

PS Exploration and Development of Siliciclastic and Carbonate Reservoirs in the Eastern Mediterranean*

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Abstract

Recent large gas discoveries off-shore Israel, Cyprus, and Egypt highlight the Eastern Mediterranean area as a hot spot for global exploration. Zohr is not the only gas field in Egypt, but West Nile Delta (WND), Nooros, and Atoll are all important gas fields that add to the national gas production. The source of this poster is a graduation project that aims at developing the student's ability to search for the required data through published researches, websites, and companies to get the answers for the following questions:

1 - Can Egypt become main energy hub in Middle East?

2 - Can Israel compete in natural gas race?

Published data covering the complex geology and hydrocarbon potential of the main gas fields in the study area have been collected and analyzed. Global LNG prices have risen to a level that makes exports via the Egyptian LNG facilities economic once more. Egyptian companies have already stuck \$15 billion deal for the import of Israel natural gas. Egypt intends to attract additional resources such as Cypriot gas to become the energy and LNG hub of the region.

Egypt is qualified to be a regional hub for energy and LNG hub due to its liquefying plants, pipeline grids, warehousing, transportation, trading of petroleum and gas products, and ports overlooking the Mediterranean and the Red Sea and refineries.

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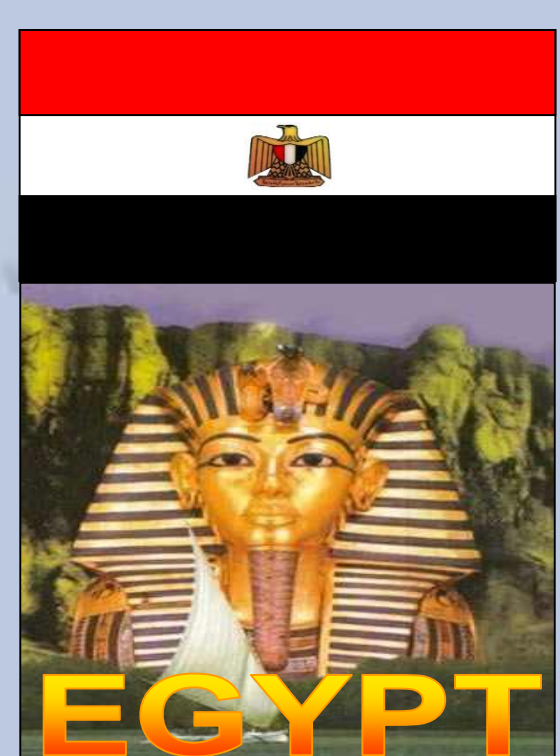
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ABSTRACT

Recent large gas discoveries off-shore Israel, Cyprus and Egypt highlight the Eastern Mediterranean area as a hot spot for global exploration. Zohr is not the only gas field in Egypt, but West Nile Delta (WND), Nooros and Atoll are all important gas fields that add to the national gas production. The source of this poster is a graduation project aims at developing the student's ability to search for the required data through published researches, websites and companies to get the answers for the following questions:

- 1- Can Egypt become main energy hub in Middle East?
- 2- Can Israel compete in natural gas race?

STRATIGRAPHIC COLUMN

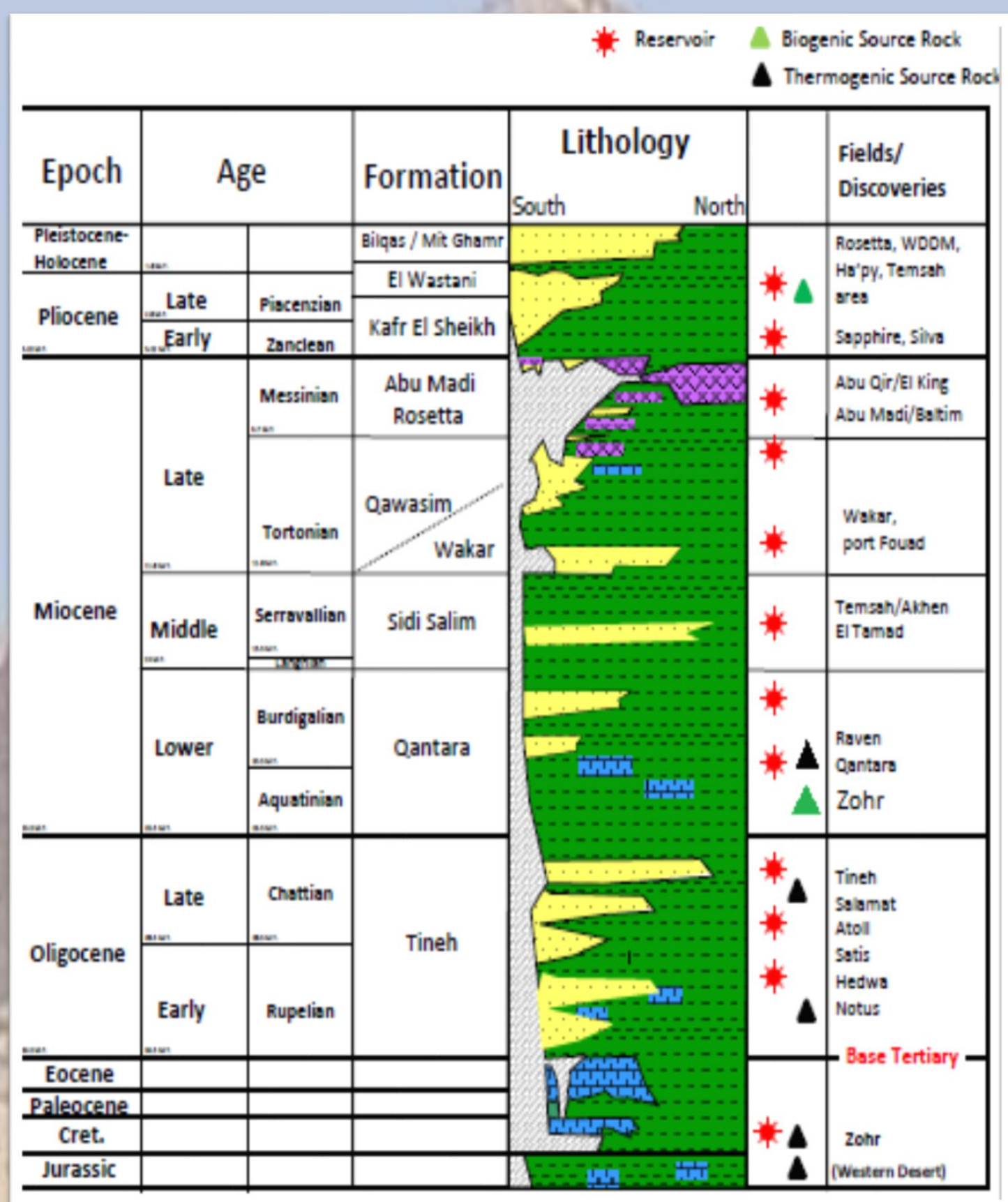


Figure 2: Nile Delta Tertiary stratigraphy mainly consists of clastic deposits (Modified after Mahmoud Khaled et al., 2019)

1) Nile Delta Stratigraphy

- Hydrocarbon fields / discoveries are proved at all levels.
- Oligocene is the main source rock in the Nile Delta.
- Significant biogenic gas potential within the Pliocene –Pleistocene interval.
- Few penetrations of the Pre-Tertiary sequence.
- The Deepest onshore well penetrated the Upper part of Jurassic Sequence.

