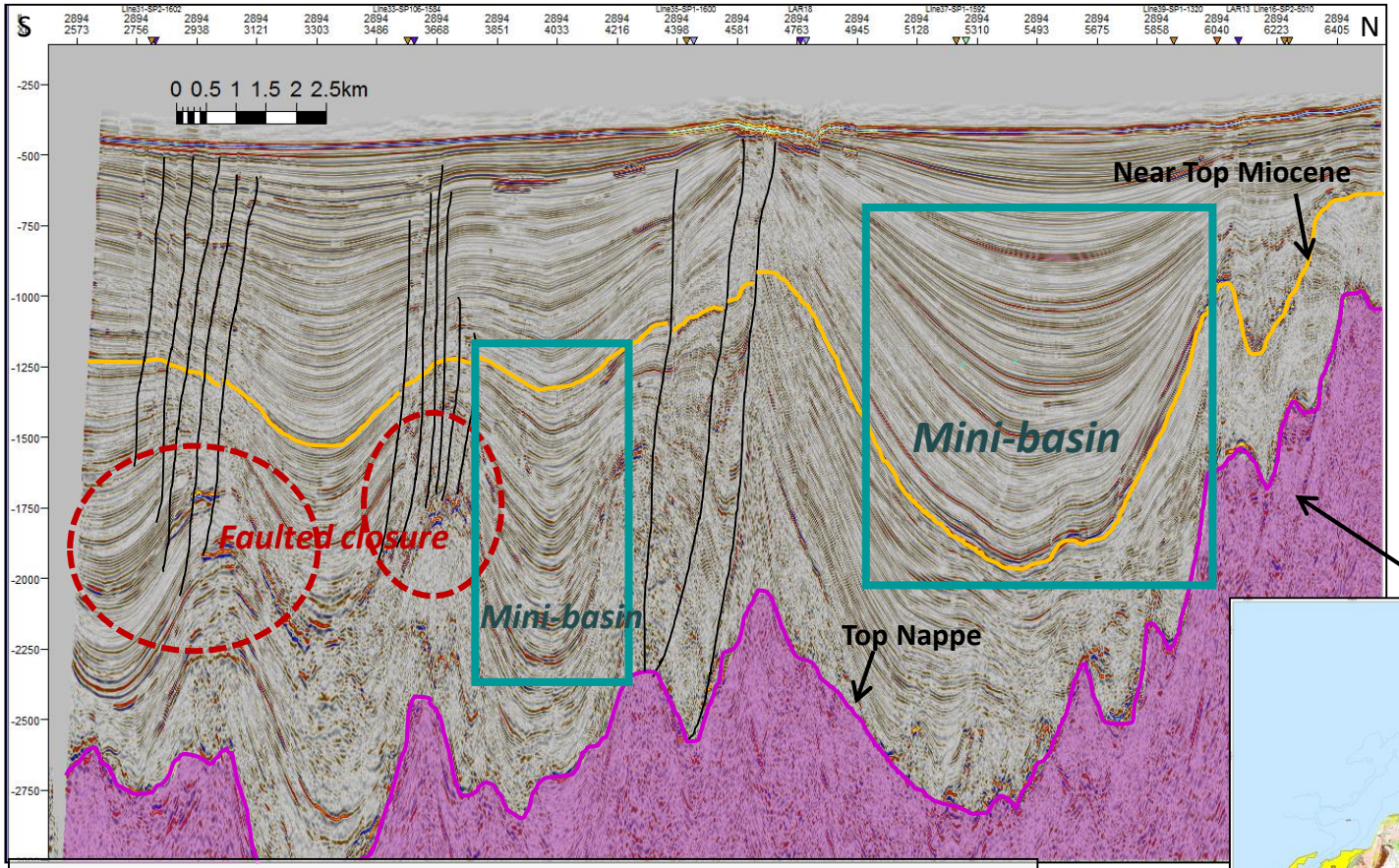
Miocene and Tortonian Reservoir Rocks

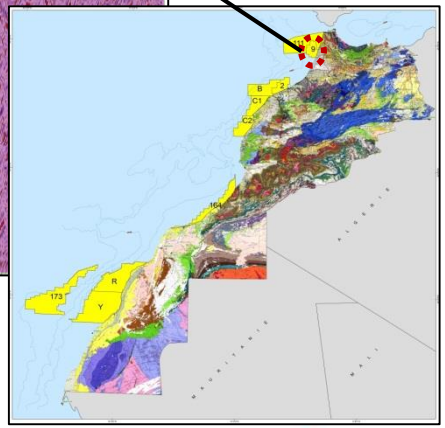
- Foredeep sandstone turbidites distributary channels and fans



TERTIARY PLAY CONCEPTS

Example of Tertiary Minibasins and 4-way closures (Lixus Offshore)



