HYDROCARBON POTENTIAL IN MOROCCO: STILL UNDEREXPLORED PROMISING BASINS

ASMAE BENARCHID
South Offshore Department Manager

www.onhym.com
<table>
<thead>
<tr>
<th>Hydrocarbon Exploration Outlook</th>
</tr>
</thead>
<tbody>
<tr>
<td>Potential Petroleum Systems</td>
</tr>
<tr>
<td>Examples of untested Plays, Leads &amp; Prospects</td>
</tr>
<tr>
<td>Offshore Atlantic Morocco</td>
</tr>
<tr>
<td>Offshore Mediterranean Morocco</td>
</tr>
<tr>
<td>Onshore Morocco</td>
</tr>
<tr>
<td>Conclusions</td>
</tr>
</tbody>
</table>
Main onshore structural domains and associated Petroleum Objectives

- **The Rif Domain**: Alpine folded and thrust belt (Mesozoic and Tertiary Objectives)
- **The Meseta Domain**: Hercynian Folded & thrust belt and Meso-Cenozoic rift & Passive margin (Paleozoic, Triassic and Jurassic objectives)
- **The Atlas Domain**: Early Mesozoic Tethysian Rift and Alpine Inverted and Folded belt (Triassic and Jurassic objectives)
- **The Anti Atlas and Saharian Platform**: Hercynian domain (Paleozoic objectives)
- **The Coastal basins**: Atlantic Mesozoic-Cenozoic Passive Margin (Triassic, Jurassic, Cretaceous and Tertiary objectives)
Main offshore structural domains and associated Petroleum Objectives

- **Alpine thrust and folded belt province:**
  Extension of the Rif domain (Jurassic, Cretaceous and Tertiary Objectives)

- **Folded Paleozoic and faulted Triassic Province:**
  Extension of the Meseta (Paleozoic and Triassic Objectives)

- **Mobile salt province:**
  Mesozoic Atlantic Rift & Passive Margin (Triassic, Jurassic, Cretaceous and Tertiary Objectives)

- **Platform and Deep Marine Province:**
  Mesozoic Atlantic Rift & Passive Margin (Jurassic, Cretaceous and Tertiary Objectives)
SEISMIC & WELLS DATABASE

Offshore Atlantic
- 2D Seismic: 163 366 Km
- 3D Seismic: 70 242 Km²
- 2D Multi-clients: 13 195.9 Km in Offshore Atlantic Morocco
- 42 exploration wells

Offshore Mediterranean
- 2D Seismic: 10 901 Km
- 2 Exploration wells

Onshore
- 2D Seismic: 56 131 Km
- 3D Seismic: 2 336 Km²
- 307 Exploration wells

Most of the open blocks is covered by either 2D & 3D Seismic
Main ongoing Exploration Activities in Offshore & Onshore Morocco:

**Partners**
- 3D & 2D seismic processing (Recent seismic acquisitions in 2018)
- G&G Evaluation of the Areas of Interest

**ONHYM**
- Integration of the new well results into regional studies (Reservoir distribution & geochemical modelling)
- G&G Evaluation of the open blocks
- Data room organization in ONHYM Offices (17 data room in 2018)

**PROJECTS ONHYM/E&P INDUSTRY PARTNERS**
- Cooperation with universities and Groups of Research (NARG, IMMAGE, Colorado School of Mines, ...)
- Cooperation with OERA & DOEM from Nova Scotia
- 2D MultiClients (GeoX) in Offshore Atlantic
- Seismic Reservoir Characterization in Offshore Agadir (CGG/Ongoing study)
The petroleum systems are widely extended in stratigraphic time from Paleozoic into Tertiary. These are proven in the Onshore and Offshore Moroccan sedimentary basins through hydrocarbon occurrences (discoveries, shows, surface oil seeps). The main peers are:

- **Palaeozoic petroleum systems (Silurian/Triassic & Silurian/Ordovician-Devonian):** e.g. Meskala gas & condensate field and High Plateaux gas discovery.

- **Jurassic petroleum systems (Toarcian-Callovian/Jurassic):** e.g. oil fields in the rides prerifaines & Essaouira and oil discovery in the Offshore.

- **Lower cretaceous petroleum systems (Jurassic-Lw. Cretaceous/Lw. Cretaceous):** e.g. oil and gas shows encountered in Offshore Atlantic.

- **Upper cretaceous petroleum systems (Cenomanian-Turonian/Upper Cretaceous-Tertiary):** e.g. Ain Hamra oil accumulation and oil shows in the Onshore.

- **Tertiary petroleum systems (Tertiary/Tertiary):** e.g. biogenic gas fields in Gharb basin.
OFFSHORE ATLANTIC MOROCCO: EXAMPLES OF UNTESTED PLAYS, LEADS & PROSPECTS
OFFSHORE ATLANTIC MOROCCO: PLAY CONCEPTS HISTORY

DEVELOPED PLAY CONCEPTS

Carbonate Platform Play (inboard)

70s-80s

2000-2008

2013-2018

Foredepth Turbidite Nappe (inboard)

Spectral Decomposition

TARFAYA BLOCK

MO-7 (projected)

MO-5

Seal 1

Seal 2

Upper Jurassic

Top Middle Jurassic

R1

R2

R3

R4

S1

S2

S3

S4

Jurassic / Triassic

Salt

Neogene Super Nappes

Pleistocene

Pliocene

Upper Miocene

Aggradational Propagation

Oblique Propagation

Incl-Oblique Propagation

Hercynian Basement

Phyllite Nappe

Intra-Nappe Imbricites

Half-graben Filling
OFFSHORE ATLANTIC MOROCCO: HYDROCARBON PLAYS

EXTENDED PLAYS FROM THE MSGBC BASIN

MSGBC:
Where is the Next Success?

