ECONOMIC AND GEOPOLITICAL IMPORTANCE OF EASTERN MEDITERRANEAN GAS FIELDS FOR GREECE AND THE E. U. EMPHASIS ON THE PROBABLE NATURAL GAS DEPOSITS OCCURRING IN THE LIBYAN SEA WITHIN THE EXCLUSIVE ECONOMIC ZONE OF GREECE

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Abstract

Assessment of undiscoverable gas resources of the Levant basin province using current technology were estimated by the USGS (U.S. Geological Survey) to be about 3.5 tcm (trillion cubic meters) of gas. Already in the Israeli E.E.Z. (Exclusive Economic Zone) an amount of 800 bcm (billion cubic meters) has discovered in the fields of Marie B, Gaza Marine, Yam 1/ 2, Levathian, Dalit and Tamar. Soon in the Cypriot part of the Levant basin a well will be drilled in the gas prone structural target "Cyprus A". Due to geological similarities with the near by Tamar gas field an estimated amount of gas reserves around 300 bcm with a probability of 90% is expected to be discovered while oil discovery of around 3 Bbl with a probability of 17% is anticipated

In the Nile delta and the E.E.Z. of the Cyprus Republic USGS has estimated a natural gas potential of 6.3 tcm, besides the 2.2 tcm of gas and 1.7 Bbbl (Billion barrels) of oil already discovered in the Egyptian E.E.Z. Out of the 6.3 tcm, roughly 3 tcm (according BEICIP/FRANLAB) should be located within the E.E.Z. of Cyprus. These estimated resources are comparable to some other large gas provinces encountered in the world. In the same region, crude oil potential reserves of about 1.7 Bbbl of oil and about 6 Bbbl of gas condensate are also estimated by USGS to exist.

Based upon existing geological similarities between the portions of Herodotus Basin located into the Cypriot E.E.Z. and the Egyptian E.E.Z., possible recoverable natural gas reserves ranging from 1 to 3 tcm have been suggested by I.F.P. for the Greek portion of the Herodotus basin. Furthermore expected recoverable gas reserves south and southwest of Crete -where a great number of mud volcanoes are active on the Mediterranean Ridge still emitting gas with simultaneous presence of gas hydrates- have not yet been assessed. However it should be noted that in the Nile Cone the presence of 7 active mud volcanoes is accompanied with 126 gas fields with proven reserves of about 1.8 Tcm. Similar relations exist throughout the world As a result Greece should proceed with extensive geological studies and detailed geological surveys in order to explore the existence of hydrocarbons offshore south, southeast and southwest of Crete.

These very large hydrocarbon reserves, especially those of natural gas found in the Eastern Mediterranean can eventually alleviate the anticipated energy deficit which Europe will face by 2020.

Key words: Hydrocarbons, Mud Flow Volcanoes, Crete, East Mediterranean

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1. Introduction

The extensive utilization of new geophysical exploration techniques applied in deep offshore (drilling beyond 3,000 meters of water, 3D seismic and reservoir characterization), paved the way in developing and producing hydrocarbons in new and promising areas of the Eastern Mediterranean and more particularly in the ultra deep offshore of the Herodotus Basin (Fig.1).

The portion of this basin, which lies within the E.E.Z. of Greece (Fig.2), seems to have huge hydrocarbon potential including probable large stratigraphic traps and working petroleum systems ascertained by D.H.I.'s (Direct Hydrocarbon Indications) on seismic data, Beicip/Franlab, 2007, Montadert and Nicolaidis, 2007, Kassinis, 2008, Krois et al., 2010.

Recently, very important oil & gas field discoveries offshore Israel were carried out in a geological environment that most probably extends into Cyprus offshore. In addition similar discoveries offshore Egypt -especially in the Nile Cone adjoining the E.E.Z. of Greece- strengthens the probability of discovering similar accumulations into the Greek offshore.

Based upon published data, this paper makes a short review of the hydrocarbon potential of the East Mediterranean offshore areas and more particularly in areas connected with the Greek offshore domain of Southern Crete. More particular we will focus on the potential of the Greek portion of the Herodotus Basin and on other neighboring geological basins offshore Crete.

2. Eastern Mediterranean Hydrocarbon Potential, Herodotus basin and Crete.

The physiography of the Eastern Mediterranean Sea is presented in Fig.3 Montadert et al., 2004. In these areas discoveries are reported in Egyptian and Israel offshore areas (USGS Technical Reports, 2010). Both oil and gas were discovered and the objectives are found at several stratigraphic levels (Peck and Horscroft, 2005). Peck, 2008, also discusses in detail the stratigraphy of the Eastern Mediterranean basins where large hydrocarbon prospects or even giant can be identified and discovered.

2.1 The Levantine Basin.

The Levantine offshore basin is located between Egypt, Israel, Lebanon, Syria, Turkey and south east Cyprus (Fig.4).

Several discoveries have been reported in the offshore of Israel (Gardosh, et. al., 2008). Light oil in the Middle Jurassic and gas in the Lower Cretaceous was discovered in Yam Tetis field. Marie B gas field, which was discovered by British Gas and is currently operated by Noble Energy, produces about 300 MMcf/day (million cubic feet per day) from 6 wells, offshore facilities having a total production capacity of 600MMcf/day. The Gaza marine field (Fig.5), has 1.4 tcf of proven reserves while the Tamar field is reported to be a giant field with 8.4 tcf reserves and a possible daily production of 1bcf (Noble Energy, 2010). The gas is said to come from Neogene sands deposited in a turbidite environment. These turbidites are inferred to be deposited by channel systems having a NW-SE direction. This trend could reach Cyprus blocks offshore in the South Eastern part (block12). In this region, very recently, Noble Energy has made a huge gas discovery 16.1 tcf (453 bcm) in the Leviathan field, west of Tamar field and anticipates to discover an additional 4.2 billion barrels of oil into deeper horizons (Figs. 6 and14). In the Levantine Basin, Noble Energy has achieved a discovery success rate approaching 100%. This is attributed to the excellent quality of seismic data. Processing of 3D reflection seismic recordings was capable to identify the exact geometry of exploration targets before drilling and to assess the nature of the hydrocarbons (natural gas) and the potential volume of the expected natural gas

