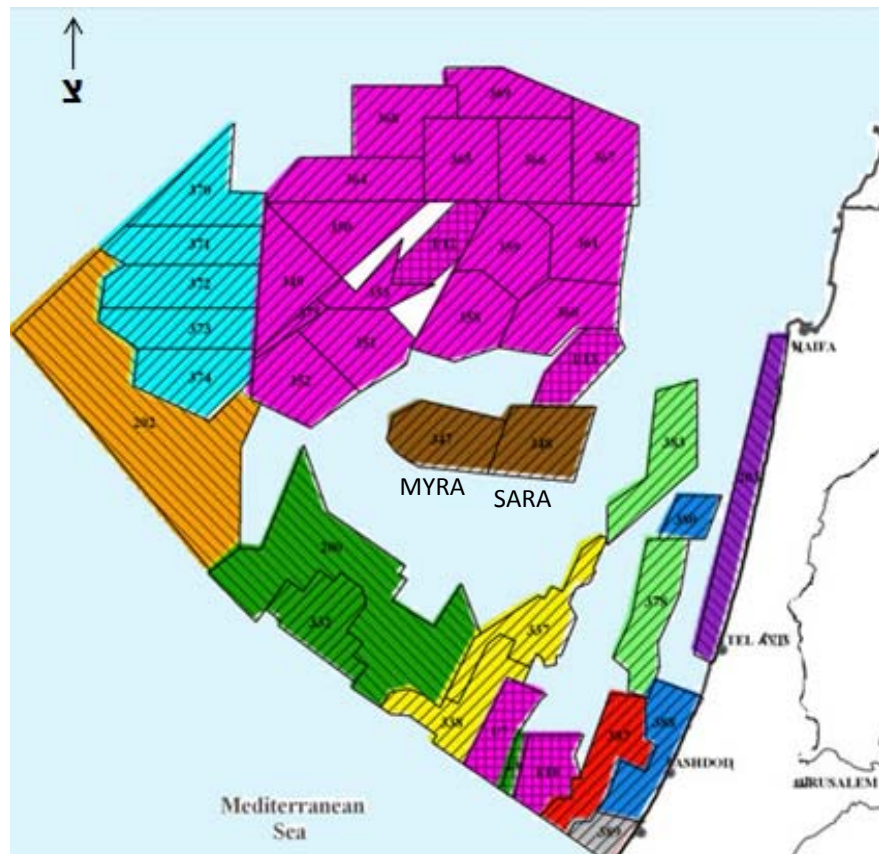


# SARA AND MYRA LICENCE AREAS OFFSHORE ISRAEL

## ENVIRONMENTAL DOCUMENT



NOVEMBER 2011

## SARA AND MYRA LICENCE AREAS OFFSHORE ISRAEL

### ENVIRONMENTAL DOCUMENT

PREPARED FOR



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## **Table of Contents**

<b>Chapter A – Background Data</b> .....	7
1.1 General Background.....	8
1.2 Area Description.....	10
1.3 Oceanography .....	28
1.4 Ecology.....	43
1.5 Fisheries.....	54
1.6 Archaeology.....	54
1.7 Infrastructure.....	54
1.8 Marine transportation.....	56
<b>Chapter B</b>	
2.1 Drilling project description .....	60
2.2 Drilling Process and Equipment.....	74
<b>Chapter C</b>	
3.1 Potential Impacts during Drilling period .....	79
3.2 mitigation measures .....	80
<b>Chapter D</b>	
4.1 Recommendations and environmental guidelines.....	82
<b>References</b> .....	83

**CD**

## List of Figures

Figure 1.2.1.1 Google-Earth image of the Mediterranean Sea

6

Figure 1.2.1.2 Google-Earth image of the Eastern Mediterranean Sea.

Figure 1.2.1.3 The breakup of the continents. Arrows indicate direction of movement. The Tethys Sea opened when Pangea broke up and later closed, as tectonic plates moved to their current positions.

Figure 1.2.1.4 The Paleo Tethys Sea and the surrounding continental areas, in Late Carboniferous (~300 million years ago), before the breakup of Pangea.

Figure 1.2.1.5 The Neo Tethys Sea and the surrounding continental areas, in early Cretaceous (~150 million years ago).

Figure 1.2.1.6 Main tectonic and geomorphologic features in the easternmost Mediterranean Sea.

Tectonic and geomorphologic features around the Levantine Basin.

Figure 1.2.1.7 Main tectonic and geomorphologic features around the Levantine Basin.

Figure 1.2.1.8 Tectonic scheme of the eastern Mediterranean Sea showing the main terrains

Figure 1.2.2.1 A simplified bathymetry and topography map of Eastern Mediterranean Sea and the surrounding land areas.

Figure 1.2.2.2. A simplified bathymetry and topography map of the Levantine Basin and the surrounding land areas.

Figure 1.2.2.3. Bathymetry map of the Levantine Basin.

Figure 1.2.3.1. A geomorphic diagram of the submarine Levantine margin.

Figure 1.2.3.2. A geomorphic diagram of the submarine Levantine margin.

Figure 1.2.4.1. Total intensity magnetic map, at sea-level.

Figure 1.2.5.1. Map of Bouguer gravity anomaly of the Eastern Mediterranean Sea.

Figure 1.2.6.1 Schematic section across the Levantine Basin, from the Eratosthenes Seamount in the northeast to the Dead Sea in the southwest.

Figure 1.2.6.2 An interpreted regional seismic cross-section through the northern Levantine Basin.

Figure 1.2.6.2 An interpreted regional seismic cross-section through the northern Levantine Basin.

Figure 1.2.6.3 Interpreted NE-SW seismic profile.

Figure 1.2.6.4 Interpreted NW-SE seismic profile.

Figure 1.2.7.1 A map of unconsolidated bottom surface sediments of the Levantine Basin.

Figure 1.2.7.2.Types of bottom sediments in the Levantine Basin.

Figure 1.3.1.1 Schematic surface circulation in the Mediterranean Sea.

Figure 1.3.1.2 Schematic surface circulation in the Mediterranean Sea.

Figure 1.3.1.3 Schematic mid water circulation in the Mediterranean Sea in winter and summer.

Figure 1.3.1.4 Schematic intermediate water circulation in the eastern Mediterranean Sea.

Figure 1.3.2.1 Distribution of surface currents in the southern Levantine Basin.

Figure 1.3.2.2 Distribution of currents in the southern Levantine Basin at 30 m and 50 m and below surface.

Figure 1.3.2.3 Distribution of currents in the southern Levantine Basin at 75 m and 100 m below surface.

- Figure 1.3.2.4 Distribution of currents in the southern Levantine Basin at 200 m and 300 m below surface.
- Figure 1.3.3.1 Salinity and temperature profiles in May in the southeast Levantine Basin.
- Figure 1.3.3.2 Average surface temperature in the Eastern Mediterranean Sea.
- Figure 1.3.3.3 Average surface salinity in the Eastern Mediterranean Sea.
- Figure 1.3.3.4 Temperature cross sections from the surface to a depth of 1000 m through the eastern half of the Mediterranean Sea.
- Figure 1.3.3.5 Salinity cross sections from the surface to a depth of 1000 m through the eastern half of the Mediterranean Sea.
- Figure 1.3.4.1 Climatological wind stress field in the eastern Mediterranean Sea.
- Figure 1.3.5.1 Annually averaged vertical profiles of hydrographic parameters.
- Figure 1.4.1.1 Transects of spatial predicted species richness. A - Latitudinal transects; - Longitudinal transects.
- Figure 1.4.1.2 spatial patterns of vertebrate species richness in the Mediterranean Sea.
- Figure 1.4.1.3 spatial patterns of non resident marine mammals in the Levantine Basin.
- Figure 1.4.1.4 Loggerhead turtle and monk seal.
- Figure 1.4.1.5 Distribution of monk seals and nesting sites of marine turtles in the Mediterranean.
- Figure 1.4.1.6 Google-Earth image of the Suez Canal, connecting the Gulf of Suez in the south to the Mediterranean Sea in the north.
- Figure 1.4.1.7 *Fistularia commersonii*, one of the Lessepsian Migrants.
- Figure 1.4.1.8 Deep Levant organisms.
- Figure 1.4.2.1 A meadow of *Posidonia oceanica*.
- Figure 1.8.1.1 – navigation routes Mediterranean sea, Israel
- Figure 2.1.1.1 A tectonic map of the eastern Mediterranean Sea, showing the confines of continental crust, terrains , oceanic crust , terrains and the Alpine tectonic belt) as well as main faults and drilling sites.
- Figure 2.1.1.2 Schematic section through the Levant Basin showing potential hydrocarbon traps in the Phanerozoic sedimentary sequence.
- Figure 2.1.2.1 Offshore drilling history and main hydrocarbon occurrences.
- Figure 2.1.3.1 A map of the Levantine Basin, showing the division of the seabed between Egypt, Israel, Lebanon and Cyprus, and the subdivision to individual Licence Area off Israel and Cyprus.
- Figure 2.1.3.2 Map showing Licence Areas onshore and offshore Israel.
- Figure 2.1.3.3 Bathymetric map of the continental margin off Israel.
- Figure 2.1.4.1 Bathymetry around The Sara-1 Rev proposed drilling location. Depth at Location is 1337 meters.
- Figure 2.1.4.2 A shaded relief image of the seabed around the Sara-1 Rev Location. The seabed is practically flat
- Figure 2.1.4.3a. Top part of the Sara-1 Rev interpreted seismic section (to the middle of the Mavqim Formation).
- Figure 2.1.4.3b. Bottom part of the Sara-1 Rev interpreted seismic section.
- Figure 2.1.5.1. Bathymetry around The Myra-1 Rev proposed drilling location. Depth at Location is 1,467 metres.
- Figure 2.1.5.2 A shaded relief image of the seabed around the Myra-1 Rev Location. The seabed is practically flat.
- Figure 2.1.5.3a. Top part of the Myra-1 Rev interpreted seismic section.
- Figure 2.1.5.3b. Bottom part of the Myra-1 Rev interpreted seismic section.

## List of Tables

Table 1.4.1.1 Species richness by taxa and regions in the Mediterranean Sea.

Table 1.4.1.2 Taxonomic classification of species reported in the Mediterranean Sea.

# Chapter A

## Background Data

## Chapter A – Background Data

### 1.1 General Background

#### Myra Licence

347 Myra (400000 dunams)                      Validity 14/07/2008 - 13/07/2011

* Emanuelle Energy Ltd.	30.013 %
Modiin Energy Partnership Limited	21.612 %
Emanuelle Energy Oil & Gas Ltd.	19.1610 % Partn.
IPC Oil and Gas Ltd. Partn.	13.6090 %
Blue Water Oil & Gas Explor. Ltd.	8.7870 %
GeoGlobal Resources (India) Inc.	5.0 %
IDB Development Corporation Ltd.	5.605 %
Israel Land Development Company	5.0 % Ltd.

#### Sara Licence

348 Sara (400000 dunams)                      Validity 14/07/2008 - 13/07/2011

* Emanuelle Energy Ltd.	30.013%
Modiin Energy Partnership Limited	21.612 %
Emanuelle Energy Oil & Gas Ltd.	19.1610 % Partn.
IPC Oil and Gas Ltd. Partn.	13.6090 %
Blue Water Oil & Gas Explor. Ltd.	8.7870 %
GeoGlobal Resources (India) Inc. (Providing all the drilling design and project management on behalf of remaining partners)	5.0 %
IDB Development Corporation Ltd.	5.605 %
Israel Land Development Company	5.0 % Ltd.

## Time Table (Spud date 1st Qtr 2011)

### Sara 1

Drilling Curve 51 days

Well Testing 28 days

### Myra 1

Drilling Curve 66 days

Well Testing 31 days

Drilling completion approx. 186 days from Spud Date.

## 1.2 Area Description

### 1.2.1 GEOLOGY

#### 1.2.1.1 Physiographic setting

The Levantine Basin occupies the south-easternmost part of the Mediterranean Sea (Figure 1.2.1.1). It is bounded by the Eratosthenes Seamount in the west, Cyprus in the north, the Lebanese and Israeli coasts in the east and the Nile delta in the south (Figure 1.2.1.2). The basin has depths of 1,500 to 2,000 m and comprises about 100,000 km<sup>2</sup>.



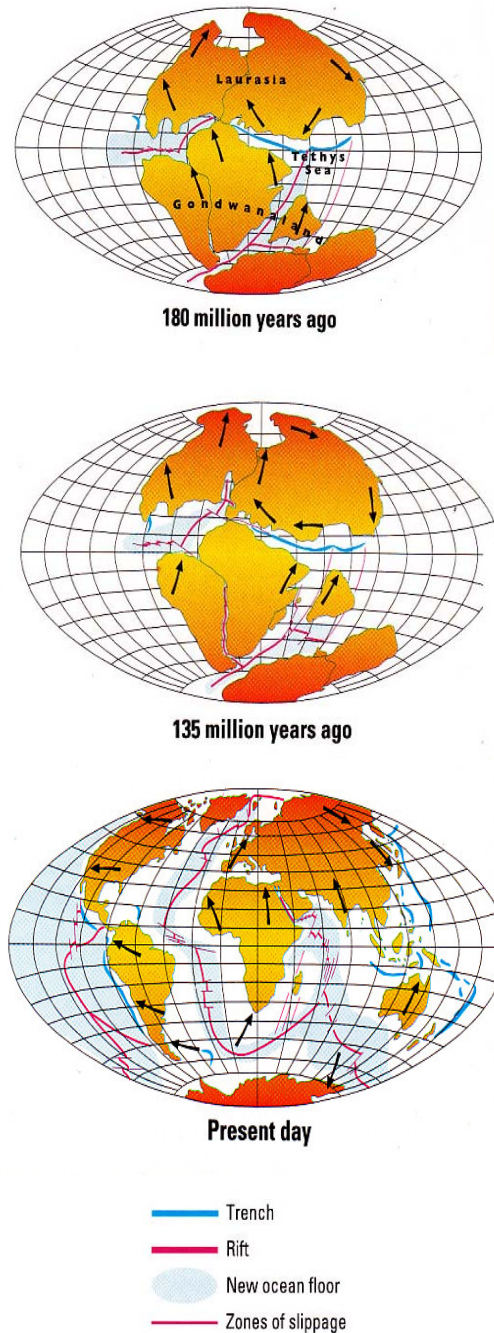
Figure 1.2.1.1 Google-Earth image of the Mediterranean Sea.



Figure 1.2.1.2 Google-Earth image of the Eastern Mediterranean Sea. Dashed ellipse indicates the approximate extent of the Levantine Basin.

### 1.2.1.2 Origin and evolution

About 200 million years ago the Pangaea land mass began to split into two continental groups, Laurasia and Gondwanaland, which further separated over time to form the present-day configuration (Fig 1.2.1.3). The Earth crust is made of a series of rigid plates which float on the soft layer of the mantle, and are moved away from each other by continental convection currents within the Earth's interior, resulting in the formation of ridges. Plates diverge and converge along margins marked by seismic activity. Plates diverge from mid-ocean ridges, where molten lava pushes upwards and forces the plates apart. Plates converge along subduction lines where the convention currents force one plate under the other.



**Figure 1.2.1.3 The breakup of the continents. Arrows indicate direction of movement. The Tethys Sea opened when Pangaea broke up and later closed, as tectonic plates moved to their current positions.**

*Source: Philip's World Atlas, 8<sup>th</sup> Edition 1998.*

Conceptual maps of the Paleo and Neo Tethys Seas, suggested by Stampfli, G.L., et al (1998), are presented in Figure 1.2.1.4 (detailing the situation depicted in the top drawing of Figure 1.2.1.3 and Figure 1.2.1.5 (detailing the situation depicted in the middle drawing of Figure 1.2.1.3).

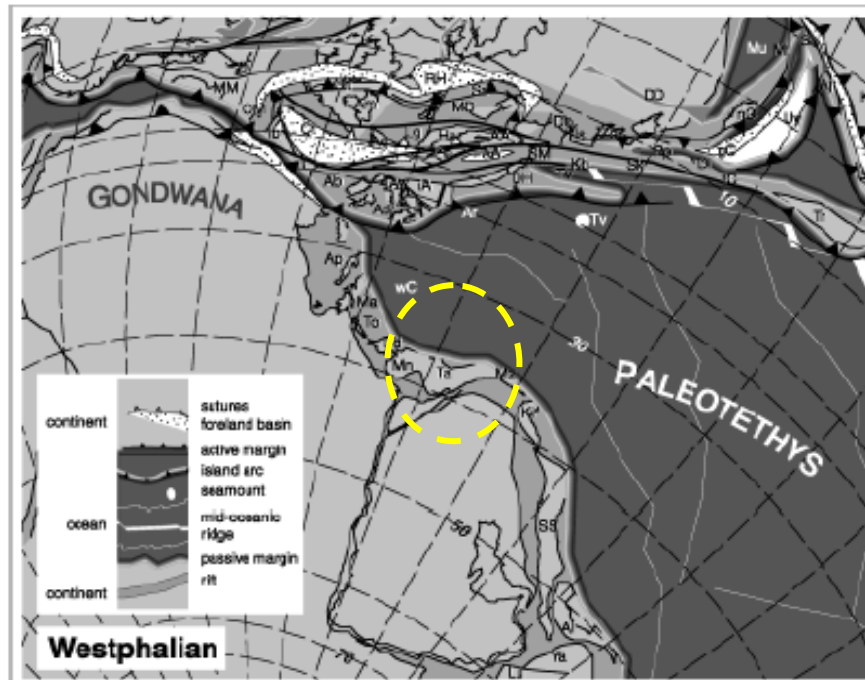


Figure 1.2.1.4 The Paleo Tethys Sea and the surrounding continental areas, in Late Carboniferous (~300 million years ago), before the breakup of Pangea. Dark areas represent oceanic crust; grey areas represent continental crust. Dashed yellow circle indicates the location of today's Levantine Basin.  
Source: Stampfli et al, 1998.

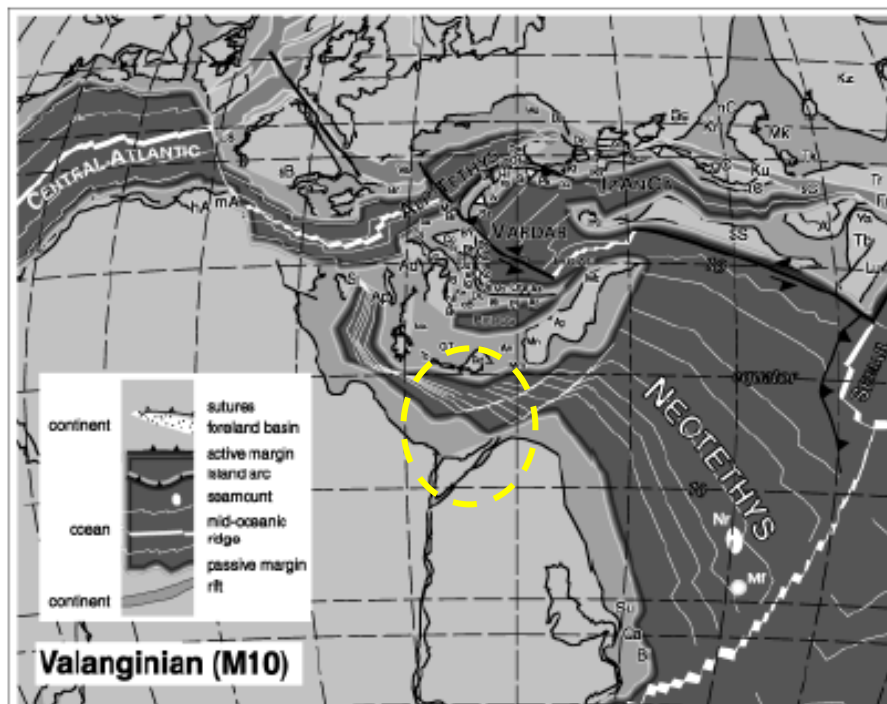


Figure 1.2.1.5 The Neo Tethys Sea and the surrounding continental areas, in early Cretaceous (~150 million years ago). Dark areas represent oceanic crust; grey areas represent continental crust. Dashed yellow circle indicates the location of the Levantine Basin.  
Source: Stampfli et al, 1998.

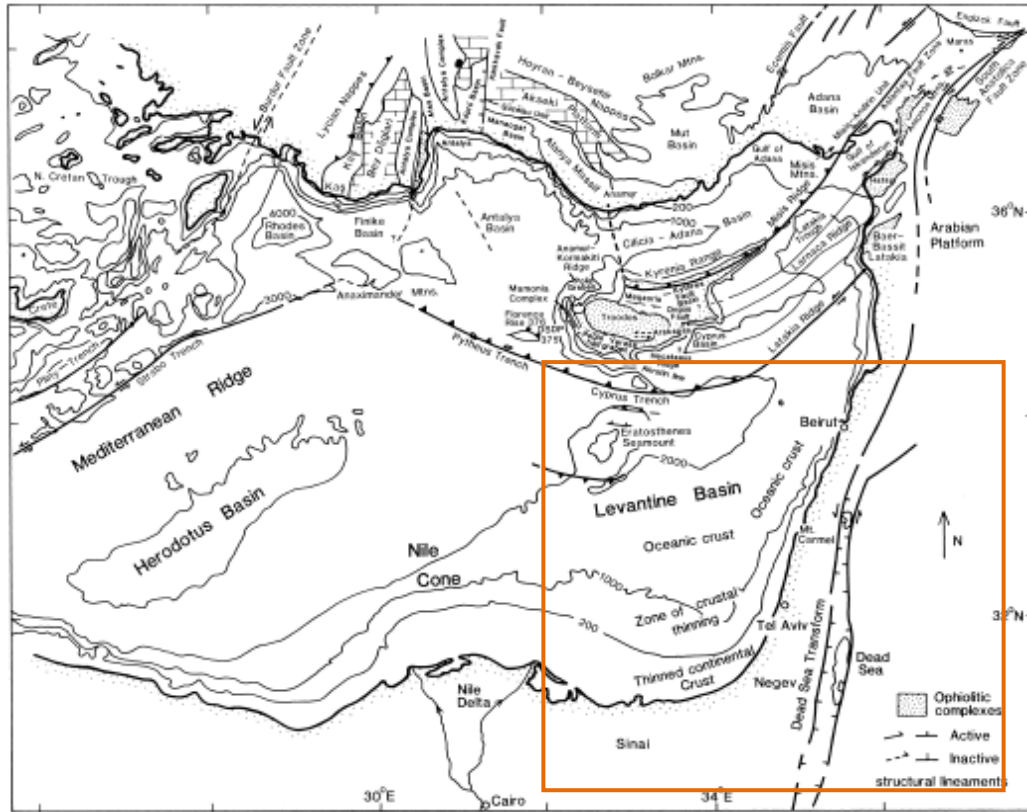


Figure 1.2.1.6 Main tectonic and geomorphological features in the easternmost Mediterranean Sea. Red box indicates area enlarged in Figure 1.2.1.7  
Source: Robertson, 1998.

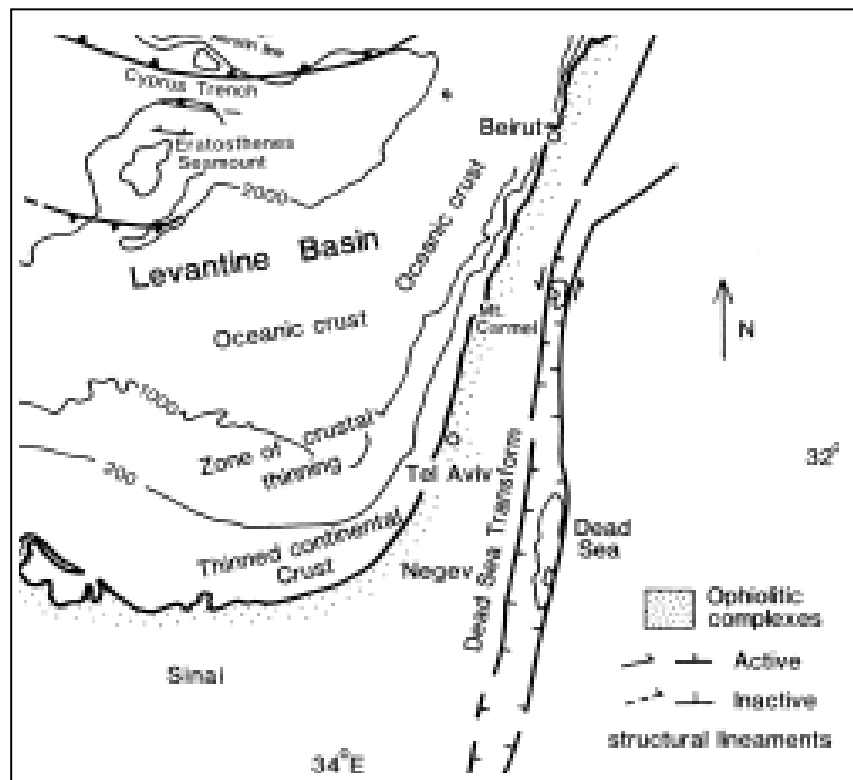


Figure 1.2.1.7 Main tectonic and geomorphological features around the Levantine Basin (enlarged from Figure 1.2.1.6)  
Source: Robertson, 1998.

### 1.2.1.3 Tectonic overview

Recent researches suggest that the eastern Mediterranean consists of four geotectonic plates – the African, Sinai, Arabian and Aegean-Anatolian Plates (Figure 1.2.1.8). The African and Sinai Plates comprise heterogeneous blocks of oceanic and continental crust bounded by deep faults. The oceanic crust of is thought to be a remnant of the Neothetys.

Three main types of crust can be identified in the area: a. platforms with a Precambrian crust, b. oceanic crust and c. a folded belt of the transition type, with a thinned continental crust. The boundaries between the various zones have not been precisely defined. The eastern Mediterranean is separated from the Arabian Platform by the Dead Sea fault system.

The folded belt comprises several terrains, namely Cyprus, Eratosthenes, Galilee-Lebanon, Judea-Samaria and Negev. Compressional seismic velocity-depth distribution for the terrains (shown in the inset) indicates a different composition of the terrains.

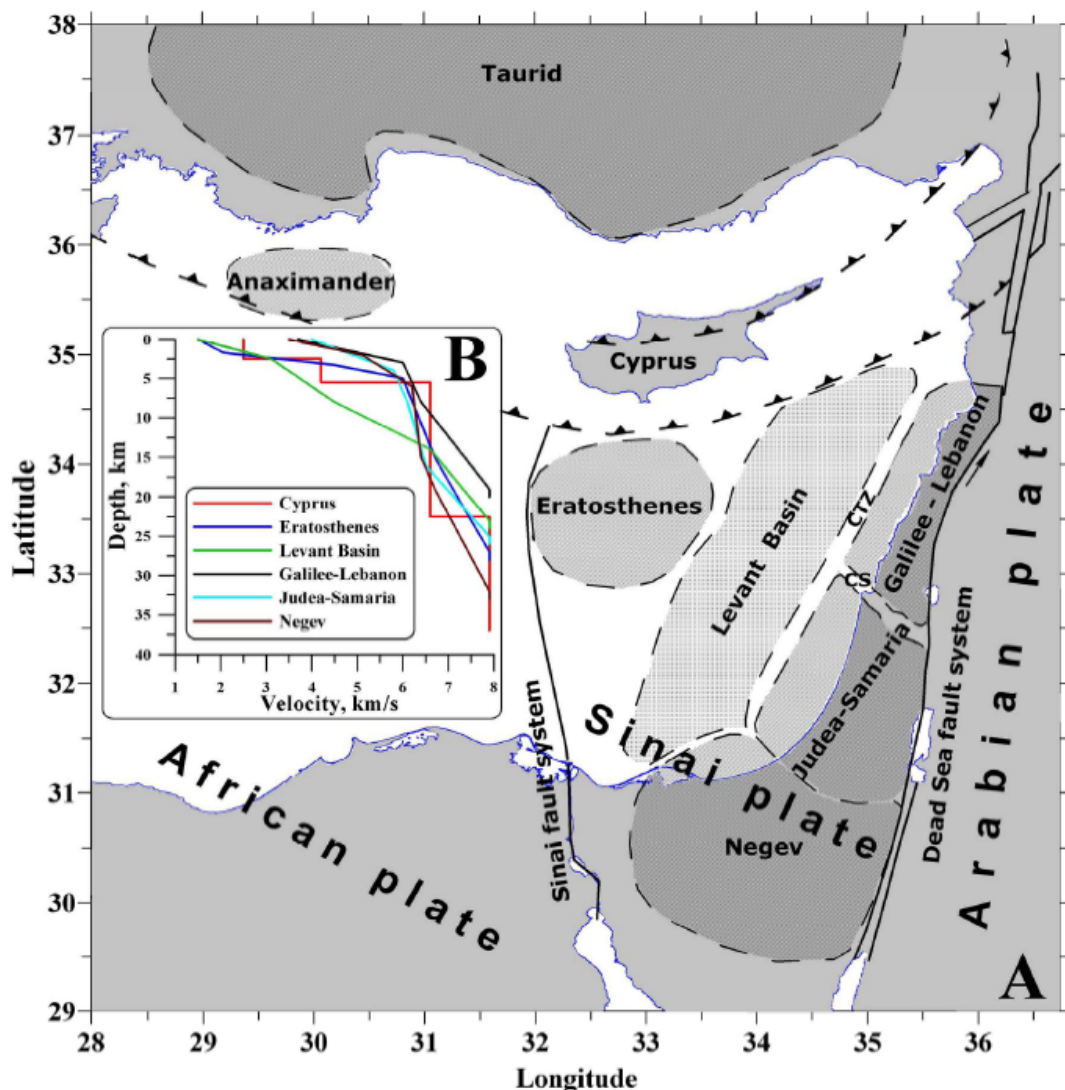


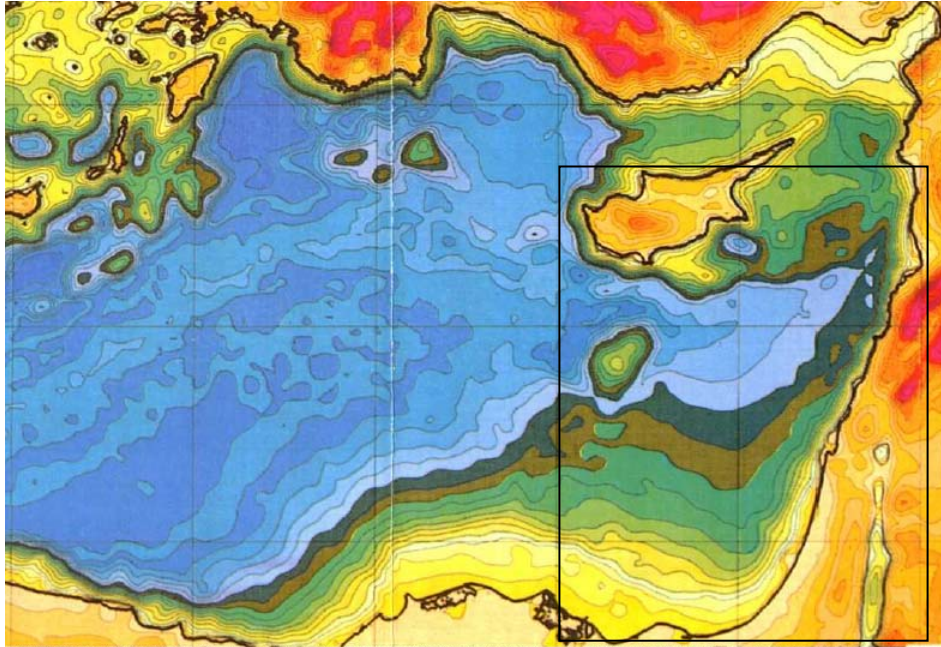
Figure 1.2.1.8 Tectonic scheme of the eastern Mediterranean Sea showing the main terrains (A) with generalised seismic sections (B). CS – Carmel Structure; CTZ – crustal transition zone.

Source: Eppelbaum and Katz, 2011.

[A terrain is a fragment of crustal material formed on, or broken off from, one tectonic plate and accreted or 'sutured' to crust lying on another plate. The crustal block or fragment preserves its own distinctive geologic history, which is different from that of the surrounding areas – hence the term "exotic" terrane].

## 1.2.2 Bathymetry

A simplified bathymetric map of the Eastern Mediterranean Sea was compiled by Makris et al (1994) and is shown in Figure 1.2.2.1.



**Figure 1.2.2.1 A simplified bathymetry and topography map of Eastern Mediterranean Sea and the surrounding land areas. Box indicates area enlarged in Figure 1.2.2.2. Depth scale in Figure 1.2.2.3.**  
*Source: Makris et al, 1994.*

The main features of and around the Levantine Basin are shown in Figure 1.2.2.2, which is an enlargement of part of Figure 1.2.2.1. The continental margin south and east of the basin is wide in the south and becoming increasingly narrow in the northeast (the 100 m isobaths is ~60 km off the coast of Sinai, 15-25 km off the coast of Israel and 1-10 km off the coast of Lebanon).

