

## Opportunities for hydrocarbon exploration - Mediterranean Sea



### Overview

The Alboran Basin is the most western Tertiary basin of the Moroccan Mediterranean Sea. It is an Alpine post-orogenic and strongly subsiding basin, which was developed on a rapidly thinned crust. It is bounded to the West by the Gibraltar arch comprised between the Moroccan Rif and the Spanish Betic systems, which resulted from the collision between the Iberian and the African plates.

<b>Basin</b>	Mediterranean
<b>Basin type</b>	Back Arc
<b>Area</b>	24 500 Sq. Km
<b>Exploratory wells</b>	2
<b>2D Seismic/3D Seismic</b>	10 775 Km of multi fold 2D seismic lines
<b>Source Rocks</b>	Messinian
<b>Reservoir Rocks</b>	Sandstones from Miocene
<b>Seal Rocks</b>	Shaly Mio-Pliocene formations

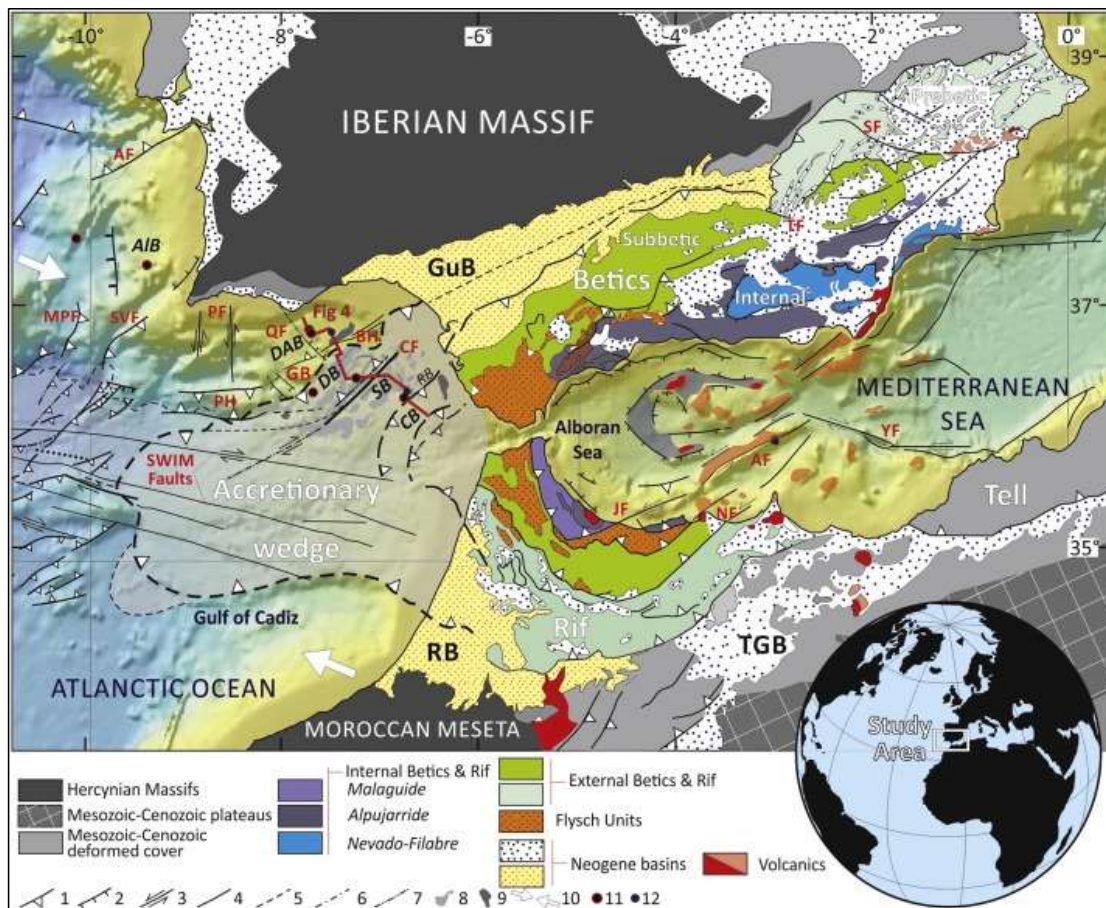


Fig.1: Tectonic framework of the western Alboran basin in relation with the Rif and Betic cordillera development (originally from Iribarren et al., 2007 and Verges and Fernandez, 2012, also including Gulf of Cadiz tectonic features described by Terrinha et al., 2002; Medialdea et al., 2004, 2009; Fernández-Puga et al., 2007; Roque et al., 2012 and Duarte et al., 2013)