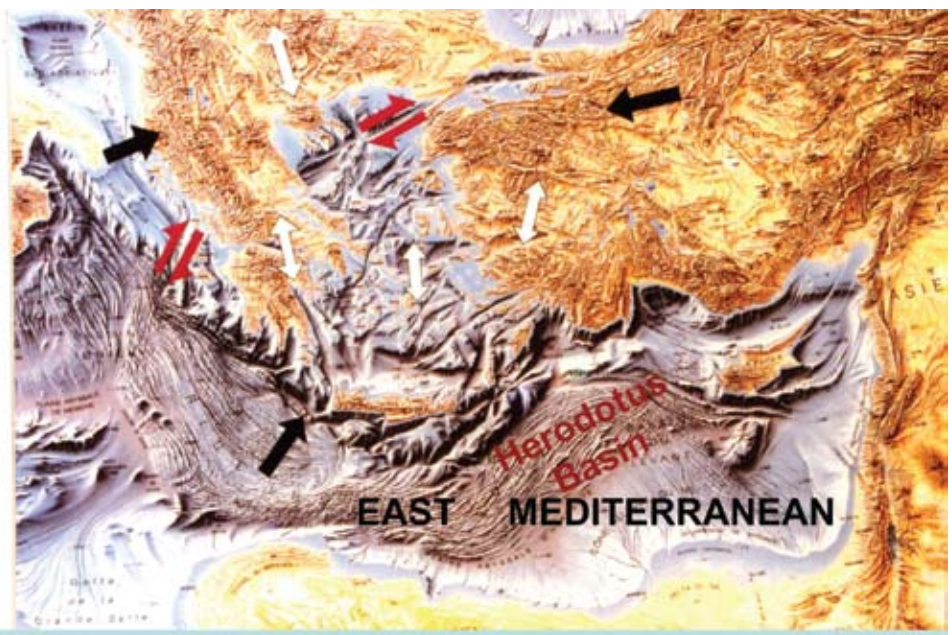


Figure 1. Geotectonic map of Eastern Mediterranean and Greece, Hachette literature generale, Paris, France, 1993.

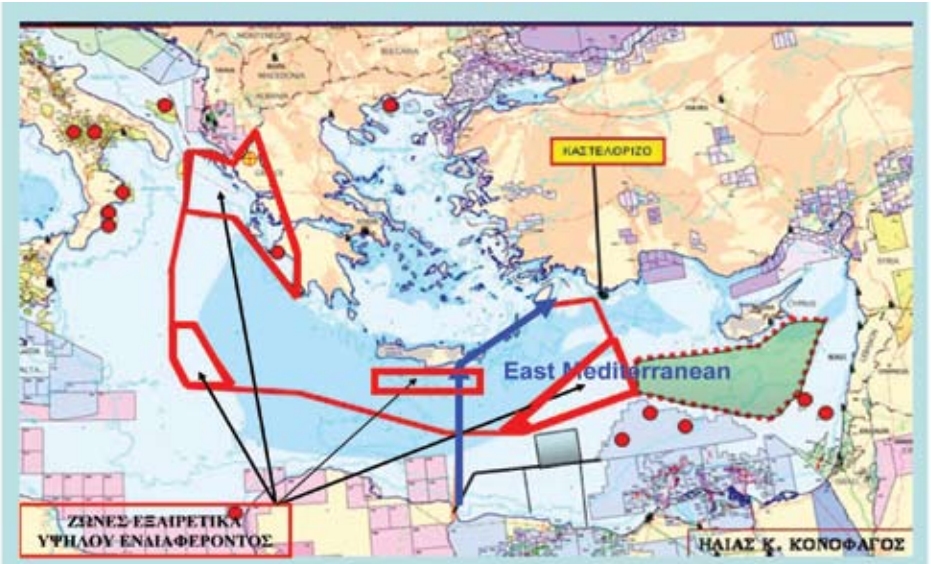


Figure 2. Prospective areas for hydrocarbon exploration within the EEZ of Greece

discovery.

The USGS 2010 report estimates that the undiscovered oil and gas resources of the Levant Province (East Mediterranean), which includes the E.E.Z. of Syria, Lebanon and Israel, to have (mean estimates) 1.7 billion barrels of recoverable oil and a mean of 122 tcf (3.45 tcm) of recoverable gas using a geology based assessment methodology (Figure 7), USGS, 2010.

2.2. The Eratosthenes Sea Mount. Emphasis between Eratosthenes Seamount and Herodotus Basin.

The Eratosthenes Sea Mount is thought to be a detached slab of the African/ Levantine platform. The lower geological section was studied by the Ocean Drilling Program Leg 160 in A. Robertson, 1998. A seismic cross section west of Eratosthnes Sea Mount and Herodotus is presented in Figs 8 and 9 (Montadert et al., 2004).

2.3. Petroleum systems, play concepts and hydrocarbon prospects.

The existence of source rocks in Egypt and the Levant which generate oil, gas condensates and gas can be extended into the offshore Cyprus. Petroleum systems were active with mature source rocks distributed in the Mesozoic and Cenozoic thick sedimentary sections found in Levantine basin, below the Nile deep sea fan (up to 12 Km) and in the Herodotus basin (from 12 to 18 km), according to Montadert et al., 2010.

Seismic profiles show many DHI's (bright spots and flat spots) which have been mapped in the Pliocene-Quaternary of the Nile delta sea in the Herodotus basin (Fig. 10). The presence of bright and flat spots in structural closures have been shown as attractive exploration targets over the NEMED block (Fig. 11), according to Kassinis, 2008. Similar features exist in the Cenozoïc on top of the eastern Cyprus arc. Gas chimneys have been frequently observed (Figure 12), and highlight the migration pathways of hydrocarbons from deep structures into shallow reservoirs, creating near surface gas pocks and sometimes, mud volcanoes or pockmarks on the sea floor. The hydrocarbon discoveries, mainly gas, made in the vicinity of

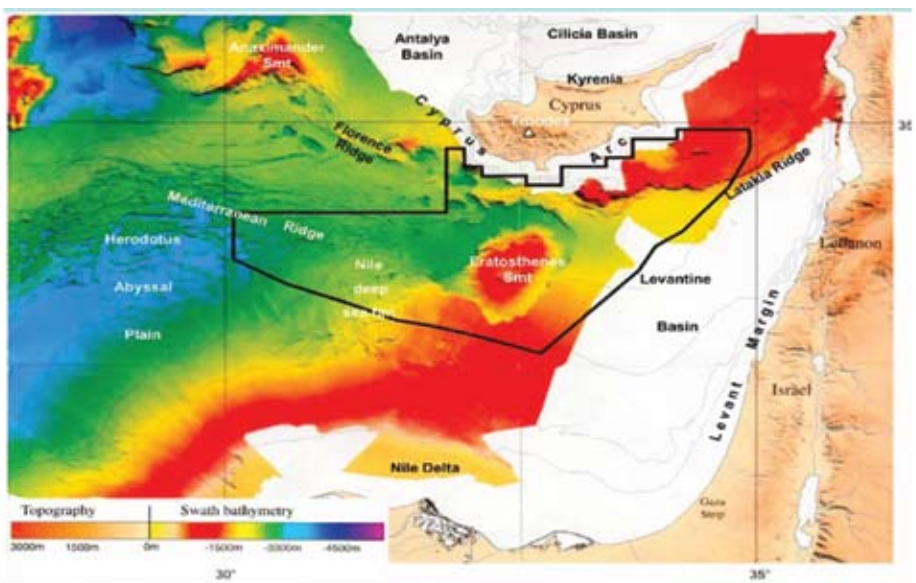


Figure 3. Physiography of Eastern Mediterranean Sea. Black boundary delineation by PGS survey, offshore Cyprus, Montadert et. al., 2007