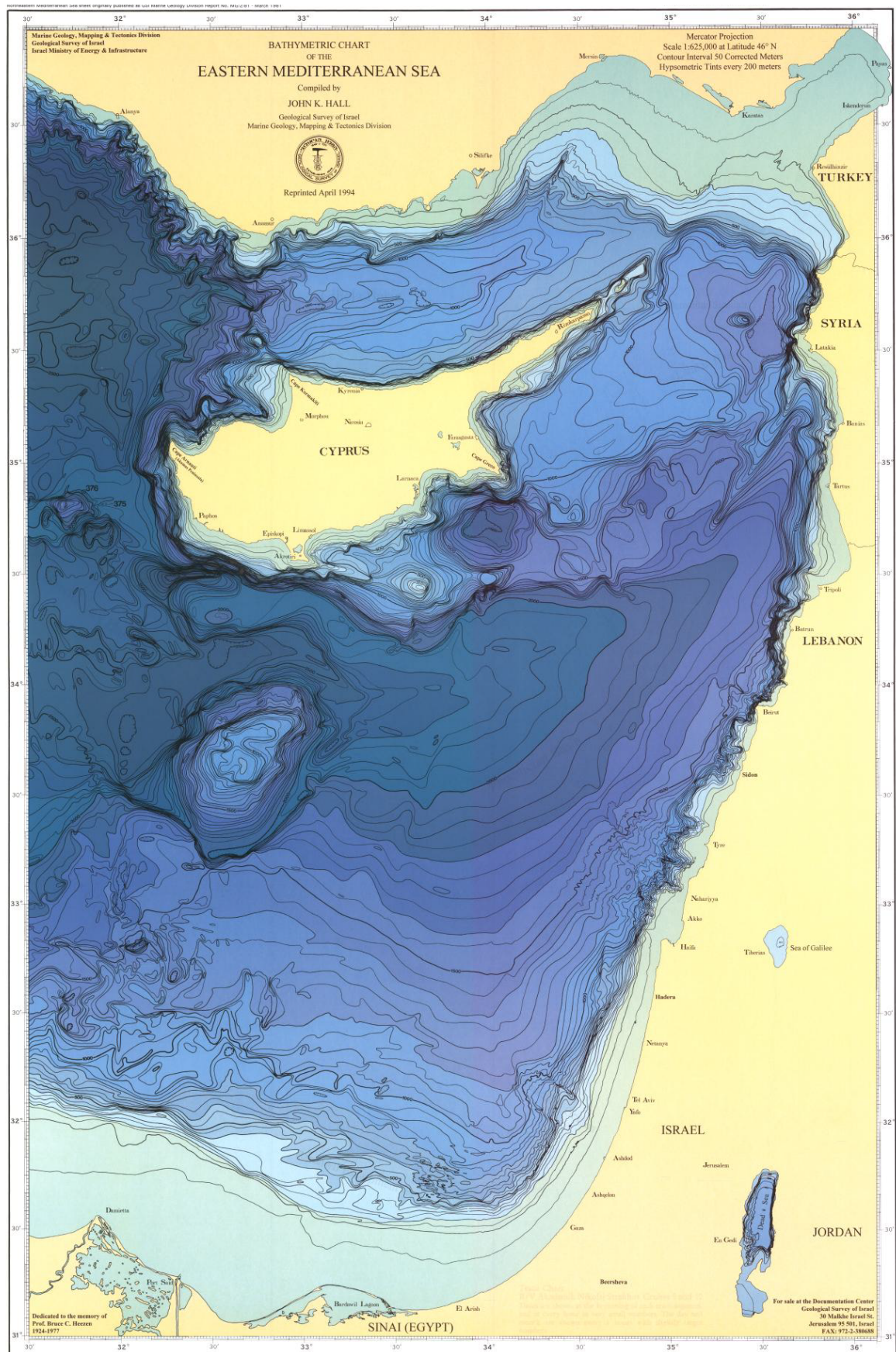
The Nile Cone in the south slopes to the northeast into the basin, whereas that of Israel and Lebanon slopes to the northwest into the basin. The Levantine Basin is thus becoming gradually deeper in its northern part, and attains its greatest depth of 2500 m south of Cyprus and east of the Eratosthenes Seamount.

An accurate and detailed bathymetric map of the Levantine Basin and the adjacent sea areas has been compiled by Hall et al (1994) and is shown in Figure 1.2.2.3. Due to the very small size of the map, contour values could not be read. From this map the irregular slopes off Sinai and the disturbed slope southwest of Tel Aviv can be discerned. North of the Carmel Structure (Haifa) the continental margin is typified by deeply incised canyons and the sediment cover is thinner.

In the north-west the Eratosthenes Seamount, which is part of the Eratosthenes Block, is rising from 2000 m in the east and 2500 m in the west to 850 m.

The bathymetry at the Myra and Sara sites is discussed in Sections 2.1.4, 2.1.5.





**Figure 1.2.2.3 Bathymetry map of the Levantine Basin. Isobath values cannot be read at this size.**  
*Source: Hall et al, 1994.*

### 1.2.3 Morphology

The main geomorphic features of the Levantine continental margin are shown on a map compiled in 1984 by Almgor and Hall (Figure 1.2.3.1). The map depicts the extents of the four disturbances (from south to north: Bardawil, Gaza, Palmahim and Dor), the extent of the evaporites where they are >200 m thick, diapir ridges, normal faults and the Messinian drainage system (see below, stratigraphy).

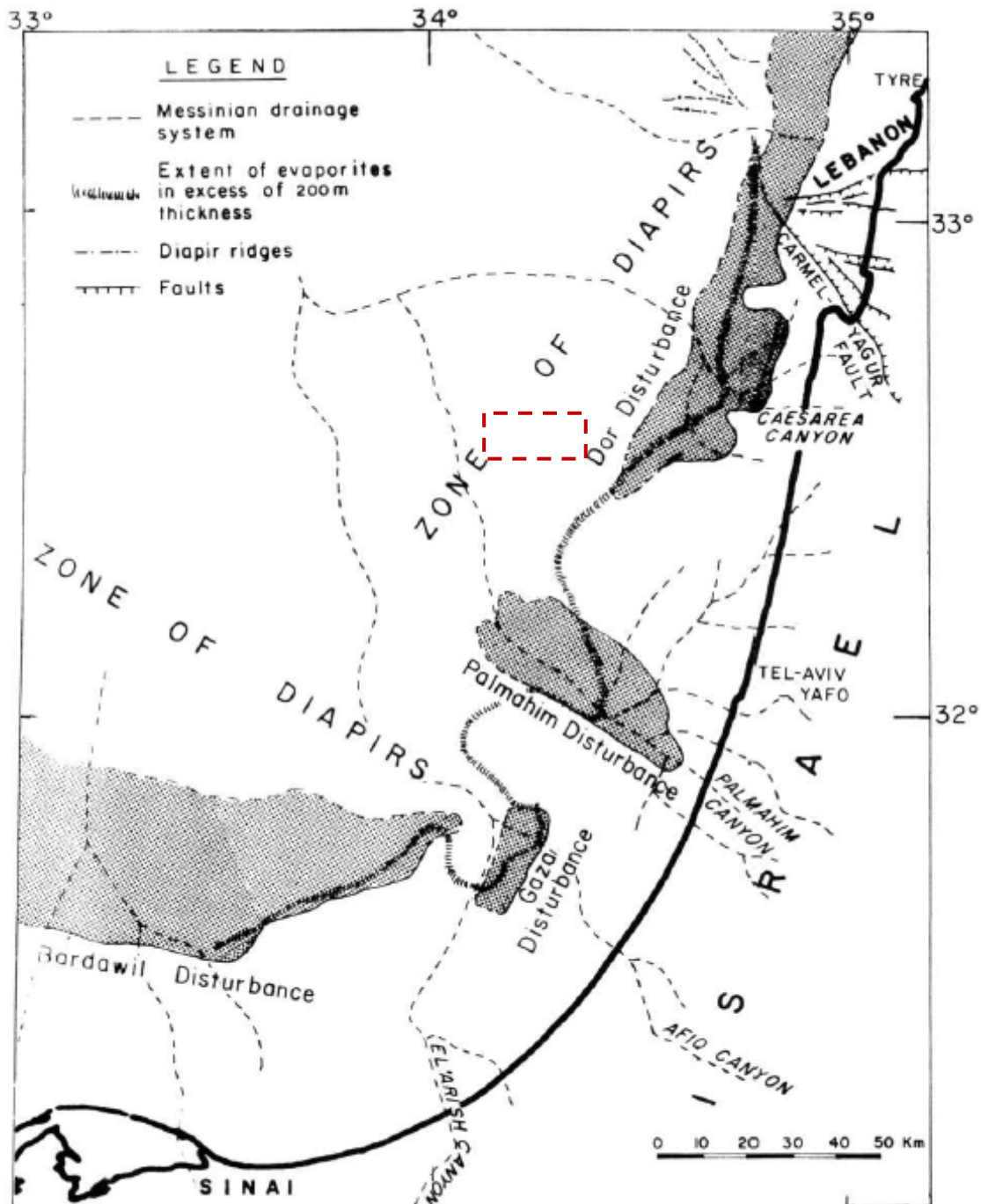
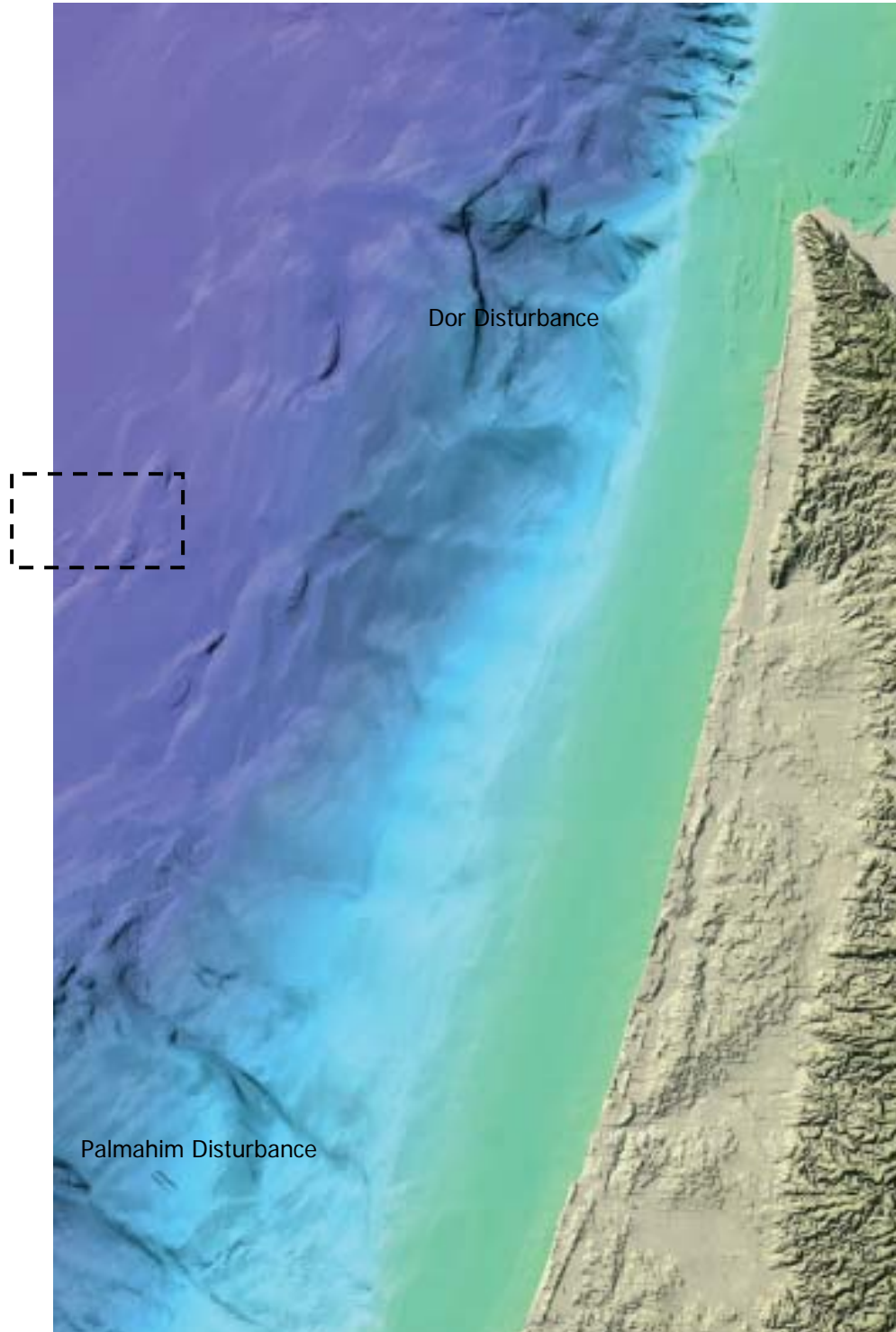


Figure 1.2.3.1 A geomorphic diagram of the submarine Levantine margin, showing the Messinian drainage network, the boundary of the Messinian evaporitic layer >200 m thick, diapir ridges and normal faults. Red rectangle indicates the approximate location of the Myra and Sara Sites.

Source: Almgor and Hall, 1984.

Shaded, coloured geomorphic image of the Israeli continental margin is shown in Figure 1.2.3.2. The nature of the continental margin off Israel and the shapes of the Palmahim and Dor disturbances are clearly discerned from the image.

The seabed morphology at the Myra and Sara sites is discussed in Sections 2.1.4, 2.1.5.



**Figure 1.2.3.2 A geomorphic diagram of the submarine Levantine margin, showing the Messinian drainage network, the boundary of the Messinian evaporitic layer >200 m thick, diapir ridges and normal faults. Dashed rectangle indicates the approximate location of the Myra and Sara Sites.**

*Source: Hall, 1984.*

### 1.2.4 Magnetic field

A map of the magnetic field of the Eastern Mediterranean Sea was compiled by Makris et al (1994) and is presented in Figure 1.2.4.1. They used, and uniformly processed all the existing data obtained to that time including data obtained onboard the R/V Strakhov.

Comparison of the magnetic anomalies after their reduction to the pole, with the observed bathymetric and topographic features of the eastern Mediterranean Sea shows that the observed magnetic anomalies correlate strongly with the bathymetric and topographic features.

They have concluded that the Levantine basin is associated with a strong negative anomaly that could be explained by an oceanic crust of inverse magnetisation. Most of the Levantine Basin is underlain by pre-Cretaceous igneous, oceanic crust, which is buried under thick sediments (12-14 km), which is in agreement with seismic survey results.

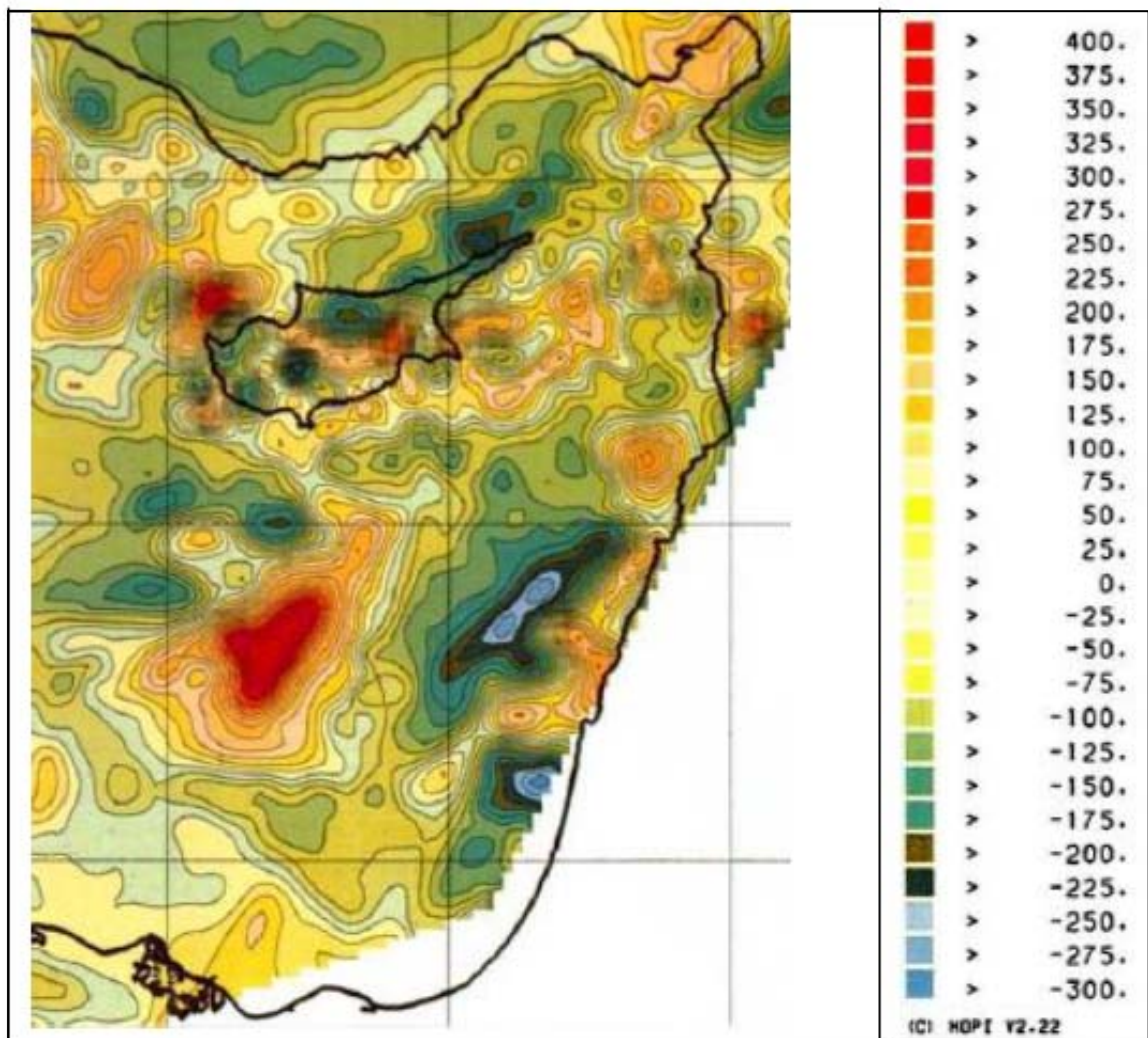


Figure 1.2.4.1 Total intensity magnetic map, at sea-level. The IGRF (International Geomagnetic Reference Field) removed. Contour interval – 25 nT.

Source: Makris et al, 1994.

### 1.2.5 Gravity

A gravity map of the Eastern Mediterranean Sea was compiled by Makris and Wang (1994) and is presented in Figure 1.2.5.1. (Bouguer gravity is the anomaly corrected for the density of the underlying rocks and for the elevation in which it is measured). The Eastern Mediterranean Sea is dominated by the gravity maximum of 220 mGal at the Herodotus Basin (located west of the Levantine Basin). The gravity anomalies decrease towards the east and are separated from the eastern part of offshore Israel and Lebanon by less intense anomalies, which range between 80 and 20 mGal. This decrease in the gravity is mainly caused by the increase in sediment thickness.

While the crust is oceanic, 5-6 km thick, sediment thickness increase from 5-6 km off western Egypt, to nearly 16 km at the Nile Cone and off Israel. On the other hand, Eratosthenes Seamount is a continental fragment (terrane) with a crustal thickness of ~24 km. It is an isolated feature, surrounded by oceanic crust. It is covered by relatively thin Mesozoic sediments and is not prominently expressed in the gravity.

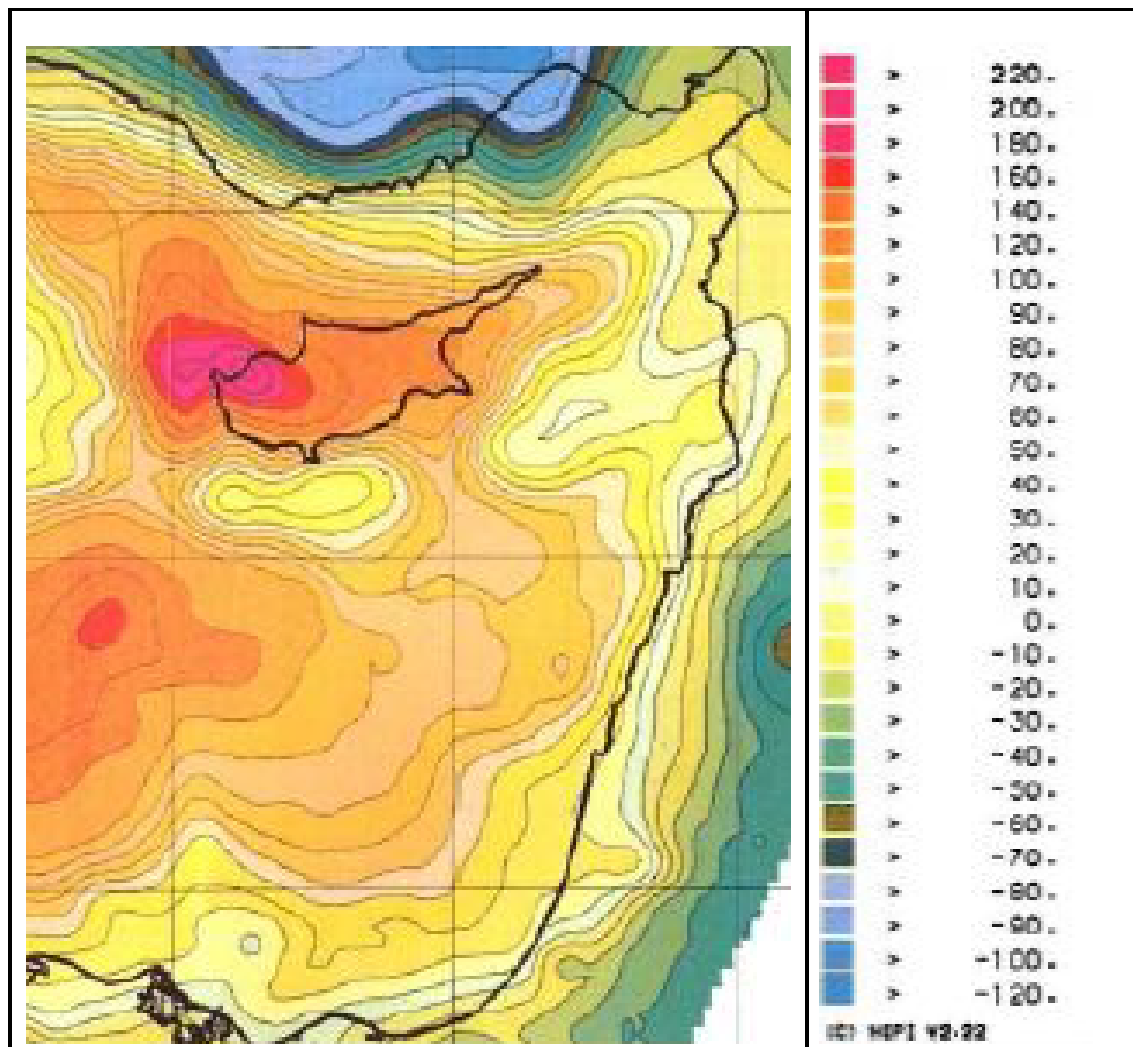


Figure 1.2.5.1 Map of Bouguer gravity anomaly of the Eastern Mediterranean Sea. The contour interval is 10 mGal.

Source: Makris and Wang, 1994.

### 1.2.6 Stratigraphy

The main stratigraphic units which underlie the Levantine Basin are shown in Figure 1.2.6.1.

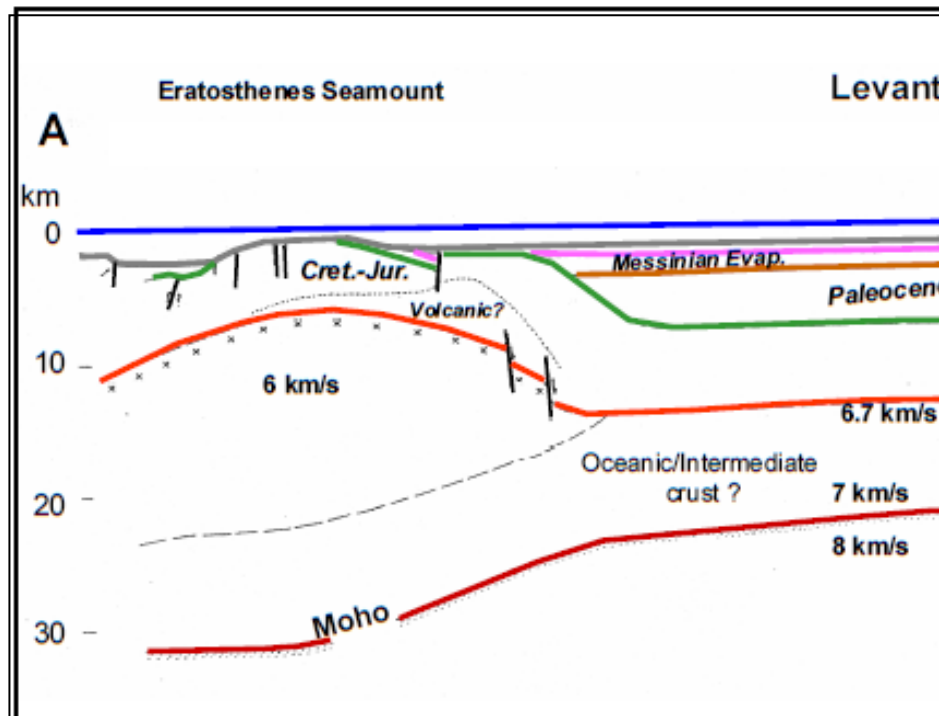
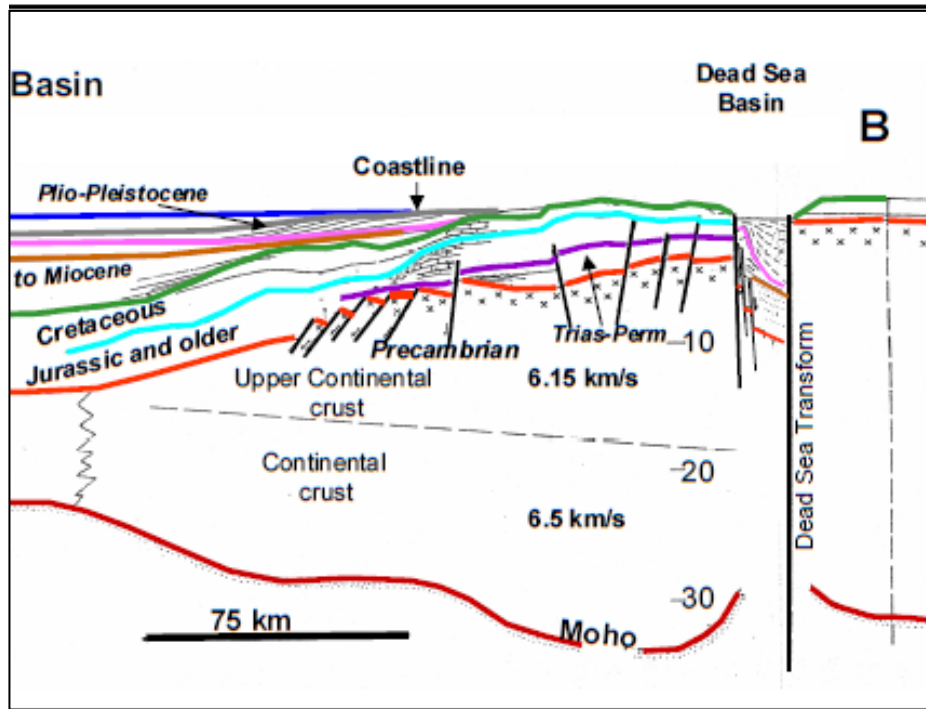
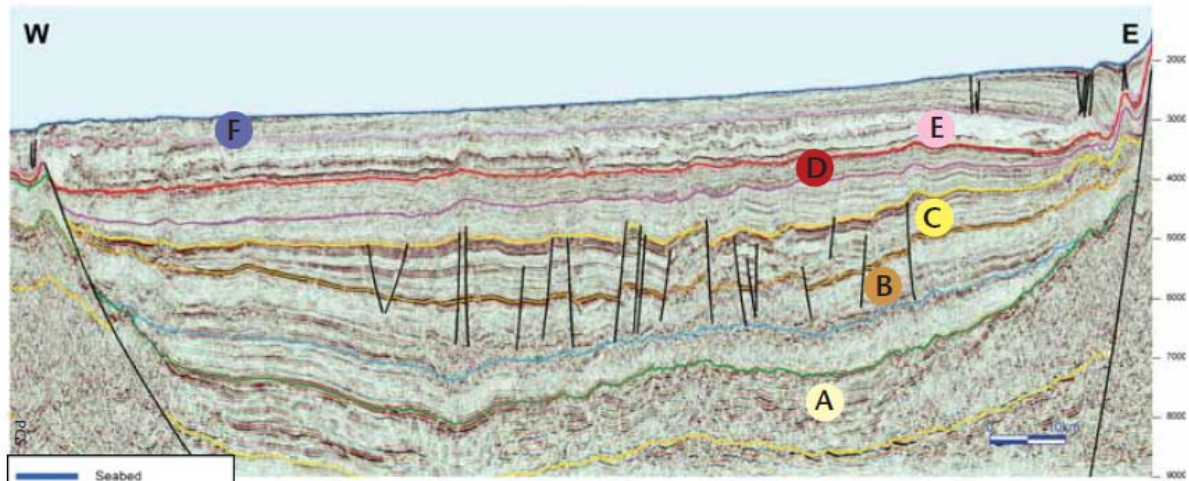


Figure 1.2.6.1 Schematic section across the Levantine Basin, from the Eratosthenes Seamount in the northeast to the Dead Sea in the southwest. The section shows the main structural element, stratigraphic units and crustal seismic velocities. Top – western part; bottom – eastern part.

Source: Garfunkel, 1998.

The following paragraphs describe the nature and composition, as well as hydrocarbon presence in the various sedimentary units, which underlie the Levantine Basin, shown in Figure 1.2.6.2.



**Figure 1.2.6.2** An interpreted regional seismic cross-section through the northern Levantine Basin (the margin of the Eratosthenes Continental Block in the west and the Levant Margin in the east), showing key stratigraphic units and major faults. Units are described in the text.

Source: Lie et al, 2011.

#### 1.2.6.1 Middle Jurassic to Senonian Unconformity (unit A)

The deepest horizon interpreted in the Levantine Basin is believed to be a Middle Jurassic event and the subsequent Jurassic and Cretaceous sedimentary infill probably consists of shales, marls, and carbonates. The Late Cretaceous Senonian Unconformity marks the onset of clastic deposition in the deeper parts of the Levantine Basin and defines the structural outline of the basin. On the Levant Margin, this Senonian event represents the near top of the Cretaceous carbonate facies.

Source rocks within this interval include the Middle Jurassic open marine shales (Barnea formation), interpreted as the principal source for the Helez field. Cretaceous source rocks include organic-rich black shales, which can be correlated to the oil prone Gevar'am formation. There are also organic-rich Senonian sediments and analysis of the asphalt seep at Hasbaya in Lebanon indicates that it is probably derived from a Senonian source rock.

On the Levant Margin, the Middle Jurassic – Middle Cretaceous platform carbonate sequence contains thick dolomites and sandstones that may constitute potentially good reservoirs. Other potential reservoirs include carbonate reefs, marine sandstones and fluvio-deltaic sediments. Possible Cretaceous fore-reef talus fans and Jurassic (Triassic?) alluvial fans can be identified in the north-eastern part of the basin up against the main fault at the margin and these could also be potential reservoirs.

#### 1.2.6.2 Senonian Unconformity to Base Miocene (unit B)

This interval is likely to be dominated by distal turbidity sequences of alternating sandstones, shales and carbonates. The seismic reflection continuity varies across the Levantine Basin but the upper boundary, Base Miocene, is a high amplitude event separating Oligocene lowstand sediments from Lower Miocene deep water sediments. An internal high amplitude event interpreted as the Eocene Unconformity represents the boundary between Eocene shales and more sandy Oligocene deposits in the basin. The Oligo-Miocene section is faulted, but all the faults are seen to die out towards the Eocene Unconformity.

An Oligocene - Lower Miocene organic-rich source rock interval, which is a proven gas source in the Nile Delta, is of great significance for the area. Potential reservoirs occur in the sandier sections of the Oligocene.

#### *1.2.6.3 Base Miocene to Base Middle Miocene (unit C)*

The Base Miocene to Base Middle Miocene interval is currently regarded as the most prospective interval in the Levantine Basin and is dominated by deep-water clastics. In the middle of the basin the Base Middle Miocene marks the top of a series of high amplitude reflectors. The isopach map shows the depocentre to be oriented NNE-SSW, roughly parallel to the basin axis. The well defined seismic character of the interval allows correlation of the Lower Miocene from the Levantine Basin to a small sub basin west of the Eratosthenes Continental Block and on to the Cyprus Arc.

The recent giant discoveries in the Levantine Basin (Dalit, Tamar, Leviathan) have good quality Lower Miocene reservoir rocks with thicknesses of 30 to 150m. At the time of deposition the area lay predominantly in a distal turbidite setting where continuous reservoirs are most likely to be located in coalescing basin floor and toe of slope fans developed during eustatic lowstands. Syrian Arc anticlines form potential traps and these include the narrow, high relief, NE-SW trending folds and lower relief, broader NNE-SSW trending anticlines. Potential pinch-out traps are present towards the Levant Margin in the east and the Eratosthenes Continental Block in the west.

#### *1.2.6.4 Base Middle Miocene to Base Messinian (unit D)*

The Upper Miocene interval generally has lower continuity and amplitude than the Lower Miocene. However, prograding systems can be identified and in the north-easternmost part of the Levantine Basin there are high amplitude events and erosional features that could indicate basin floor fans and channel complexes. This Upper Miocene interval has a similar set of anticlinal structures to the Lower Miocene but the depocentre (the site of maximum deposition within a sedimentary basin, where the thickest development of the sedimentary sequence will be found) has moved slightly north-east towards the Levant Margin. Observed, minor syn-depositional faulting could have assisted in ponding turbidite sands in topographic lows on the seafloor, prior to evaporite development.

#### *1.2.6.5 Base Messinian to Base Pliocene (unit E)*

The base of the Messinian succession is a distinct seismic event in the Levantine Basin. It marks the onset of the regional deposition of more than 1,500 m of evaporites during the Messinian salinity crisis. The strong internal reflectors that occur are likely to represent different types of evaporites or clastics locally. These reflectors are highly deformed in places, confirming the stress regimes in the region. The thickness of the interval is consistent over the greater part of the Levantine Basin but with thinning towards the margins and the Cyprus Arc. Over the Eratosthenes Continental Block only some tens of meters of Messinian evaporites are expected.

#### *1.2.6.6 Base Pliocene to Seabed (unit F)*

The Base Pliocene can have a conformable or an erosive character. It correlates to the top of the Messinian evaporites and marks the onset of deep water clastic deposition in the Mediterranean. The uplift of onshore Lebanon influenced the Pliocene, with gravitational slide of the Messinian evaporites causing extensional salt rollers in the proximal areas and compression in the distal areas toward the Eratosthenes Continental Block. The onset of the Pliocene is marked by a meandering channel system which is mappable in the 3D area and in the mid-Pliocene there is a slightly chaotic, high amplitude feature to the east that is thought to represent channels. The Base Pliocene to Seabed is thick at the margin and thins out in mid-basin.