### Tectonic and sedimentary evolution

The geodynamic evolution of the Alboran Sea (fig.1) started in Oligocene-Early Miocene time with the collision of the African and European continental plates. The development of over-thrusted nappes to the North (Ronda Nappe in Spain) and to the South (Beni-Boussera Nappe in Morocco), was an important consequence of this convergence. During the Early and Middle Miocene, the Alboran basin was influenced by extension tectonics. In late Miocene (end of Tortonian), an intensive compressive phase produced imbrications and thrust faults which were occasionally marked by large amplitude movements. This was followed by collapsing movements, which created a basin expansion. The latter movements have reorganized the basin setting in a way that continues up to present.

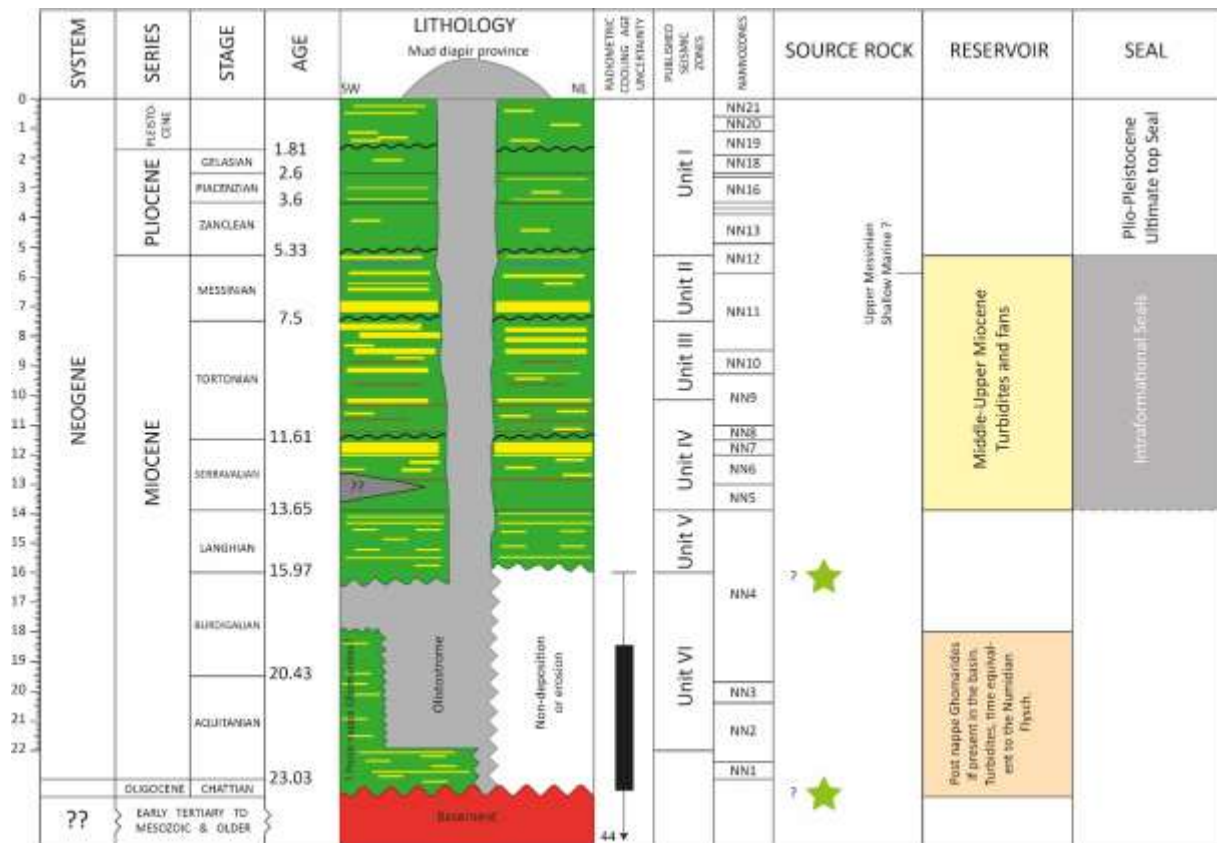


Fig.2: Lithostratigraphic column and petroleum systems components of the Alboran basin (Mubadala Petroleum /ONHYM 2016, 2017)

## Database

Since 1974, 10 775 km of multi fold 2D seismic lines have been acquired in the area. During the 1983 - 1985 period, two wells were drilled for exploration.