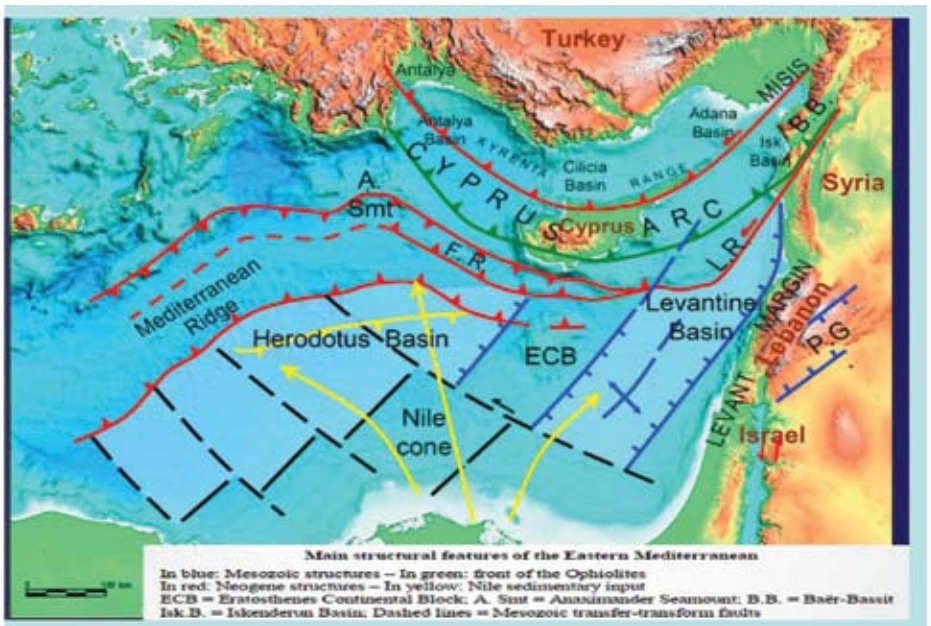


Figure 4. Main structural features of the Eastern Mediterranean, Montadert et. al., 2010

Cyprus, in the deep offshore of Egypt, Shell, Kj 45-1, Kg 49-1, La52-1 (The wells were drilled by the Stena Tay semisub in water depths of up to 2,400m a record depth for the Mediterranean in 2003)[1] (Fig.13), and the BP 2010 Hodoa well discovery, WSDW-7, as well offshore Israel, Tamar and Leviathan, are very encouraging. Noble Energy Company expects to discover 300 bcm of natural gas in Cyprus A field due to geological similarities with the Tamar and Leviathan hydrocarbon field, (Figure 14).

According to Semb, 2009 the oil and gas reserves in the seas surrounding Cyprus are estimated to be between 1 to 1.5 tcm of natural gas corresponding to about 6 to 8 Bbbloe oil equivalent.

2.4. Nile Delta Petroleum System

The Nile Delta corresponds to a very thick clastic wedge of prograding sediments dated Paleogene to actual. The sedimentary thickness may exceed 4,000/5,000m. The Miocene and Pliocene sands reservoirs have produced a large amount of gas: 3.8 billions boe reported in 2000 and more than 62 tcf (1.75 tcm) of proven reserves, Niazi, and Dahli, 2004. A few oil fields have also been discovered in the Lower Cretaceous (Mango/TOTAL)- (Fig. 15), according to Kassinis, 2008.

The petroleum system of the Nile deep sea fan lying in deep and ultra deep water seems very promising. Shell Company has just made a gas discovery in its deep NEMED block, Kg 45-1, Kj 49-1 and La 52-1, west of the Herodotus basin, Northeast Mediterranean (NEMED) concession Phase 1&2, 2003 and reported a DHI in the Pliocene interval (Figs 10 and 11), according to Semp, 2009. Shell has forecasted reserves in the NEMED area of 15 tcf of gas and 4 bbloe (Egypt the Western Desert and offshore, The Free library, 2010).

The undiscovered oil and gas of the Nile Delta Basin, Eastern Mediterranean has been assessed (mean estimate) by USGS, 2010, using a geology-based assessment methodology, at 1.8 billion barrels of oil, 6 billion barrels of natural gas liquids and 223 trillion cubic feet (6.31 tcm), according to USGS fact sheet 2010. The assessed province, which includes part of the

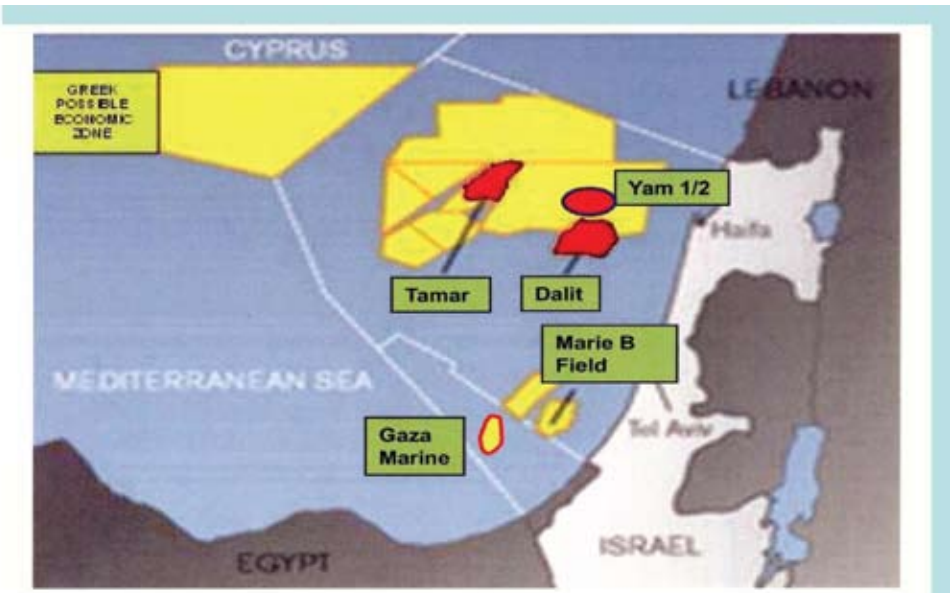


Figure 5. Natural gas deposits in the EEZ of Israel, Southern Levantine Basin, Noble Energy, 2010

Greek Herodotus basin, encompasses 250,000 square kilometres of the Eastern Mediterranean (Fig.16).