Interpreted seismic sections provide a further insight into the stratigraphy and main geological features of the area in question. Figure 1.2.6.3 is a seismic line south of Sara and Myra Sites and Figure 1.2.6.4 is a line north of them.

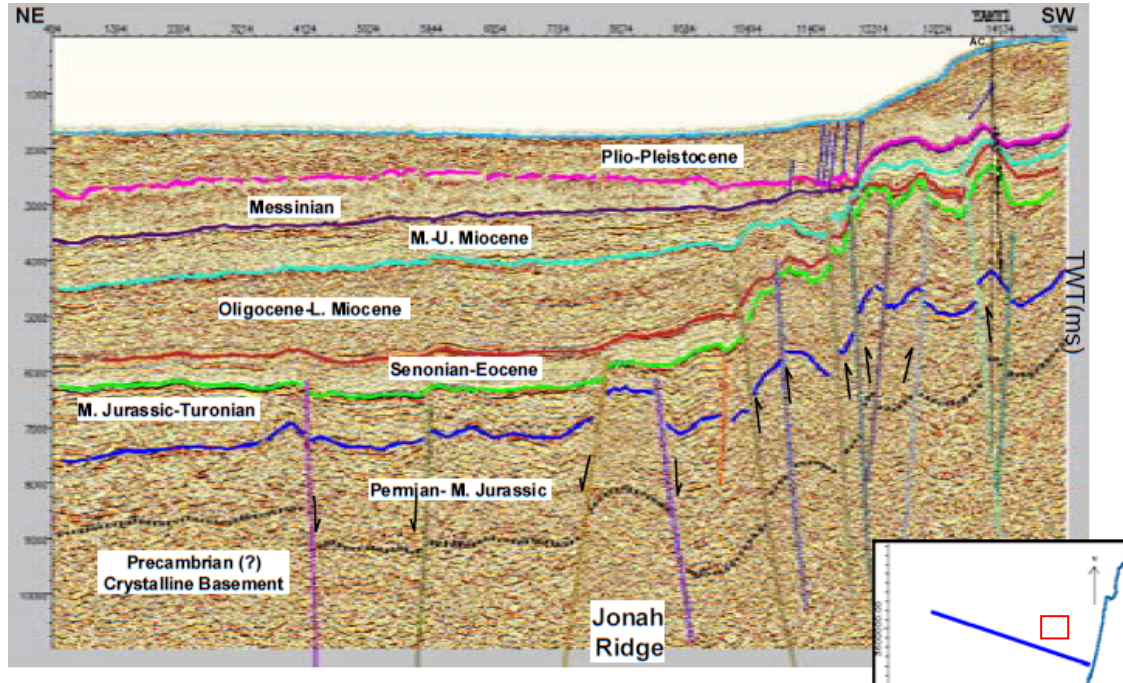


Figure 1.2.6.3 Interpreted NE-SW seismic profile (see inset for line location; the red box indicates the approximate location of Myra and Sara Sites) showing stratigraphic units and main faults.  
*Source: Gardosh et al, 2008.*

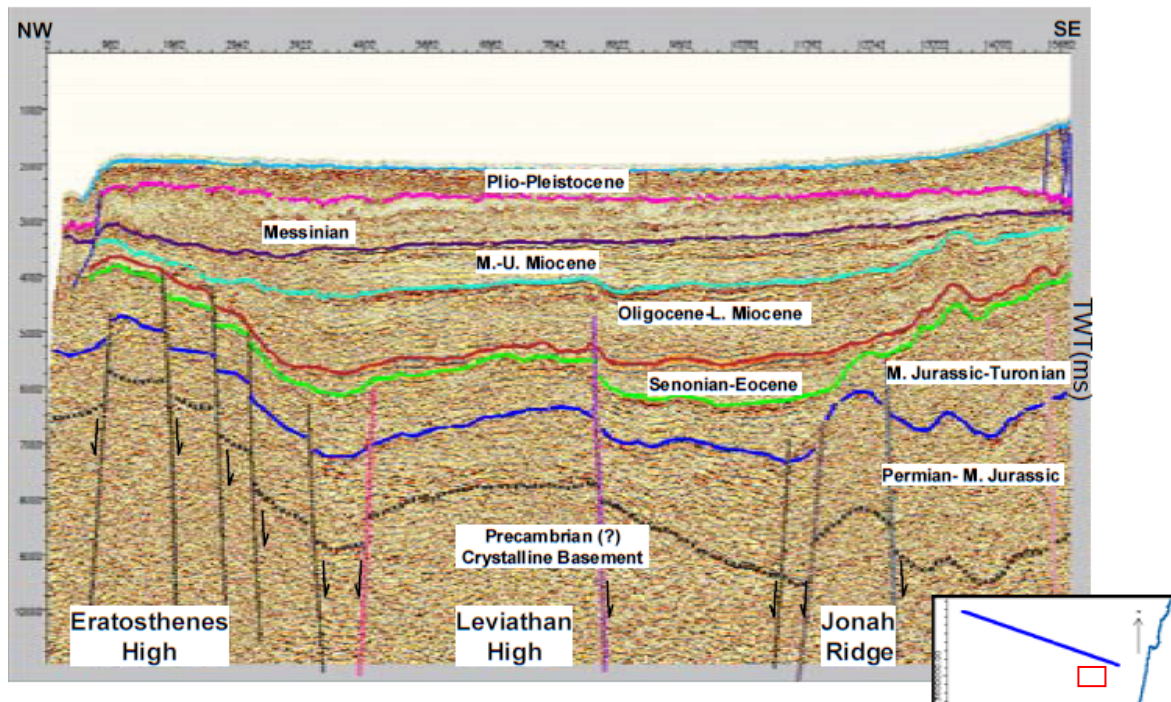
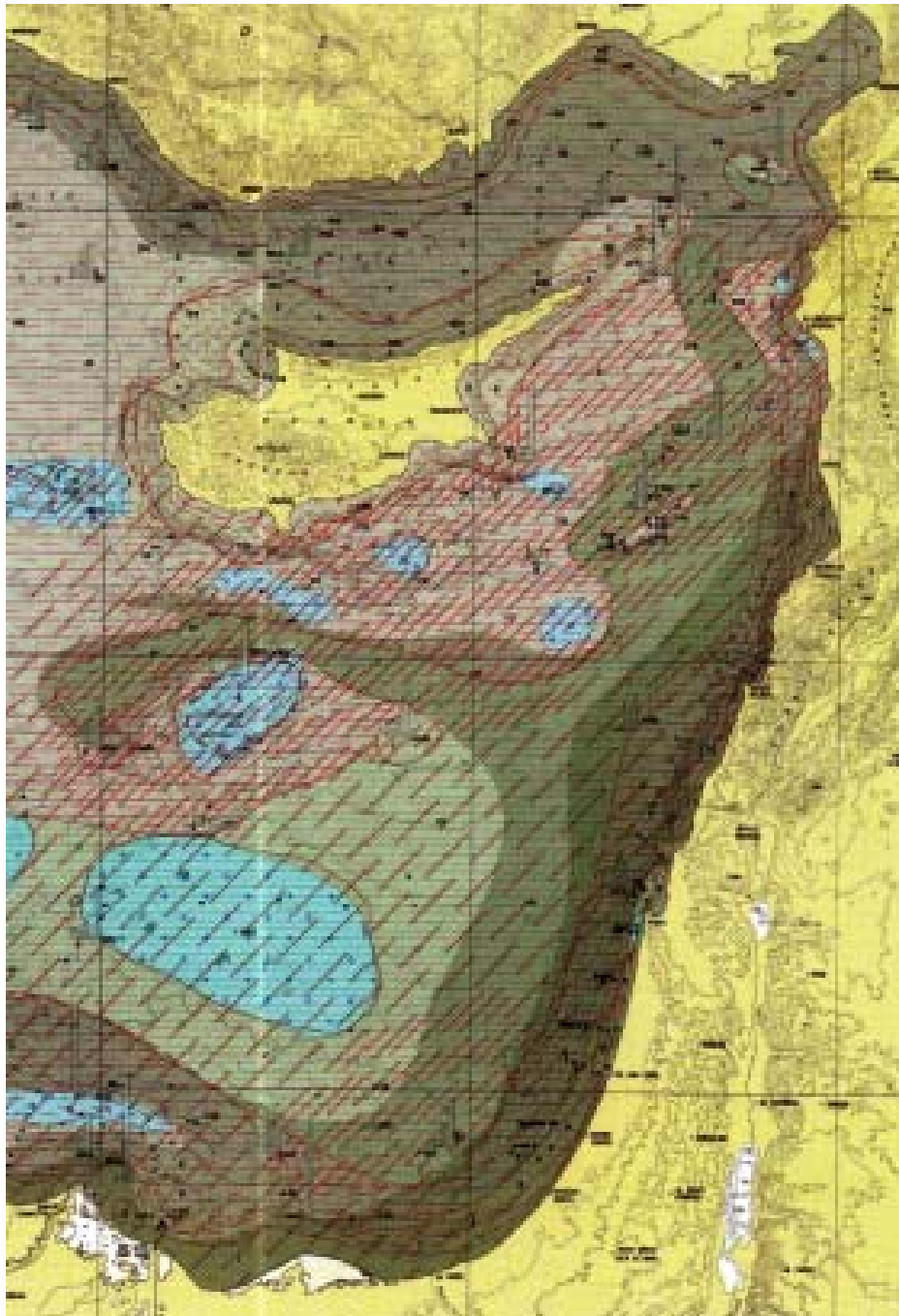


Figure 1.2.6.4 Interpreted NW-SE seismic profile (see inset for line location; the red box indicates the approximate location of Myra and Sara Sites) showing stratigraphic units and main faults.  
*Source: Gardosh et al, 2008.*

### 1.2.7 Bottom surface sediments

A map of the unconsolidated bottom surface sediments of the Mediterranean and Black Seas was compiled by Emelyanov et al (2005). The Levantine Basin and the adjacent sea areas are shown in Figure 1.2.7.1. The composition of the sediments in the south of the basin was controlled by the material introduced into the sea by the Nile River.

Detailed map of the types of recent unconsolidated sediment in the Levantine basin was compiled by Emelyanov (1994), and is shown in Figure 1.2.7.2.



**Figure 1.2.7.1** A map of unconsolidated bottom surface sediments of the Levantine Basin. The dark brown indicates terrigenous sediments with >50% terrigenous material and with a general trend of decreasing CaCO<sub>3</sub> quantities with increasing depth; the green indicates terrigenous carbonate sediments, with 50-70% CaCO<sub>3</sub> and 30-50% terrigenous material; the light blue indicates biogenic carbonate sediments, with 70-90% CaCO<sub>3</sub> and 10-30% terrigenous material.

*Source: Emelyanov et al, 2005.*

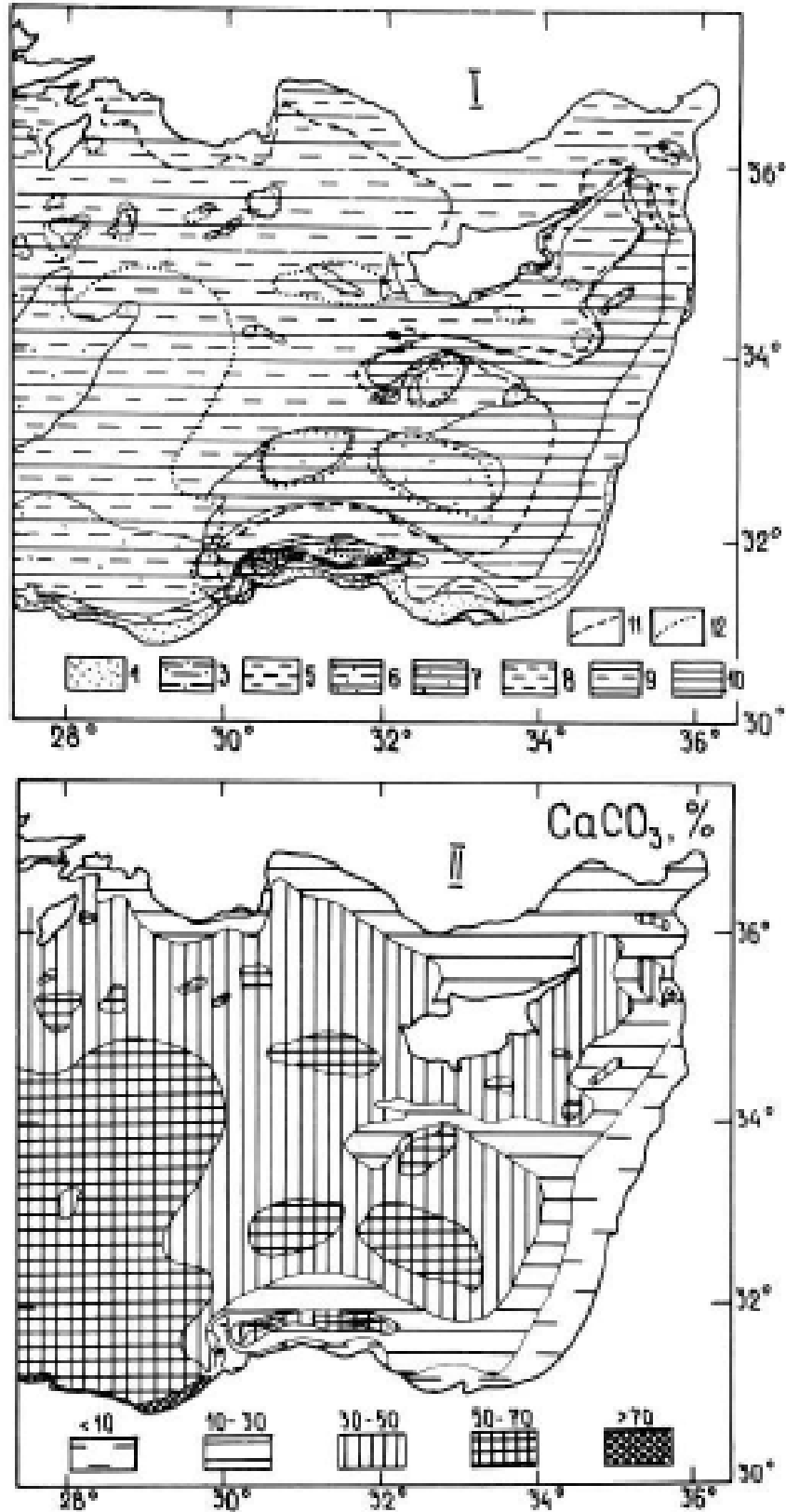


Figure 1.2.7.2 Types of bottom sediments in the Levantine Basin (top layer of 0-5 cm deep). Top – composition; bottom – CaCO<sub>3</sub> content. Legend: 1- sand; 2- silty sand (not shown); 3- muddy sand; 4- clayey sand; 5- sandy silt; 6- sandy mud; 7- sandy clay; 8- silt; 9- mud (silt and clay); 10- clay; 11 and 12- contours of CaCO<sub>3</sub> content: 11- 30%; 12- 50%.

Source: Emelyanov, 1994.

## 1.3 Oceanography

### 1.3.1 General circulation

Mediterranean hydrodynamics are driven by three layers of water masses: a surface layer, an intermediate layer, and a deep layer that sinks to the bottom; a separate bottom layer is absent. Deepwater formation and exchange rates and the processes of heat and water exchange in the Mediterranean have provided useful models for studying the mechanisms of global climatic change.

The surface layer has a thickness varying from 75 to 300 m. This variable thickness is determined in the western basin by the presence of a minimum temperature at its lower limit. In the eastern basin the temperature minimum is generally absent, and a layer of low-temperature is found instead. The intermediate layer is infused with warm and saline water coming from the eastern Mediterranean and is characterized by temperature and salinity maxima at 400 m. This layer is situated at depths between 300 and 600 m. The deep layer - containing the great bulk of Mediterranean water - occupies the remaining zone between the intermediate layer and the seabed. In general, the water of this layer is very homogeneous (see Figure 1.3.1.1).

The Mediterranean Sea receives from the rivers that flow into it only about one-third of the amount of water that it loses by evaporation. In consequence, there is a continuous inflow of surface water from the Atlantic Ocean. After passing through the Strait of Gibraltar, the main body of the incoming surface water flows eastward along the north coast of Africa. This current is the most constant component of the circulation of the Mediterranean. It is most powerful in summer, when evaporation in the Mediterranean is at a maximum. This inflow of Atlantic water loses its strength as it proceeds eastward, but it is still recognizable as a surface movement in the Sicilian Channel and even off the Levant coast.

A small amount of water also enters the Mediterranean from the Black Sea as a surface current through the Bosphorus, the Sea of Marmara, and the Dardanelles.

In summer Mediterranean surface water becomes more saline through the intense evaporation, and, correspondingly, its density increases. It therefore sinks, and the excess of this denser bottom water emerges into the Atlantic Ocean over the sill forming the shallow Strait of Gibraltar as a westward subsurface current below the inward current. The inflowing water extends from the surface down to 70 or 80 m. The Mediterranean has been metaphorically described as breathing, inhaling surface water from the Atlantic and exhaling deep water in a counter-current below.

Surface circulation of the Mediterranean consists basically of a separate counter-clockwise movement of the water in each of the two basins. Because of the complexity of the northern coastline and of the numerous islands, many small eddies and other local currents form essential parts of the general circulation. Tides, although only significant in range in the Gulf of Gabes and in the northern Adriatic, add to the complications of the currents in narrow channels such as the Strait of Messina.

Historically, large seasonal variations in the Nile discharge influenced the hydrology, productivity, and fisheries of the southeastern part of the Mediterranean. The Nile's inflow reduced the salinity of the coastal waters and increased both the stratification and productivity of these waters. The Aswan High Dam (1970) stopped the seasonal fluctuation of the discharge of the Nile water into the Mediterranean. The Suez Canal between the Mediterranean and Red seas passes negligible amounts of Red Sea water into the Mediterranean.

The general surface circulation in the Mediterranean Sea is shown in Figures 1.3.1.1 and 1.3.1.2. The intermediate water circulation, in summer and in winter, is shown in Figures 1.3.1.3 and 1.3.1.4.

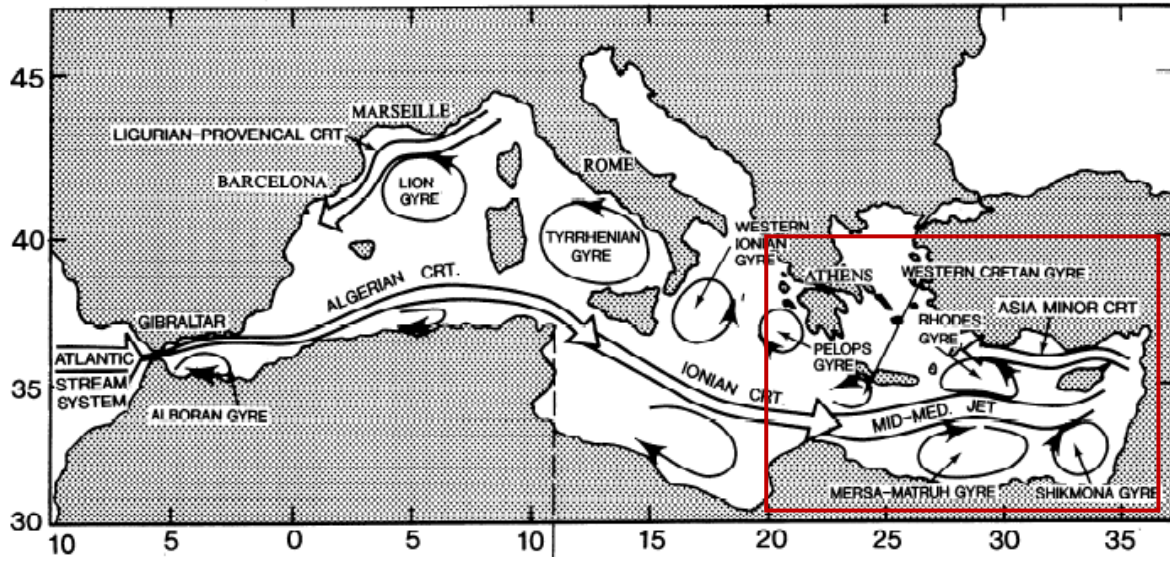


Figure 1.3.1.1 Schematic surface circulation in the Mediterranean Sea. Red box indicates area enlarged in Figure 3.1.2.

Source: Roussenov et al, 1995.

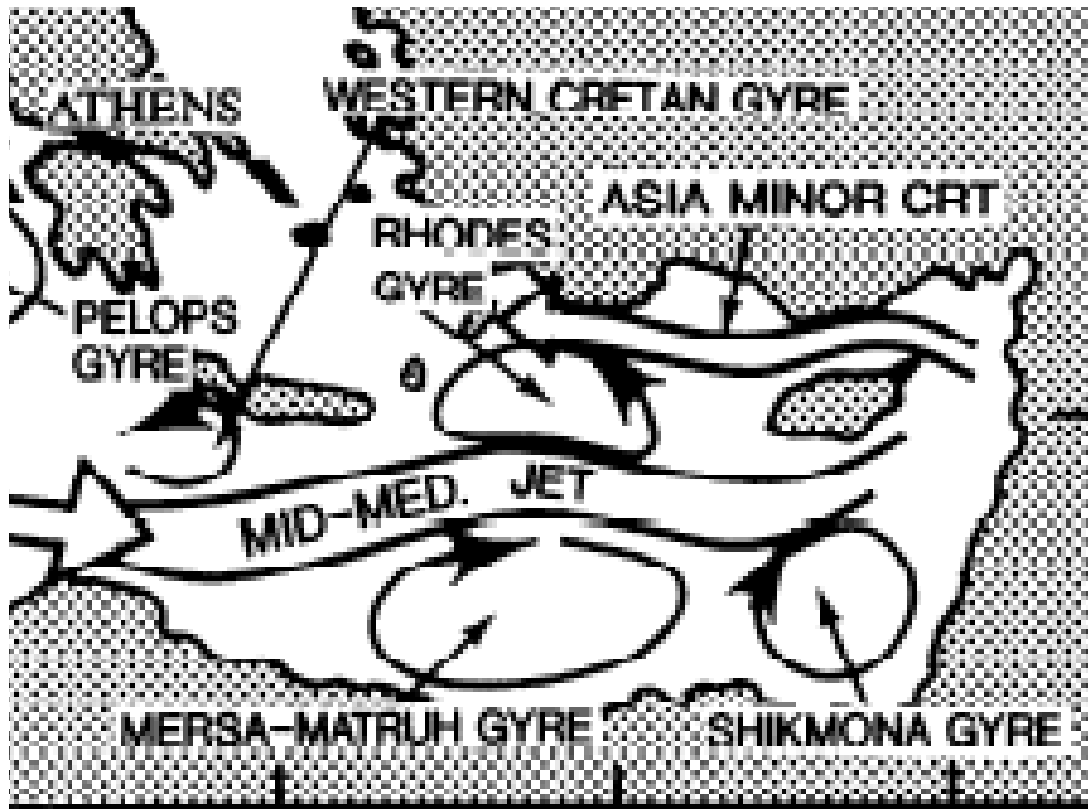
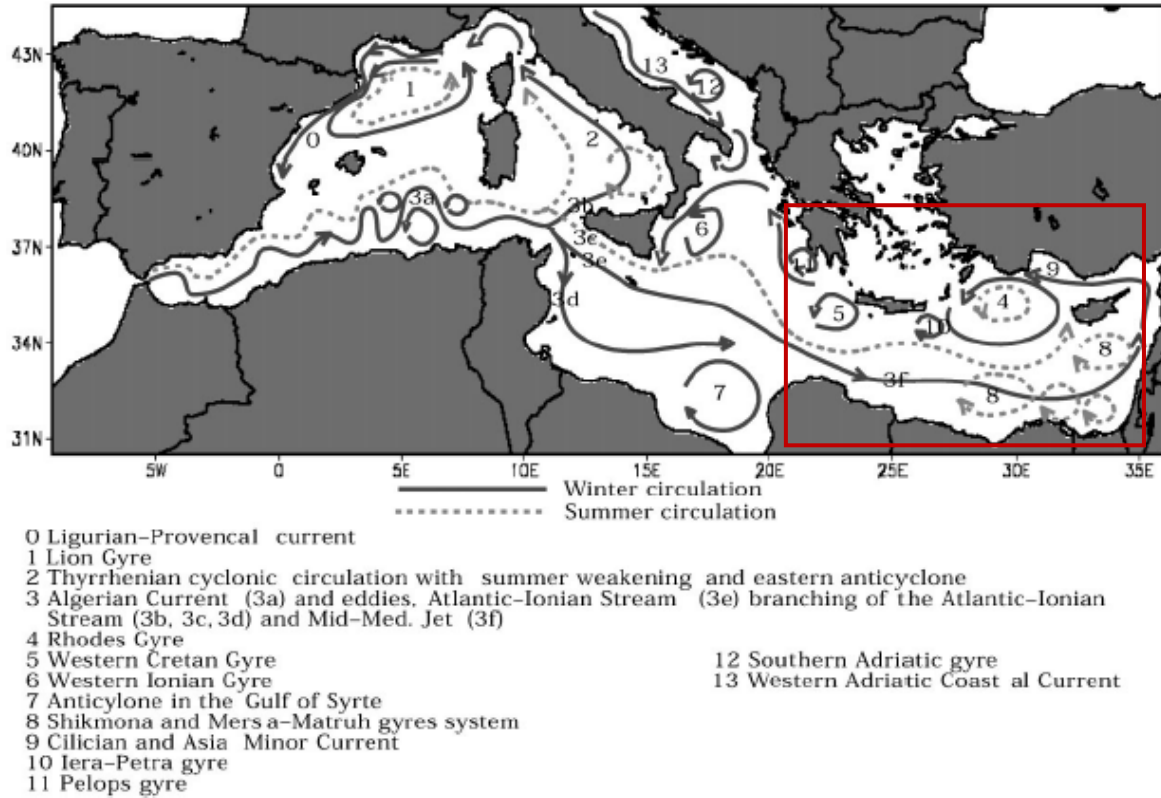
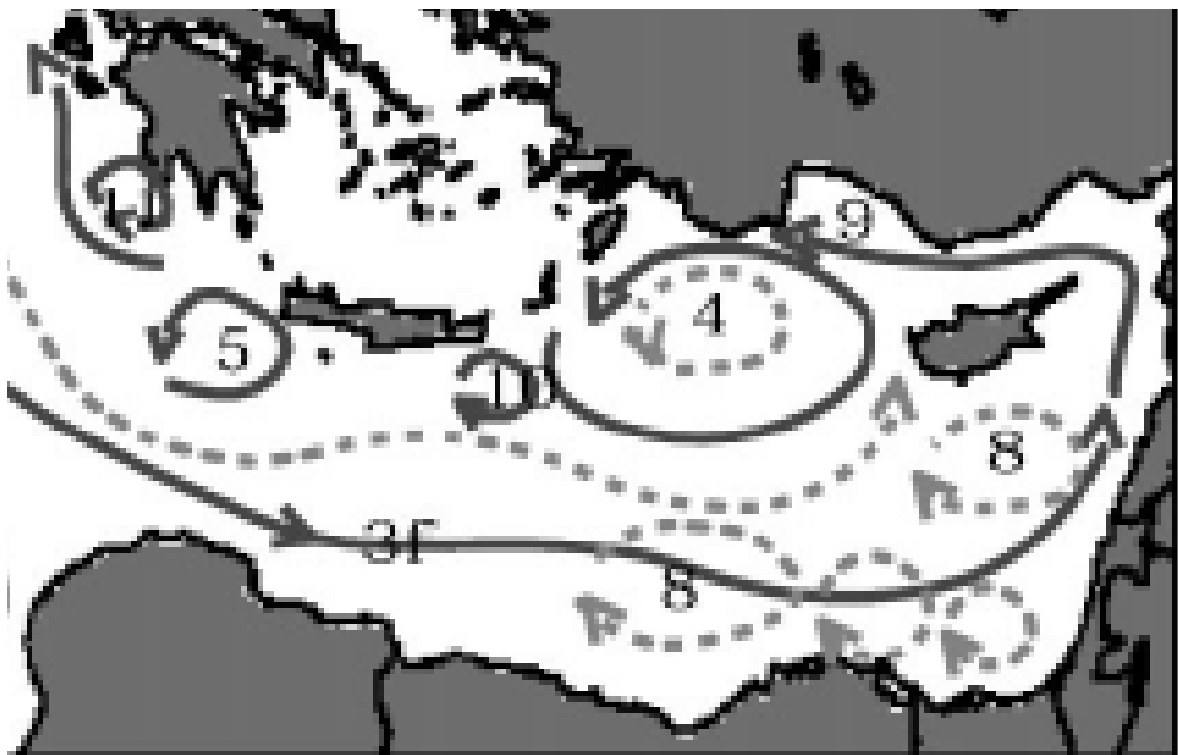


Figure 1.3.1.2 Schematic surface circulation in the Mediterranean Sea. Whereas the general circulation is counterclockwise, the Mersa Matruh and Shikmona Gyres are flowing clockwise.

Source: Roussenov et al, 1995.



**Figure 1.3.1.3 Schematic mid water circulation in the Mediterranean Sea in winter and summer. Red box indicates area enlarged in Figure 1.3.1.4.**  
*Source: Pinardi et al, 2000.*



**Figure 1.3.1.4 Schematic intermediate water circulation in the eastern Mediterranean Sea.**  
**Legend: 4 – Rhodes Gyre; 8 – off Lebanon: Shikmona Gyre; off Egypt: Mersa Matruh Gyre.**  
*Source: Pinardi et al, 2000.*

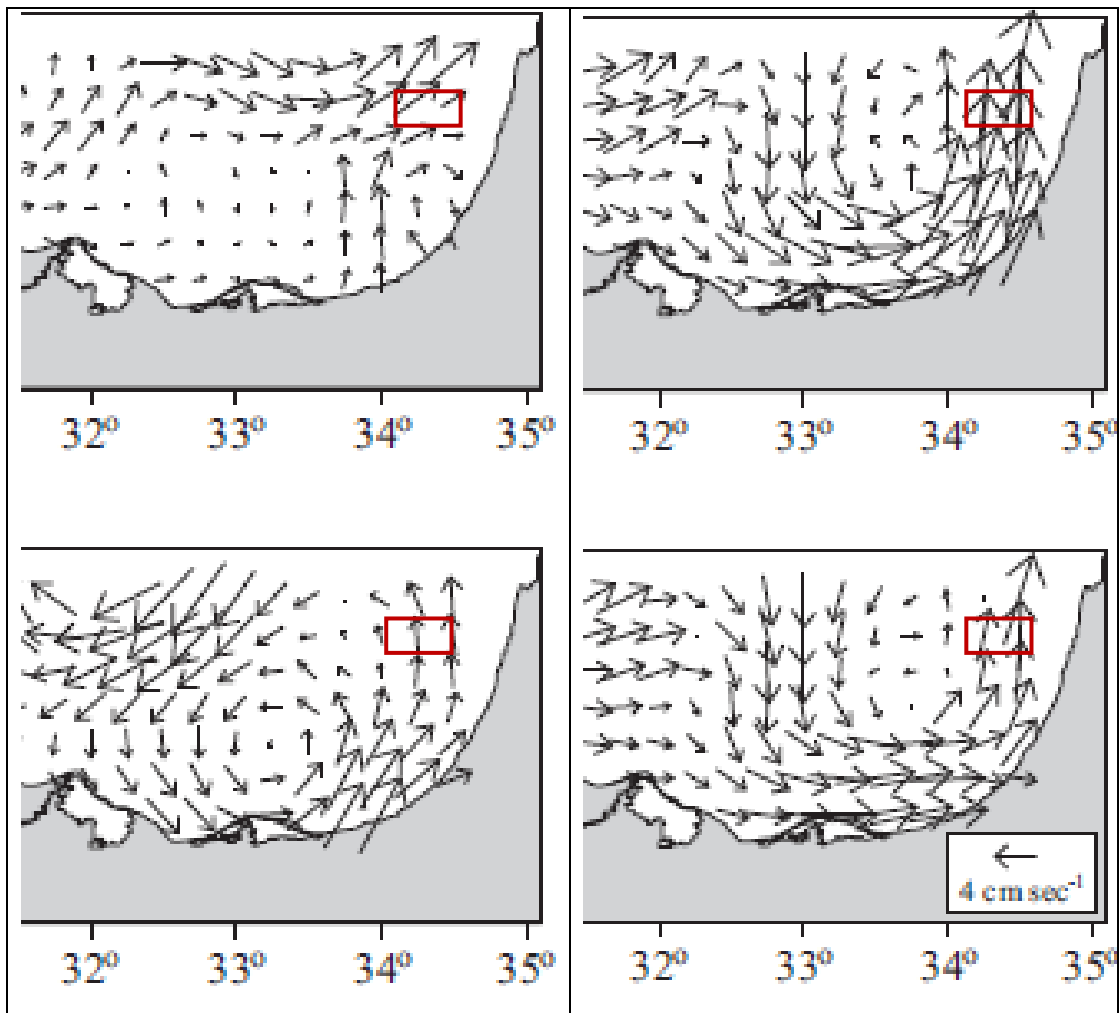
### 1.3.2 Currents

Currents in the south and south-eastern Levantine Basin, at the surface and at depths of 30, 50, 75, 100, 200 and 300 metres, during the four seasons, were calculated using objectively analysed hydrographic data by Kamel (2005), and are presented in Figures 1.3.2.1 to 1.3.2.4.

In the upper layers the current runs eastward along the coast and is dominated by some circulation patterns and gyres. The current velocity is higher in summer and autumn and very low in spring. In near shore areas, at deeper levels (intermediate water) the current velocity is quite low. The currents reverse and attains a south and west direction.