2) Explored Plays and Zohr Play Concept

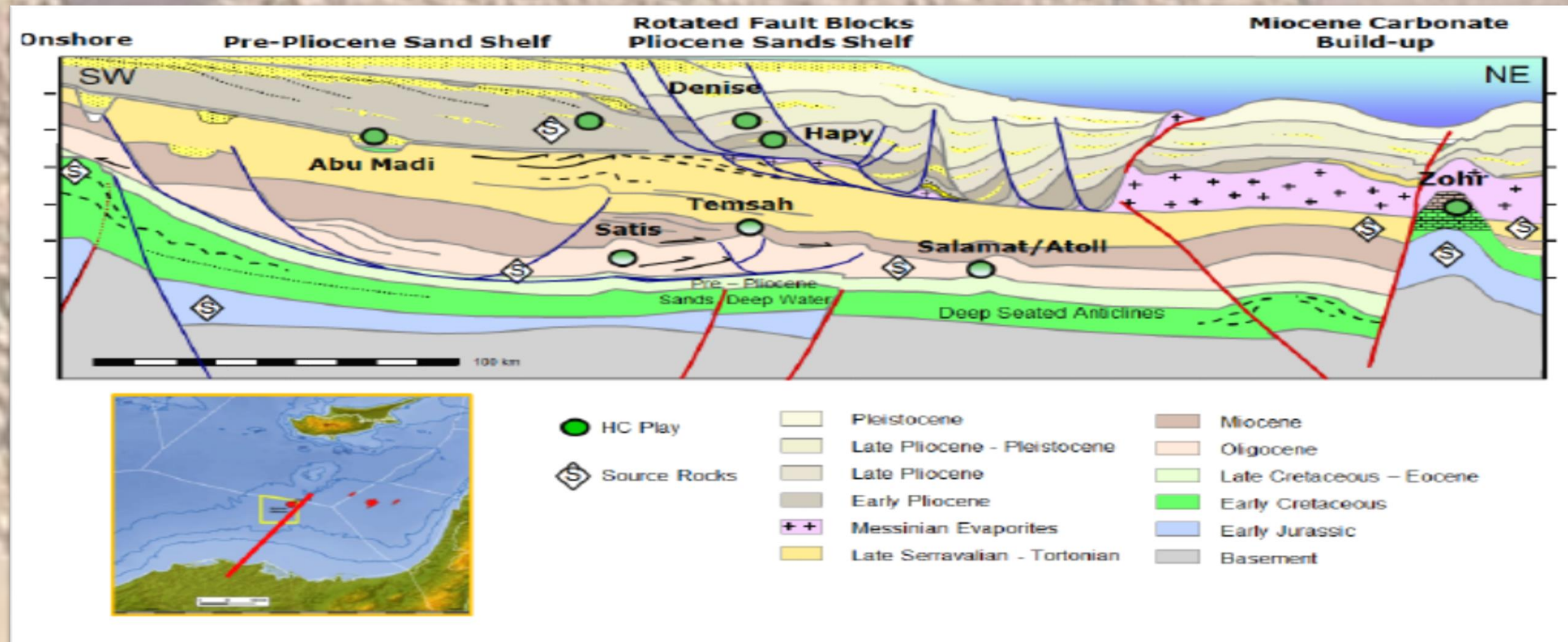


Figure 3: Offshore Nile delta- explored plays and Zohr play concept (after Francesco Bertello, Hamed Harby and Stella Brandolese 2016)