The Nile Cone, assessed units (AU) is thought to be sourced from thermally mature Neogene deltaic source rocks, but also there might be a significant biogenic gas component (Vandre et al., 2007) . The Nile Cone contains 2 oil fields and 126 gas fields.

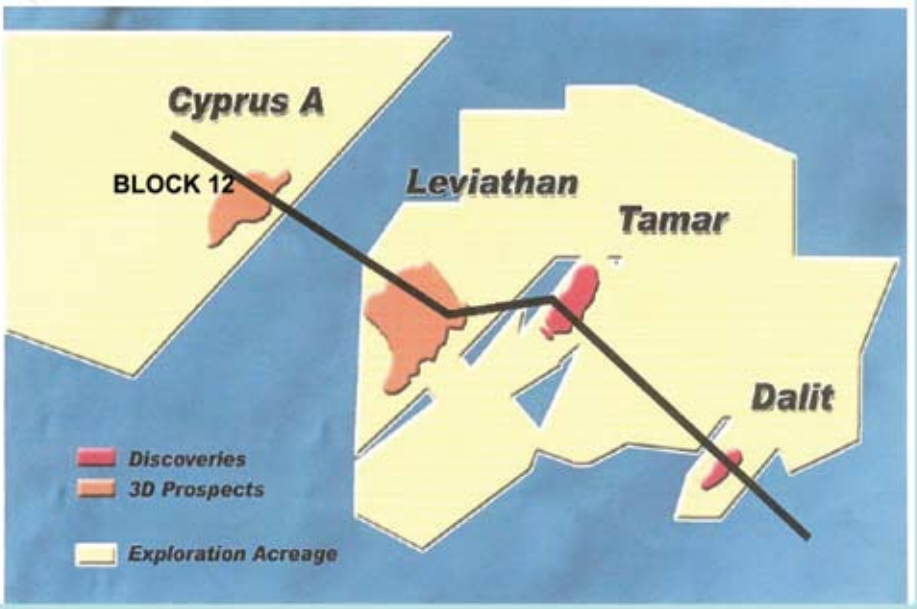


Figure 6. Exploration discoveries within the EEZ of Israel and Cyprus, Noble Energy, 2010.

2. 5 Herodotus Basin Potential

The boundaries of the Herodotus basin are the Egyptian shelf and Nile delta in the South, the Qattara Eratosthenes fault to the East, the Mediterranean Ridge to the West and the Florence ridge to the North. The water depth ranges from 1,000m to more than 3,000m (Woodside et al., 2002; Montadert et al., 2010). Therefore most of the area corresponds to deep or ultra deep exploration. Sections presented by BEICIP/FRANLAB (Fig.17) show a thick Pliocene and thick Messinian evaporates (Biju-Duval, et. al, 1978). Surveys using Large Beam Sonar (Swath survey) indicate a large system of channels coming from the upper Nile delta and feeding the deep large fans and the turbidite lobes in the Herodotus basin (Figures 18, and 19).

More recent seismic shot in Egyptian waters by Veritas show the presence of large turbitic channels and lobes of more than 10 km in both Miocene and Pliocene sections revealing the possible existence of giant hydrocarbon fields (Niazi and Dahli, 2004). A section presented by Semb (Semb, 2009), shows very strong DHI's which demonstrates that Pliocene reservoirs above salt dome structures are charged by hydrocarbons. The probability to discover gas at this depth is higher than oil but the modelling study presented in the Abdel Aal et. al., 2000, publication concerning their deep MEMED block allows deducing that in the same stratigraphic intervals and greater water depths the potential exists for both oil and gas to be present. Many analogs of hydrocarbon generation and trapping in such deep and evaporitic basin can be presented: Mexico Gulf, Mauritania, Equatorial Guinea, Brazil (Krois et al, 2009). Recent work on the Deepwater province of Northwest Egypt which was carried inside the Greek portion of the Herodotus basin confirms its high hydrocarbons potential through numerous tectonic and structural traps (figs 20 and 21), according to Krois et. al., 2009.

The last figure shows many specific structural and stratigraphic traps and demonstrates that the Herodotus basin has a high potential. Geophysical surveys by TGS-NOPEC inside the Greek Herodotus basin, Fig.22 (GR lines), should be bought soonest by the Greek Government in order to study further, confirm the hydrocarbon potential of the basin and expand further non-exclusive seismic surveys in the region.

Greek Herodotus basin (Fig.23) is worth exploring. The potential of the northern part of the Herodotus basin resting at the front of the Florence Ridge remains more hypothetical because it is located far from clastic sources.

2.6 Mud Flow Volcanoes of Southern Crete, Olimpi and United Nations Rise, and their Implications for Hydrocarbon Exploration

Subsea or under water mud volcanoes, sometimes called hydrocarbons volcanoes are important visible sign of gas sources feeding surrounding possible reservoir sedimentary formations. Mud volcanoes are geological formations which are created by the expulsion of pressurized gases and mud. They are encountered in tectonically subduction zones and orogenic belts and upon venting they create the hydrocarbon clathrate hydrate which are very often associated with hydrocarbon deposits (Wikipedia, Link, 1952, Jones

[1]. Shell back for Egypt Deep, 2005, Africa Oil and Gas volume 8, issue 24, page 4