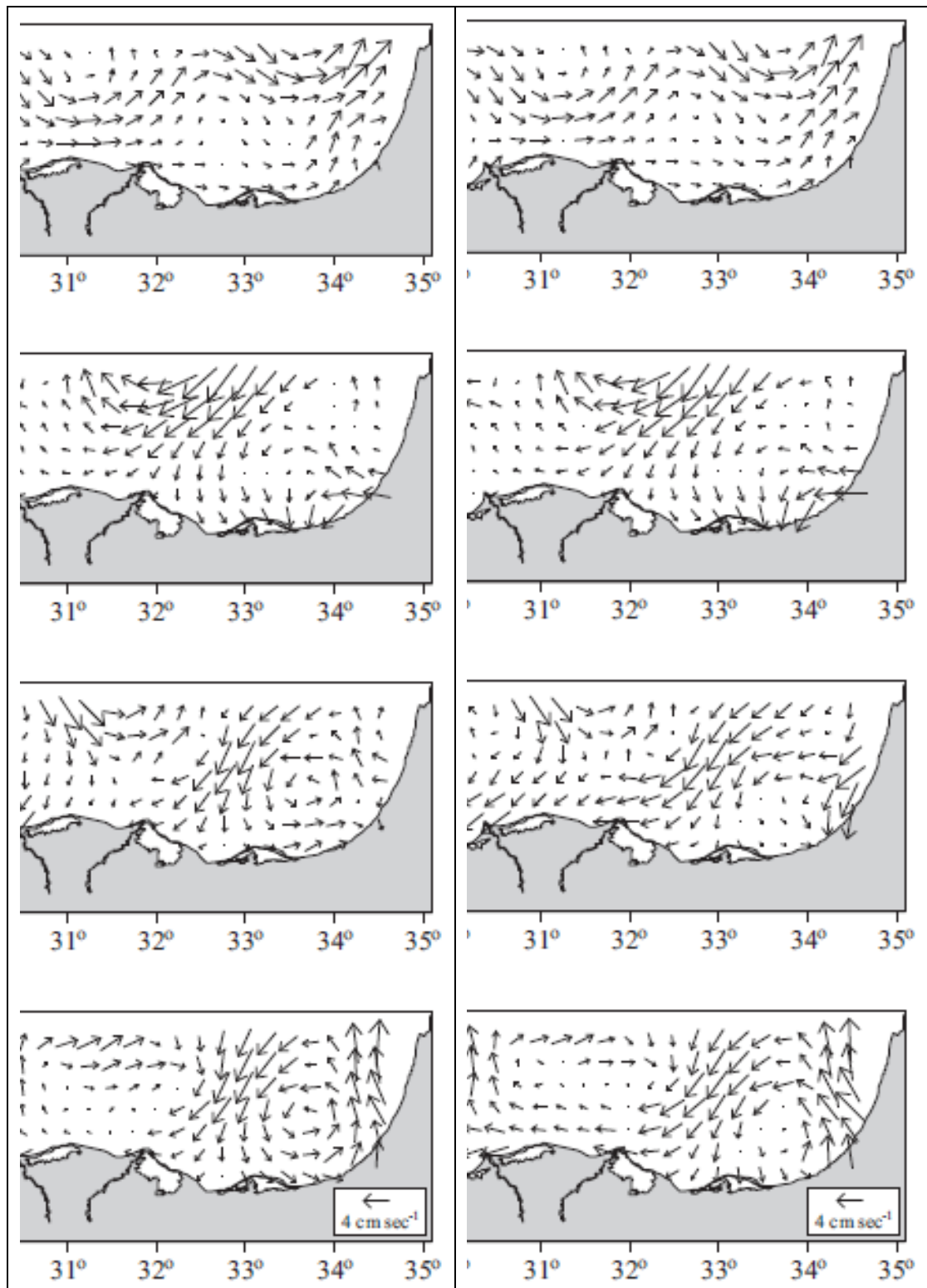
Kamel's calculations depict a much more detailed, and slightly different, picture of the circulation in the Levantine Basin.

The general circulation pattern along the Israeli coast is prevailed in northward direction during most of the year, in keeping with the general counter clockwise gyre of the Eastern Mediterranean. This current is locally modified by the configuration of the coastline and the topography of the narrow continental shelf.



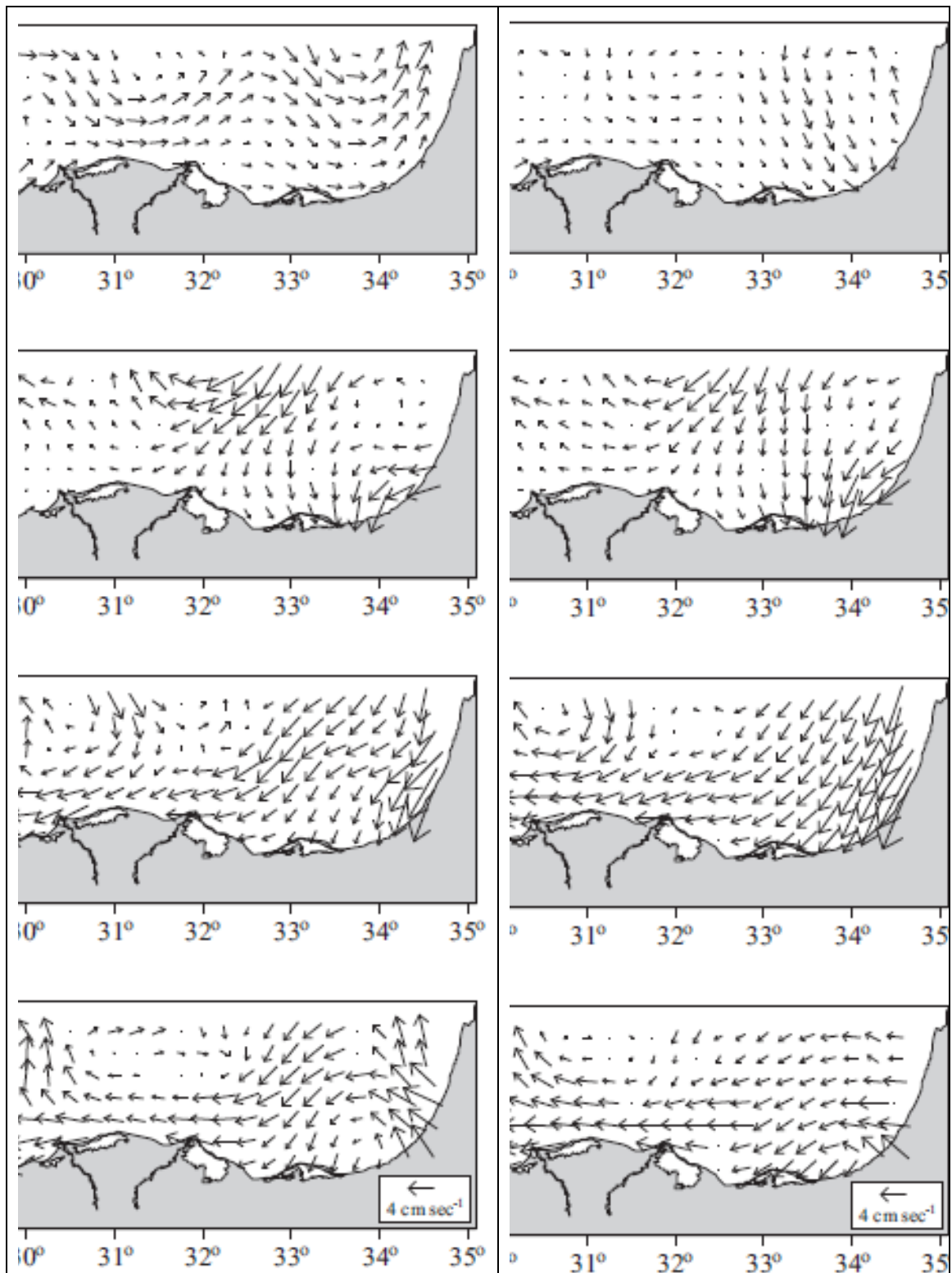
**Figure 1.3.2.1** Distribution of surface currents in the southern Levantine Basin in winter (top left), spring (bottom left), summer (top right) and autumn (bottom right). Red box indicates the approximate location of the Sara and Myra Sites.

*Source: Kamel, 2010.*



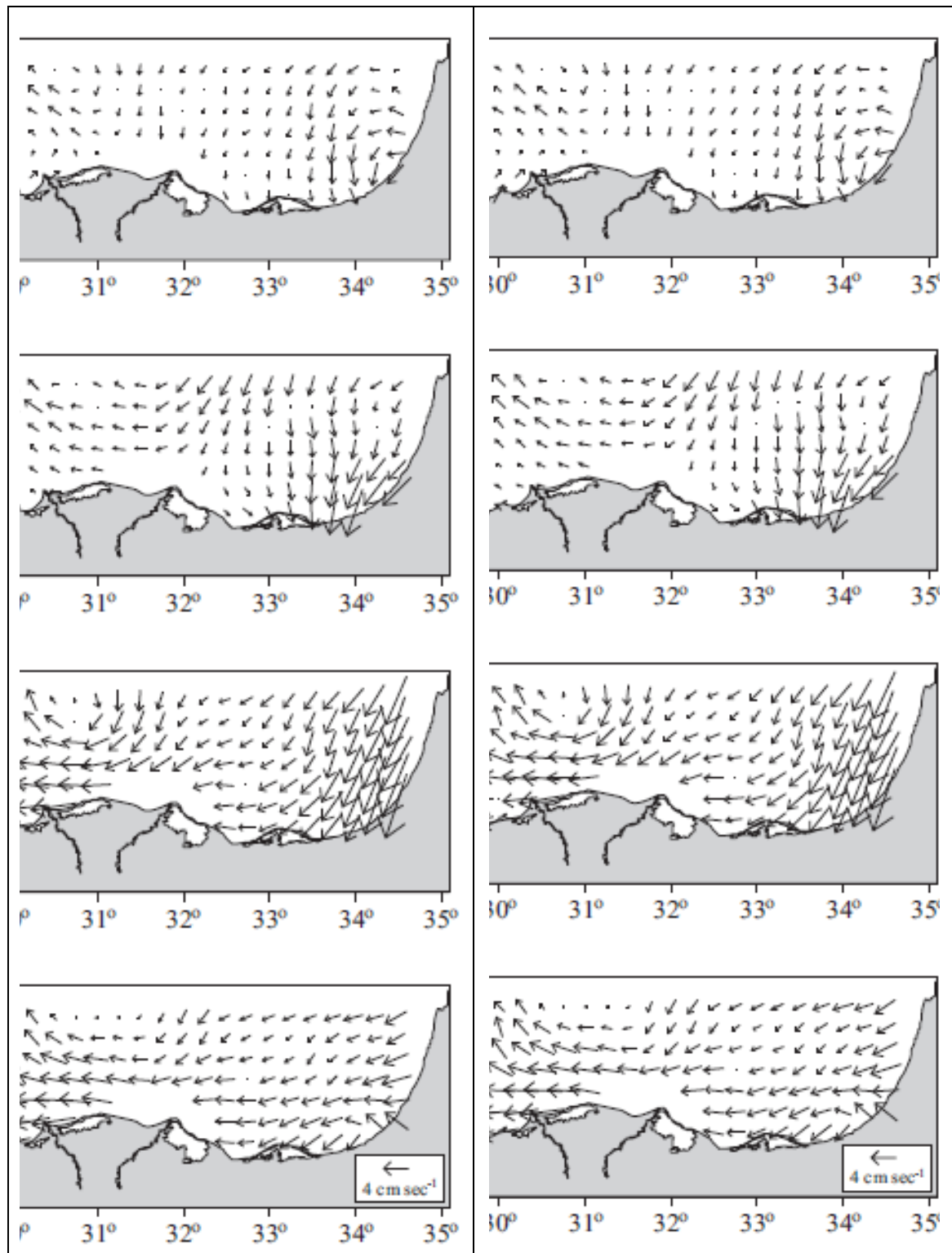
**Figure 1.3.2.2** Distribution of currents in the southern Levantine Basin at 30 m (left) and 50 m (right) below surface in winter (top), spring (second from top), summer (second from bottom) and autumn (bottom).

Source: Kamel, 2010.



**Figure 1.3.2.3 Distribution of currents in the southern Levantine Basin at 75 m (left) and 100 m (right) below surface in winter (top), spring (second from top), summer (second from bottom) and autumn (bottom).**

*Source: Kamel, 2010.*

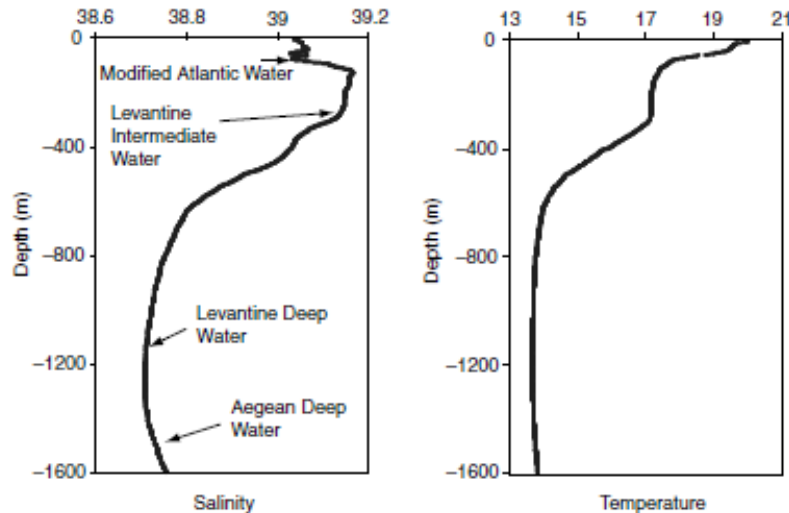


**Figure 1.3.2.4** Distribution of currents in the southern Levantine Basin at 200 m (left) and 300 m (right) below surface in winter (top), spring (second from top), summer (second from bottom) and autumn (bottom).

Source: Kamel, 2010.

### 1.3.3 Temperature and salinity

Hydrological conditions of the eastern part of the Levant basin are characterised with two annual thermohaline phases: a cold water winter phase (December-March) and a warm water phase during hot and dry summer (June-November). A short inter-season in April-May separates the two phases (Figure 1.3.3.1). During



**Figure 1.3.3.1 Salinity and temperature profiles in May in the southeast Levantine Basin.**

*Source: Krom et al 2004.*

During his investigation of the 'tropicalisation' of the Levantine Basin waters off the coast of Lebanon, Lakkis (2009) has found that homothermic conditions in the whole water column keep the temperature at its lowest annual average (16-18°C). During the hot and dry phase, the surface temperature increases to reach the maximum of 30°C in August. Water layer stratification is accompanied with the forming of a thermo cline between 35m and 75 m.

Salinity increases up to a maximum of 39.75‰ at the surface because of the strong evaporation, the lack of precipitation and the shortage of freshwater input from rivers. In spring inter-season in April-May, moderate temperature and salinity are suitable for development of phytoplankton standing crop followed with zooplankton development.

Multiannual fluctuations during the last four decades has show an increasing trend in temperature ( $\Delta \sim 0.40$  °C) and salinity of ( $\Delta 0.35$ ‰), is due not only to the stop of the Nile flood but also to the global warming affecting the East Mediterranean. Monthly variations of temperature and Multiannual trend of temperature salinity at an offshore stations during 1991,92,93. and salinity during 1970-2004.

The annual range of surface temperature between the minimum average in February and maximum in September is about 14°C. The thermo cline starts to form in June-July between the depths of 35-75 m and reaches the highest intensity in August-September. Inversely, homothermal conditions are formed in winter (January-March) with the mixing water masses and turnover of water layers.

As for salinity, the annual range is very small, it varies at the surface and offshore seawater between 39.25‰ in winter and 39.75‰ in summer because of shortage of freshwater input and the intense evaporation. The vertical evolution of the salinity is much less pronounced than that of temperature; at 200 m depth the salinity average remain constant between 30.35 and 39.38‰.

Monthly changes pattern of phosphates and nitrates are similar with a maximum concentration rate in February-March and a minimum rate in spring-summer corresponding to the maximum development of phytoplankton cells which uptake the nutrients for growth. Multidecadal fluctuations show a little increasing trend, whereas for phosphate, the trend is in slight decrease during the last decades.

The average surface and vertical profiles of temperature and salinity in the eastern Mediterranean Sea are shown in Figures 1.3.3.2 to 1.3.3.5.

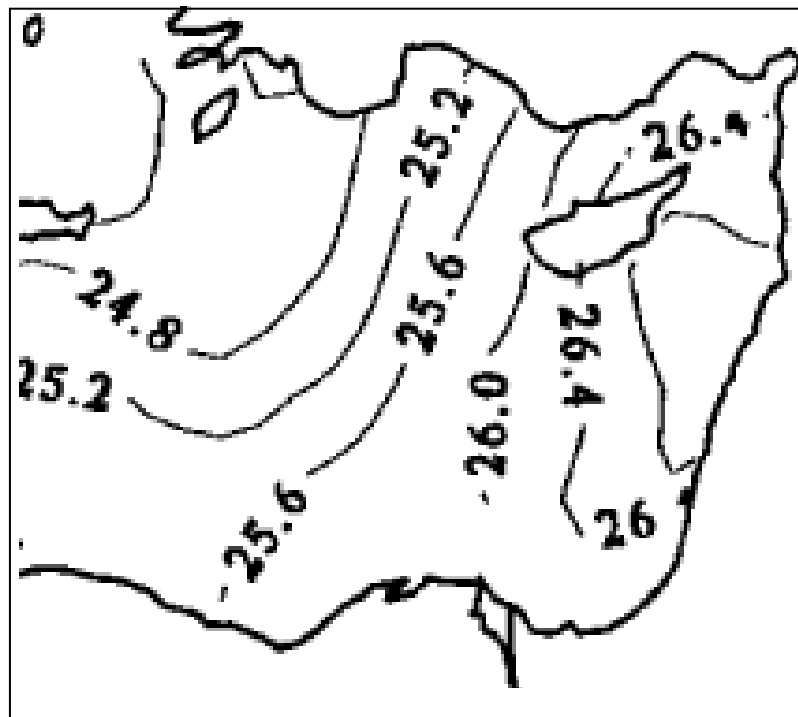
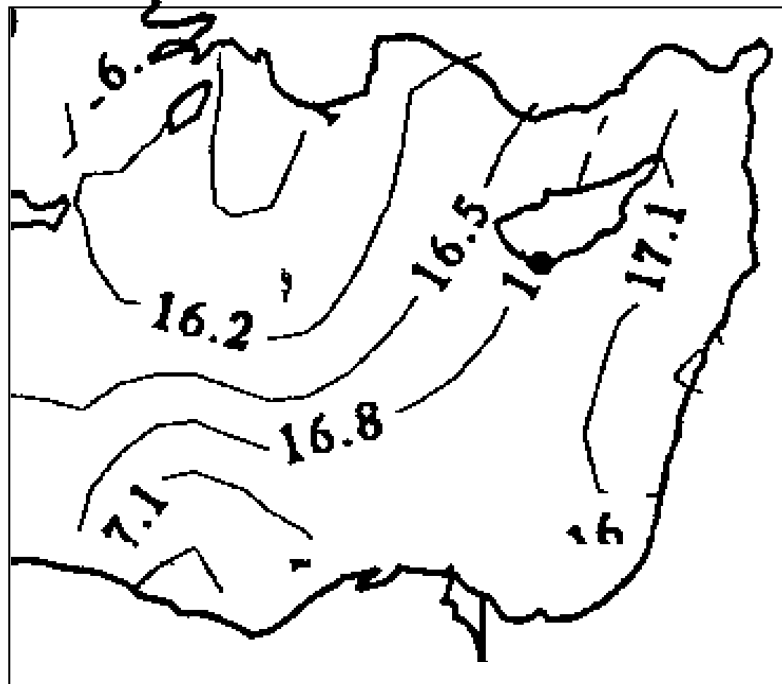


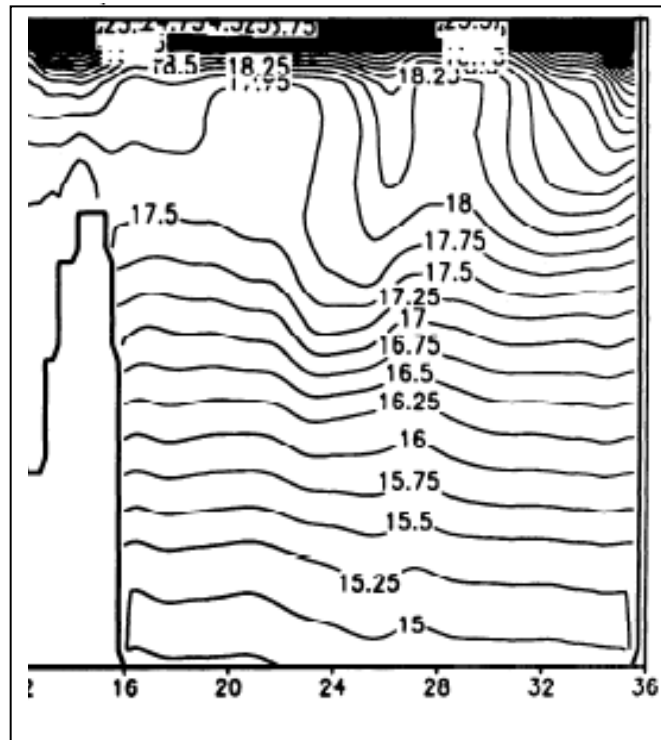
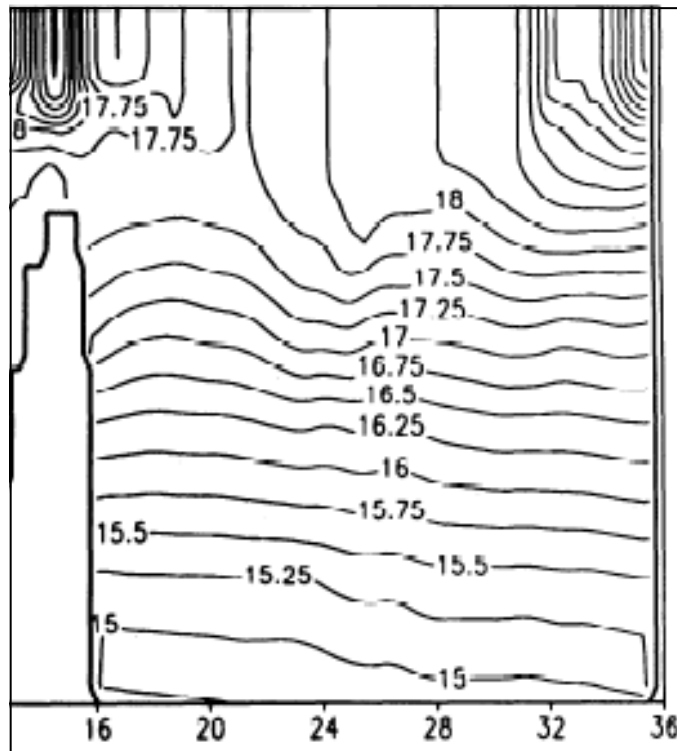
Figure 1.3.3.2 Average surface temperature in the Eastern Mediterranean Sea. Top – winter; bottom – summer.

Source: Tziperman et 1991.



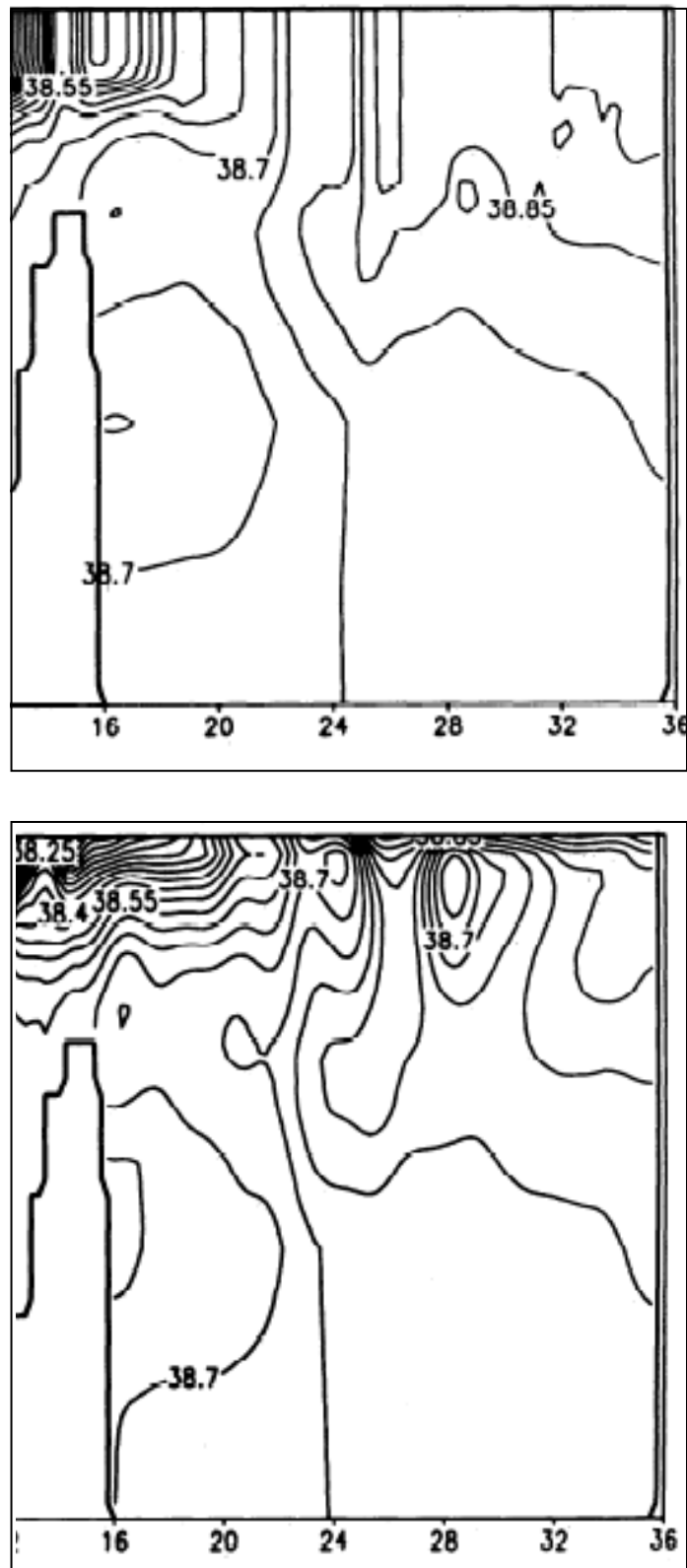
Figure 1.3.3.3 Average surface salinity in the Eastern Mediterranean Sea. Top – winter; bottom – summer.

Source: Tziperman et 1991.



**Figure 1.3.3.4 Temperature cross sections from the surface to a depth of 1000 m through the eastern half of the Mediterranean Sea in winter (top) and in Summer (bottom).**

*Source: Tziperman and Malanotte-Rizzoli 1991.*



**Figure 1.3.3.5 Salinity cross sections from the surface to a depth of 1000 m through the eastern half of the Mediterranean Sea in winter (top) and in Summer (bottom).**

*Source: Tziperman and Malanotte-Rizzoli 1991.*

### 1.3.4 Wind stress field

The average wind stress over the Levantine Basin is from the west and northwest in summer and in winter, as shown in figure 1.3.4.1.

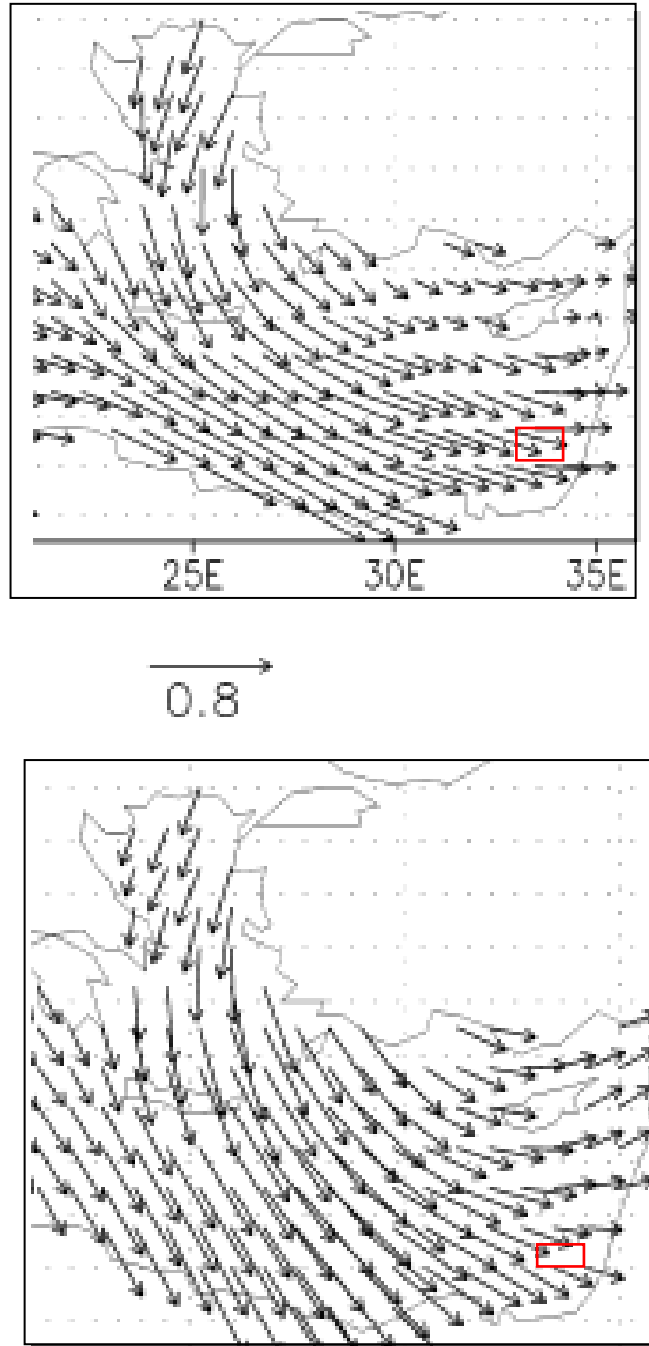


Figure 1.3.4.1 Climatological wind stress field in the eastern Mediterranean Sea. Top – January; bottom – July. Units are in dyne / cm<sup>2</sup>; a reference arrow is given between the panels. Red box indicate the approximate location of the Sara and Myra Sites.

Source: Pinardi et al, 2000.

### 1.3.5 Chemical oceanography

The chemistry of the Levantine Basin was investigated and summarised by Krom et al (2003).

The Eastern Mediterranean constitutes a unique marine ecosystem. The sea is nearly land-locked and in spite of receiving anthropogenic nutrients from atmospheric and land-based sources, it is ultra oligotrophic. It has very low depth integrated chlorophyll, low annual primary productivity, a summer deep chlorophyll maximum deeper than 100 m and a high content of pico- and nano-plankton. This is due to the low level of nutrients in the water column, where phosphate reaches a maximum of  $<0.3 \mu\text{mol kg}^{-1}$  and nitrate of  $\sim 6 \mu\text{mol kg}^{-1}$  in the deep water. The reasons for this low nutrient concentrations and ultra-oligotrophic water is that nutrients are exported from the system at the Straits of Sicily by the anti-estuarine circulation in the system.

The eastern Mediterranean Sea is also unusual in being the largest body of water in the world in which the primary productivity is phosphorus-limited. The annual phytoplankton bloom takes place in winter as soon as deep mixing occurs and ceases when the phosphate is depleted. The nitrate which remains is enriched in heavy  $\text{N-NO}_3$ . Nutrient enrichment experiments of bacteria show P limitation throughout the year. There is no evidence of Fe limitation in this system, and thus far no evidence of significant N-fixation by phytoplankton has been found.

After the winter bloom, water column stratification occurs in March-April, which results in the formation of the DCM (depth of chlorophyll maxima), which is characteristic of the system for the remainder of the year. The stratification starts in the offshore area in the southeast Levantine Basin and spreads from there to the west and the north. In summer the DCM is partially greater than 100 m deep, while the water above it is depleted in inorganic N and P but contains significant amounts of dissolved organic nitrogen and phosphorus.

The phytoplankton community in the offshore region is dominated by pico- and nano-plankton, with micro plankton and eukaryotes (organisms whose cells contain complex structures enclosed within membranes). Only important in coastal regions and upwelling areas associated component of such nutrient-depleted system. Both depth-integrated chlorophyll *a* and primary productivity levels are extremely low, characteristic of ultra oligotrophic systems.

Meso scale features can be locally important in controlling biogeochemical processes. The Rhodes cold-core gyre is a locus of nutrient upwelling and an important source of both nutrients and productivity for the whole Levantine Basin. It is also the major source of LIW (Levantine intermediate water). The Cyprus warm-core eddy has elevated productivity in winter as nutrients are brought to the euphotic zone by deep winter mixing. The depth-integrated chlorophyll decreases during the year but never becomes as low as the area around the eddy. Satellite images show the importance of transient meso scale features as loci for seasonal biomass changes and for nutrient transfer.

Although it is known that anthropogenic inputs of nutrients are important and possibly dominant in the overall supply to the system, there are no long-term nutrient data sets available to monitor changes in nutrients with time, as there are in the western Mediterranean. It is however known that there have been recent changes in the deep water circulation in the eastern Mediterranean, which are probably caused by climatic and / or anthropogenic changes. The eastern Mediterranean is extremely sensitive to such changes.

Only 5000 years ago the Levantine Basin had, like the Black Sea, an oxygen-depleted deep water. It is still unclear what were the exact conditions which caused the major shift from an ultra oligotrophic to a eutrophic system. Increases in nutrient supply and paleoclimatic changes may be the reasons.

Annually averaged vertical profiles of some hydrographic parameters are given in Figure 1.3.5.1.