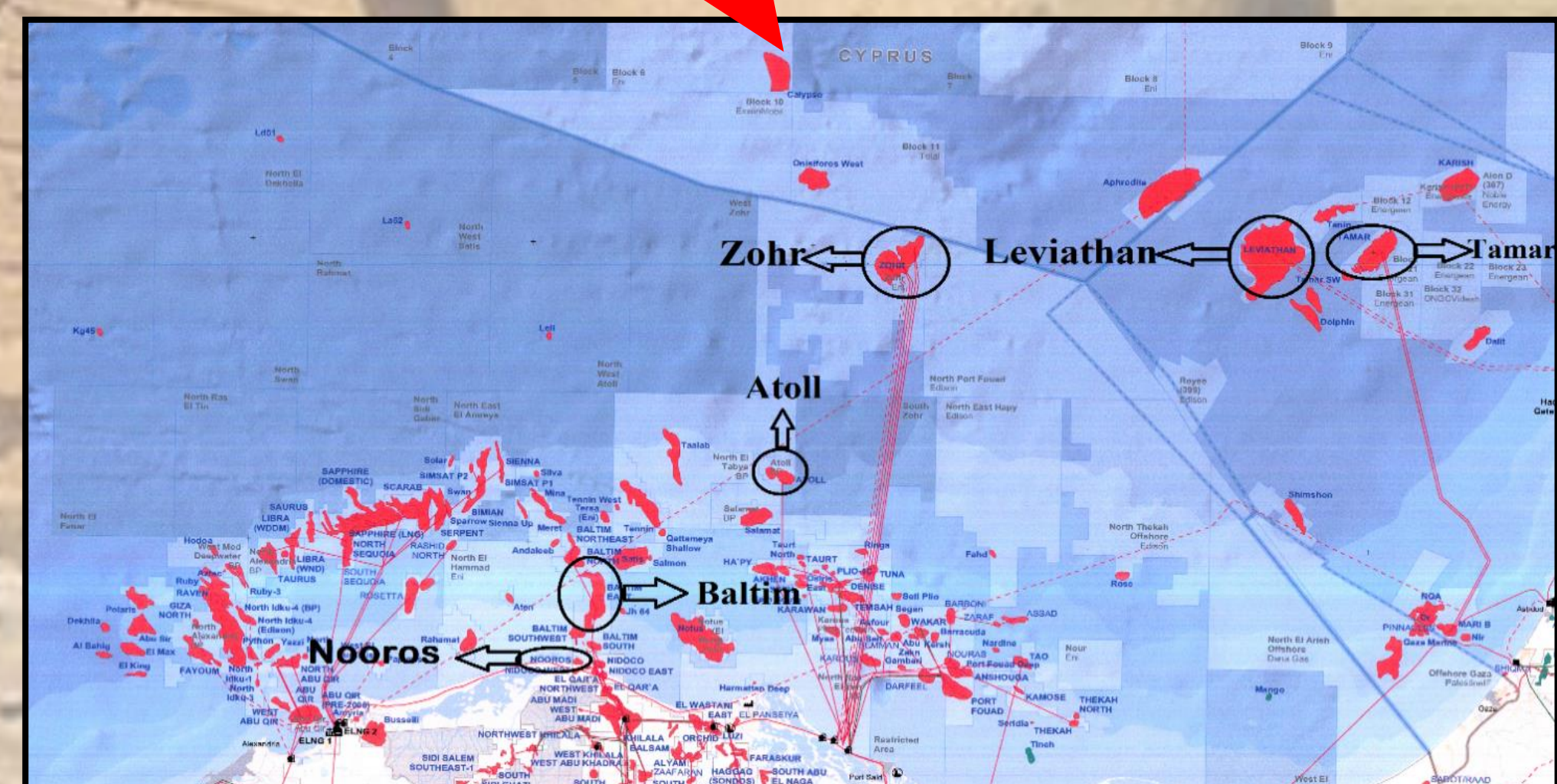


Figure 1: Location map of the Eastern Mediterranean, showing the location of the study area (after Wood Mackenzie 2018)

Exploration and Development in the Eastern Mediterranean in Egypt and Israel

1) Zohr Gas Field

Eni is an Italian multinational oil and gas company headquartered in Rome. An agreement was signed in January 2014 with the Egyptian Ministry of Petroleum, the Egyptian Natural international Bid Round. Zohr is the largest offshore natural gas Gas Holding Company (EGAS) and ENI following a competitive field discovery ever made in Egypt and in the Mediterranean Sea. At the end of August 2015, Eni announced to have achieved through its subsidiary IEOC an outstanding gas discovery in the Shorouk Concession, situated in the northernmost part of the Egyptian Mediterranean waters. From the geological point of view, the Shorouk Concession is located at the intersection of the Nile Delta Basin and of the Levantine Basin. The Zohr structure is located in about 1500 m of water depth. Zohr 1 NFW was drilled to a total depth of 4,131 meters and hit 630 meters of hydrocarbon column in a carbonate sequence of Miocene age with excellent reservoir characteristics (430 meters plus of net pay). According to the well and seismic information available, the discovery could hold a potential of **30 trillion cubic feet** of lean gas in place.

Petroleum System of Zohr Gas Field

Source Rock:
Thermogenic gas and oil from Oligocene and deeper SR (Fig. 6)

Reservoir:
The reservoir rocks are carbonate platform interpreted as ramps with bio-intraclastic (Fig. 6).

Seal (Cap rock):
Condensed pelagic mudstone and shale early Miocene (Fig. 6).

Trap:
Structure and Stratigraphic traps provide the main trapping style (Fig. 6).

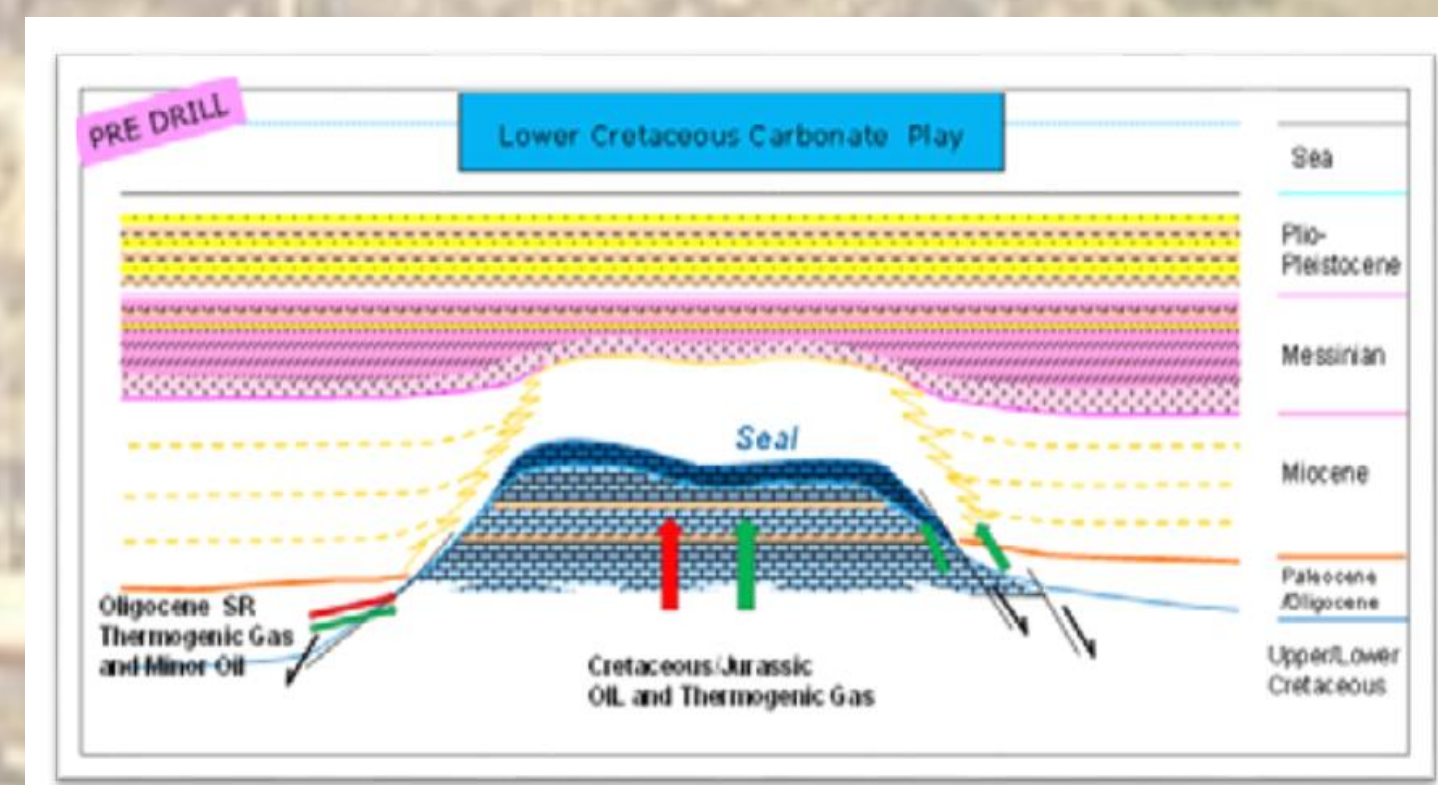


Figure 6: Zohr play concept of Lower Cretaceous carbonate play (after Francesco Bertello, Hamed Harby and Stella Brandolese 2016).