Seismic database includes vintage databases since 1974 to 2001. Most of this data have been reprocessed in 2015.

## Petroleum Systems

### Source rocks

The presence of shaly marine sediments in the whole Tertiary stratigraphic section (fig.2) is an indication of the presence of potential organic rich beds, which are related to the high sedimentation rate and confined environment. Few geochemical analyses carried out in 2000 on the Messinian outcrops in the northern part of the Rif foreland revealed TOC values of about 2% and HI = 429 of immature sediments. Nevertheless, we assume that in the deep offshore areas, these shales would be sufficiently buried to be in the oil or gas window.

### Reservoir rocks

Reservoirs have been identified in turbidite type deposits, which may include sandstones whose porosity is about 20% as shown in the log study of Miocene sandy beds of the El Jebha-1 well.



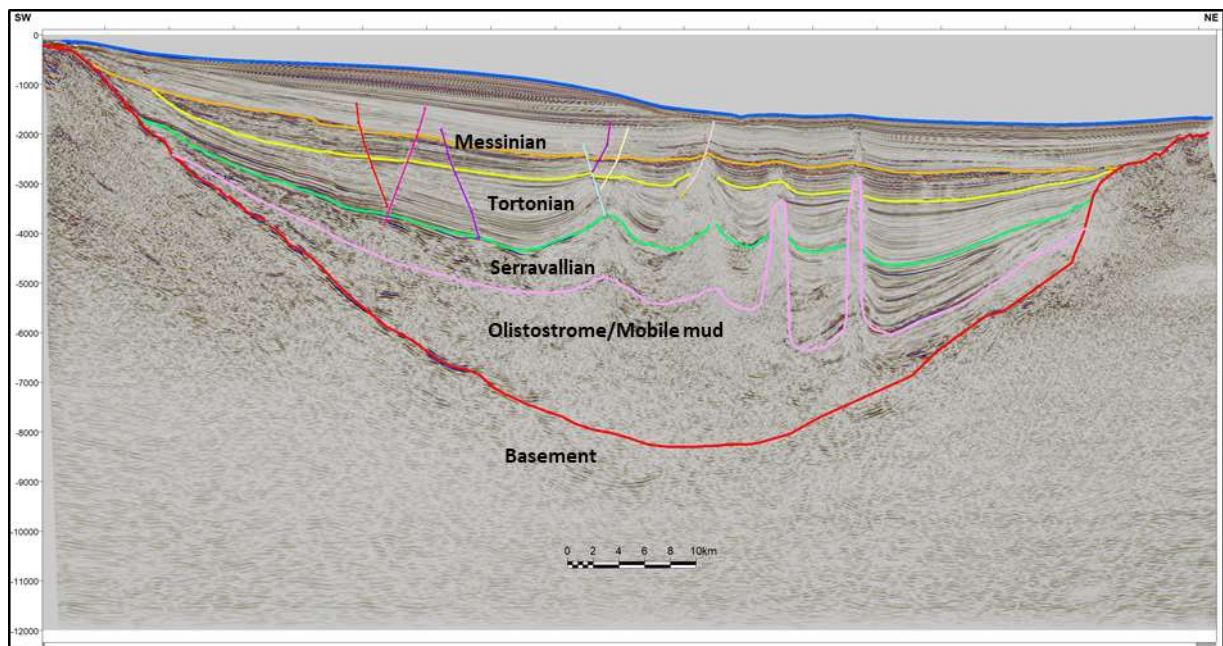
In the eastern portion of the Mediterranean domain, even the Miocene section is relatively reduced, the same reservoirs as in the western basin are expected.