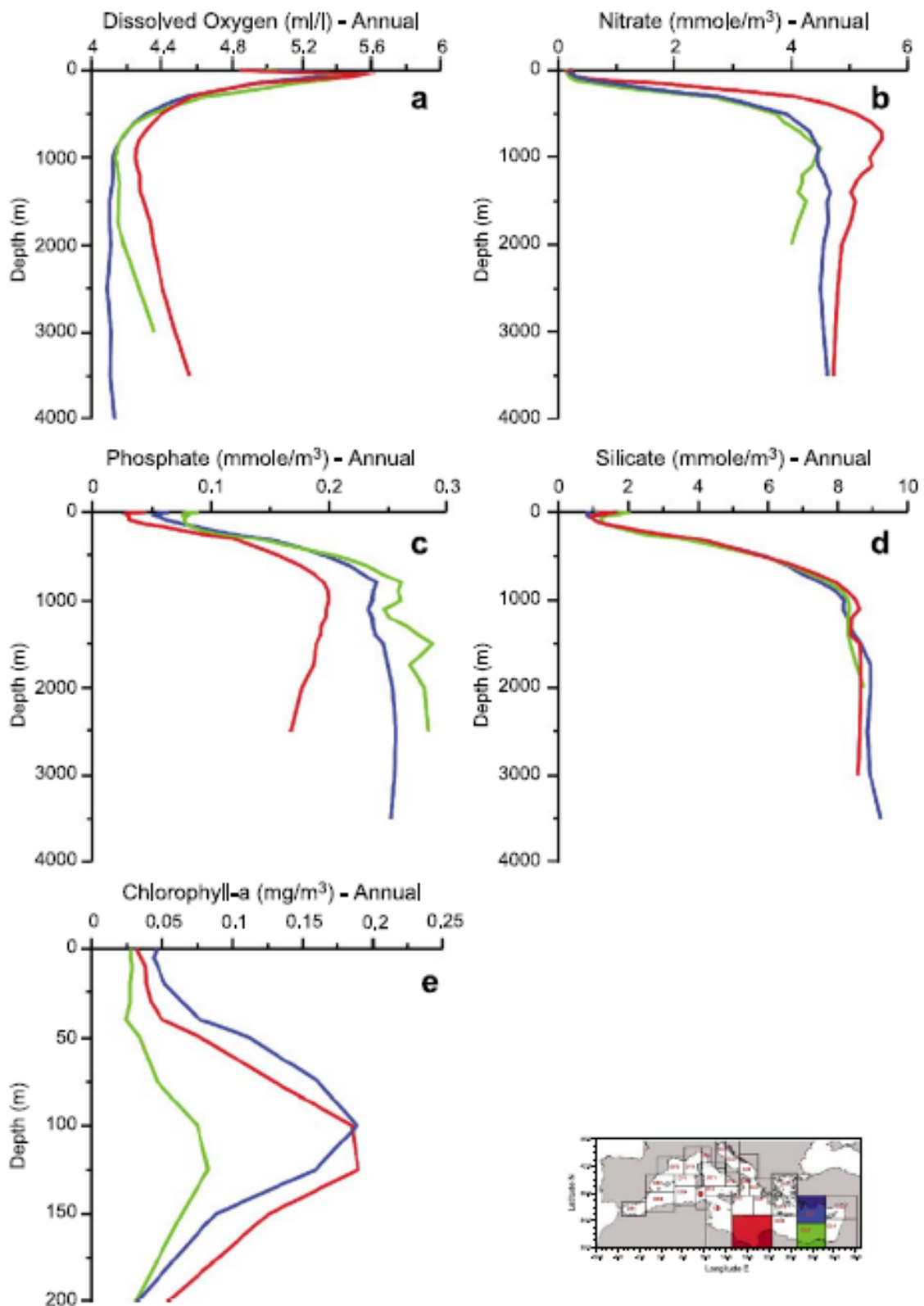


Figure 1.3.5.1 Annually averaged vertical profiles of hydrographic parameters. The green profile is for the Levantine Basin. a – dissolved oxygen; b – nitrate; c – phosphate; d – silicate; e- chlorophyll.

Source: Manca et al, 2004.

## 1.4 Ecology

### 1.4.1 BIOLOGY

#### 1.4.1.1 Overview

The recent marine biota in the Mediterranean Sea is primarily derived from the Atlantic Ocean, but the wide range of climate and hydrology has contributed to the co-occurrence and survival of both temperate and subtropical organisms. High percentages of Mediterranean marine species are endemic. The Mediterranean has as well its own set of emblematic species of conservation concern, such as sea turtles, several cetaceans, and the critically endangered Mediterranean monk seal. It is the main spawning grounds of the eastern Atlantic bluefin tuna. There are several unique and endangered habitats, including the seagrass meadows of the endemic *Posidonia oceanica*, vermetid reefs built by the endemic gastropod *Dendropoma petraeum*, coralligenous assemblages, and deep-sea and pelagic habitats that support unique species and ecosystems. Many sensitive habitats exist within the coastal ecosystems. There are 150 wetlands of international importance for marine and migrating birds, and some 5,000 islands and islets.

#### 1.4.1.2 Diversity estimates in the Mediterranean Sea

Investigations and summaries of Mediterranean Sea diversity were compiled by Coll et al (2010). Their analysis revealed approximately 17,000 species occurring in the Mediterranean (Table 1.4.1.1). Of these, at least 26% were prokaryotic (Bacteria and Archaea) and eukaryotic (Protists) marine microbes. However, the data available for Bacteria, Archaea, and Protists were very limited, so these estimates have to be treated with caution (see next section), as well as data for several invertebrate groups (such as Chelicerata, Myriapoda, and Insecta).

	W Med <sup>1</sup>	E Med <sup>2</sup>	NW Med	Alboran Sea	SW Med	Adriatic Sea	Central Med	Ionian Sea	Aegean Sea	Tunisian Pl. <sup>3</sup> /Gulf of Sidra	Levantine Basin <sup>10</sup>
Ceramiales (Rhodophyta)	248					198	211		193		
Phaeophyceae			161		119 <sup>(4)</sup>	160	183 <sup>(5)</sup>	122 <sup>(6)</sup>			74
Porifera			432	181	123	230		181	200	90	94
Anthozoa	151					100		58	90		38
Gastropoda	1148					462	582		622		83
Cephalopoda	61	55				45					
Polychaeta	946	877									
Harpacticoid copepoda	254								96		
Cumacea	85	74	78	43	42	13	50 <sup>(5)</sup>	28	43	4	48
Mysidacea	90	55	62	9	2	34	64 <sup>(5)</sup>	7	5	30	
Euphausiacea	13					12	13		12		11
Isopoda	149					47	26		74		34
Cirripedia	34					17	17		17		13
Amphipoda	421					242	160		260		144
Decapoda <sup>(1)</sup>	316					228	205		252		59
Decapoda <sup>(2)</sup>						293 <sup>(7)</sup>			260		230
Echinodermata	144 <sup>(8)</sup>					101	98 <sup>(9)</sup>		107		73
Sipuncula			45	19	15	36	36			16	
Ascidacea	193	167									

**Table 1.4.1.1 Species richness by taxa and regions in the Mediterranean Sea.**

Source: Coll et al, 2010.

Within the Animalia, the greater proportion of species records were from subphylum Crustacea (13.2%) and phyla Mollusca (12.4%), Annelida (6.6%), Platyhelminthes (5.9%), Cnidaria (4.5%), the subphylum Vertebrata (4.1%), Porifera (4.0%), Bryozoa (2.3%), the subphylum Tunicata (1.3%), and Echinodermata (0.9%). Other invertebrate groups encompassed 14% of the species, and Plantae included 5%.

Available information showed that the highest percentage of endemic species was in Porifera (48%), followed by Mysidacea (36%), Ascidiacea (35%), Cumacea (32%), Echinodermata (24%), Bryozoa (23%), seaweeds and seagrasses (22%), Aves (20%), Polychaeta (19%), Pisces (12%), Cephalopoda (10%), and Decapoda (10%). The average of the total endemics was 20.2%. In some groups the percentage of endemics was now lower than in the past, partly due to new finding of Mediterranean species in adjacent Atlantic waters.

#### 1.4.1.3 The biodiversity at high trophic levels

Species that occupy the upper trophic levels, normally beyond the level of secondary consumers, are classified as predators. They have lower diversity than other taxonomic groups. There is still some discussion about diversity estimates for these taxonomic groups. For fish species, for example, several estimates of Mediterranean diversity exist, ranging from 580 to 664 species. Fish diversity estimates also change as new species are described or reclassified. The updated list of exotic fish species reveals that the Mediterranean currently contains 116 exotic species, although more species are likely to be cited. Approximately 80 fish species are elasmobranchs, although the status of some is uncertain because of infrequency or uncertain reporting.

Nine species of marine mammals are encountered regularly in the Mediterranean. Of these species, five belong to the Delphinidae, and one each to the Ziphiidae, Physteridae, Balaenopteridae, and Phocidae. Other fourteen species are sporadically sighted throughout the basin and are considered “visitors” or “non-residents.”

Of the seven living species of sea turtles, two (the green and the loggerhead *Chelonia mydas* and *Caretta caretta* - Cheloniidae) commonly occur and nest in the Mediterranean, and one (leatherback turtle *Dermochelys coriacea* - Dermochelyidae) is regularly sighted but there is no evidence of nesting sites. The other two (hawksbill and Kemp's riddle turtles *Eretmochelys imbricata* and *Lepidochelys kempfi* - Cheloniidae) are extremely rare and considered to be vagrants in the Mediterranean.

Seabirds from the Mediterranean have a low diversity (15 species) and their population densities are small, consistent with a relatively low-productivity ecosystem compared with open oceans, and particularly with upwelling regions. Ten of the Mediterranean species are gulls and terns (Charadriiformes), four are shearwaters and storm petrels (Procellariiformes), and one is a shag (Pelecaniformes). Three of the ten species are endemics.

The majority of aliens in the Mediterranean entered through the Suez Canal (Erythrean aliens) (53%), and an additional 11% were introduced primarily through the Canal and then dispersed by vessels. Introductions from vessels from other parts of the world account for 22% of introduced species, and aquaculture accounts for 10%. A further 2% arrived with the introduction of aquaculture and were secondarily spread by vessels. The means of introduction differ greatly among the phyla: whereas of the alien macrophytes, 41% and 25% were introduced through mariculture and vessels, respectively, the majority of alien crustaceans, mollusks, and fish are Erythrean aliens (59%, 64%, and 86%, respectively), and mariculture introductions are few (4%, 5%, and 4%, respectively).

The numbers of alien species that have been recorded over the past century have increased in recent decades. The increasing role of the Mediterranean as a hub of international commercial shipping, a surge in the development of marine shellfish farming over the last 25 years, and the continued enlargement of the Suez Canal have contributed to the resurgence of introductions since the 1950s. Many introduced species have established permanent populations and extended their range: 214 alien species have been recorded from three or more peri-Mediterranean countries, and 132 have been recorded from four or more countries.

Taxonomic classification of species reported in the Mediterranean Sea is given in Table 1.4.1.2. Spatial predicted species richness is given in Figures 1.4.1.1 to 1.4.1.5.

<b>Taxonomic group</b>	<b>No. species<sup>1</sup></b>
<b>Domain Archaea</b>	Unknown
<b>Domain Bacteria</b>	Unknown (165 macroscopically identifiable cyanobacteria described)
<b>(including Cyanobacteria)</b>	
<b>Domain Eukarya</b>	
<b>Protoctista and Chromista</b>	Unknown, first estimate approx. 4400 <sup>4</sup>
Dinomastigota (Dinoflagellata)	673
Bacillariophyceae	736
Coccolithophores	166
Foraminifera	>600
Heterokontophyta	277
<b>Plantae<sup>5</sup></b>	854
Chlorophyta	190 (180 <sup>6</sup> )
Rhodophyta	657
Magnoliophyta	7
<b>Animalia</b>	11595
Porifera	681
Cnidaria	757
Platyhelminthes	1000
Mollusca	2113
Annelida	1172
Crustacea	2239
Bryozoa	388
Echinodermata	154
Tunicata (Ascidiacea)	229
Other invertebrates	2168
Vertebrata (Pisces)	650
Other vertebrates	43
<b>SUBTOTAL</b>	
<b>TOTAL REGIONAL DIVERSITY<sup>3</sup></b>	<b>16848</b>

Table 1.4.1.2 Taxonomic classification of species reported in the Mediterranean Sea.  
Source: Coll et al, 2010.

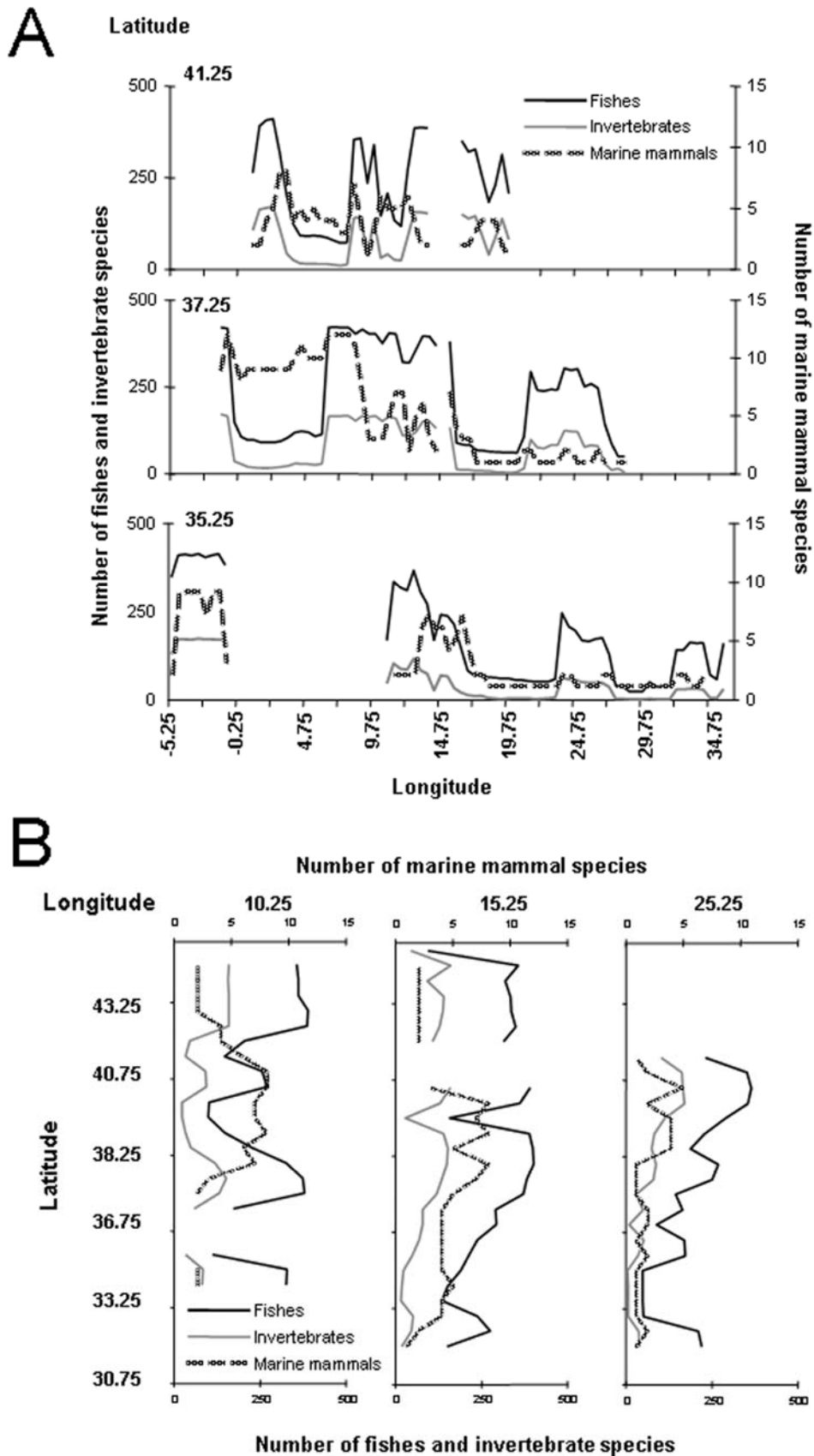


Figure 1.4.1.1 Transects of spatial predicted species richness. A - Latitudinal transects; - Longitudinal transects. The contribution of fishes, invertebrates and marine mammals to geographic gradients in biodiversity is shown.

Source: Coll et al, 2010.

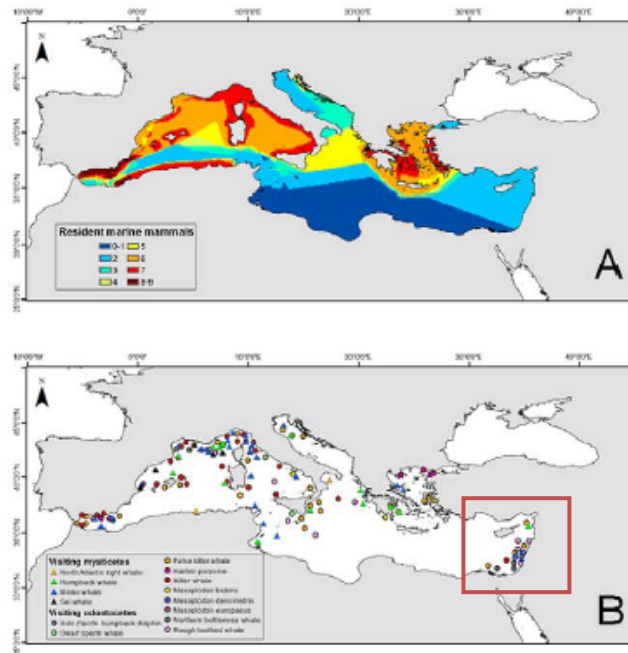


Figure 1.4.1.2 Spatial patterns of vertebrate species richness in the Mediterranean Sea. A – resident marine mammals: dark blue – none or one species; light blue – one to two species. B – non resident marine mammals. Legend in Figure 4.1.3. Red box indicates area enlarged in Figure 4.1.3.

Source: Coll et al, 2010.

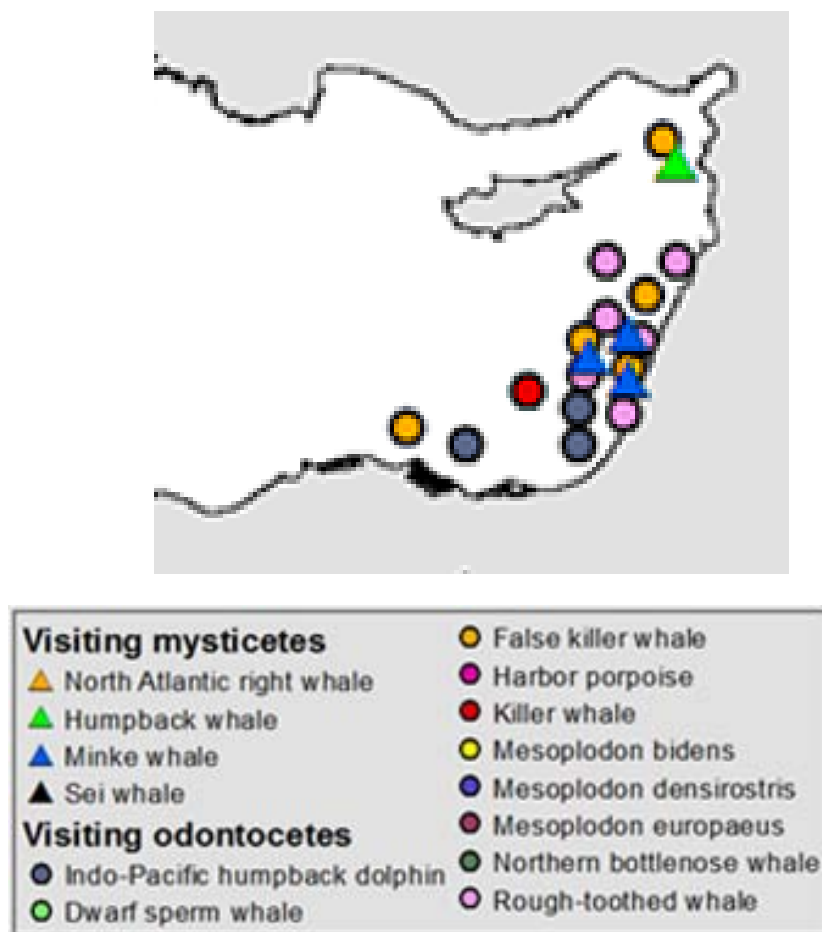
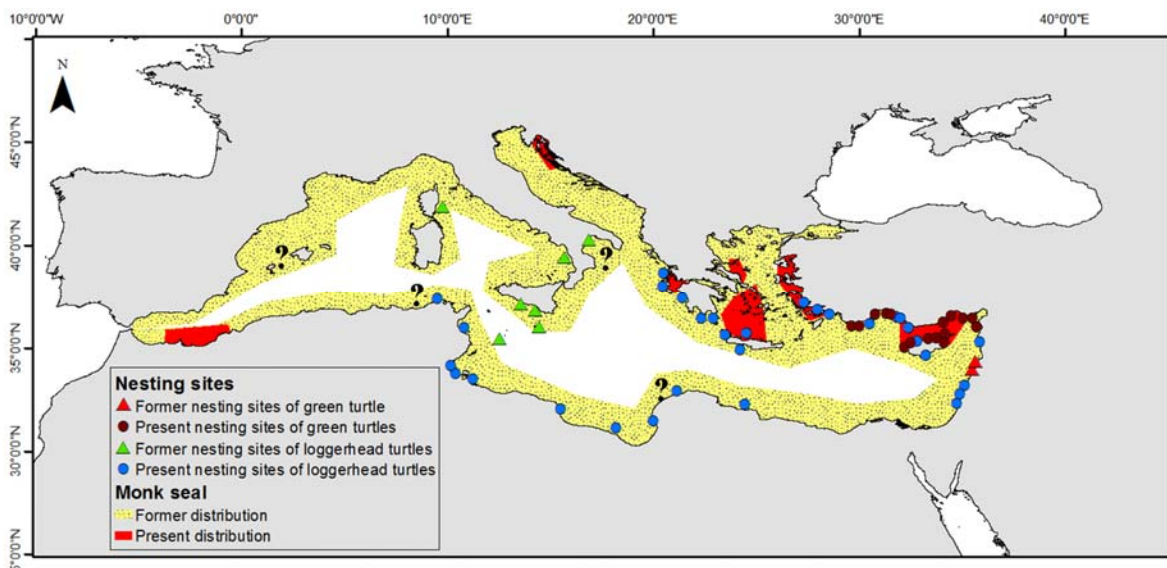


Figure 1.4.1.3 Spatial patterns of non resident marine mammals in the Levantine Basin.

Source: Coll et al, 2010.



**Figure 1.4.1.4 Loggerhead turtle (top) and monk seal (bottom)**  
*Source: Cortes et al, 2004 and Wikipedia.*



**Figure 1.4.1.5 Distribution of monk seals and nesting sites of marine turtles in the Mediterranean. Present (red areas) and historical (yellow areas) distribution of the Mediterranean monk seal and nesting sites for loggerhead turtle and green turtle. Green and red triangles are, respectively, the former nesting sites for loggerhead turtle and green turtle; green and red dots are the present sites. Question marks represent sites where one or a few Mediterranean monk seals have been recently seen.**

*Source: Coll et al 2010.*

#### 1.4.1.4 The Lessepsian migration

In order to present a complete picture of the biology of the Levantine Basin, the invasion of the Mediterranean Sea by species from the Indian Ocean is briefly discussed.

The Lessepsian migration (also called Eritrean invasion) is the ongoing migration of marine species through the Suez Canal (Figure 1.4.1.6) from the Red Sea to the Mediterranean Sea and, rarely, in the opposite direction. It is named after Ferdinand de Lesseps, the engineer in charge of the canal's construction.



**Figure 1.4.1.6 Google-Earth image of the Suez Canal, connecting the Gulf of Suez in the south to the Mediterranean Sea in the north.**

The opening of the Suez Canal in 1869 created a water passage between two biogeographical areas inhabited by characteristic and very different biota: the Red Sea province is part of the warm-temperate Atlantic-Mediterranean Region, and the subtropical Levantine Basin, which is part of the warm-temperate Atlantic-Mediterranean Region. These regions have been partially separated since the early Miocene (ca. 20 Ma ago) and have been completely separated since the Miocene (Serravalian, ca 13.5 Ma ago).

The Red Sea is higher than the Eastern Mediterranean. The canal serves as a tidal strait that introduces Red Sea water into the Mediterranean. The Bitter Lakes, which are hypersaline natural lakes that form part of the canal, blocked the migration of Red Sea species into the Mediterranean for many decades, but as the salinity of the lakes gradually equalized with that of the Red Sea, the barrier to migration was removed, and plants and animals from the Red Sea have begun to colonise the eastern Mediterranean.

The Red Sea is generally saltier and more nutrient-poor than the Atlantic, so the Red Sea species have advantages over Atlantic species in the less salty and nutrient-rich Eastern Mediterranean. Accordingly, most invasions are of Red Sea species into the Mediterranean, and only few in the opposite way. The construction of the Aswan High Dam across the Nile River in the 1960s reduced the inflow of freshwater and nutrient-rich silt from the Nile into the eastern Mediterranean, making conditions in the eastern Mediterranean even more like the Red Sea, thus increasing the impact of the invasions and facilitating the occurrence of new ones.

Species which invaded the Mediterranean Sea are called Lessepsian Migrants, and the Levant area inhabited by them became the Lessepsian Province. One of the Lessepsian Migrants is shown in Figure 1.4.1.7.



**Figure 1.4.1.7 *Fistularia commersonii*, one of the Lessepsian Migrants.**

Invasive species originated from the Red Sea and introduced into the Mediterranean by the construction of the canal have become a major component of the Mediterranean ecosystem, and have serious impacts on the Mediterranean ecology, endangering many local and endemic Mediterranean species. To this day, about 300 species native to the Red Sea have been identified in the Mediterranean Sea, and there are probably others yet unidentified. In recent years, the Egyptian government's announcement of its intentions to deepen and widen the canal have raised concerns from marine biologists, fearing that this will worsen the invasion of Red Sea species into the Mediterranean, facilitating the crossing of the canal for additional species.

Several marine biologist investigated the Lessepsian Migration. Among the most recent are Ben Eliahu and Ten Howe (2011) (Serpulidae), Oral (2010) (fishes), and Ben Rais Lasram and Mouillot (2009) (invasion changes). Their researches support that which has been concluded by earlier researches: the introduction of alien species to new ecosystem is a major threat to its biodiversity, structure and function.

To date more than 790 alien species have been introduced to the Mediterranean sea, most of them are benthos and fish species. The majority of them (macrophytes, invertebrates and fish) have an Indo-Pacific origin. Movement of species as a reaction to global warming will increase the spatial overlap between exotic and endemic species.

With the increasing temperature of the Mediterranean Sea, endemic fish species are encountering a growing number of exotic species. Exotic invasion can, eventually, reduce the abundance of native species, alter basic ecosystem processes and introduce new pathogens to indigenous populations. Native species can be driven to extinction by competitive interactions, by predation or simply by demographic stochasticity when many new individuals enter the community and occupy a part of the carrying capacity of native species.

#### 1.4.1.5 Biology of the Levantine Basin

The Levantine Basin is situated in a subtropical region where hydro-climatic conditions are close to those prevailing in the Red Sea, namely high seawater temperature and salinity and heavy oligotrophy (the survival of organism in an environment that offers very low levels of nutrients). Many species inhabiting the Levantine Basin show certain tropical affinity.

Many endemic species living in the Mediterranean equally inhabit the Red Sea and Indo-Pacific or the temperate and tropical Atlantic. In this case and after the opening of Suez Canal and the start of the migration process, there was an invasion of hundreds Indo-Pacific and Eritrean species into the East Mediterranean; it is sometimes difficult to distinguish between a native species and an exotic invader. In any case the opening of the Suez Canal was an important event of great biological importance inducing changes in the hydro-biology of the East Mediterranean, particularly on the east Levantine ecosystem, with strong impact on the marine biodiversity. On the other hand, this manmade event has contributed to enhance certain “tropicalisation” of the Levantine ecosystem.

Furthermore, the regulation of the Nile River by the Aswan High Dam resulting in the stop of the flood has contributed to strengthen this “tropicalisation”, which induces and increases the biological invasion process. In comparing between the hydrological conditions prevailing in the Levantine Basin and those of the Red Sea, namely the high salinity and temperature, the high oligotrophy and low primary productivity rate are the most significant.

The first reliable records of “Lessepsian” fishes and other marine species in the Levantine Basin date from 1902. During the last four decades then number of Lessepsian migrants has increased dramatically. This is due, not only in the progress of the sampling and taxonomical analysis techniques, but also to the global warming of the seas, following the general climate change observed worldwide during the last decades.

There are three different kind of newcomer invaders: (a) the “established”, which adapts to the new environment in establishing permanent populations, (b) the “alien” which is recorded once or twice, even in high numbers, and disappear without establishing populations and (c) the “doubted” invader, about which there is no certainty on whether it has established populations or not. The ecological adaptation which involve nutritional competition between species, successful reproduction, development and succession of several generations, may take a long time to be achieved.

The impact of the newcomers on the biodiversity is observed through the abundance and even dominance of certain species in the community. The striking example is observed in the fish species *Stephanolepis diaspros*, *Sargocentron rubrum*, *Siganus rivulatus*, *S.luridus* and recently *Fistularia commersonii*. These species and many other established invaders, became very abundant, even dominant and are exploited in fisheries. Another example is observed within brown algae *Styopodium shimperi*, which invade large coastal areas and the stinging, harmful jellyfish *Rhopilema nomadica* which create the fear of swimmers and damage to the fishermen nets.

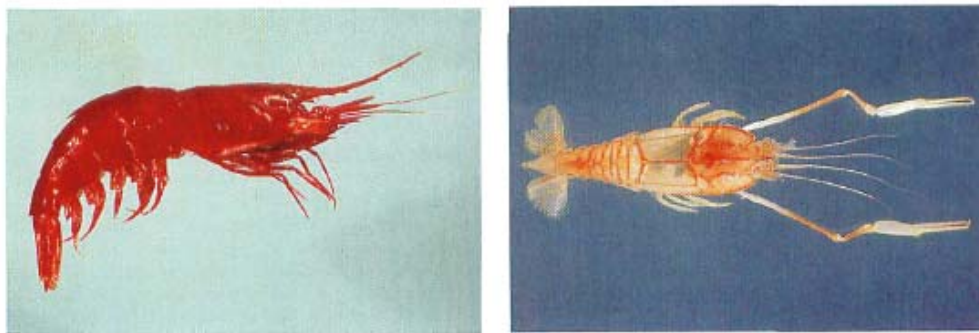
The hundred of invaders which established their ecological niches in the area show a negative impact on the biodiversity of local species. They disturb the development of many populations in occupying vital space and competing on food with many native species, in such a way that the biodiversity could be reduced or endangered in creating certain ecological imbalance.

Many species have doubtful records, either because of misidentification or insufficient sampling frequency. Introduction of planktonic aliens species in the Levantine Basin is still going on and the increasing process was observed after the deepening of Suez Canal and the construction of Aswan High Dam. It is well known that the introducing species arrive in the Eastern Mediterranean coast not only through the canal pathway northward current, but also by means of ships' ballast water and hulls. The import of commercial decorating and exotic aquarium marine organisms into the Mediterranean is also a major factor of transport tropical species into the Mediterranean.

The migration of pelagic organisms is more indicative than that of the benthic organisms, as their distribution by currents and water mass movements is more pronounced. On the other hand, several Atlantic species, either from temperate or from tropical regions may enter the Mediterranean through the Straits of Gibraltar and then taken by currents to the Levantine Basin.

The planktonic and nektonic populations off Lebanon were studied by Lakkis (2010). The plankton of the Levant Margin waters is of Atlanto-Mediterranean temperate type, with certain subtropical affinity. Most of planktonic groups and species inhabiting the temperate Atlantic and west Mediterranean are present in the Levantine Basin. A decrease in the number of species was noticed in recent decades. Macroalgae of the Lebanese coastal water show high species and taxonomic diversity. All Mediterranean groups are present and most Atlanto-Mediterranean species inhabit the Levantine Basin. In addition to those, several exotic tropical species were introduced in the area where they form ecological niches and permanent populations.

The deep fauna (750 to 1550 m) off the northern coast of Israel (next to the Sara and Myra Licence Areas) was investigated by Galil (1994 and 2004) (two examples are shown in Figure 1.4.1.8). Her work confirmed the floro-faunistic impoverishment of the Eastern Mediterranean compared with the Western Mediterranean species richness, and that gradational decrease in species is more conspicuous for the deep benthos than in the entire fauna.



**Figure 1.4.1.8 Deep Levant organisms. Left – *Acantheephyra eximia*; right – *Polycheles typhlops*.**  
Source: Galil and Goren, 1994.

Compared with the Atlantic ocean, the depths of the Mediterranean Sea lack major taxonomic groups, as well as cold stenotherm species (organism that function only within a narrow temperature range). This qualitative and quantitative poverty of the deep Mediterranean is considered to result from the fauna's relatively recent entry from the Atlantic, the impediment posed by the shallow sill at Gibraltar, the sea's oligotrophy and high homothermy and the climatic fluctuations during the Quaternary.

The poverty of the Levantine deep water fauna is clearly evident, it being the poorest in the Mediterranean. The prevalent low-diversity, low-density conditions are considered related to the basin's oligotrophy, its distance from the point of faunal entry at Gibraltar, and the shallow Sicilia - Tunisia sill. It has been suggested that larval ecology is the main cause of the faunal scarcity, and that much of the Mediterranean deep-sea fauna is made up by non-reproducing pseudopopulations. However, gravid benthic decapod crustaceans and fish were collected from the depths of the Levantine basin.

The extreme poverty of the Levantine depths compared to the rest of the Mediterranean may be explained by its past. Multiple layers of sapropels (dark-coloured sediments that are rich in organic matter) were discovered in the eastern Mediterranean but were not recorded west of the Strait of Sicily. Warming of the surface water together with large-volume flooding of fresh and low salinity water caused by deglaciation, resulted in restricted thermohaline convection, stagnation of subsurface water and deposition of sapropels at water depths greater than 600-1000 m.