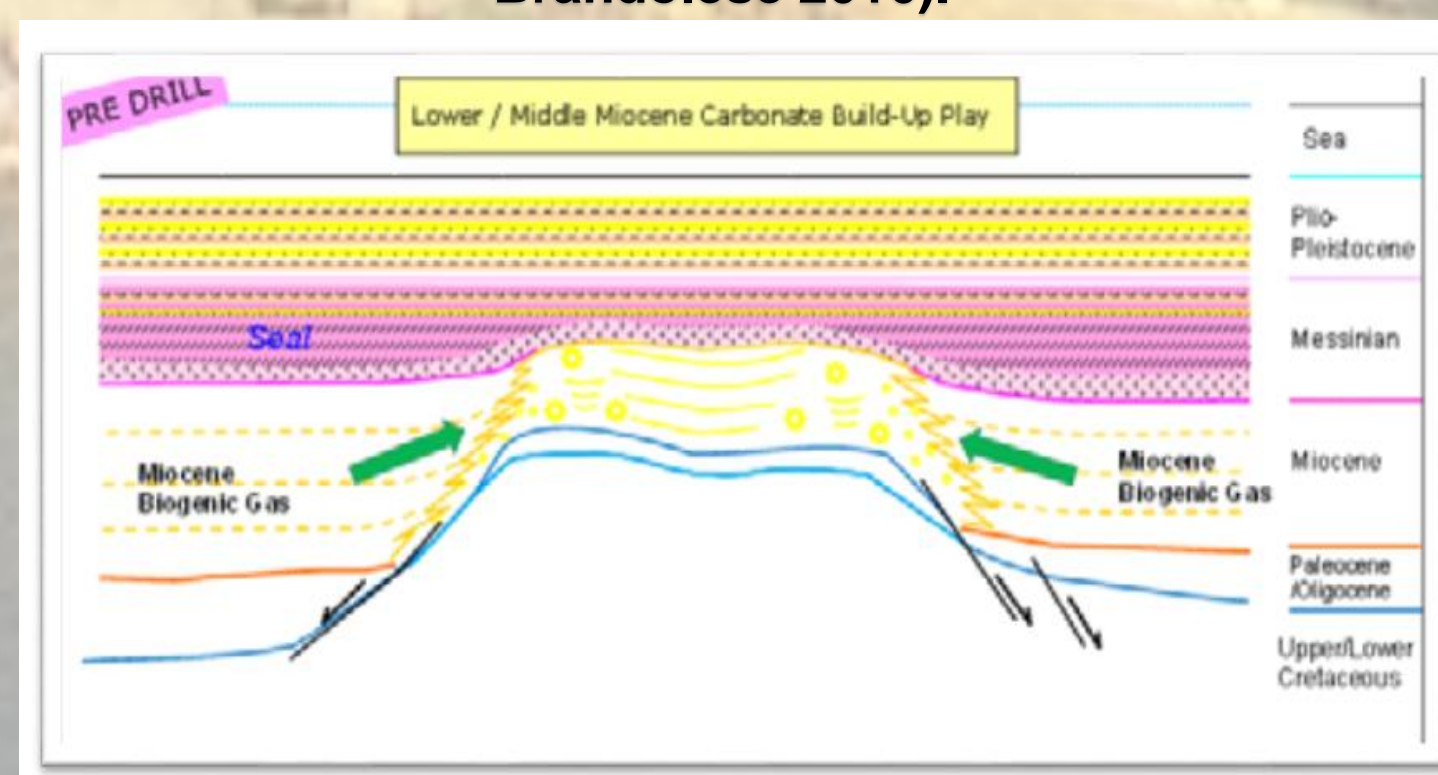


Figure 7: Zohr play concept of Lower / Middle Miocene carbonate build-up play (after Francesco Bertello, Hamed Harby and Stella Brandolese 2016).

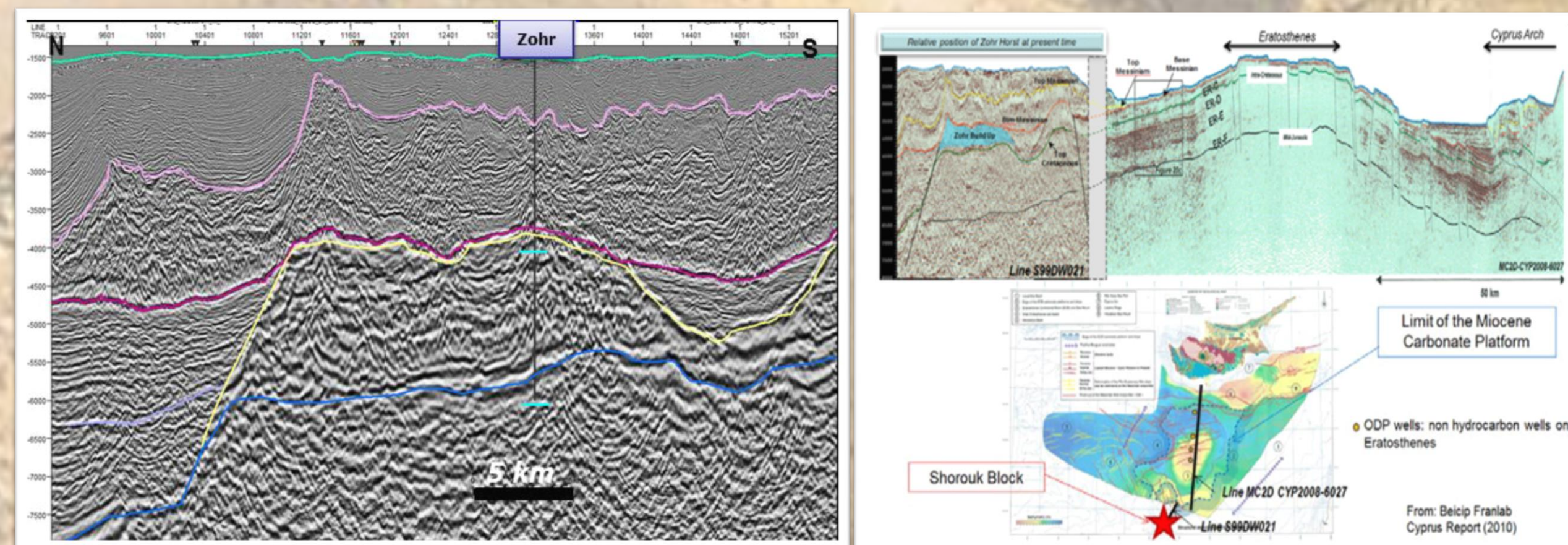


Figure 4: Seismic section of Zohr-1 field, showing petroleum system of well (after Francesco Bertello, Hamed Harby and Stella Brandolese 2016).