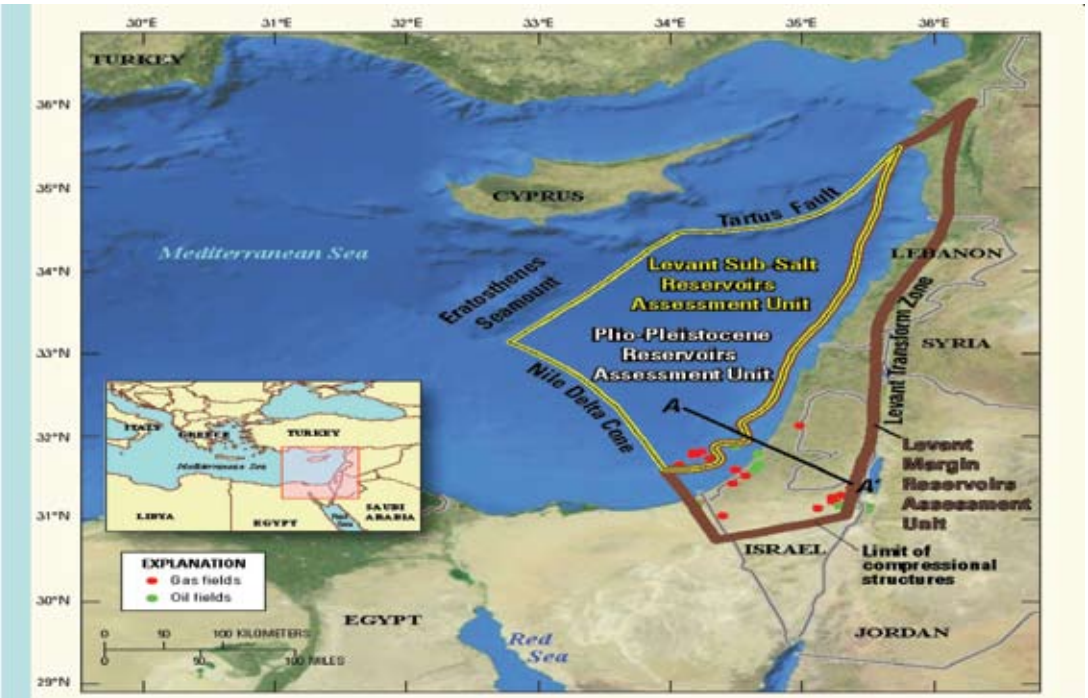
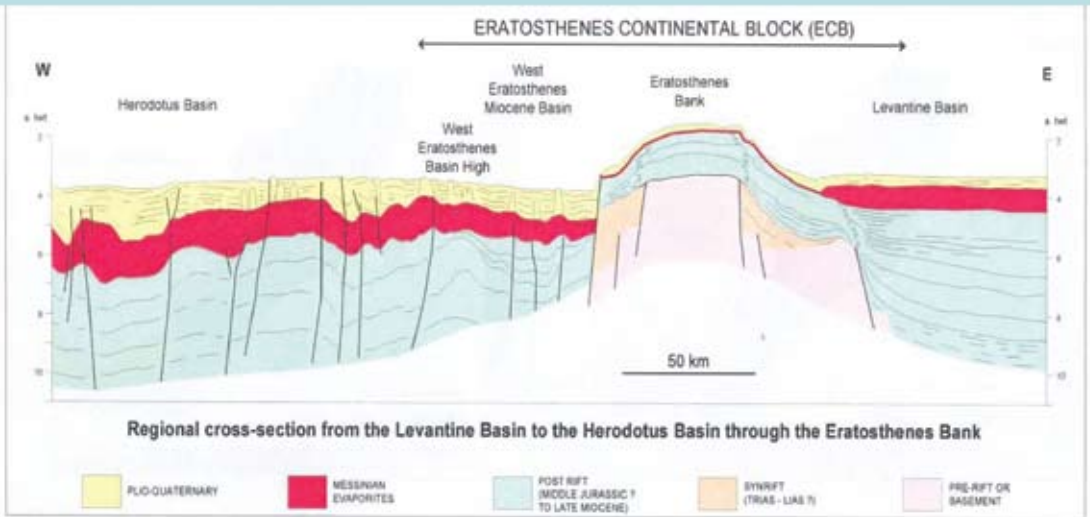


Figure 7. The Levantine Basin with its recent oil and gas discoveries. Assessed potential for further discoveries of natural gas 122 tcf and oil 1,7 billion barrels, USGS Technical Report, 2010



Regional cross-section from the Levantine Basin to the Herodotus Basin through the Eratosthenes Bank

Figure 8. Regional cross – section from the Levantine basin to Herodotus Basin through the Eratosthenes Bank. Montadert and Nikolaides, 2007.

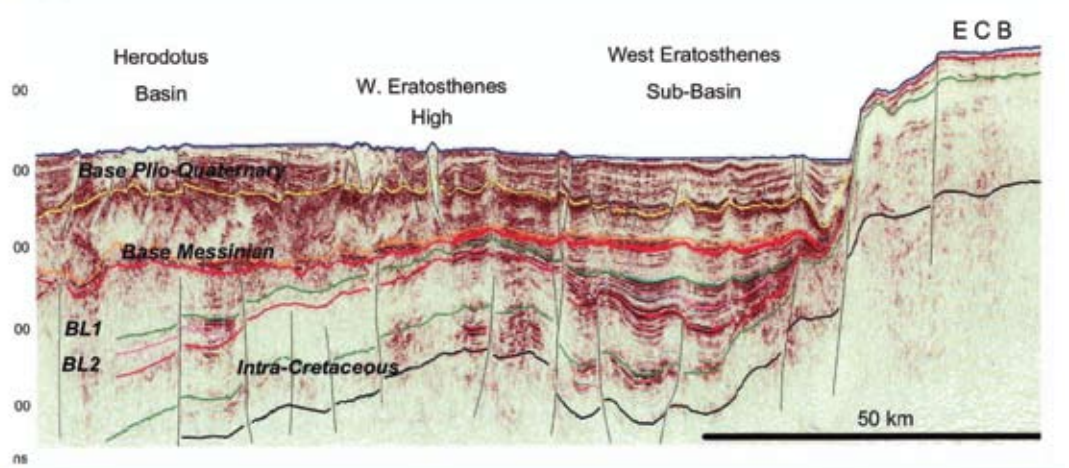


Figure 9. West Eratosthenes to Herodotus sub-basin and high, Montadert and Nikolaides, 2010