The Levantine depths underwent faunal extinctions induced by environmental deterioration during interglacial stagnant episodes, followed by partial replenishment in glacial periods. We, thus, suggest that the poverty of the Levantine deep fauna results from it being doubly afflicted: during glacial periods the prevailing high temperature and salinity prevented settlement by members of the stenothermic and stenohalinic Atlantic deep water, as far as they were able to cross the Gibraltar and Sicilian sills, while anoxic conditions during the postglacial restricted recolonisation. Thus, the Levant basin, with its recurrent stagnant events, the last one terminating only 6000 yrs B.P), serves as unique opportunity to examine the process of faunal recolonisation of its depths.

#### 1.4.2 Flora

Both Sara and Myra drilling sites are below the euphotic zone, and thus there is no flora there. One unique flora species - the *Posidonia oceanica* (Figure 1.4.2.1). – is discussed here, nevertheless, due to its significance to the ecology of the Mediterranean Sea.



**Figure 1.4.2.1 A meadow of *Posidonia oceanica*.**

Source: Cortes et al, 2004.

*Posidonia oceanica* (commonly known as Neptune Grass or Mediterranean tapeweed) is a seagrass species that is endemic to the Mediterranean Sea. It forms large underwater meadows that are an important part of the ecosystem. The fruit is free floating and known in Italy as 'the olive of the sea'. Balls of fibrous material from its foliage, known as *egagropili*, wash up to nearby shorelines.

*P. oceanica* is a flowering plant which lives in dense meadows or along channels in the sands of the Mediterranean. It is found at depths from 1–35 metres (3.3–115 ft), according to water clarity. Subsurface rhizomes and roots stabilize the plant while erect rhizomes and leaves reduce silt accumulation.

provides a host of 'ecosystem services', that are crucially important to the region's ecological, physical and economic well-being.

The *P. oceanica* meadows provide habitat for a quarter of the sea's endemic species and serves as the sea's most important fish production areas. They also stabilise the shoreline, mitigate nutrient and sediment pollution, protect against beach erosion, help with water quality monitoring, encourage water transparency and absorb carbon dioxide emissions (UNEP 2010).

The *P. oceanica* is regarded "an international treasure, which remains largely hidden from our view, sustains life and is an important indicator of human impacts along the coastal zone".

## 1.5 Fisheries

Most of the fishing in the coastal Mediterranean of Israel is shallow water fishing, resulting in great strain and causing depletion of fish. In an attempt to reduce the depletion of fish stock, fishing is therefore highly controlled.

Last years there is no activity of trawlers in the area of Myra & Sara. Before, there were some trawlers working in the area.

Sporadically, especially at spring and beginning of summer, there is some activity of Blue Fin Tuna and Sword Fish fishing there.

Some sharks species accompanied the Tuna fishing.

## 1.6 Archaeology

There are no data about antiquities at the area of Myra & Sara.

## 1.7 Infrastructures

Infrastructures in the vicinity of Myra & Sara are:

1. Tamar drilling site rig (and Dalit in the future).
2. Communication cables from/to Israel, as shown in figure 1.7.1.1.

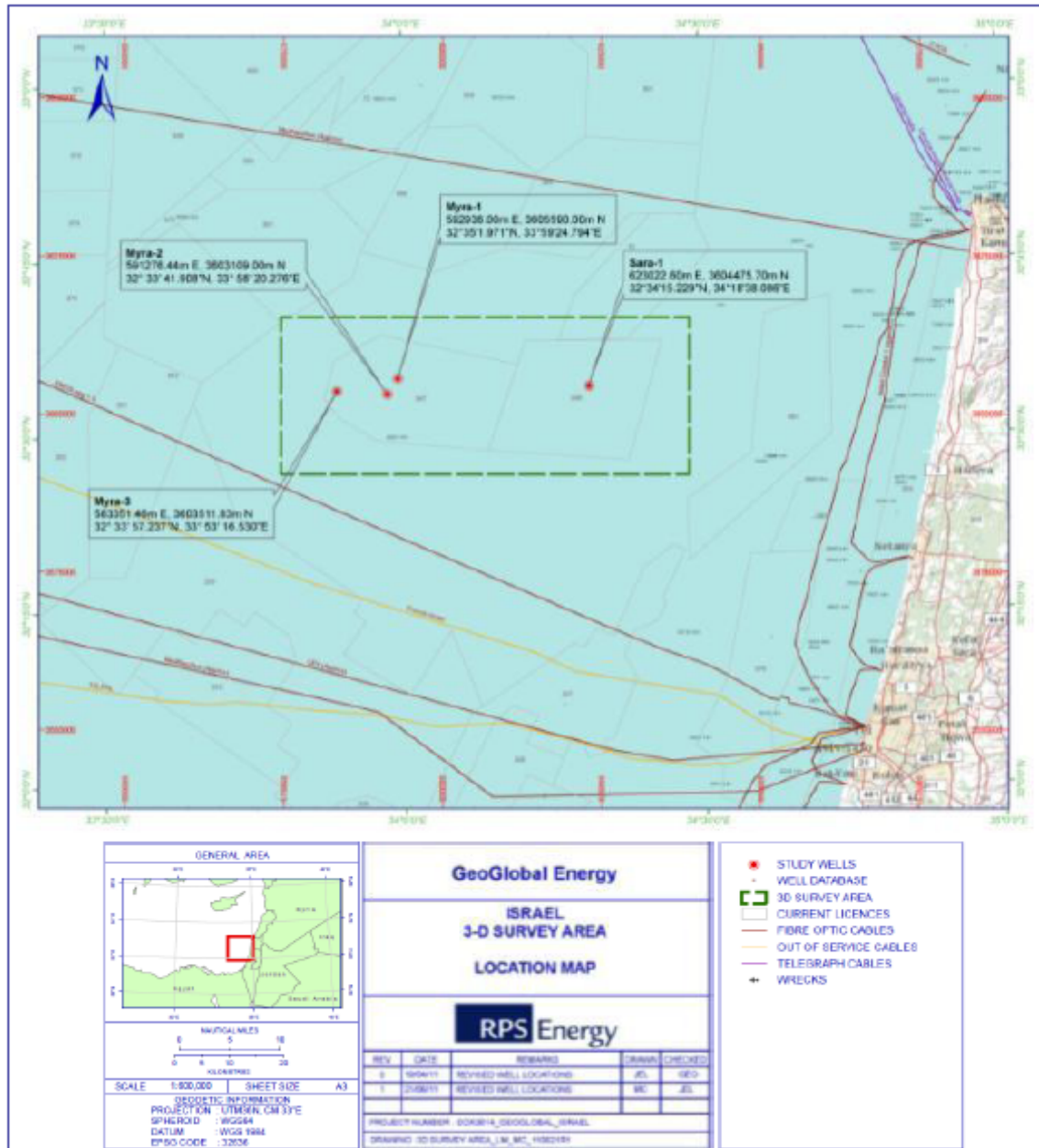


Figure 1.7.1.1 – Communication cables

## 1.8 Marine Transportation

### 1.8.1 Sailing routes

The Survey of Israel and the Transportation ministry, the administration of shipping and ports, prepared a map of the "Mediterranean sea in Israel (No.1)" that shows the depths of the sea, recommended sailing routes to all vessels navigating to and from Israeli ports, entry prohibited areas, and reference to oil and gas pipes

The navigating route for the entry to Hadera port is located south of Sara and Myra sites. (Figure 8.1.1 – sailing routes near Sara and Myra Drilling areas) .

### 1.8.2 Notice to mariners

The transportation ministry (the administration of shipping and ports, the Inspectorate and safety division) and the infrastructure ministry needs to get the plan details of the drilling rigs, in order to mark it on the navigation maps and in order to publish a Notice to mariners.

Following is an example of a published Notice to Mariners for an oil rig from October 2011:

"

NO. 40/2011 New drilling position, oil rig "PRIDE NORTH AMERICA"

Sunday, 02 October 2011 15:54

**Subject:** New drilling position, oil rig "PRIDE NORTH AMERICA".

**Charts affected:** Survey of Israel - Charts No 1 B.A. - Charts No. 2634.

This is to advise all mariners that the oil rig "PRIDE NORTH AMERICA", changed drilling position.

#### **The new position is:**

32° 47, '3 N

033° 48. '33 E

Duration of drilling 120 days about from 02/10/2011.

**All vessels are requested to keep clear 5 miles off the oil rig."**

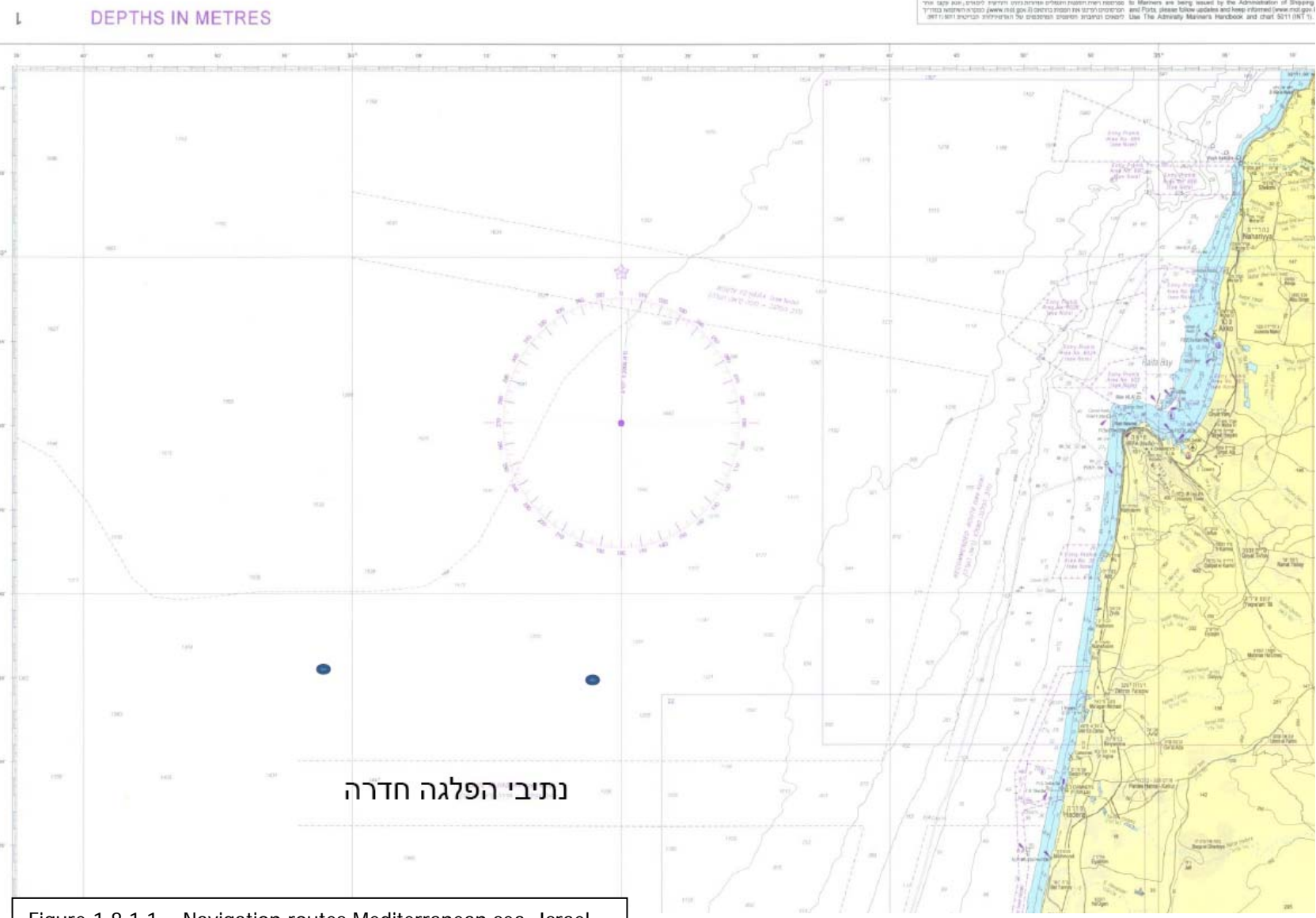


Figure 1.8.1.1 – Navigation routes Mediterranean sea, Israel



Sara and Myra Licence Areas  
Offshore Israel  
Environmental Document  
November 2011



# Chapter B

## Drilling project description

## Chapter B - Drilling project description

### 2.1 SARA AND MYRA SITES

#### 2.1.1 Hydrocarbon potential

Drilling for oil and gas in the Levantine Basin and the adjacent land areas to the south and the east has taken place in the last four decades. The high gas potential offshore Israel has only been discovered in recent years. Figure 2.1.1.1 is a general geology map of the eastern Mediterranean Sea, showing drilling sites in the Levantine Basin and in the land areas to the south and the east.

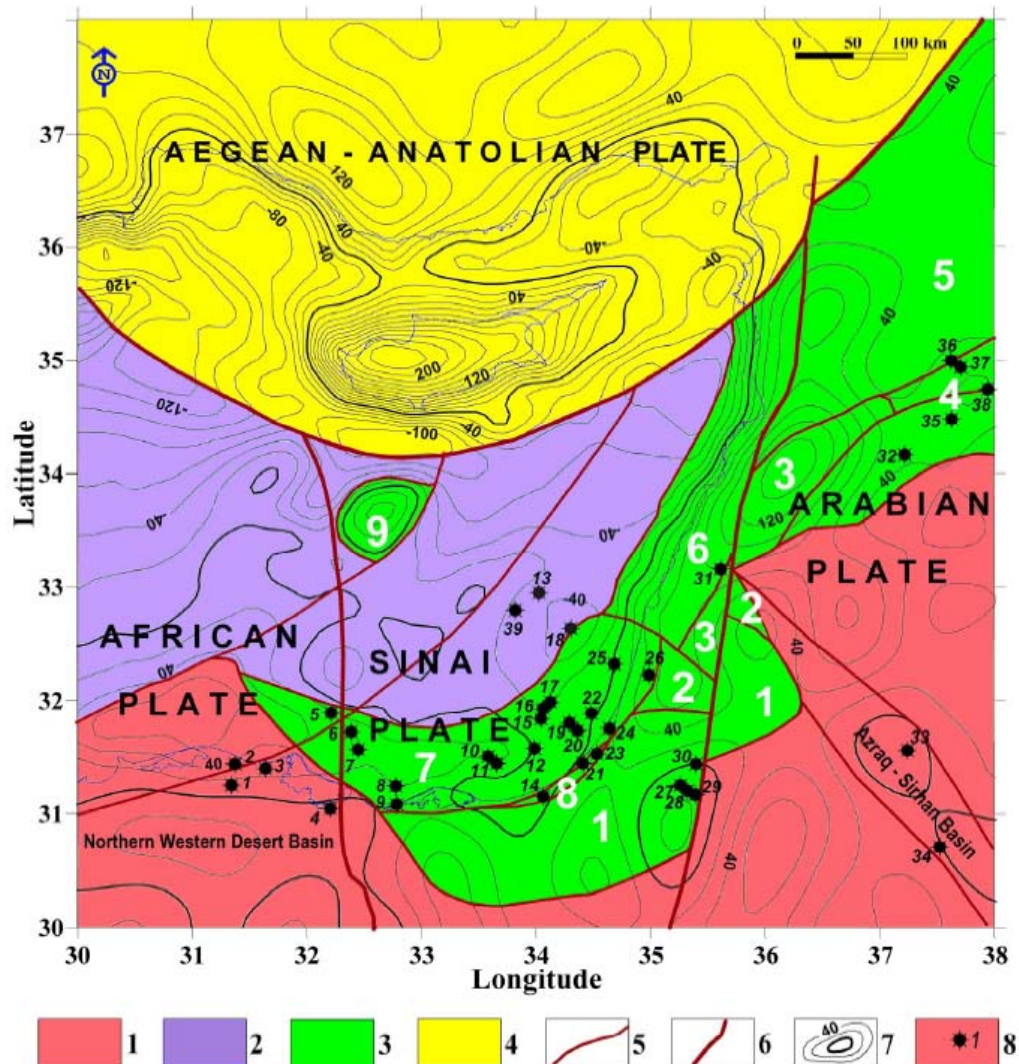


Figure 10. Tectonic map of the eastern Mediterranean overlaid on the smoothed gravity map. Terranes position (white numbers): 1 – Negev, 2 – Judea-Samaria, 3 – Antilebanon, 4 – Palmyride, 5 – Aleppo, 6 – Galilee-Lebanon, 7 – Pleshet, 8 – Heletz, and 9 – Eratosthenes. (1) Precambrian plates with continental crust, (2) oceanic crust, (3) Mesozoic terranes, (4) Alpine tectonic belt, (5) main tectonic faults, (6) intraplate tectonic faults, (7) gravity isolines, mGal, (8) boreholes with discovered hydrocarbon reserves (black numbers): 1 – Khelala-1, 2 – El-Qara-1, 3 – Wastani-1, 4 – Quantara-1, 5 – Temsah-1, 6 – Kersh-1, 7 – Port Fouad-1, 8 – Tineh-1, 9 – Bougaz-1, 10 – Mango-1, 11 – Mango-2, 12 – Gaza Marine, 13 – Tamar-1, 14 – Sadot-1, 15 – Noa South-1, 16 – Noa-1, 17 – Or-1, 18 – Dalit-1, 19 – Mari-1,2, 20 – Nir-1,2, 21 – Shiqma-1, 22 – Yam-2, 23 – Heletz, 24 – Ashdod, 25 – Yam-Yafo-1, 26 – Meged-2, 27 – Zahar-8, 28 – Gurim-1, 29 – Zuk-Tamrur-4, 30 – Emunah-1, 31 – Hula, 32 – Qaruatene-1, 33 – Hamza, 34 – Wadi Sirhan-4, 35 – Cheriffe-1, 36 & 37 – boreholes with unknown names, 38 – Al Shaier-1, 39 – Leviathan-1.

Figure 2.1.1.1 A tectonic map of the eastern Mediterranean Sea, showing the confines of continental crust (red), terranes (green), oceanic crust (purple), terranes (green) and the Alpine tectonic belt (yellow) as well as main faults and drilling sites.

Source: Eppelbaum and Katz, 2011.

Hydrocarbon is present through the entire geological sequence since the Permian. It is trapped in alluvial fans, buried hills, channels and turbidity lobes and sheets. These traps and other features indicative of hydrocarbon are shown in Figure 2.1.1.2.

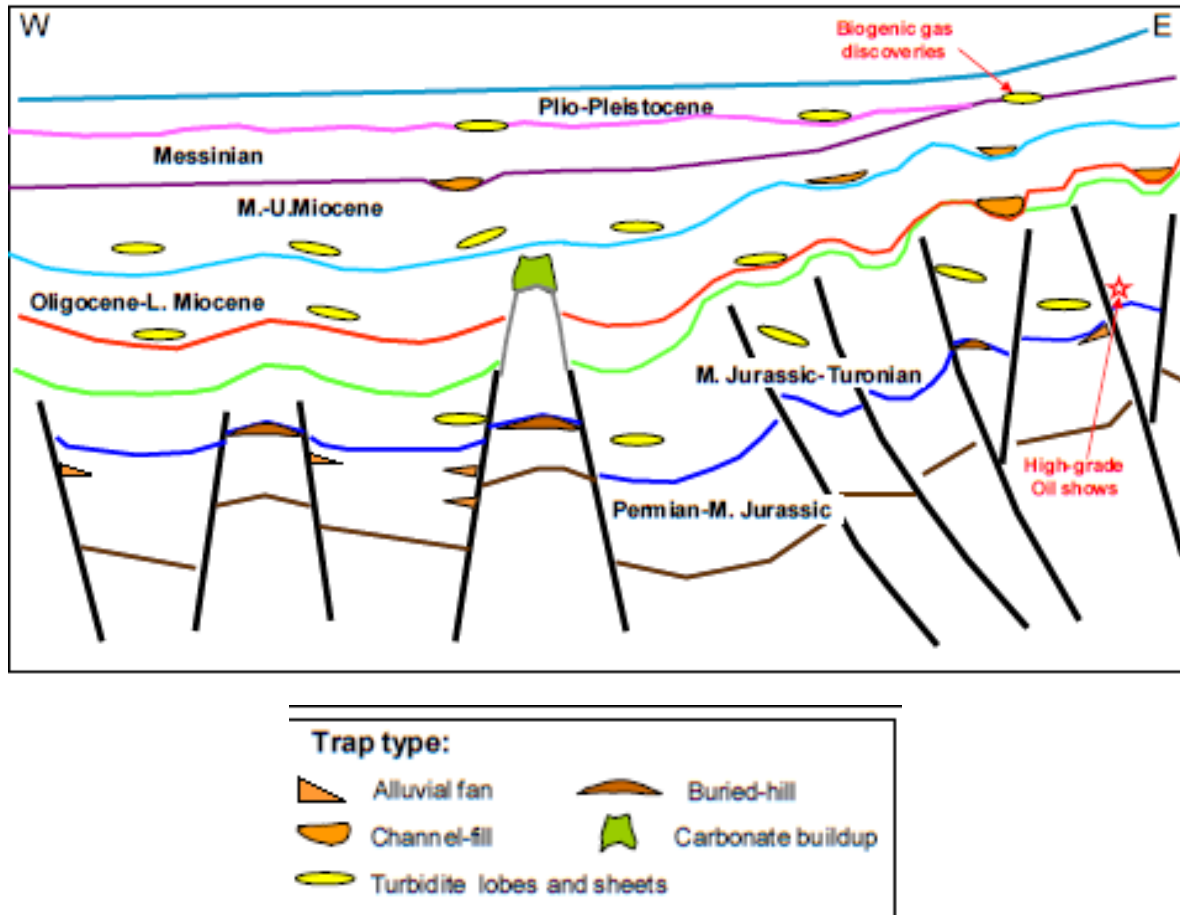


Figure 2.1.1.2 Schematic section through the Levant Basin showing potential hydrocarbon traps in the Phanerozoic sedimentary sequence. Pliocene gas discoveries in the southern part of the basin and high-grade oil shows in the Mesozoic section indicate the existence of biogenic and thermogenic petroleum systems.

Source: Gardosh et al 2008.

### 2.1.2 Drilling history

Several drillings were carried out offshore Israel and Sinai during the last 40 years. They are shown in Figure 2.1.2.1.

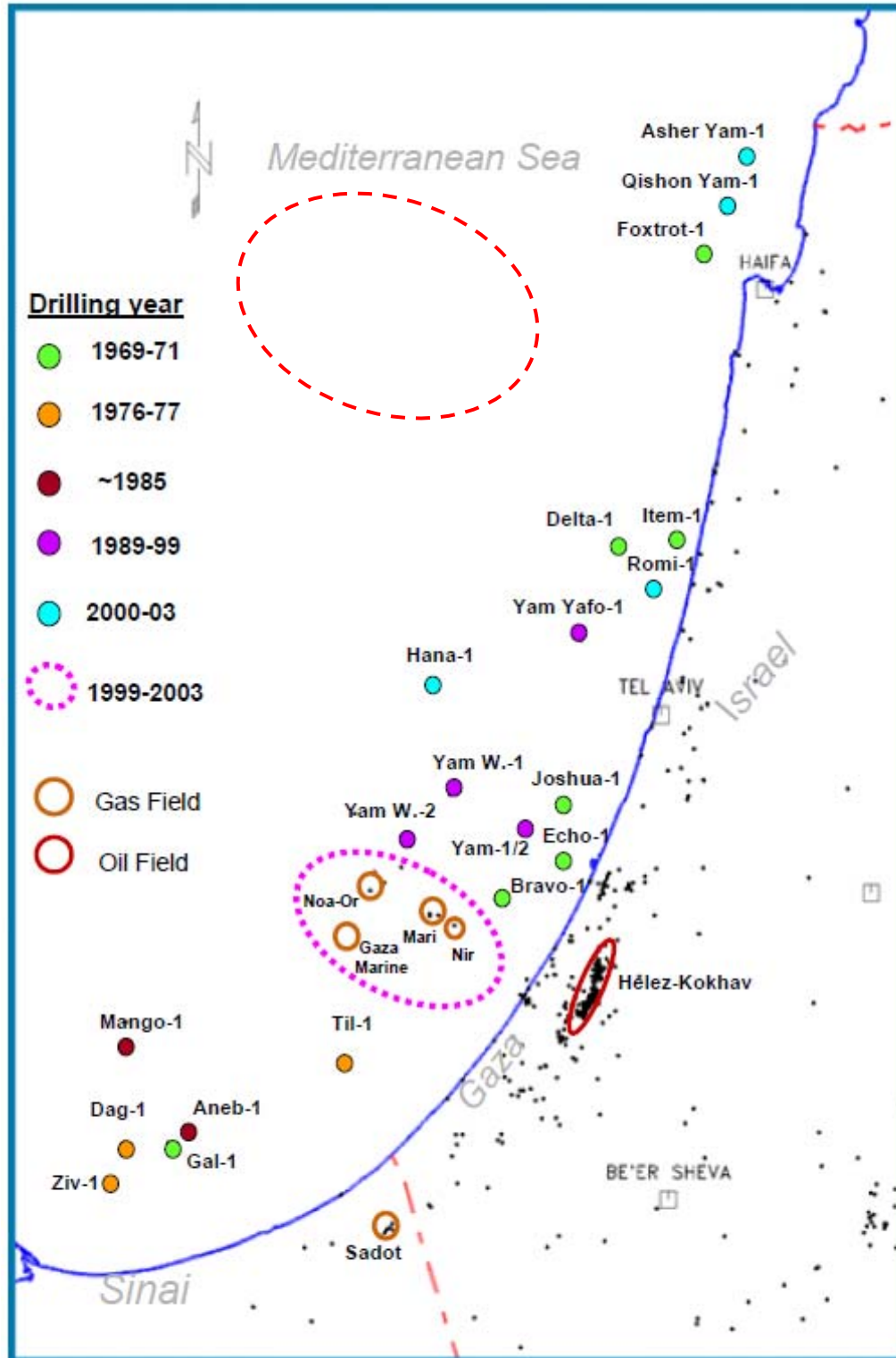
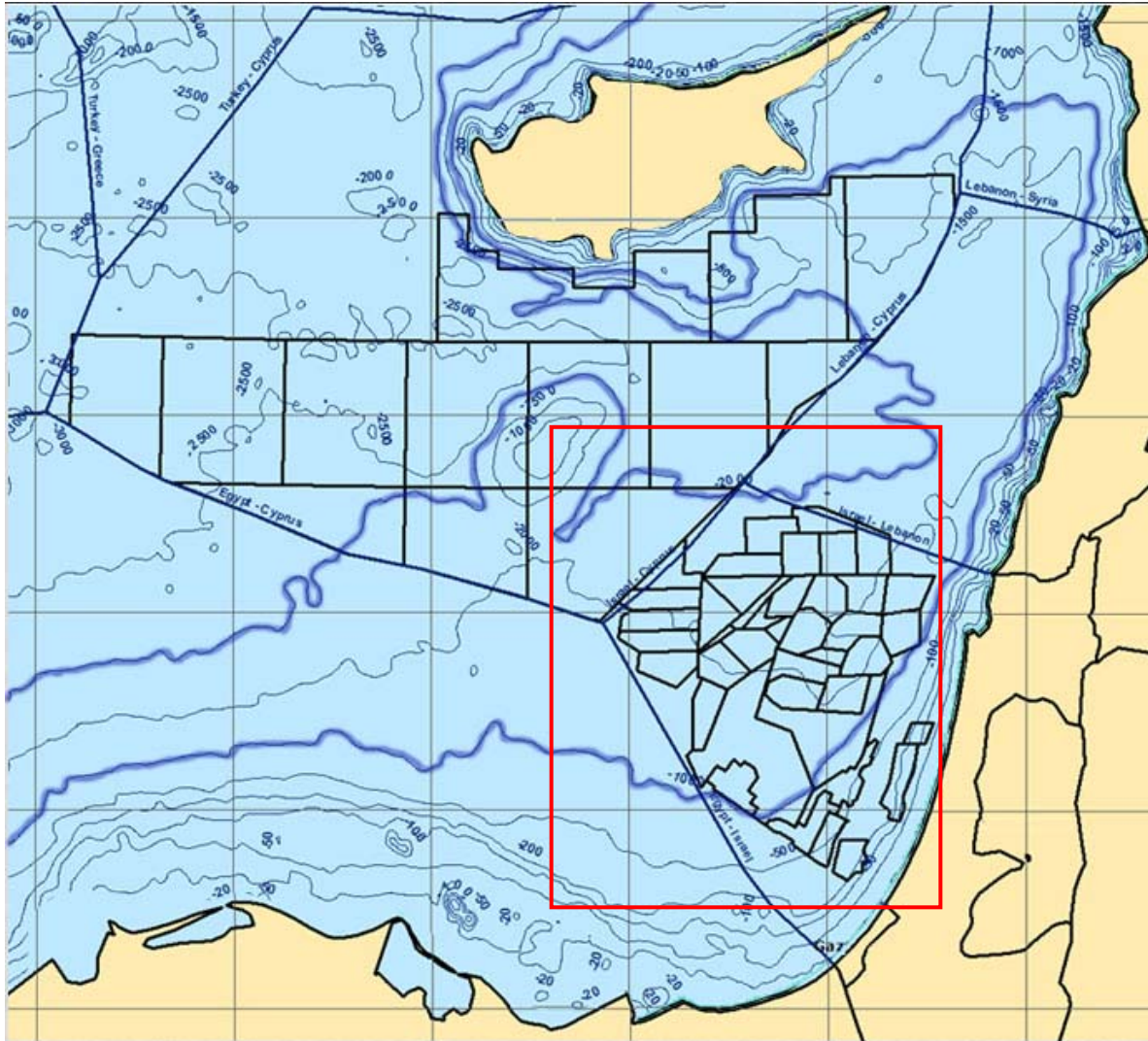


Figure 2.1.2.1 Offshore drilling history and main hydrocarbon occurrences. The dashed red ellipse, (indicating the approximate area of the existing Dalit, Tamar and Leviathan drillings and the proposed Sara and Myra drillings) has been added to the original map.

Source: Gardosh et al, 2000.

### 2.1.3 Licence areas location

The seafloor of the Levantine Basin was divided between Egypt, Israel, Lebanon and Cyprus, as shown in Figure 2.1.3.1.



**Figure 2.1.3.1** A map of the Levantine Basin, showing the division of the seabed between Egypt, Israel, Lebanon and Cyprus, and the subdivision to individual Licence Area off Israel and Cyprus. The red box indicates the section enlarged in Figure 2.1.3.2.

*Source: Langotsky, 2010.*

The Sara (348) and Myra (347) Licence Areas are located approximately 90 and 120 km offshore Israel respectively (Figure 2.1.3.2).

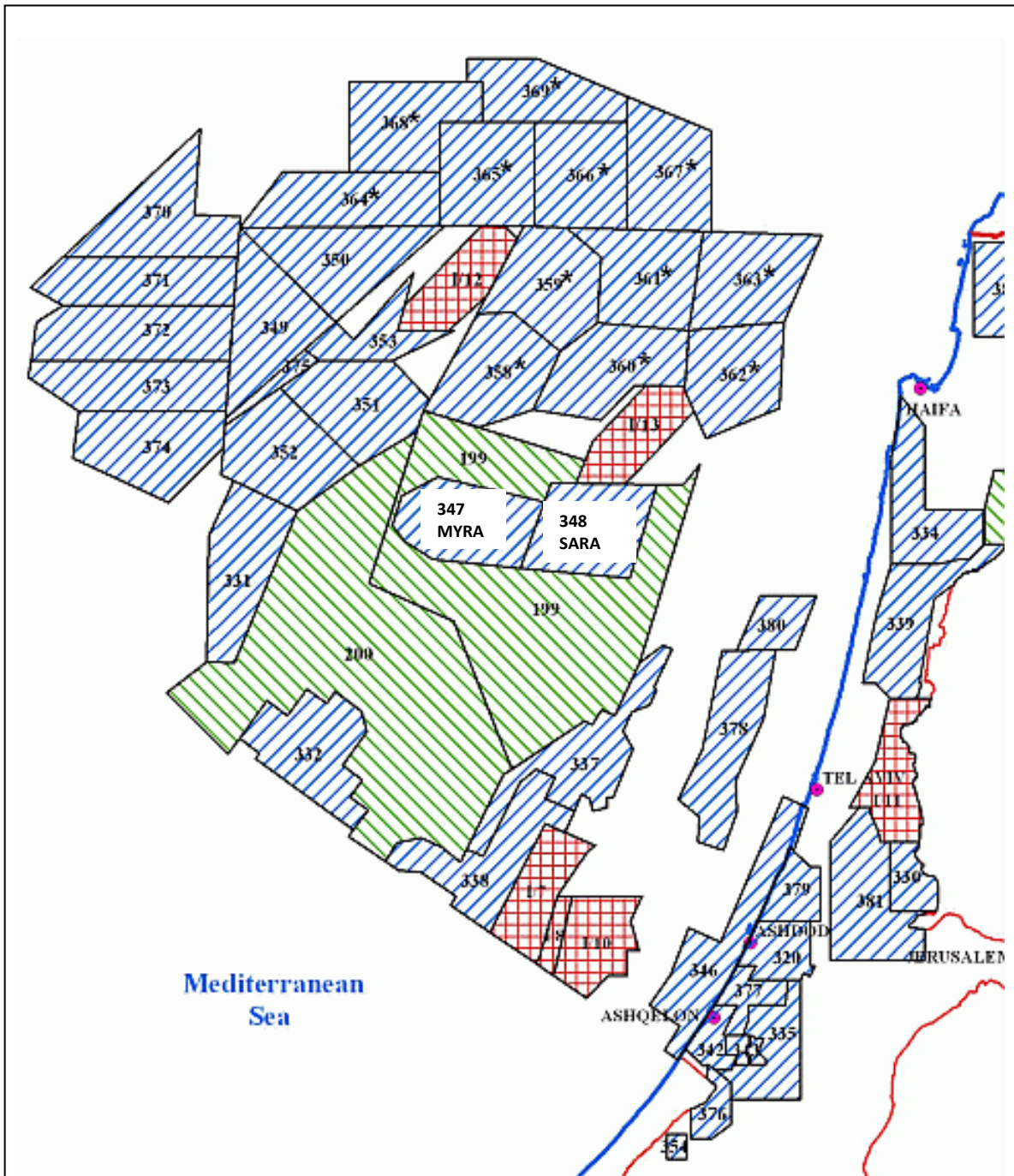
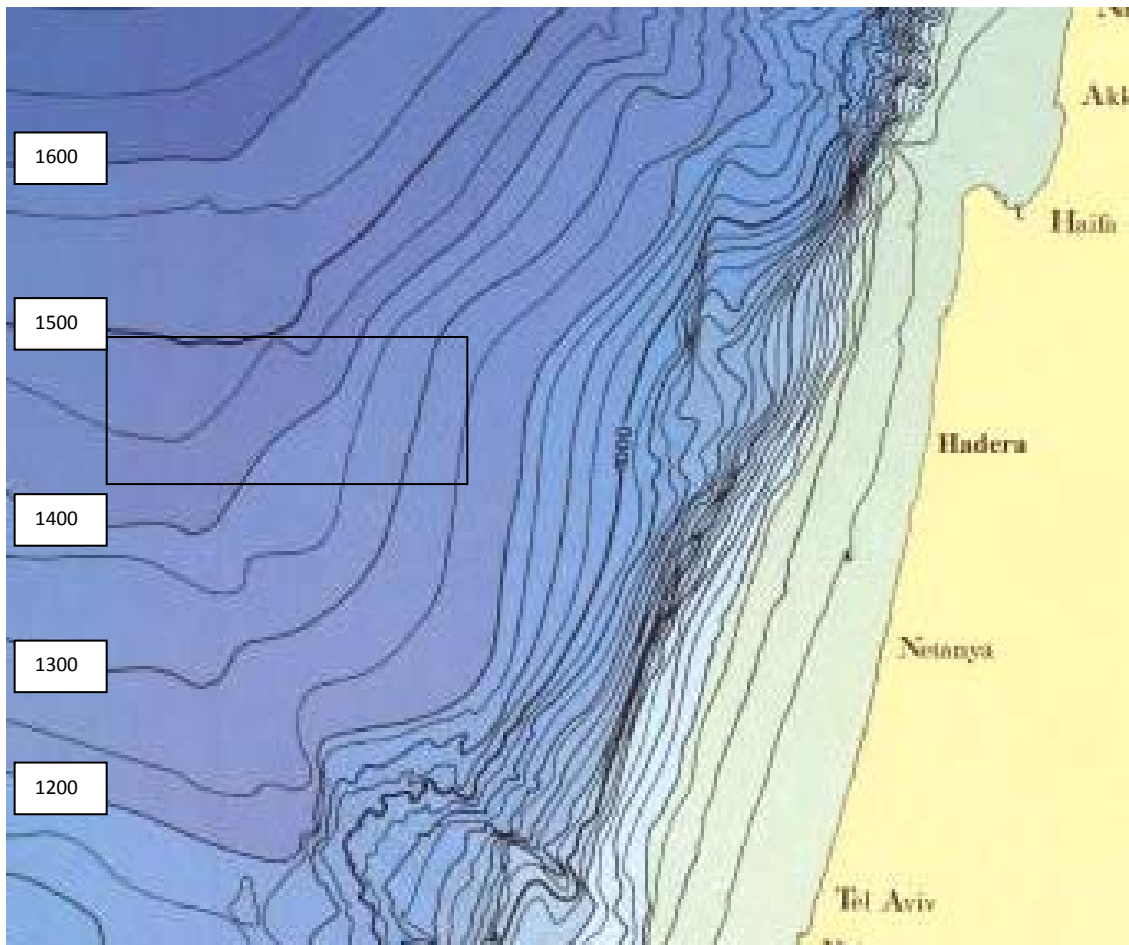


Figure 2.1.3.2 Map showing Licence Areas onshore and offshore Israel. Sara (348) and Myra (347) Licence Areas are located in the middle of the offshore Licence Areas. Licence Area 113, immediately north of Sara (red grid), is Noble's Dalit Site. Licence Area 112, ~50 km north of Myra (red grid), is Noble's Tamar 1 and 2. Noble's Leviathan Licence comprises Areas 349 and 350.