Moroccan Atlantic Margin

Area
- 337,569 km² (to 4,000 m bathymetry)

Seismic
- 2D Seismic: 163,366 km + 13,196 km (MC)
- 3D Seismic: 70,242 km²

Wells
- 42 Exploration wells

Source: GEOExPro Vol. 15, no. 5 - 2018
**OFFSHORE ATLANTIC MOROCCO : TURBIDITE PLAY**

**UPPER CRETACEOUS CANYONS (UNTESTED OBJECTIVES)**

<table>
<thead>
<tr>
<th>Prospect</th>
<th>Water Depth (m)</th>
<th>Closure (Km²)</th>
<th>Unrisked recoverable resources - Mean (MMbbls)</th>
</tr>
</thead>
<tbody>
<tr>
<td>B1</td>
<td>1200</td>
<td>7.61</td>
<td>169</td>
</tr>
<tr>
<td>B2</td>
<td>980</td>
<td>7.45</td>
<td>133</td>
</tr>
</tbody>
</table>

1. Source Rock: Turonian marls  
2. Migration: Vertical short pathway  
3. Reservoir: Turonian sands  
4. Trap: Stratigraphic  
5. Seal: Vertical regional MFS and lateral pinch-out on the carbonate platform
Sand bearing Inverted minibasins would be the focus in the next phase of the exploration in the salt province (example of Apto-Albian fan complex).

PROSPECT

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Water Depth (m)</td>
<td>975</td>
</tr>
<tr>
<td>Closure (Km²) (P10)</td>
<td>57</td>
</tr>
<tr>
<td>P mean Resources (MMBO)</td>
<td>871</td>
</tr>
</tbody>
</table>

1. Source Rock: Lower Jurassic marls & carbonates
2. Migration: Vertical salt welds
3. Reservoir: Aptian-Albian turbidite sandstones
4. Seal: Tertiary shale and Upper Cretaceous MTC
5. Trap: Structural
OFFSHORE MEDITERRANEAN MOROCCO: EXAMPLES OF UNTESTED PLAYS, LEADS & PROSPECTS
OFFSHORE MEDITERRANEAN MOROCCO : HYDROCARBON PLAYS

Area
- 24 500 Km²

Seismic
- 2D Seismic: 10 901 Km (Between 1975 & 2001)

Wells
- 2 Exploration wells

1 – Mud diapir flank
2 – Mud diapir drape
3 – Inversion
4 – Truncation
5 – Canyon flank
6 – Onlap basement
7 – Onlap on diapir
8 – Faulted drapes

Area
- 24 500 Km²

Seismic
- 2D Seismic: 10 901 Km (Between 1975 & 2001)

Wells
- 2 Exploration wells
INTERPRETED GAS CHIMNEY AND BRIGHT SPOTS
1. Source Rock: Paleogene/Early to Middle Miocene age
2. Migration: Vertical
3. Reservoir: Serravalian turbidite sandstones
4. Seal: Tertiary interbedded Marls & shale
5. Trap: Stratigraphic (truncation beneath the unconformity)

<table>
<thead>
<tr>
<th>WD (m)</th>
<th>Area (Km²)</th>
<th>Crest (m TVDSS)</th>
<th>Vertical relief (m)</th>
<th>BOE in place MMstb (unrisked) (Mean)</th>
</tr>
</thead>
<tbody>
<tr>
<td>250</td>
<td>170</td>
<td>1,240</td>
<td>&gt; 250</td>
<td>363</td>
</tr>
</tbody>
</table>
ONSHORE MOROCCO: EXAMPLES OF UNTESTED PLAYS, LEADS & PROSPECTS
ONSHORE MOROCCO: HYDROCARBON PLAYS

WORKING/PROVEN PLAYS IN THE PRE-RIF BASIN

Objectives:
Tertiary sandstones & Jurassic carbonates and sandstones

Source Rocks:
Cenomanian-Turonian & Toarcian
Unected targets:
• Sub-thrust: 1
  ▪ Domerian platform limestone
  ▪ Mid. Jurassic sandstones (Haricha formation)
• Pre-salt: 2
  ▪ Triassic fluvial sandstones
ONSHORE MOROCCO: HYDROCARBON PLAYS IN THE ZAG BASIN

PALAEOZOIC STRUCTURES (UNTESTED OBJECTIVES)

**Objectives:**
Strunian sandstones & Lower Devonian sandstones (Rich formation) & Ordovician sandstones (Bani formation)

**Source Rocks:**
Silurian hot shales and Frasnian shales

Total Gas Recoverable Resources (Lower Carboniferous and Lower Devonian): 1.45 TCF
CONCLUSIONS

● Moroccan geology is, by its sedimentary and tectonic diversity, significantly favorable for oil and gas exploration and production: good evidences for the existence of viable petroleum systems;

● The Offshore & Onshore Morocco are still largely underexplored with a total of 351 wells, of which 44 wells drilled in offshore;

● The different play concepts developed have a wide stratigraphic and geographic extension and are analogue to those identified in North Africa, Nova Scotia, West Africa and the Gulf of Mexico;

● Myriad of prospects and leads were identified in different sedimentary basins and different geological times in Morocco;

● The so far drilled wells have discovered modest local hydrocarbon to prove existence of working petroleum systems. However, there is more promising hydrocarbon potential which deserves to be assessed;

● The exploration effort remains insufficient and in order to better assess the identified structures, acquiring 2D seismic or 3D seismic is required;

● Morocco remains a point of interest and an attractive area. Its sedimentary basins are still underexplored and promising. ONHYM, with its partners, will continue the impulse of the Hydrocarbon Exploration.
THANK YOU

Booth #006