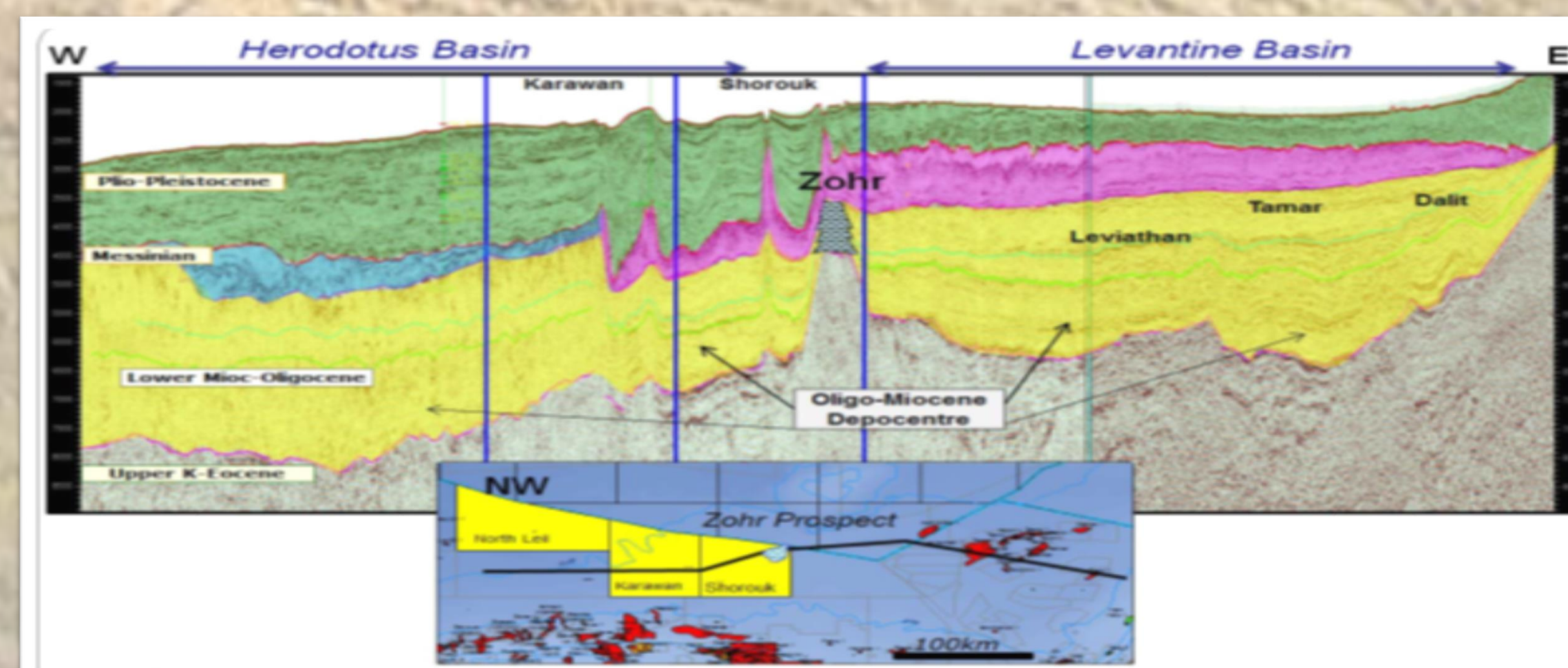


Figure 5: Mediterranean Sea vs Levantine regional seismic line (after Francesco Bertello, Hamed Harby and Stella Brandolese 2016).