Sources: [www.bizportal.co.il](http://www.bizportal.co.il) and <http://img2.tapuz.co.il/CommunaFiles/42397054.ppt>

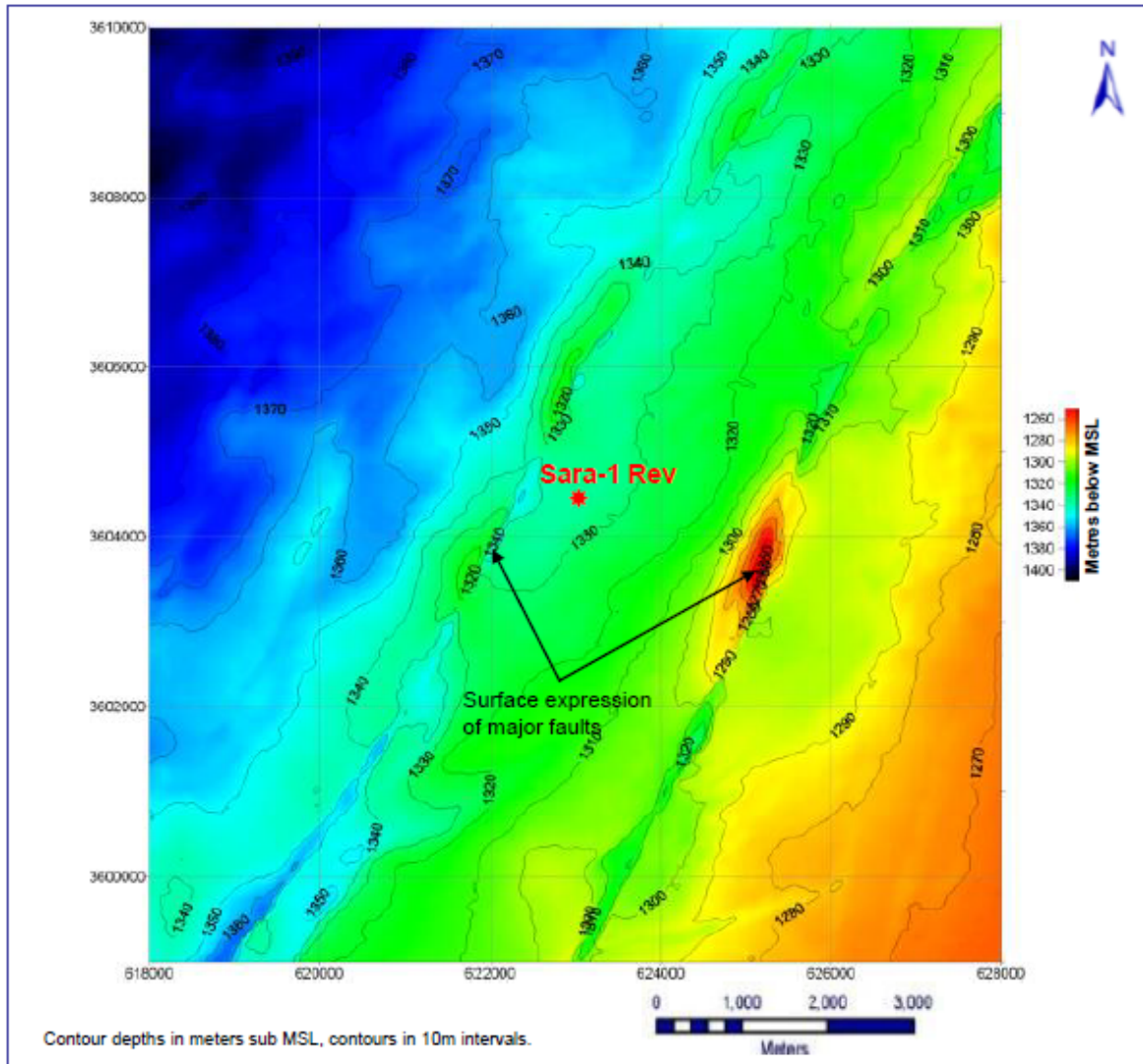
The Sara and Myra Licence Areas are approximately located between the isobaths of 1250 m in the east and 1500 m in the west, as shown in Figure 2.1.3.3.



**Figure 2.1.3.3 Bathymetric map of the continental margin off Israel, showing (black rectangle) the approximate location of the Sara and Myra Licence Areas, between the isobaths of 1250 and 1500 m.**  
*Source: Hall et al, 1994.*

### 2.1.4 Sara drilling site

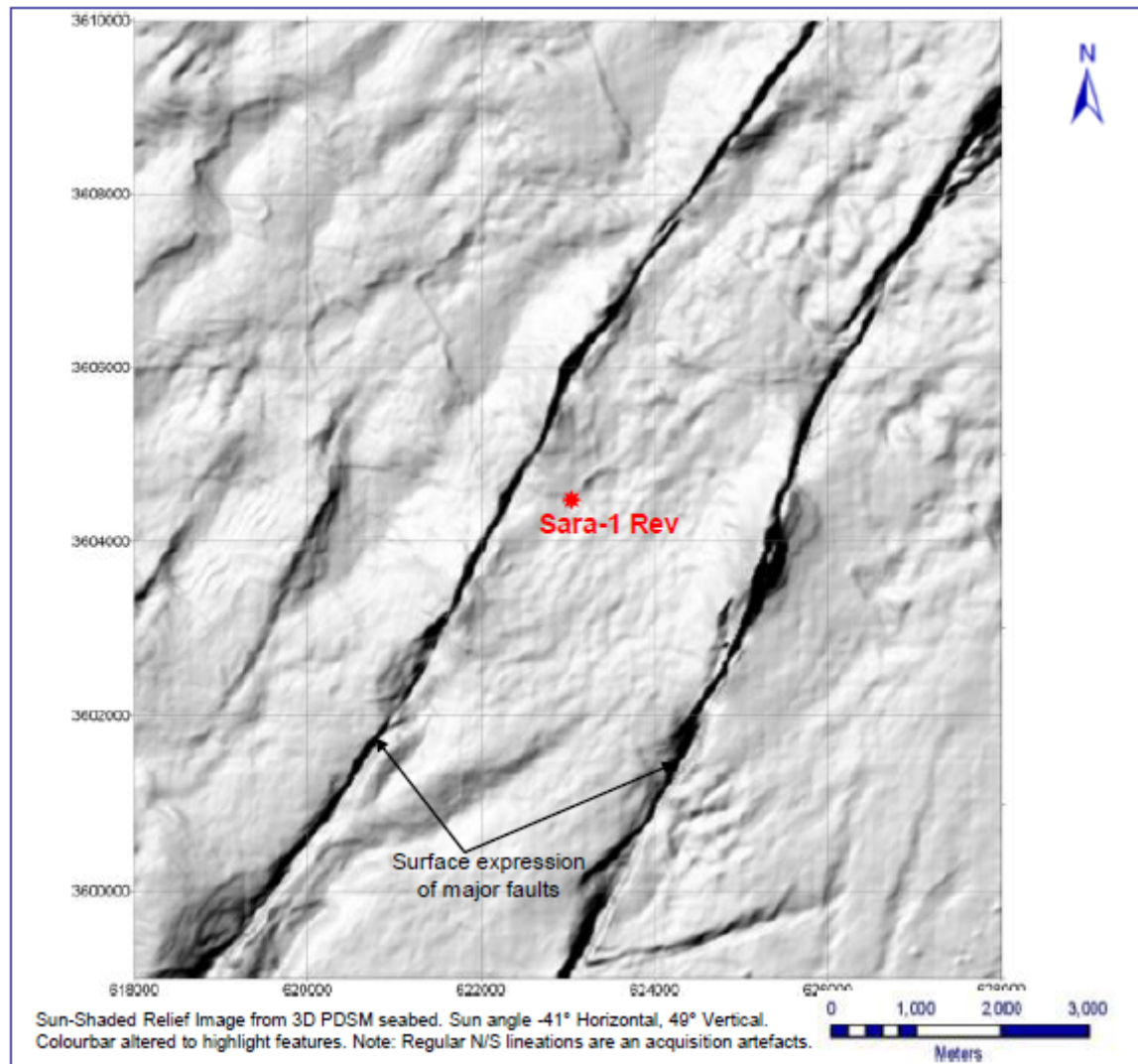
The bathymetry around Sara-1 Rev drilling location is shown in Figure 2.1.4.1.



**Figure 2.1.4.1 Bathymetry around The Sara-1 Rev proposed drilling location. Depth at Location is 1337 meters. The generally flat seabed is gently sloping to the northeast. Two fault scarps can be discerned ~600 m NW of Location and ~2400 m SE of Location.**

*Source: RPS Energy, 2011b.*

The seabed at the proposed Sara-1 Rev site is practically flat, with minor undulations. Two nearly straight, parallel features are the expression of major faults (Figure 2.1.4.2).



**Figure 2.1.4.2 A shaded relief image of the seabed around the Sara-1 Rev Location. The seabed is practically flat. The two parallel features are the expression of major faults.**

*Source: RPS Energy, 2011a.*

The geology underlying the Sara-1 Rev drilling site is shown in an interpreted seismic section (Figures 2.1.4.3a and 2.1.4.3b; for better clarity the section is shown in two parts – top and bottom).

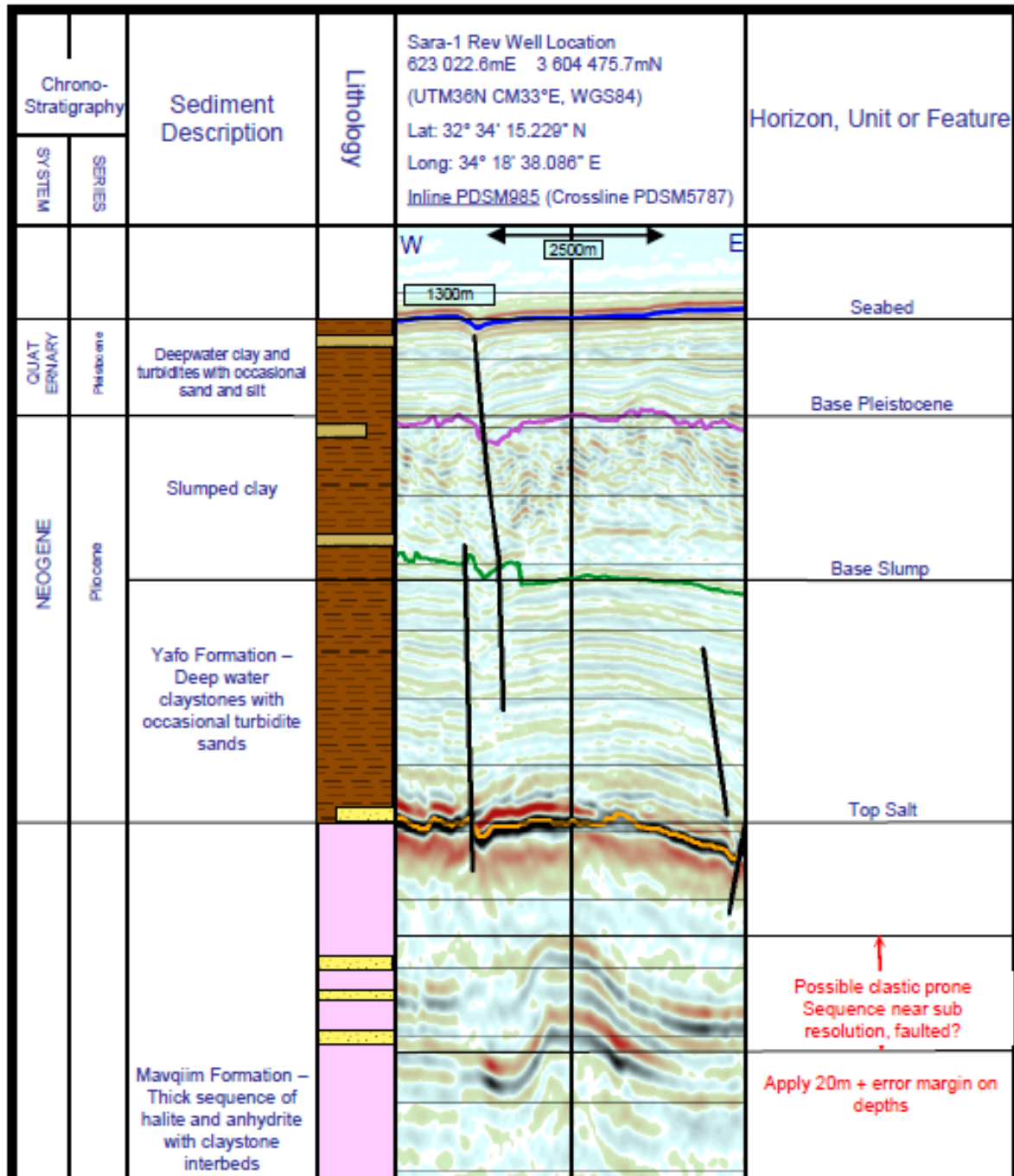


Figure 2.1.4.3a. Top part of the Sara-1 Rev interpreted seismic section (to the middle of the Mavqim Formation). Faults can be discerned. The morphological expression of the top fault can be seen in Figure 2.4.2.

Source: RPS Energy, 2011a.

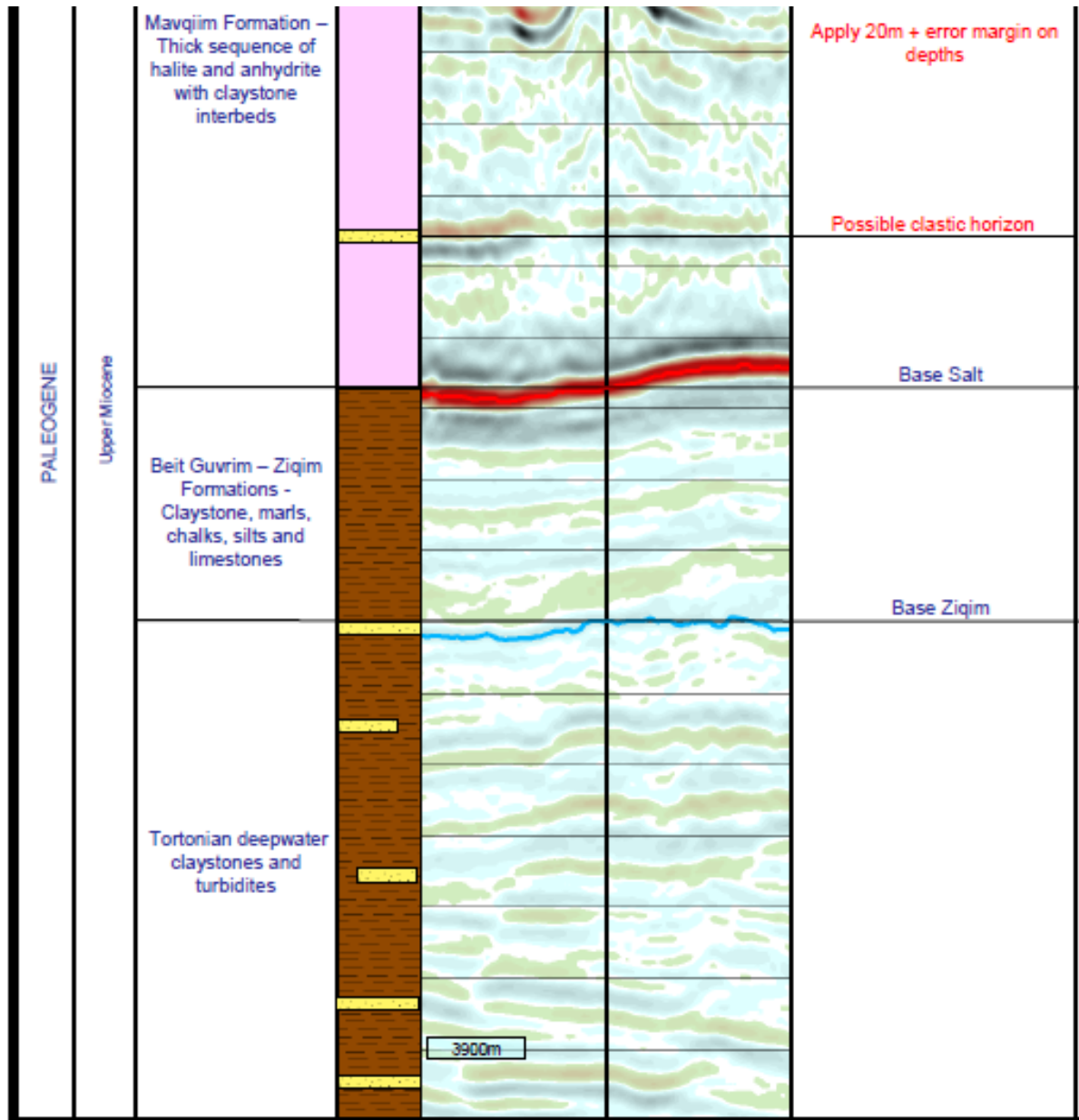
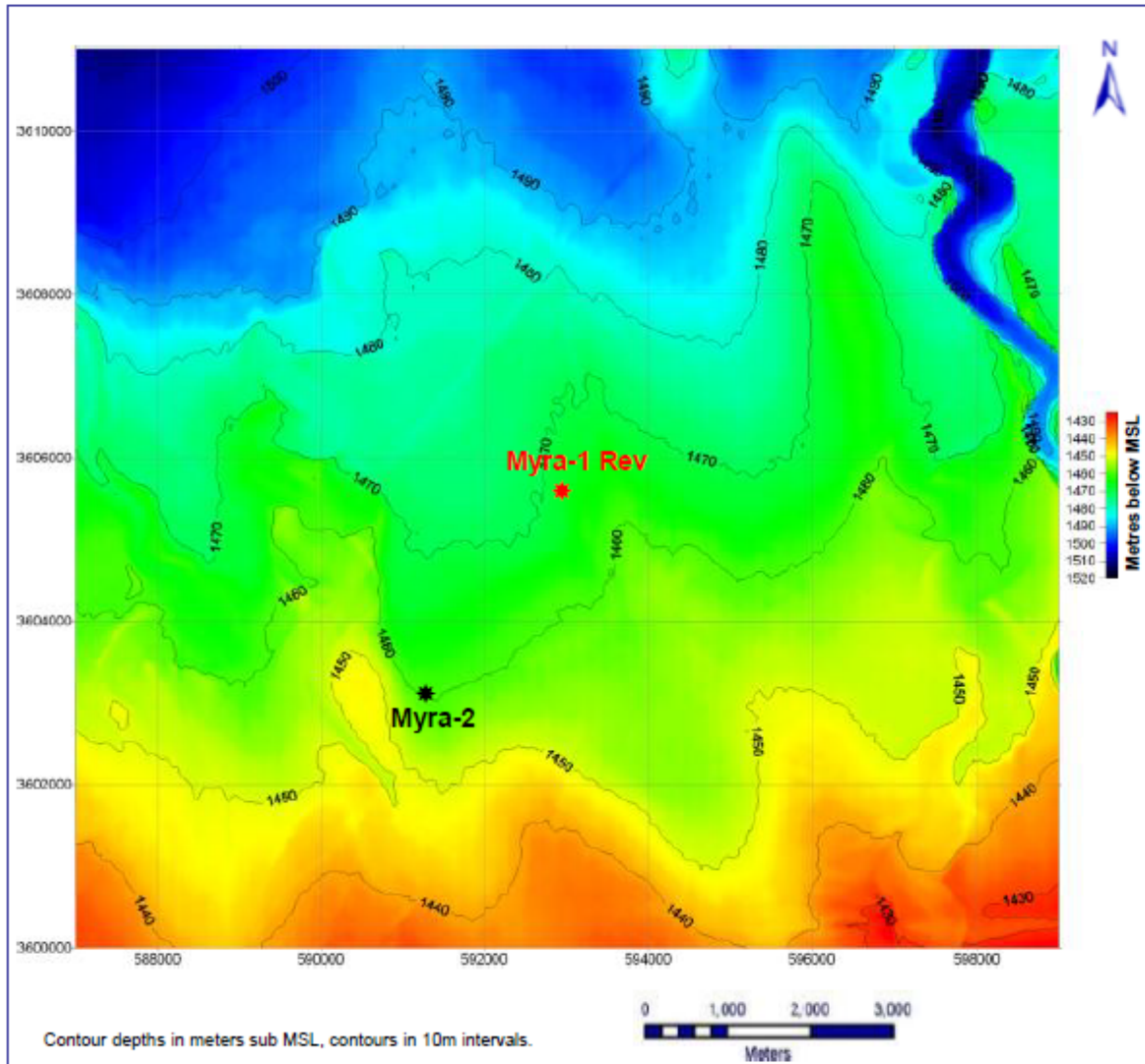


Figure 2.1.4.3b. Bottom part of the Sara-1 Rev interpreted seismic section (from the seabed to the middle of the Mavqim Formation downwards).

Source: RPS Energy, 2011a.

### 2.1.5 Myra drilling site

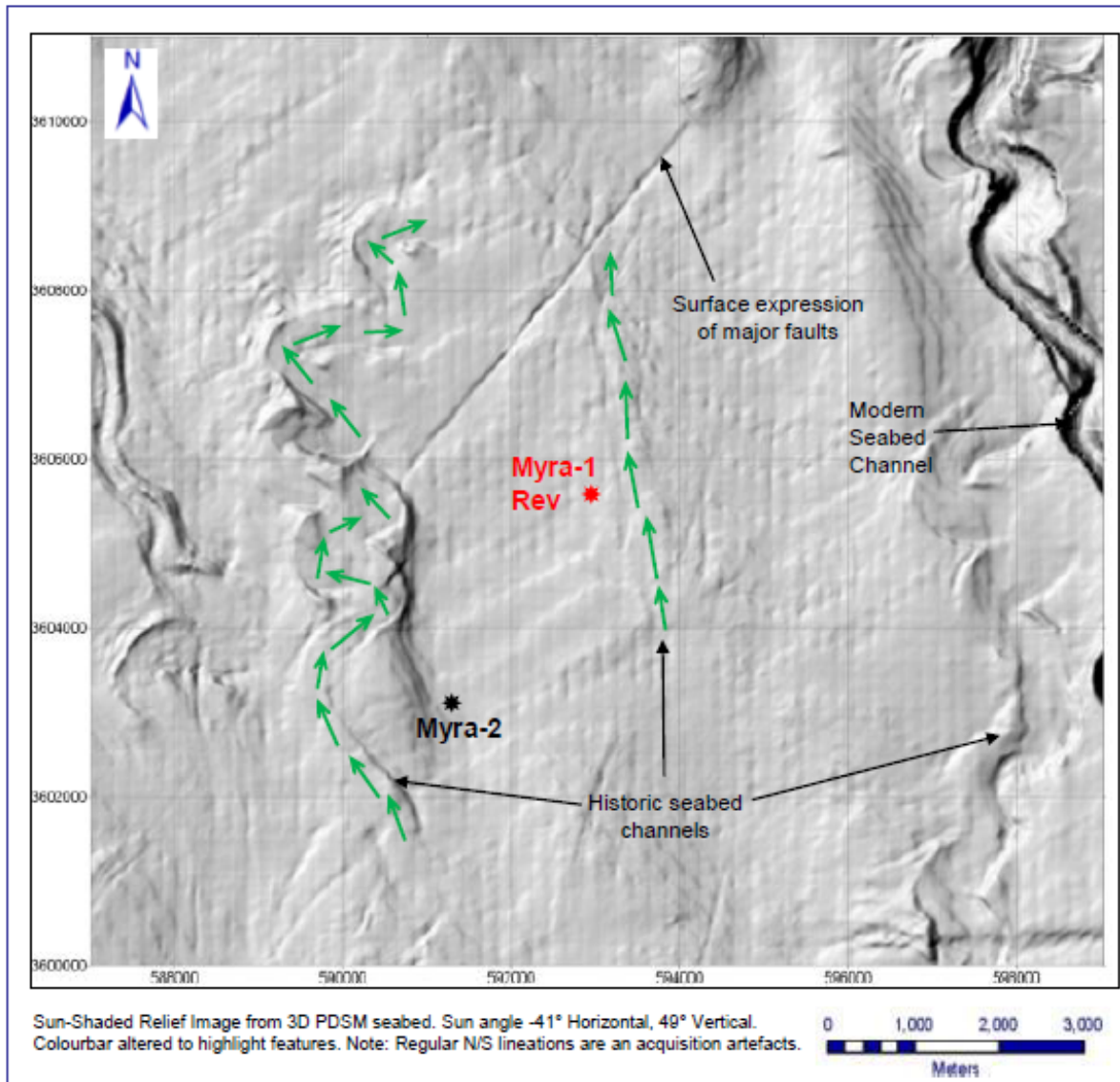
The bathymetry around Myra-1 Rev drilling location is shown in Figure 2.1.5.1.



**Figure 2.1.5.1. Bathymetry around The Myra-1 Rev proposed drilling location. Depth at Location is 1,467 metres. The generally flat seabed is gently sloping to the north. A channel can be discerned ~6000 m ENE of Location.**

*Source: RPS Energy, 2011b.*

The seabed at the proposed Myra-1 Rev site is practically flat, with at least three buried channels trending N-S. A modern channel, also on a N-S direction is located further to the east (Figure 2.1.5.2).



**Figure 2.1.5.2** A shaded relief image of the seabed around the Myra-1 Rev Location. The seabed is practically flat. Three (historic) partially covered channels and the surface expression of a major fault crossing them on a SW-NE direction, as well as a modern channel can be discerned.

*Source: RPS Energy, 2011b.*

The geology underlying the Myra-1 Rev drilling site is shown in an interpreted seismic section (Figures 2.1.5.3a and 2.1.5.3b); for better clarity the section is shown in two parts – top and bottom).

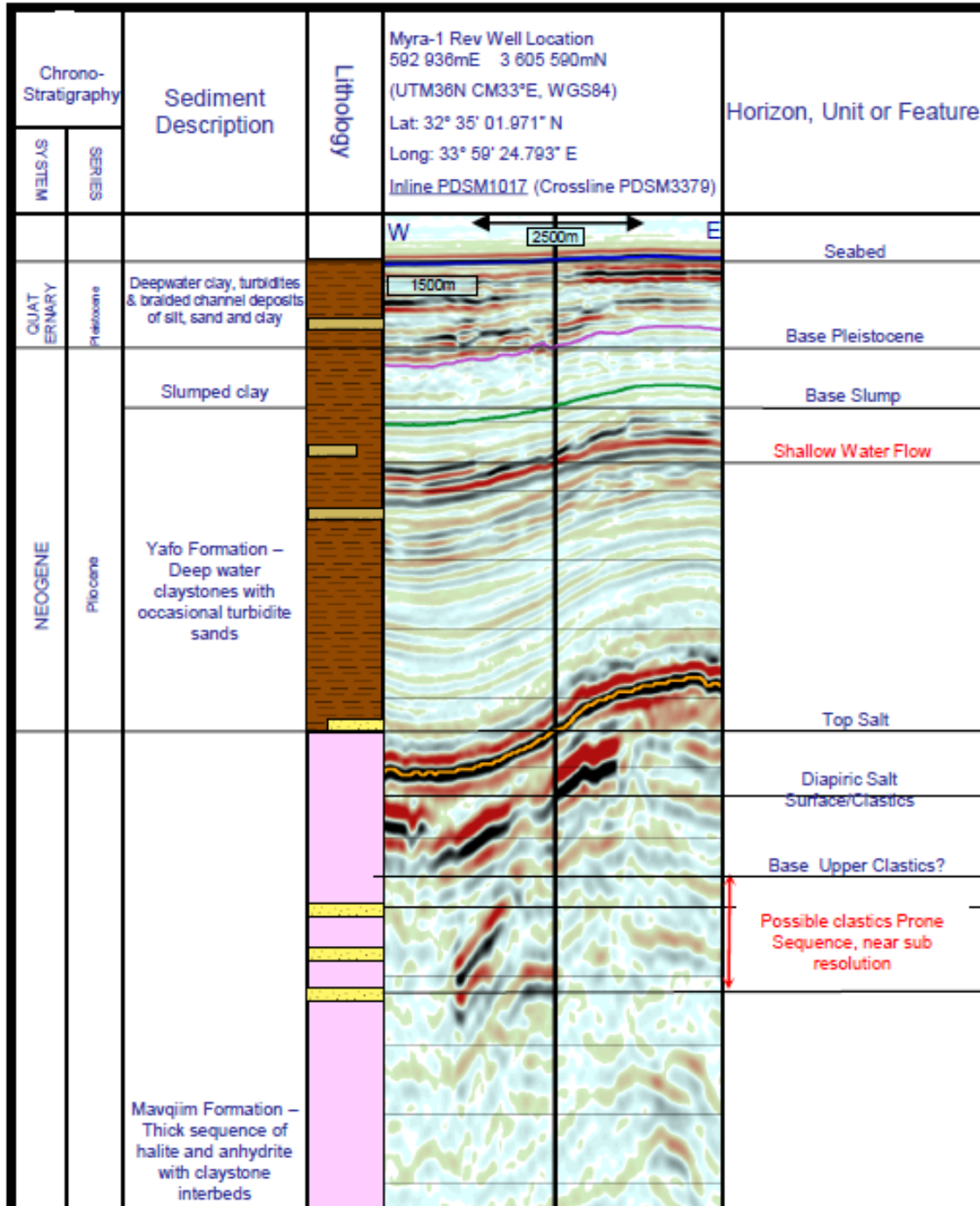
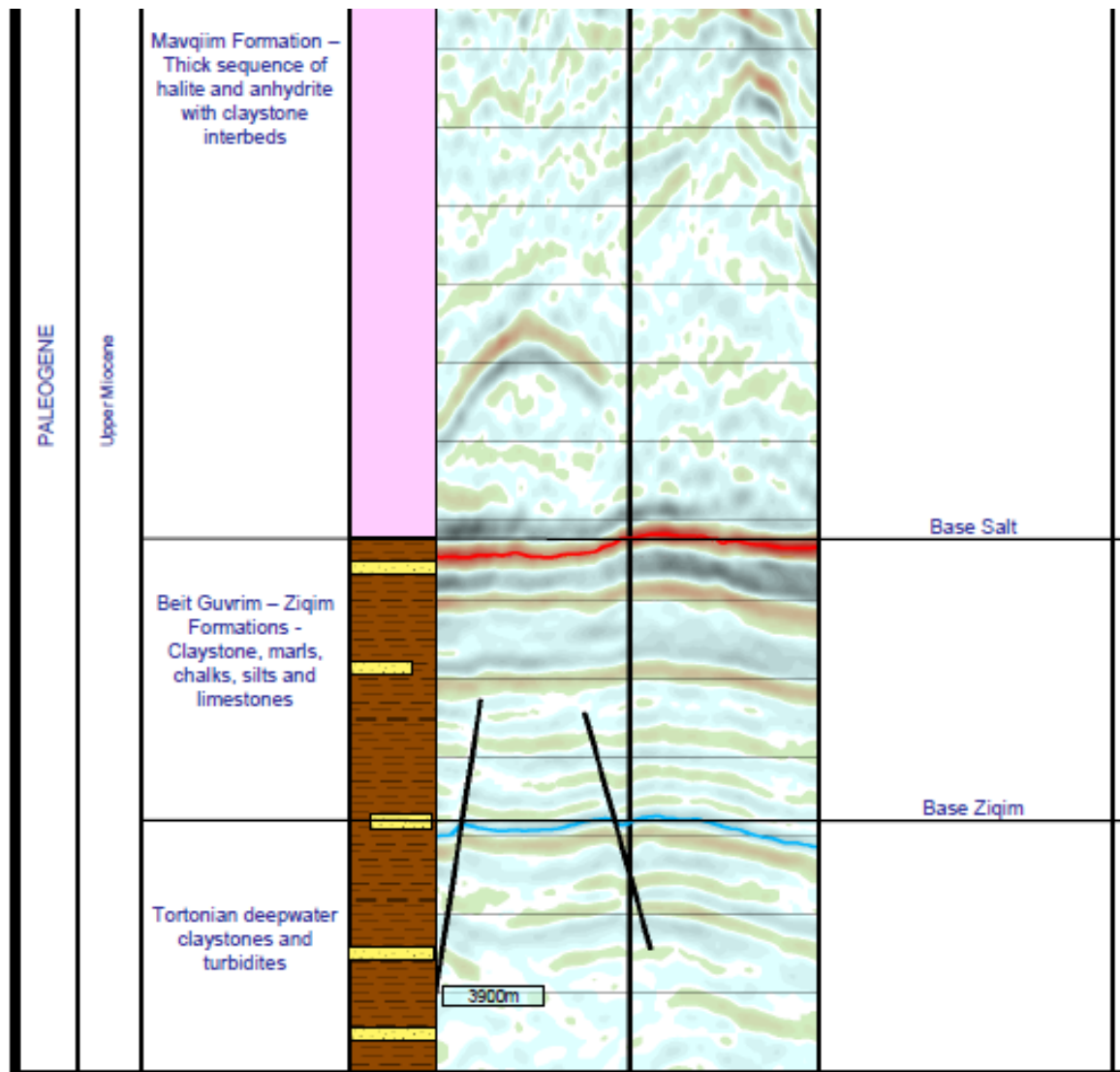


Figure 2.1.5.3a. Top part of the Myra-1 Rev interpreted seismic section (from the seabed to the middle of the Mavqim Formation).  
Source: RPS Energy, 2011b.