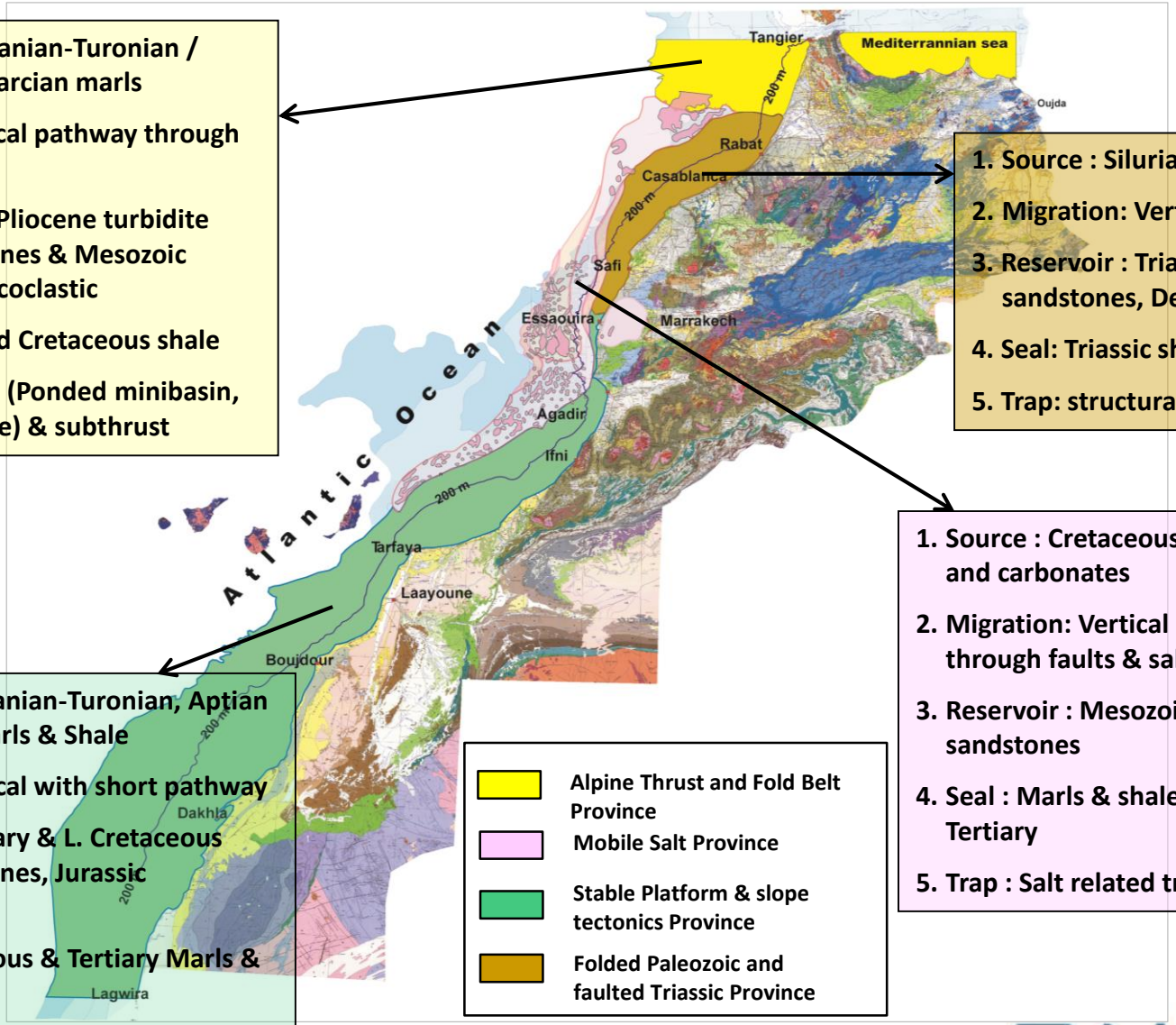


1. Source : Miocene/Cenomanian-Turonian marls
2. Migration: Vertical short pathway through faults
3. Reservoir : Mio-Pliocene turbidite channel sandstones
4. Seal: Plio-Pleistocene hemipelagic shale drapping over reservoir levels
5. Trap: Combined (Ponded minibasin, 4 &3-way closure)

ONHYM

PETROLEUM SYSTEMS SUMMARY

1. Source : Cenomanian-Turonian / Miocene and Toarcian marls
2. Migration: Vertical pathway through faults
3. Reservoir : Mio-Pliocene turbidite channel sandstones & Mesozoic Carbonate & silicoclastic
4. Seal: Tertiary and Cretaceous shale
5. Trap: Combined (Ponded minibasin, 4 &3-way closure) & subthrust



1. Source : Silurian & Frasnian shale
2. Migration: Vertical through faults
3. Reservoir : Triassic & Ordovician sandstones, Devonian carbonates
4. Seal: Triassic shale and evaporites
5. Trap: structural and combined

1. Source : Cretaceous and Jurassic marls and carbonates
2. Migration: Vertical & Lateral pathway through faults & salt flanks
3. Reservoir : Mesozoic & Cenozoic sandstones
4. Seal : Marls & shale (U. Cretaceous & Tertiary
5. Trap : Salt related traps

1. Source : Cenomanian-Turonian, Aptian and Toarcian marls & Shale
2. Migration: Vertical with short pathway
3. Reservoir : Tertiary & L. Cretaceous channel sandstones, Jurassic carbonates
4. Seal: U. Cretaceous & Tertiary Marls & shale
5. Trap: Stratigraphic and combined

ONHYM

CONCLUSIONS

The hydrocarbon exploration efforts carried out so far in Morocco have brought encouraging results (small hydrocarbon accumulations, numerous hydrocarbon shows and oil seeps) related to various play concepts ranging from Paleozoic to Tertiary and proved a working petroleum systems but failed to find suitable reservoir rocks at the appropriate location.

Therefore, ONHYM and its partners consider necessary to revisit the rocks, reinterpret the existing geological studies and well data in order to better understand the potential reservoir rocks depositional systems, predict their distributions in the explored areas and consequently upgrade the developed leads and prospects.

The unconventional is another key potential of Morocco which needs to be boosted.

ONHYM


For more informations
Thanks to
Stop by our booth
2328