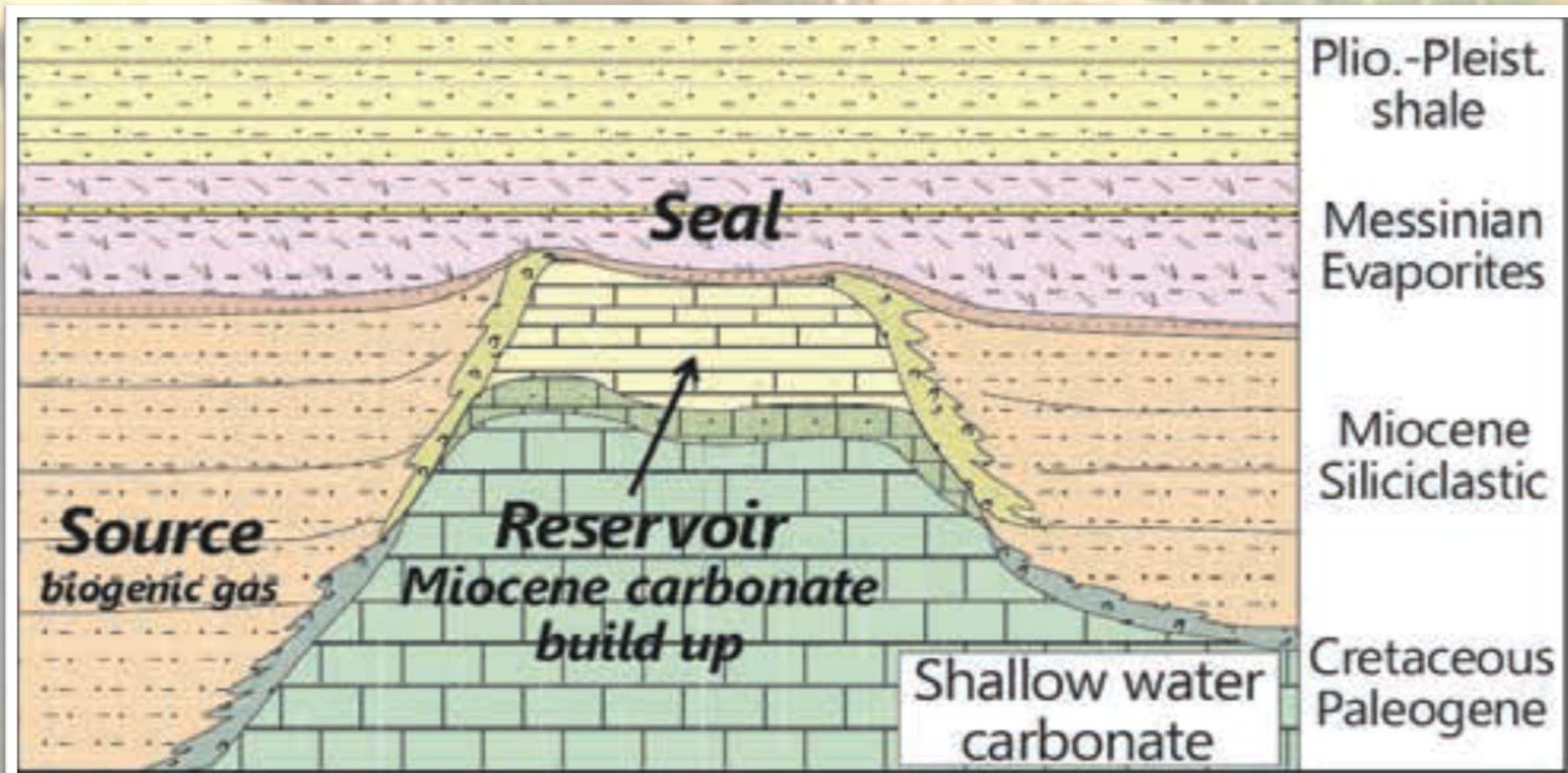


Figure 8: Geological sketch of the Zohr Discovery reprinted from ENI press release, (after Paolo Esestime, Ashleigh Hewitt and Neil Hodgson, 2016)

Production

The huge Zohr gas field offshore Egypt has increased its production six fold since it started production in January 2016, Egypt's Petroleum Minister Tarek el-Molla said. Production at Zohr in the Mediterranean has increased to 2 billion cubic feet per day (bcfd) in January 2018. Eni and its partners aim to reach plateau **production in excess of 2.7 bcf/d in 2019**, the Italian company says.

2) Baltim Gas Field

Baltim area lies to the north of the Nile Delta about 25 km off the Egyptian Coast. It covers an area of about 500 km², with a length of 25 km and a width of 18.75km. Baltim area is considered as the northwest extension of Abu Madi. Baltim East was discovered in 1993 and the production started in April 2000. Baltim North was discovered in 1995. The production started only in November 2005. The Baltim gas field's natural gas reserves are estimated to be **1 trillion cubic feet (tcf)**.

Petroleum System of Baltim Gas Field

Source Rock:
Majority of Abu Madi kerogen belongs to mature type III in the principal zone of oil generation, Ro values range from 0.5 to 1%. With small amounts of kerogen immature type III, where Ro is less than 0.5%. Plot of hydrogen index versus oxygen index also indicates the predominance of organic matter of type III.

Reservoir:
In addition, a subordinate sand level could be identified in between levels III and II, being denoted as level III A. The fields comprise two separate gas pools referred to as the "level III main" and "level III lower" within the Late Messinian Abu Madi Formation.

Seal (Cap rock):
The Upper Miocene (Messinian) Abu Madi Formation consists mainly of sandstone intercalated with siltstone and shale interbeds. In Baltim area levels III upper unit, III A, II, and I are shale-out.

Trap:
The sedimentary section in the Nile Delta area with gas potential seems to be limited to the Neogene formations trapped against listric faults or draped over tilted fault blocks.

Production

Belayim Petroleum Company (Petrobel) is working on expediting the production of Baltim field, adding **500 million standard cubic feet per day (mmscf/d) of natural gas**, a source at the company told Amwal Al Ghad.

By

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3) Nooros Gas Field

- The Nooros field was discovered in July 2015 in the Nile Delta offshore area and put into production in record time the following month. It is currently Eni’s main gas producing field in its Egyptian asset portfolio as well as an example of the success of the company’s integrated model. The discovery perfectly exemplifies Eni’s “near field” exploration strategy, aimed at locating potential additional reserves located in proximity to already existing upstream infrastructures.
- In the Nile Delta Concession, where Nooros is located, Eni holds a 75% stake through its affiliate IEOC Production BV, while BP holds the remaining 25%.

Petroleum System of Nooros Gas Field

Source Rock:
Oligocene shales have values of TOC ranges from 0.8 to 2.2% with low-medium hydrogen index 100-300 and a kerogen type II – III (oil and gas prone kerogen). Qantara shales represent a fair - good source rocks, mainly of type III, gas prone kerogen. Mixed kerogen type II-III oil & gas prone was reported in certain areas. The TOC values up to 2-5%, with low-medium hydrogen index.

Reservoir:
Reservoir rocks concerned of late Miocene are constituted by sand & sandstone in Qawasim and AbuMadi Fms., which showed good petrophysical characteristics.

Seal (Cap rock):
Seal is provided by intra-formational shale of Qawasim and post-rift megasequence. Thick shale intervals present at the lowermost portion of the Kafr el Sheikh Fm., provide the seal for Abu Madi deposits seal rocks are age late Miocene to early Pliocene.

Trap:
The sedimentary section in the Nile Delta area with gas potential seems to be limited to the Neogene formations trapped against listric faults or draped over tilted fault blocks. However pre-Miocene formations of the base of this Neogene sequence may also be considered as future exploration plays.

Production

The reserve of the field reaches **2 trillion cubic feet**.
Its production rate is 1.2 billion cubic feet per day of gas.
The first production of the well was in August 2015 at the rate of 80 million cubic feet.
The number of wells reached 14 wells **at 1.2 billion cubic feet per day**.

4) Atoll Gas Filed

The Atoll field was discovered by BP in March 2015 by drilling the Atoll-1 deepwater exploration discovery well. The well was drilled using the sixth generation semi-submersible rig Maersk Discoverer to a depth of 923m the drilling site is located 15km north of Salamat discovery, 80km north of the city of Damietta, and 45km north-west of Tamsah offshore facilities.
The exploration well was drilled to a depth of 6,400m and encountered approximately 50m of gas pay in high-quality sandstones. It is the operator’s second most significant Oligocene discovery in the area after the Salamat discovery of 2013.
The field is estimated to contain approximately **1.5 trillion cubic feet (tcf) of natural gas** and 31 million metric barrels (mmbbl) of condensates. An estimated 350 million metric standard cubic feet a day (mmscfd) of gas along with 10,000 barrels of condensate per day (bpd) is transported to the Egyptian domestic gas market.