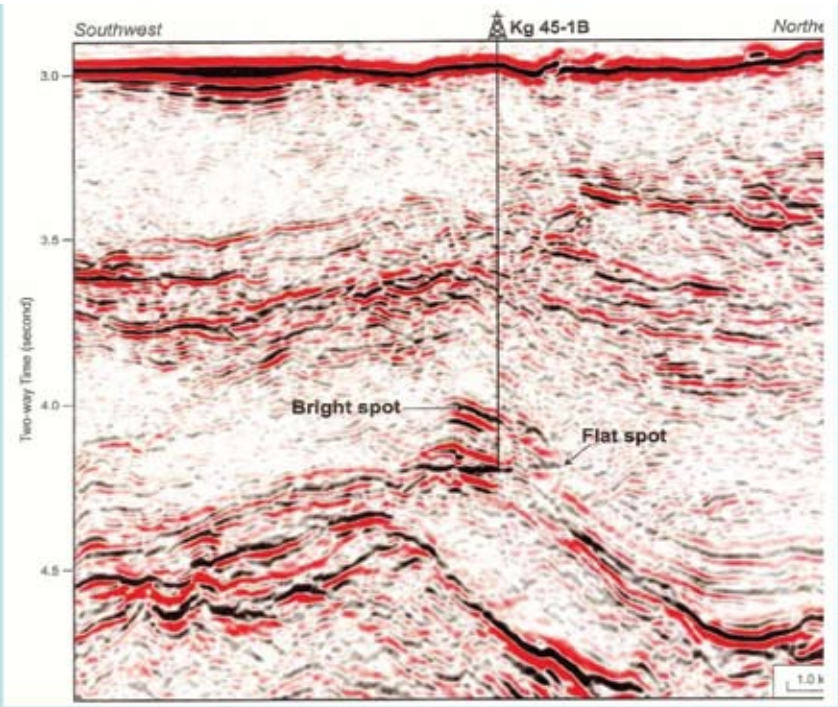


Figure 10. Direct Hydrocarbon Detection (DHI) seismic flat spot tested by Shell's successful Well Kg 45-1B in the Egyptian Nile Cone, Semb, 2009.

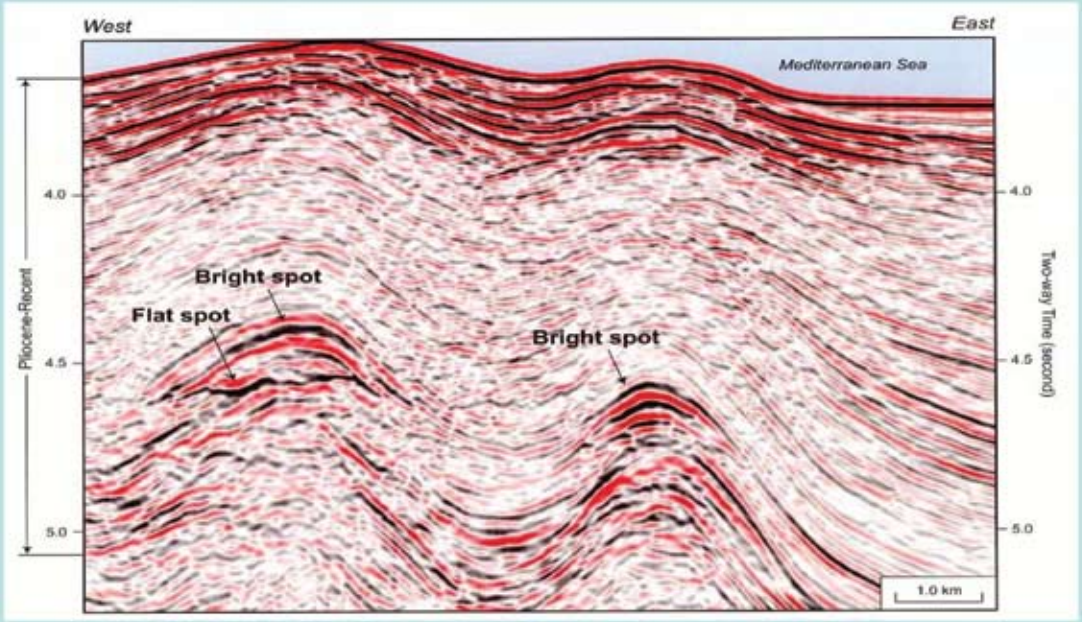


Figure 11, Seismic flat spot and two bright spots identified in the PGS 2-D in offshore Cyprus. These DHIs are believed to occur in the same interval as in Shell's discovery in the North Western Nile Cone, Figure 12, Semb, 2009

and Drozd, 1983, Rakhmanov, 1987).

The correlation of hydrates with gas venting mud volcanoes is ubiquitous on earth, Milkov, 2000 (Dimitrov, 2003, Milkov, 2005 Akesson 2008, Etiope, 2009). The association of mud volcanoes and gas hydrates is found in the Gulf of Mexico and the Caribbean (Milkov, 2000; Bertolini et al., 2003), in Azerbaijan (Etiope et al., 2004), Caspian Sea (Guliev et al., 2004, Yusinov and rabinowitz, 2004), Lake Baikal (Samsonov et al., 2009), the Western Basin of Africa (Graue...), Black Sea (Bohrmann ...), Calabrian Arc, gulf of Gadiz and Sorotkin Trough (Foucher ...), as presented in Figs 24 and 25. Work by Praeg, et al., 2007 shows the extent of Mediterranean gas hydrates areas and the relevant pay zones thicknesses (Fig. 26). Such an association between mud volcanoes, Figures 27 and 28 (Dupre et al., 2008), and gas fields is found in the Nile Cone, Figures 29 and 30 (Rigzone, 2010, Neftegaz Ru, 2010).

In southern Crete the existence of active mud volcanoes has been also the subject of an intensive research by many scientists (Cita, et., 1981, Camerleghi, et. al., 1992, Limonov, et al., 1994, 1996, Chaumillon, et. al., 1996, Cronin, et., al., 1997, Huguen, et. al., 2004, 2006, Loncke, et.al., 2004, Costa, et. al., 2004, Haase et. al., 2006, and many more). According to Huguen et al., 2004, there are 2 fields with mud flow volcanoes: the Olimpi with 7 volcanoes (Figs 31 and 32) and the United Rise with 2 volcanoes (Fig. 33). In addition there are smaller fields such as Prometheus II, Pan di Zucchero and Cobblestone (Fig.31).

The volume of gas expelled only from the Olimpi field has been estimated to range between 1.68 x 106 m^3/year to 2.85 x 107 m3/year, Kopf 1999. Since the age of the 2 volcanoes within the Olimpi field, Torino and Napoli, is estimated to be over a million years (Robertson and Kopf, 1998), a rough estimate of the expelled volume of gas can be calculated. This ranges from 1.68 x 1012 m^3 to 28.5 x1012 m^3. Part of it is converted to hydrate.

Based upon the existence of numerous active mud volcanoes, thermogenic pock marks and/or mounds (Figs 34 and 35), Loncke et al., 2004, have proposed the potential pre-Messinian source rocks/reservoirs for the mud cones as well as the pre-Messinian source source rock/reservoirs for the gas chimneys. Roberts and Peace, 2007, have shown satellite pictures where gas bubbles (literally millions of bubbles) derived from the activity of mud volcanoes upon reaching the sea surface burst and the oily film which surrounds them collapse onto the sea surface. All these small oil films combine together to form an oil slick that calms the waters (Fig.36).