### Cap Rocks

The shaly Mio-Pliocene formations are sufficiently thick to form a good seal for any Miocene reservoir.

### Play Concepts

The main exploration play concepts that have been identified in the Moroccan Alboran offshore are associated with shale diapirs (fig.3). The reservoir rocks are represented by the Miocene turbiditic sandstones, which could be sourced either vertically or laterally from the interbedded shales. Various types of traps are defined:



*Fig.3: Seismic line illustrating exploration play types in Moroccan Alboran offshore (ONHYM, 2017)*

- Hanging wall anticlines
- Unconformity Messinian traps
- Mini-basin fans related to the paleo highs.
- Combined stratigraphic and structural traps created by the inversion of the mini-Basin fans.

The fig.4 illustrates an example of the stratigraphic leads represented by Serravallian turbidite sandstones most likely sourced from Paleogene to Early/Middle Miocene and sealed by Tertiary interbedded marls and shales.

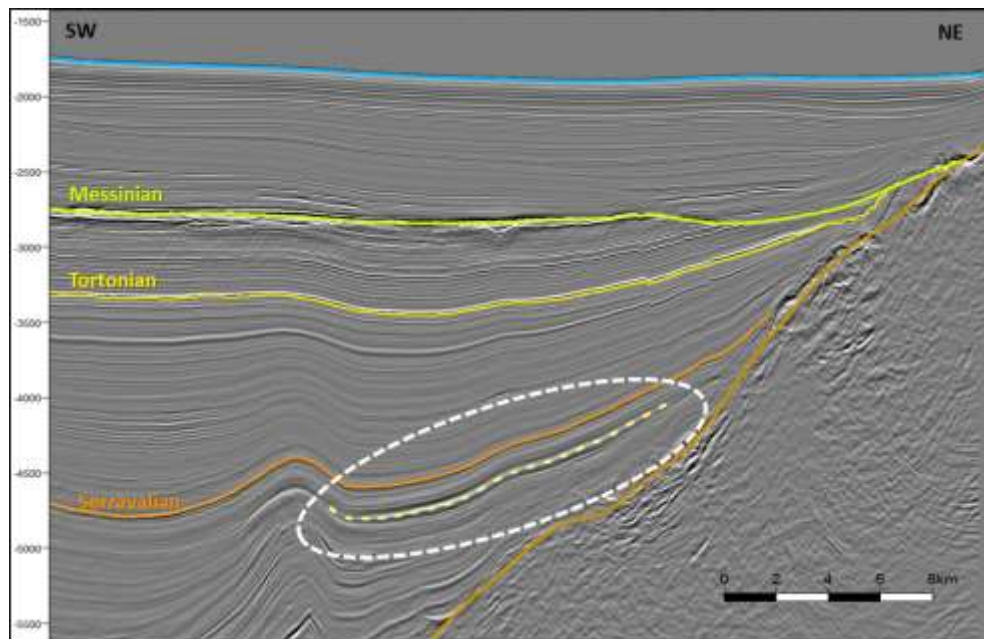


Fig.4: Example of stratigraphic leads with Serravalian turbidite sandstones objective (ONHYM, 2020)

### Conclusion

The Mediterranean deep water area of Morocco is an interesting exploration frontier domain where various leads (fig.5) associated with Tertiary turbidite sandstones have been identified and could represent the future exploration targets in the western Mediterranean Sea.



Fig .5: Map of the Mediterranean prospects and Leads: Pliocene: (4); Messinian: (20); Tortonian: (14); Serravalian: (31) (Mubadala Petroleum/ONHYM, 2017)