5) Leviathan Gas Field

Located in the eastern Mediterranean Sea area off the coast of Israel. Leviathan Natural Gas Field was discovered in December 2010. The discovery is situated in 1,645m of water in the Levantine Basin. Noble Energy commenced drilling on the Leviathan-1 well in October 2010 In the first stage, the well was drilled to a depth of 6,500m. It encountered a minimum of 67m of natural gas pay. The Leviathan gas field’s natural gas reserves are estimated to be **18 trillion cubic feet (tcf)**.

Petroleum System of Leviathan Gas Field

Source Rock:
The Lower Miocene (or Oligo-Miocene) contains the main biogenic gas of shale.

Reservoir:
The Oligocene-Miocene reservoir section in leviathan field is a sequence of Deep water turbidate sandstone interbedded with variable amounts of siltstone and mudstone. Clean end member sands are quartz arenites (>=95% quartz), with porosity >20% and permeability> 500 mD.

Seal (Cap rock):
Regional seal of Missinian Evaporities in upper Miocene this salinity crisis is an important event in the Mediterranean basin. The thick evaporit deposits (up to 2000m thick), that were deposited during a Late Miocene of the Mediterranean Sea.

Trap:
The trap is Syrian arc fold and uplifted structures and normal fault.

Production

The Leviathan gas field’s natural gas reserves are estimated to be **18 trillion cubic feet (tcf)**. Besides natural gas, the field is said to contain 600 million barrels of oil beneath the gas layer.
he development plan allows for future expansion from its **initial 1.2 billion cubic feet per day (Bcf/d) capacity to 2.1 Bcf/d**.

6) Tamar Gas Field

The Tamar field is a natural gas field located roughly 90 km west of Haifa, at an overall depth of about 4,875 meters below sea level, and in waters that are 1,700 meters deep. The Tamar field is considered to have proven reserves of 200 billion cubic meters (**7.1 trillion cubic feet**) of natural gas.

Petroleum System of Tamar Gas Field

Source Rock:
The Tamar sand package is markedly continuous and covers an area that is about 120 km long and 60 km wide. and the source rocks are Oligocene biogenetic gas shale.

Reservoir:
The Oligocene-Miocene reservoir section in Tamar Field is a sequence of Deepwater turbidite sandstones interbedded with variable amounts of siltstone and mudstone. Clean end-member sands are quartz arenites (>=95% quartz), with porosity > 20% and permeability > 500 mD.

Seal (Cap rock):
regional seal of Missinian Evaporites in upper Miocene.

Trap:
The trap are Syrian arc folds and uplifted structures

Production

The natural gas in Tamar is extracted through five unique production wells, built in such a way as to each **produce between 7.1 and 8.5 million cubic meters of gas per day**.

ISRAEL-EGYPT GAS EXPORT DEAL

Practical steps have been taken that could eventually enable gas from Israel’s offshore to be piped to Egypt.

Israel's Delek, the US-based firm Noble and Egypt's East Gas have established a company (Emed) to buy 39% of the 26 in, 90 km East Mediterranean Gas pipeline for \$518 m. This investment, combined with a transportation agreement, will provide the partners with the exclusive rights to use all the pipeline's capacity.

Of the \$518 m, the Leviathan and Tamar offshore gas field partners will each pay \$125 m, whilst Delek and Noble will each pay another \$60 m. Most significantly, the East Gas company, which also owns the pipeline from Aqaba in Jordan to el-Arish in Egypt, will invest \$148 m, which is a considerable amount for Egypt. This strategic partnership with a leading Egyptian infrastructure owner provides "skin in the game" and an Egyptian umbrella for the entire transaction to sell Israeli gas to Egypt.

Global demand for gas is growing. Bloomberg New Energy Finance predicted that global demand for liquefied natural gas would increase from 284 m tones a year in 2017 to 450 m t/y in 2030, while analyst Sanford C Bernstein puts this figure at 575 m t/y.

CONCLUSIONS

- Zohr is not the only gas field in Egypt, but West Nile Delta (WND), Nooros and Atoll are all important gas fields that add to the national gas production.
- Egypt had reached self-sufficiency in natural gas production during 2018, as a result of a six-fold increase in Egypt’s Eastern Mediterranean Zohr Field’s production. The country’s gas output is expected to reach peak production in 2019, as it is expected that Zohr will produce 3 billion SCFD in 2019.
- Egypt is qualified to be a regional hub for energy due to its liquefying plants, pipeline grids, Warehousing, transportation, trading of petroleum and gas products and ports overlooking the Mediterranean and the Red Sea and refineries.
- Egyptian companies have already stuck \$15 billion deal for the import of Israel natural gas. Egypt intends to attract additional resources such as Cypriot gas to become the energy and LNG hub of the region.
- Israel is aware of the competing and more favorable Egyptian offer compared to its relatively expensive and technically challenging proposal.