Both, Olimpi and United Nations mud volcano fields are located on the down slope of the Mediterranean Ridge towards Crete (Figure 34) where the sedimentary

cover thickens to more than 10 Km (Makris et. al., 2011). The origin of these thick sediment deposits is discussed in details by Dornsiepen, et. al. 2001.

From the above is more than obvious that a correlation between active mud volcanoes and hydrocarbon reservoirs is an established fact. As a result of the existence of many active mud volcanoes south of Crete, over 9, hydrocarbon reservoirs should exist as is the case with the Nile Delta Cone, Caspian and Black Seas. Hence the hydrocarbon plays and prospectivity of the Mediterranean Ridge should be investigated, especially after the work done by Maravelis et. al., 2011. The areas worth exploring south, southwest and west of the island of Crete, are indicated by Maravelis et al., 2011 and the authors (Fig.37).

3. Geopolitical Implications from the Existence of Hydrocarbon deposits in the Eastern Mediterranean and Southern Crete. Their importance to the Energy Independence of the European Union.

By 2020 the European Union will be facing a serious energy shortage not only because oil production will decrease dramatically but also because Russia and North Africa will not be able to satisfy the ever increasing demands in natural gas. This gap could be easily counterbalanced from the newly discovered hydrocarbon reserves (proven and potentially existing) from the Eastern Mediterranean and offshore Crete. Specifically:

A. Crude Oil. Crude oil production has been steady at 86 million barrels/day since 2005 (Figure 38). From this amount only 42 million barrels /day is currently available for export (Figure 39) and this amount is steadily dropping.

In 2005 the exported amount was 46 million barrels/day which means that the producing countries have increased their internal consumption. From the exported amount, USA, China, Japan and currently South Korea absorb 25 million barrels/day, BP Statistical Review of World Energy 2010. Europe requires 11 million barrels/day besides its own production of 3,5 million barrels/day. Hence the remaining World has to satisfy its needs with 6 million barrels/day. This explains why the price of crude oil hovers around $115/ barrel.

According to IEA, 2009, in 2020, the daily global oil production is expected to fall to 65 million barrels, Fig.40 and Fig.41, this amount could not satisfy the E.U. crude oil daily needs taking into account that the free trade availability will amount less than 25 million barrels daily, an amount that could not even cover the needs of the U.S., China, Japan and India altogether.

So Europe by 2020 will not be able to find the much needed extra 11 to 12 million barrels of oil per day and the countries which will suffer the most are Portugal,

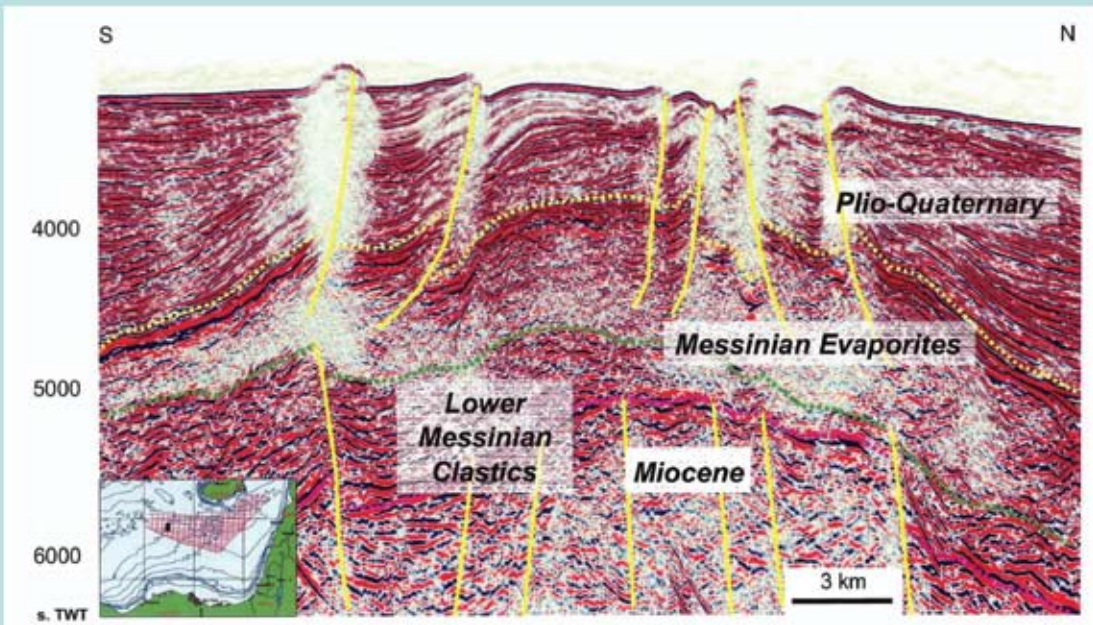


Figure 12. Large anticline on the toe of deep Nile delta fan with Messinian low-stand delta clastic sand faulted pre-Messinian. Gas chimneys are highly visible, Montadert and Nikolaides, 2010.