**Figure 2.1.5.3b. Bottom part of the Myra-1 Rev interpreted seismic section (from the middle of the Mavqim Formation downwards).**

*Source: RPS Energy, 2011b.*

## 2.2 Drilling Process and Equipment

### 2.2.1 Exploring and production rigs

While drilling on land the ground provides a platform from which to drill, at sea a Drilling Rig or Mobile Offshore Drilling Unit (MODU) is the preferred cost effective option.

There are many kinds and forms of rigs, each with its characteristics and advantages, depending on the characteristics of the well to be drilled, including how far underwater the drilling target is. One of the most important pieces of equipment is the subsea drilling template. Essentially, this piece of equipment connects the underwater well site to the drilling platform on the surface of the water. This device, resembling a cookie cutter, consists dependent on the number of wells to be drilled. This drilling template is placed over the well site, and usually lowered into the exact position required using GPS technology. A relatively shallow hole is then dug, in which the drilling template is connected into place. The drilling template, secured to the sea floor and attached to the drilling platform above with cables, allows for accurate drilling to take place, but allows for the movement of the platform, which will inevitably be affected by shifting wind and water currents.

In addition to the drilling template, a Blow Out Preventer (BOP) is installed on the sea floor. This system prevents any oil or gas from seeping out into the water. Above the blowout preventer, a specialized system known as "marine riser" extends from the sea floor to drilling Rig above. The marine riser is designed to house the drill bit and drillstring, and yet be flexible enough to deal with the movement of the drilling platform. Strategically placed slip and ball joints in the marine riser allow the subsea well to be unaffected by the pitching and rolling of the drilling platform.

#### Semisubmersible rig

Drilling Myra & Sara will be done by a semisubmersible rig.

Semisubmersible rigs are the most common type of offshore drilling rigs, combining the advantages of submersible rigs with the ability to drill in deep water. This kind of rig works on the principle of ballasting of its lower hull to achieve the desired draft and trim for stable operations which can be modified depending on changing weather conditions. When the water is allowed to enter the lower hull, the rig is partially submerged, but still floats above the drill site. When drilling, the lower hull filled with water provides stability to the rig. They are held in place by huge anchors, combined with the submerged portion of the rig, ensure that the platform is stable and safe enough to be used in turbulent offshore waters.

#### Drilling fluids

The drilling fluids, conventionally simply called as muds, have lots of important functions in the drilling process. Main functions are as follows:

Removal of cuttings from the bottom of the hole to the surface. Cuttings are separated from the mud at the shale shaker. These cuttings and samples of the mud are analyzed to study geological properties of the soil/rock penetrated, and to find out the indication of oil and gas in the formations.

- Controlling hydraulic pressure in the hole by adjusting the density of the mud to prevent collapse of the wall of the borehole, and to contain formation fluids in the formations.
- Cooling and lubricating the bit and the drill stem.
- The drilling fluids are composed of base fluids, clay minerals, chemicals and inert solids.
- Base fluids are classified as follows: water-based muds, oil-based muds, air or gas drilling. Bentonite, a kind of clay, is preferred to make up water-based muds. A small quantity of chemicals adds in the mud to control the viscosity and filtration properties. Inert solids such as barite are mixed in the mud to adjust density.
- The drilling fluid is circulated down to the bit through the drill stem, and up to the surface through the annular space between the drill stem and the borehole or casing. The drilling fluid returned to the surface flows to the shale shaker to separate cuttings and fluid. The fluid is circulated again.

## The Casing

The casing consists of lengths of steel pipes joined to another. A number of strings of casing are set in the well. The purposes of casing are to protect fresh water sands, to prevent drilling problems such as heaving formations and high pressure zones' and finally to provide a means of production of oil and gas if the well is productive.

The annular space between the casing and the borehole should be filled with cement to support the casing and prevent the flow of underground fluids up to the surface and/or into freshwater zones.

### 2.2.2 MYRA-1 Operations Summary

Noble Homer Ferrington rig will be moved to Myra-1 location, and anchors deployed.

The 36" Conductor, Low Pressure Wellhead Housing, Mud Mat, 26" Jetting Bottom Hole Assembly and Cam Actuated Drill Ahead (CADA) tool will be run through open water to spud the well. The 36" Conductor will be jetted using seawater with weighted sweeps.

The CADA will be released from the Low Pressure Housing. The 26" hole will be drilled using seawater with weighted sweeps. The drilling fluid will be switch to a Saturated Brine while drilling into the Top of Salt. The hole will be displaced with Pump And Dump (PAD) mud before POOH.

The 20" surface casing, together with the 18.3/4" High Pressure Wellhead Housing (Nominal Seat Pro-tector pre-installed) will be run through open water and stabbed, with ROV assistance, into the 36" conductor. The 20" casing will be set +/- 10 m off bottom, and cemented with to seabed using an inner string cementing technique.

The Blow Out Preventer Stack will be run on the marine riser, observed by the ROV, and landed/locked onto the 18.3/4" HP Wellhead Housing. The 20" casing and BOP connector will be pressure tested. No requirement to test BOPs as previously stump tested.

The 17.1/2" drilling assembly will be run in hole. The shoetrack will be drilled out with seawater. Prior to drilling 3 m of new formation, the well will be displaced to Saturated Brine. A Formation Integrity Test (FIT) will be performed. Whilst drilling ahead the mud weight will be increased.

Prior to exiting the salt a wiper trip back to the previous casing shoe will be performed and the "Salt Exit Strategy" will be implemented. Prior to exiting the salt the mud system will be displaced to a High Performance Water Based Mud System.

The 17.1/2" TD/13.5/8" casing shoe will be picked on real time Kick Tolerance Limitations.

At section TD the wellbore will be conditioned for running casing

TD wireline logs will be run as per wireline evaluation program.

The 13.5/8" casing string will be run to +/- 10 m off bottom and cement with a subsea release plug system. Top of cement is planned to be 100m inside Base of Salt. The casing and BOPs will be pressure tested.

The 12.1/4" drilling assembly will be run in the hole. The shoetrack and 3 m of new hole will be drilled and a LOT performed.

Section TD is based on real time Kick Tolerance Limitations.

At section TD the wellbore will be conditioned for running casing

TD wireline logs will be run as per wireline evaluation program.

The 9.5/8" casing string will be run to +/- 10 m off bottom. The 9.5/8" casing string will be cemented with a subsea release plug system. Top of cement is planned to be 150m above any Hydrocarbon bearing formations. The casing, BOPs and Standpipe Manifold will be pressure tested

The 8.1/2" drilling assembly will be run in hole. The shoetrack and 3 m of new hole will be drilled and a LOT performed.

The 8.1/2" hole section will drilled to well TD at +/- 3732m BML

At section TD the wellbore will be conditioned for running casing

TD wireline logs will be run as per wireline evaluation program.

The well will be abandoned as per Abandonment Program.

Pull BOP and marine riser back to surface.

Move off location (The wellhead will be left at sea bed and not retrieved). Perform final site survey with ROV.

### 2.2.3 SARA-1 Operations Summary

Noble Homer Ferrington rig will be moved to Sara-1 location, and anchors deployed.

The 36" Conductor, Low Pressure Wellhead Housing, Mud Mat, 26" Jetting Bottom Hole Assembly and Cam Actuated Drill Ahead (CADA) tool will be run through open water to spud the well. The 36" Conductor will be jetted using seawater with weighted sweeps.

The CADA will be released from the Low Pressure Housing. The 26" hole will be drilled using seawater with weighted sweeps. The drilling fluid will be switch to a Saturated Brine while drilling into the Top of Salt. The hole will be displaced with Pump And Dump (PAD) mud before POOH.

The 20" surface casing, together with the 18.3/4" High Pressure Wellhead Housing (Nominal Seat Pro-ector pre-installed) will be run through open water and stabbed, with ROV assistance, into the 36" conductor. The 20" casing will be set +/- 10 m off bottom, and cemented with to seabed using an inner string cementing technique.

The Blow Out Preventer Stack will be run on the marine riser, observed by the ROV, and landed/locked onto the 18.3/4" HP Wellhead Housing. The 20" casing and BOP connector will be pressure tested. No requirement to test BOPs as previously stump tested.

The 17.1/2" drilling assembly will be run in hole. The shoetrack will be drilled out with seawater. Prior to drilling 3 m of new formation, the well will be displaced to Saturated Brine. A Formation Integrity Test (FIT) will be performed. Whilst drilling ahead the mud weight will be increased.

Prior to exiting the salt a wiper trip back to the previous casing shoe will be performed and the "Salt Exit Strategy" will be implemented. Prior to exiting the salt the mud system will be displaced to a High Performance Water Based Mud System.

The 17.1/2" TD/13.5/8" casing shoe will be picked on real time Kick Tolerance Limitations.

At section TD the wellbore will be conditioned for running casing

TD wireline logs will be run as per wireline evaluation program.

The 13.5/8" casing string will be run to +/- 10 m off bottom and cement with a subsea release plug system. Top of cement is planned to be inside Base of Salt. The casing and BOPs will be pressure tested.

The 12.1/4" drilling assembly will be run in the hole. The shoetrack and 3 m of new hole will be drilled and a LOT performed.

The 12.1/4" hole section will be drilled to well TD at +/- 2663m BML

At section TD the wellbore will be conditioned for running casing

TD wireline logs will be run as per wireline evaluation program.

The well will be abandoned as per Abandonment Program.

Pull BOP and marine riser back to surface.

Move off location (The wellhead will be left at sea bed and not retrieved). Perform final site survey with ROV.

## Acronyms

BOP	Blow Out Preventer
CADA (Tool)	Cam Actuated Drill Ahead (Tool)
COSHH	Containment Of Substances Hazardous to Health
FIT	Formation Integrity Test
GPS	Global Positioning System
LOT	Leak Off Test
MARPOL	Marine Pollution (International Convention)
MODU	Mobile Offshore Drilling Unit
PAD (Mud)	Pump And Dump (Mud)
ROV	Remotely Operated Vehicle
SOPEP	Shipboard Oil Pollution Emergency Plan
TD	Total Depth

# Chapter C

## Drilling impacts on the environment and mitigation measures

## Chapter C - Drilling impacts on the environment and mitigation measures

### 3.1 Potential Impacts during Drilling period

#### 3.1.1 Main Environmental issues relate to unplanned releases as a result of failures during operations

In advance of an Environmental Management Plan being finalized, the main Environmental issues relate to unplanned releases as a result of failures during operations:

- Catastrophic blowout and breach of well at the seabed releasing hydrocarbons subsea.
- Vessel Collision with the Rig causing damage to the Stability of the rig and potential loss of fuel and Oils, from the rig and the vessel.
- Loss of containment of diesel fuel during bunkering operations between the vessel and the rig.
- Release of hydrocarbons during Well Testing Operations.
- Helicopter crash resulting in oil and fuel being lost to sea.

#### More Environmental Issues

- **Mud and brines** losses to the sea.
- **Human activity** on rig – Minor impacts from human activity as food remains, solid waste, detergents.
- **Oil and fuel** losses during backload..
- **Acoustics** impacts on marine mammals and possibly big fish from the rig activities.
- **Marine Transportation** – Notice to mariners will be published when the rig will be in its location to all vessels and ships passing in the area of drillings.
- **Air quality** – impact on air quality from systems operation as engines, generators etc.
- **Marine Organisms** - impact on marine organisms from organic materials. The impact is minor due to small effected area.

## 3.2 Mitigation Measures

### 3.2.1 General safety measures to prevent environmental incidents

#### a. Noble Drilling (drilling contractor, rig owner) safety measures

- Safety Management System, involving environmental management system
- Emergency Response Plans, covers prevention and action needed in the event of an environmental incident
- Health Safety Environmental Safety Case, includes preventive measure for eliminating environmental incidents
- Adherence to MARPOL regulation
- Chemical Handling/Storage Procedures
- Oily water separator installed on MODU
- Oil/Fuel transfer procedures
- Shipboard Oil Pollution Emergency Plan (SOPEP)
- MODU drain plugs
- Zero discharge policy
- Garbage management plan, includes waste segregation, recycling etc
- Chemical inventories
- COSSH training, and paint management procedure to limit amount of paint mixed
- Personnel trained in oil spill response

#### b. GRIL safety measures

- Safety Management System
- Environmental Management Plan
- Oil Spill Response Plan
- Major Emergency Management Training
- Tier 1-3 Oil Spill Response equipment and vessels, supply vessels fitted with detergent spray booms for quick response
- Chemical Handling Plan
- Waste Management Plan
- Bunkering procedures
- Emergency Response Plans
- Chemical Inventories

# Chapter D

## Recommendations and environmental guidelines

## Chapter D - Recommendations and environmental guidelines

### 4.1 Proposed Environmental Guidelines

Since the drilling area is not included in the Israel Territorial Zone, but in the economic region of the State of Israel, we propose the following guidelines that will allow a certain monitoring of environmental and technical data and knowledge accumulation of the Levantine Basin.

1. Due to lack of oceanographic, geological, geophysical, seismic, bathymetric, biotic and environmental data in the drilling region, the company will submit all Environmental survey data and works done by the company on Sara and Myra drilling sites. This will add using the data by the State of Israel in the future.
2. Monitoring of the Marine Environment will be implemented in the drilling areas before starting and after ending of the drilling operations and works.  
The monitoring plan will be checked and recommended for operation by the MOEP, (the marine and coastal department).
3. The company is obligated to keep all international regulations, laws, treaties, procedures related to the gas and oil drillings and also to the internal procedures mentioned in this document.
4. The company is obligated to inform immediately to the relevant Israeli authorities on accidents, leaks, or any disorder operation according to the relevant Israeli regulations.

## **References:**

### **References cited**

- Almagor, G., Hall, J.K., 1984. Morphology of the Mediterranean continental margin of Israel (a compilative summary and a bathymetric chart). *Geol. Surv. Isr., Bull.* 77, 31p.
- Ben Eliahu, M. N., Ten Howe, H. A., 2011. Serpulidae (Annelida: Polychaeta) from the Suez Canal – from a Lessepsian migration perspective (a monograph). *Zootaxa*, 2848, 1-147.
- Ben Rais Lasram, F., Mouillot, D., 2009. Increasing southern invasion changes congruence between endemic and exotic Mediterranean fish fauna. *Biol. Invasions* 11, 697-711.
- Calvert, S.E., 1987. Oceanographic controls on the accumulation of organic matter in marine sediments. Geological Society, London, Special Publications 1987, v. 26, 137-151.
- Cartes, J.E., Maynou, F., Sarda, F., Company J. B., Lloris D. 2004. The Mediterranean deep sea ecosystems, Part 1: an overview of their diversity, structure, functioning and anthropogenic impacts. In: Tudela, S., Simard, F., (eds.), IUCN – The World Conservation Union. Published by IUCN Centre for Mediterranean Cooperation, Malaga, Spain and WWF Mediterranean Programme, Rome, Italy. 66 p.
- Coll, M., Piroddi, C., Steenbeek, J., Kaschner, K., Ben Rais Lasram, F., et al, 2010. The biodiversity of the Mediterranean Sea: Estimates, patterns and threats. In: Bogard, S.J. (ed) (NOAA/ NMFS/ SWSFC, USA) PLoS ONE Vol. 5(8): e11842, 36 p.
- Emelyanov, M., 1994. Recent bottom sediments of the Levantine Sea. Geological Structure of the North-eastern Mediterranean (Cruise 5 of the research vessel Akademik Nikolaj Strakhov), Historical Productions-Hall, Ltd., Jerusalem, 141-158.
- Emelyanov, M., Shimkus, M., Kuprin, N., 2005. Unconsolidated sediments of the Mediterranean Sea. In: Hall, J. K. et al (ed.), Geological Framework of the Levant, Volume II: The Levantine Basin and Israel, 183 - 214.
- Eppelbaum, L., Katz, Y., 2011. Tectonic-geophysical mapping of Israel and the eastern Mediterranean: Implications for hydrocarbon prospecting. *Positioning*, 2, 36-54.
- Galil, B.S., 2004. The limit of the sea: the bathyal fauna of the Levantine Sea. *Scieita Marina* 68 (supplement 3) 63-72.
- Galil, B.S., Goren, M., 1994. The deep sea Levantine fauna – new records and rare occurrences. *Senckenbergiana maritima*, 25 (1/3), 41-52.
- Gardosh, M., Druckman, Y., Buchbinder, B., Rybakov, M., 2008. The Levant Basin Offshore Israel: stratigraphy, structure, tectonic evolution and implications for hydrocarbon exploration. Geological Survey of Israel Report GSI/4/2008 / Geophysical Institution of Israel Report GI429/328/08. 120pp.
- Garfunkel, Z., 1998. Constraints on the origin and history of the eastern Mediterranean Basin. *Tectonophysics*, 298, 5-35.
- Hall, J.K., Udintsev, G.B., Odinkov, Y.Y., 1994. The bottom morphology of the Levantine Sea. In: Krashennnikov, V., A., and Hall, J., K. (eds.), Geological Structure of the North-eastern Mediterranean (Cruise 5 of the research vessel Akademik Nikolaj Strakhov), Historical Productions-Hall, Ltd., Jerusalem, 5-32.
- Homberg, C., Bachmann M., 2010. Evolution of the Levant margin and western Arabia platform since the Mesozoic: introduction. Geological Society, London, Sp. Publications 2010; v. 341, 1-8.

- Kamel, M.S., 2010. Geostrophic current patterns off the Egyptian Mediterranean coast. *Oceanologia*, 52 (2), 299-310.
- Krom, M.D., Groom, S., Zohary, T., 2003. The eastern Mediterranean. In: Black, K. D., Shimmiel, K.G., (eds.), 2003. *Biochemistry of marine systems*, Blackwell Publishing, UK., p 91 – 125.
- Lakkis, S. 2009. Global warming inducing “Tropicalisation” of the Levantine Basin (east Mediterranean). Does it affect marine biodiversity? In Hall, J., Harrison, D.E., Stammer, D (eds.), *Proceedings of OCEANOBS'09: Sustained ocean observations and information for society*. 10p.
- Langotsky, Y., 2010. Change of phase in future gas exploration. Power Point presentation (Hebrew), 15 slides.
- Lie, Ø., Skiple, C., Lowrey, C., 2011. *Geo Expro Magazine* No. 1, Vol. 8, 24-27 (article by Petroleum Geo-Services).
- Makris, J. and Wang, J., 1994. Bouguer gravity anomalies of the Eastern Mediterranean Sea. In: Krashennnikov, V., A., and Hall, J., K. (eds.), *Geological Structure of the North-eastern Mediterranean (Cruise 5 of the research vessel Akademik Nikolaj Strakhov)*, Historical Productions-Hall, Ltd., Jerusalem, 87-98.
- Makris, J., Wang, J., Odintsov, S.D., Udintsev, G.B., 1994. The magnetic field of the eastern Mediterranean Sea. In: Krashennnikov, V.A., Hall, J.K., (eds.), *Geological structure of the Northeastern Mediterranean, (Cruise 5 of the research vessel Akademik Nikolaj Strakhov)*, Historical Productions-Hall, Ltd., Jerusalem, 75-85.
- Manca, B. Burca, M., Giorgetti, A., Coatanoan, C., Garcia, M.-J., Iona, A., 2004. Physical and biochemical averaged vertical profiles in the Mediterranean region: an important tool to trace the climatology of water masses and validate incoming data from operational oceanography. *Journal of Marine Systems*, 48, 83-116.
- Netzeband, G.L., Gohl, K., Hübscher, C.P., Ben-Avraham, Z., Dehghani, D.A., Gajewski, D., Liersch, P., 2006. The Levantine Basin: crustal structure and origin. *Tectonophysics* 418, 167-188.
- Oral, M., 2010. Alien Fish species in the Mediterranean – Black Sea Basin. *J. Black Sea / Mediterranean Environment*, Vol. 16 (1), 87 – 132.
- Pinardi, N., Masetti, E., 2000. Variability of large scale general circulation of the Mediterranean Sea from observations and modelling: a review. *Paleogeography, Paleoclimatology, Paleoecology*, 158, 153-173.
- Robertson, A.H.F., 1998. Mesozoic-Tertiary tectonic evolution of the easternmost Mediterranean area: integration of marine and land evidence. In: Robertson, A.H.F., Eneis, K.C., Richter, C. and Camerlenghi, A. (eds.), *Proceed. Ocean Drilling Prog., Scientific Results*, 160, 723-782.
- Roussenov, V., Stanov, E., Artale, V., Pinardi, N., 1995. A seasonal model of the Mediterranean Sea general circulation. *Journal of Geophysical Research*, Vol. 100, No. C7, 13,515 – 13,538.
- RPS Energy, 2011a. Proposed Sara-1 (Revised) well: location drilling constrains and geohazard study, 25 p.
- RPS Energy, 2011b. Proposed Myra-1 (Revised) well: location drilling constrains and geohazard study, 25 p.
- Rybakov, M., Goldshmit, V., & Rotstein, Y. 1997. New regional gravity and magnetic maps of the Levant. *Geophys. Res. Lett.* 24 , 33-36.
- Stampfli, G.M., Mosar, J., Favre, P., Pillecuit, A. and Vannay J.-C., 2001. Permo-Mesozoic evolution of the western Tethyan realm: the Neotethys East-Mediterranean Basin connection.

Tziperman, E., Malanotte-Rizzoli, P., 1991. The climatological seasonal circulation of the Mediterranean Sea. *Journal of Marine Research*, 49, 411 - 434.

UNEP (United Nations Environment Program), Mediterranean Action Plan, 2010. MedWaves No. 59: the Mediterranean Action Plan Magazine: focus on Biodiversity.

**RPS Energy, Surrey, GU21 3LG, Geoglobal Resources Inc. Proposed Myra-1 (Revised) Well Location Drilling Constrains and Geohazard Study, July 2011.**

**RPS Energy, Surrey, GU21 3LG, Geoglobal Resources Inc. Proposed Sara-1 (Revised) Well Location Drilling Constrains and Geohazard Study, July 2011.**

#### Websites visited

Physiography and geology

<http://epic.awi.de/Publications/Net2005c.pdf>  
<http://geology.geoscienceworld.org/cgi/content/abstract/3/12/683>  
<http://www.offshore-mag.com/index/article-display/4296290598/articles/offshore/geology->  
<http://www.aapg.org/explorer/2011/04apr/levant0411.cfm>  
<http://geology.gsapubs.org/content/39/4/355.full>  
<http://geology.com/usgs/nile-delta-oil-and-gas/>  
[http://gallery.usgs.gov/photos/04\\_07\\_2010\\_hlc5FRq11Y\\_04\\_07\\_2010\\_0](http://gallery.usgs.gov/photos/04_07_2010_hlc5FRq11Y_04_07_2010_0)  
<http://www.pennenergy.com/index/petroleum/display/357311/articles/offshore/>  
<http://www.mendeley.com/research/tectonic-isolation-levant-basin>  
<http://media.zionoil.com/2011/03/12Israel.pdf>  
<http://www.slideshare.net/plsderrick>  
<http://sp.lyellcollection.org/content/341/1/1.full>  
<http://www.wfs.org/content/israels-natural-gas-discovery-five-possible-scenarios>  
<http://www.scirp.org/journal/PaperInformation.aspx?paperID=3892>  
<http://gashydrates.iqsoft.co.in/2009-11-22/>  
<http://www.glossary.oilfield.slb.com/default.cfm>  
<http://www.geo365.no/exploration/levantine-basin/>  
[http://www.geoexpro.com/magazines/1\\_11\\_preview.pdf](http://www.geoexpro.com/magazines/1_11_preview.pdf)  
[http://www.newworldencyclopedia.org/entry/Mediterranean\\_Sea](http://www.newworldencyclopedia.org/entry/Mediterranean_Sea)  
<http://www.gsi.gov.il/Uploads/1043GSI-37-2009.pdf>  
<http://www.agu.org/pubs/crossref/1997/96GL03617.shtml>  
<http://www.scirp.org/journal/PaperInformation.aspx?paperID=3892>

Bathymetry

[http://www-3.unipv.it/cibra/edu\\_Mediterraneo\\_uk](http://www-3.unipv.it/cibra/edu_Mediterraneo_uk)  
[http://www.gebco.net/about\\_us/gebco\\_science\\_day/documents/proactive\\_bathy\\_mapping\\_israel](http://www.gebco.net/about_us/gebco_science_day/documents/proactive_bathy_mapping_israel)

Biology

<http://digital.csic.es/bitstream/10261/5535/1/introduction.pdf>  
<http://www.sciencedaily.com/releases/2011/05/110523171111.htm>  
[http://www.environmental-services.com/projects/programs/RedSeaCD/DATA/PDF/RedSea\\_Fish\\_Migr](http://www.environmental-services.com/projects/programs/RedSeaCD/DATA/PDF/RedSea_Fish_Migr)  
<http://www.plosone.org/article/info:doi/10.1371/journal.pone.0011842>  
<http://www.blackmeditjournal.org/blackmeditjournal.org/pdf/87-132%20sayfa.pdf>  
<http://search.babylon.com/?s=web&babsrc=home&q=Biology+of+the+Eastern+Mediterranean>



Sara and Myra Licence Areas  
Offshore Israel  
Environmental Document  
November 2011



<http://www.annalsofgeophysics.eu/index.php/annals/article/viewFile/3129/3174>  
<http://www.medit-mar-sc.net/files/200812/17-11575669-77.pdf>  
<http://www.iasonnet.gr/abstracts/zenetos.html>  
<http://www.njgonline.nl/publish/articles/000317/article.pdf>  
[http://en.wikipedia.org/wiki/Lessepsian\\_migration](http://en.wikipedia.org/wiki/Lessepsian_migration)  
<http://www.unepmap.org/index>

#### Oceanography - circulation

<http://www.bgu.ac.il/~ashkena/Papers/PhysicaA-accepted-2011.pdf>  
<http://meetingorganizer.copernicus.org/EGU2011/EGU2011-9115.pdf>  
[http://www.hcmr.gr/hnodc/upload\\_files/File/Mancaetal\\_JMS.pdf](http://www.hcmr.gr/hnodc/upload_files/File/Mancaetal_JMS.pdf)  
<http://ichthyology.bio.auth.gr/files/pdf/paper12.pdf>  
<http://www.ciesm.org/online/monographs/Malta09.pdf>  
<http://robinson.seas.harvard.edu/PAPERS/encyrc.pdf>  
<http://www.britannica.com/EBchecked/topic/372694/Mediterranean-Sea/>  
[www.vliz.be/imisdocs/publications/113358.pdf](http://www.vliz.be/imisdocs/publications/113358.pdf)  
[http://www.ciesm.org/online/archives/abstracts/PDF/39//PG\\_0162.pdf](http://www.ciesm.org/online/archives/abstracts/PDF/39//PG_0162.pdf)  
<http://ocean0.uma.es/publicaciones/P19.pdf>  
<http://utmea.enea.it/staff/artale/referred%20papers/95JC00233.pdf>  
[http://www.gfdl.noaa.gov/bibliography/related\\_files/mz9501.pdf](http://www.gfdl.noaa.gov/bibliography/related_files/mz9501.pdf)  
[http://www.medclivar.eu/Final\\_Conference](http://www.medclivar.eu/Final_Conference)  
<http://www.onr.navy.mil/reports/FY10/popoula2.pdf>  
[http://ssg.mit.edu/~willsky/publ\\_pdfs/137\\_pub\\_JTEC.pdf](http://ssg.mit.edu/~willsky/publ_pdfs/137_pub_JTEC.pdf)  
[http://modb.oce.ulg.ac.be/colloquium/2010/Presentations/Monday/AM/Menna\\_M\\_et\\_al.pdf](http://modb.oce.ulg.ac.be/colloquium/2010/Presentations/Monday/AM/Menna_M_et_al.pdf)  
[http://www.oceanobs09.net/proceedings/ac/FCXNL-09A02-1767504-1-RGERIN\\_OceanObs09.pdf](http://www.oceanobs09.net/proceedings/ac/FCXNL-09A02-1767504-1-RGERIN_OceanObs09.pdf)  
[http://www.1yachtua.com/medit-marinas/Mediterranean\\_Sailing/mediterranean\\_currents.shtml](http://www.1yachtua.com/medit-marinas/Mediterranean_Sailing/mediterranean_currents.shtml)  
<http://docsdrive.com/pdfs/medwelljournals/ojesci/2007/180-187.pdf>  
[http://www.engg.uaeu.ac.ae/ejer/issues/V15/pdf\\_iss1\\_15/7.pdf](http://www.engg.uaeu.ac.ae/ejer/issues/V15/pdf_iss1_15/7.pdf)  
[http://www.ifremer.fr/lobtln/OTHER/ext\\_abstr\\_East\\_Sea\\_workshop\\_TLM.pdf](http://www.ifremer.fr/lobtln/OTHER/ext_abstr_East_Sea_workshop_TLM.pdf)  
<http://www.refdoc.fr/Detailnotice?cpsidt=1742449&traduire=fr>  
<http://www.seas.harvard.edu/climate/eli/reprints/Tziperman-Rizzoli-1991.pdf>  
<http://www.mendeley.com/research/21st-century-mediterranean-sea-level-rise-steric-and-atmosph>  
<http://www.iopan.gda.pl/oceanologia/522kamel.pdf>  
<http://www.lifesciences.napier.ac.uk/teaching/env/Med4.htm>  
[http://www.eoearth.org/article/Levantine\\_Sea?topic=49523](http://www.eoearth.org/article/Levantine_Sea?topic=49523)  
<http://decapoda.nhm.org/pdfs/29589/29589.pdf>  
[http://www.medclivar.eu/workshopdocs/presentations/Day1\\_OpeningTalk\\_Malanotte-Rizzoli.pdf](http://www.medclivar.eu/workshopdocs/presentations/Day1_OpeningTalk_Malanotte-Rizzoli.pdf)

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[http://users.ntua.gr/mathan/pdf/Pages\\_from\\_WIND\\_WAVE\\_ATLAS\\_MEDITERRANEAN\\_SEA\\_2004](http://users.ntua.gr/mathan/pdf/Pages_from_WIND_WAVE_ATLAS_MEDITERRANEAN_SEA_2004)  
[http://www.envirtech.org/doc/b37\\_STAB1006.pdf](http://www.envirtech.org/doc/b37_STAB1006.pdf)  
[http://www.fas.harvard.edu/~epsas/dynamics/interactions/mechanisms\\_of%20eastern\\_med\\_.pdf](http://www.fas.harvard.edu/~epsas/dynamics/interactions/mechanisms_of%20eastern_med_.pdf)  
[http://www.intechopen.com/source/pdfs/10402/InTech-Ocean\\_wind\\_fields\\_from\\_satellite\\_active](http://www.intechopen.com/source/pdfs/10402/InTech-Ocean_wind_fields_from_satellite_active)  
<http://journals.ametsoc.org/doi/full/10.1175/JAM2498.1>  
<http://www.nat-hazards-earth-syst-sci.net/8/1249/2008/nhess-8-1249-2008.pdf>  
<http://www.adv-geosci.net/12/67/2007/adgeo-12-67-2007.pdf>  
<http://library.csum.edu/navpubs/pub132bk.pdf>  
[http://www.nrlmry.navy.mil/forecaster\\_handbooks/Med\\_2/](http://www.nrlmry.navy.mil/forecaster_handbooks/Med_2/)