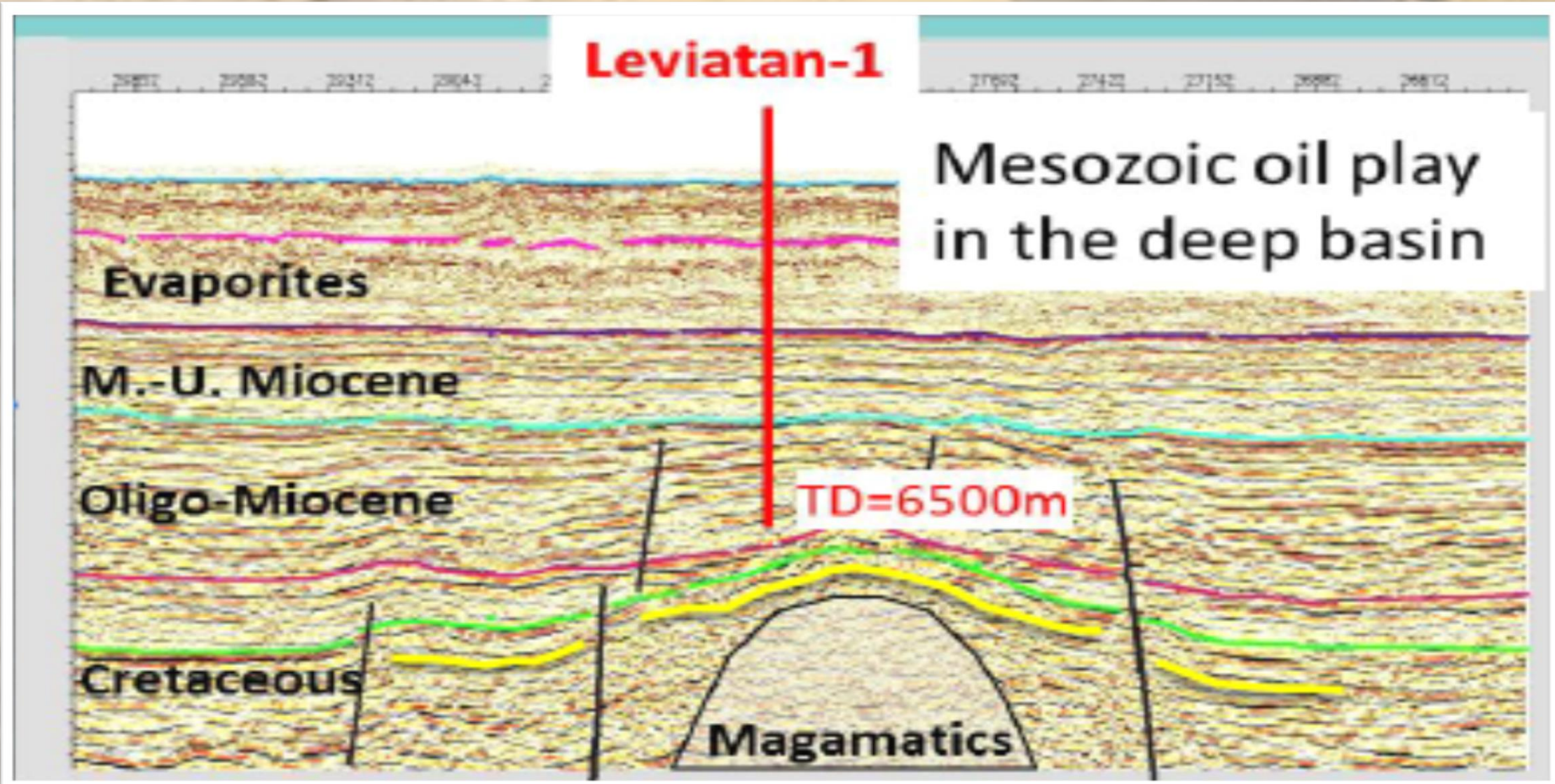


Figure 11: Seismic section of Leviathan-1 field showing petroleum system of Levantine basin. (from Delek Energy website, 2018).

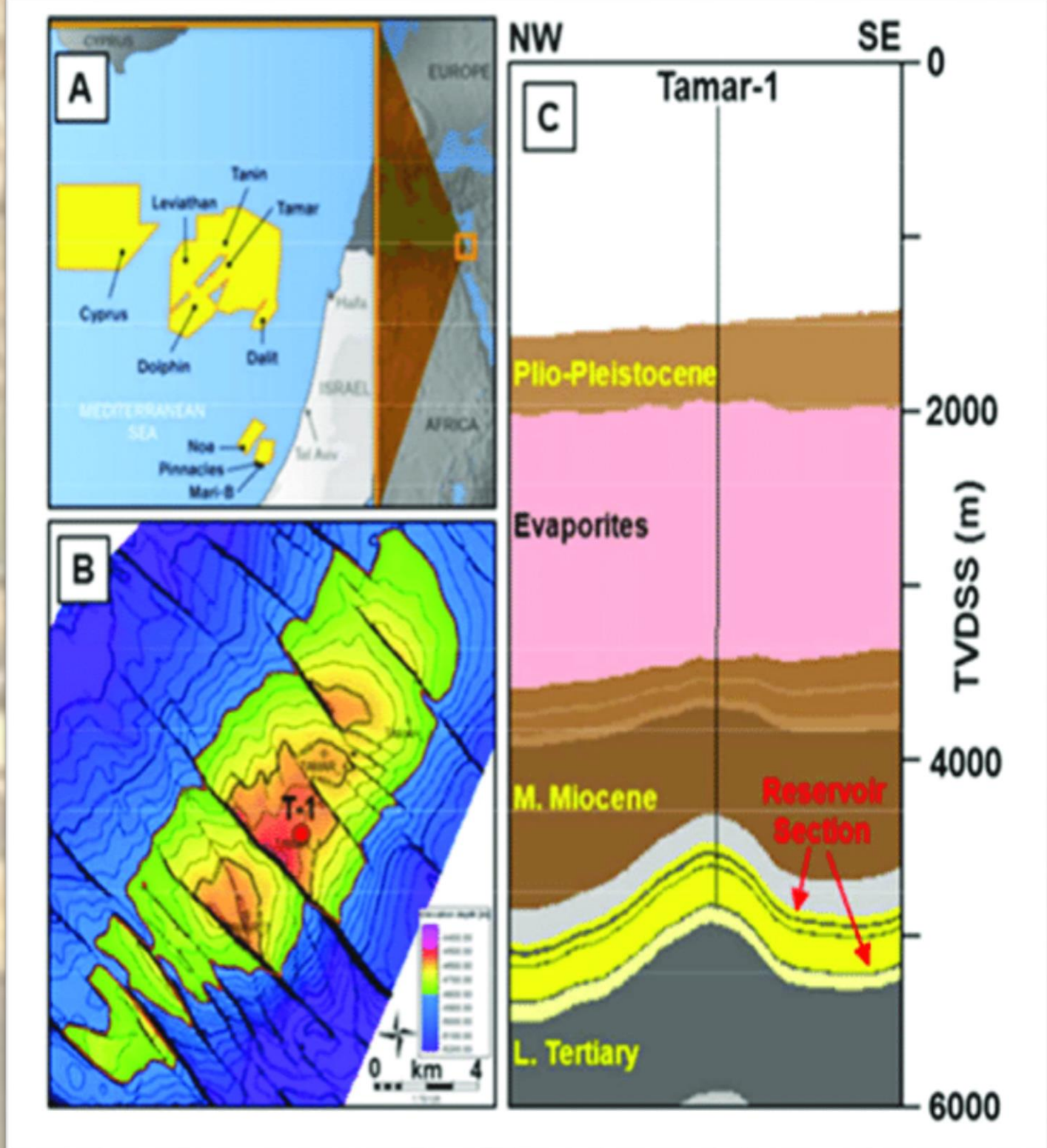


Figure 12: Overview of the Tamar field showing (a) location map, (b) structure map of top reservoir, and (c) structural cross-section (NW to SE) through the Tamar-1 discovery well T-1 (Christensen and Powers, 2013).



Figure 13: Possible gas pipeline from the East Mediterranean to Europe (after Meliksetian 2019)