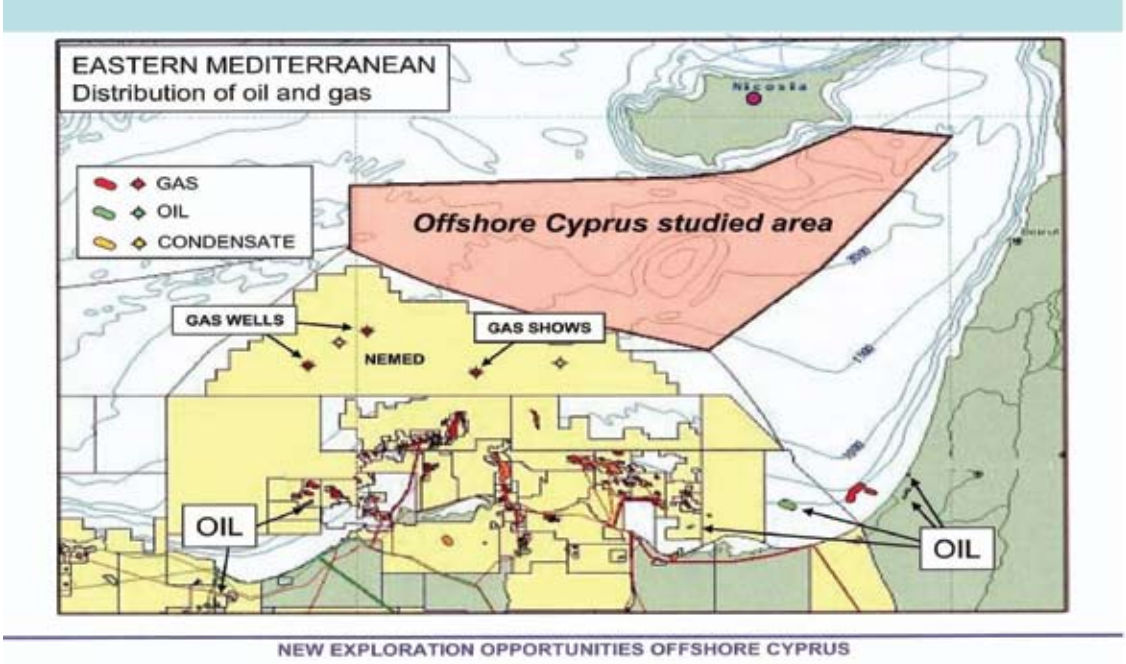


Figure 13. Distribution of oil and gas Fields and Discoveries in Eastern Mediterranean. Of interest are the 2 gas fields discovered by Shell, due to their proximity to the Greek and Cypriot Herodotus Basin. BEICIP/FRANLAB, 2007

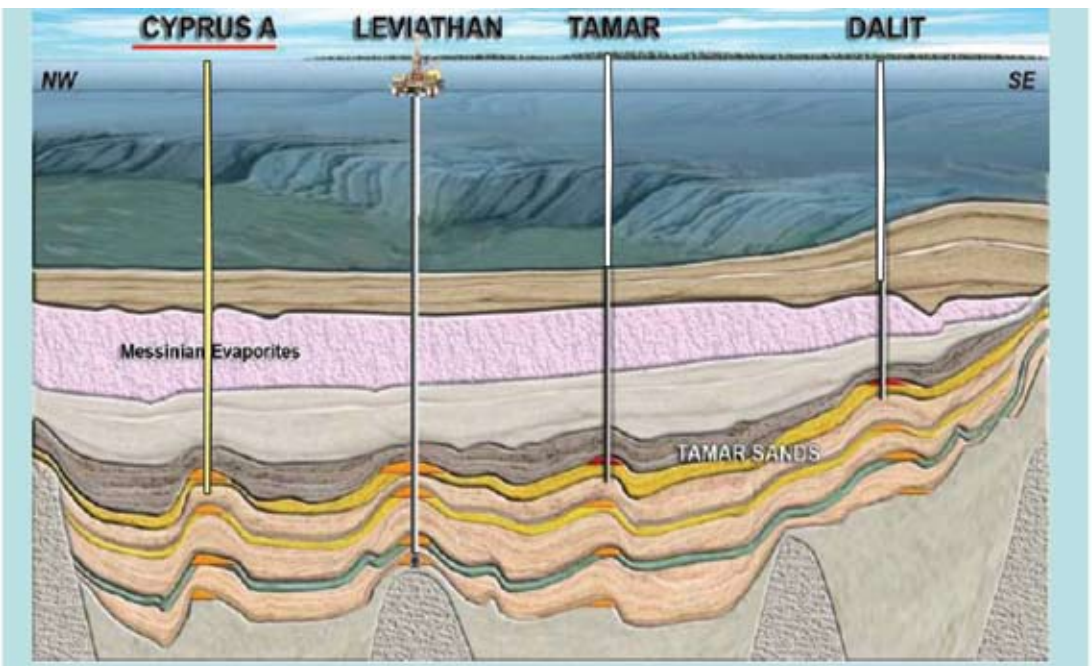


Figure 14. A cross section of the Messinian Evaporites and the Tamar sands along with the gas discoveries in Dalit, 15 billion M^3, Tamar, 240 billion M^3 and the Leviathan, 455 billion M^3 and the anticipated Cyprus A, with 300billion M^3, Noble Energy, 2010

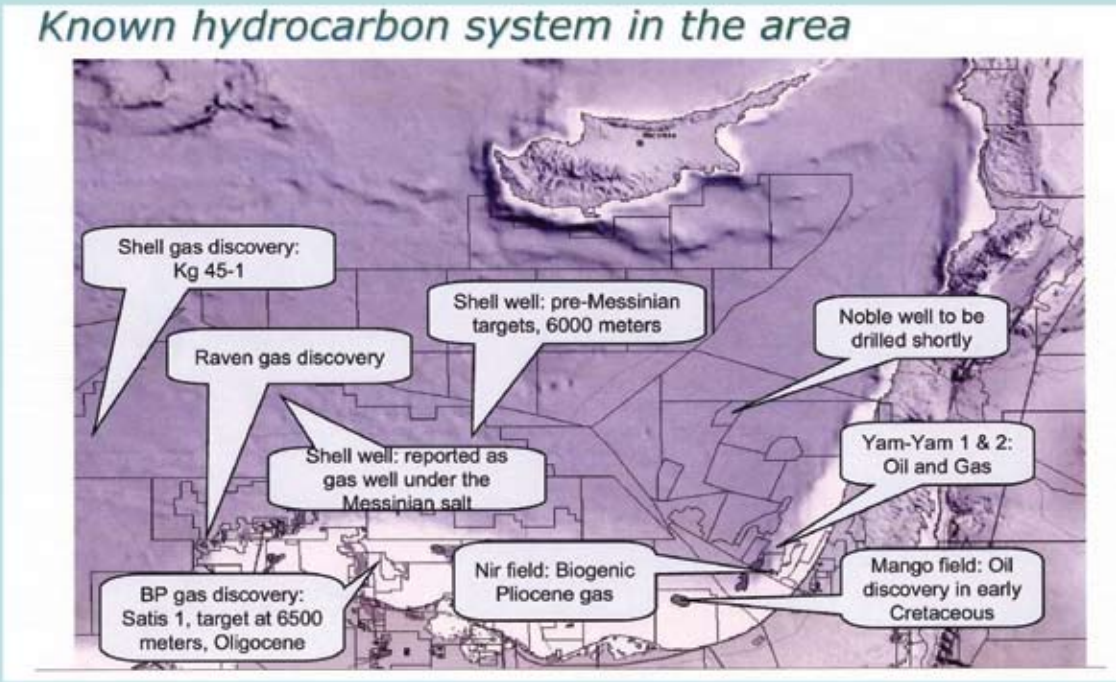


Figure 15. Hydrocarbon discoveries in the Nile Cone and Southern Levantine Basin, Kassinis, 2008

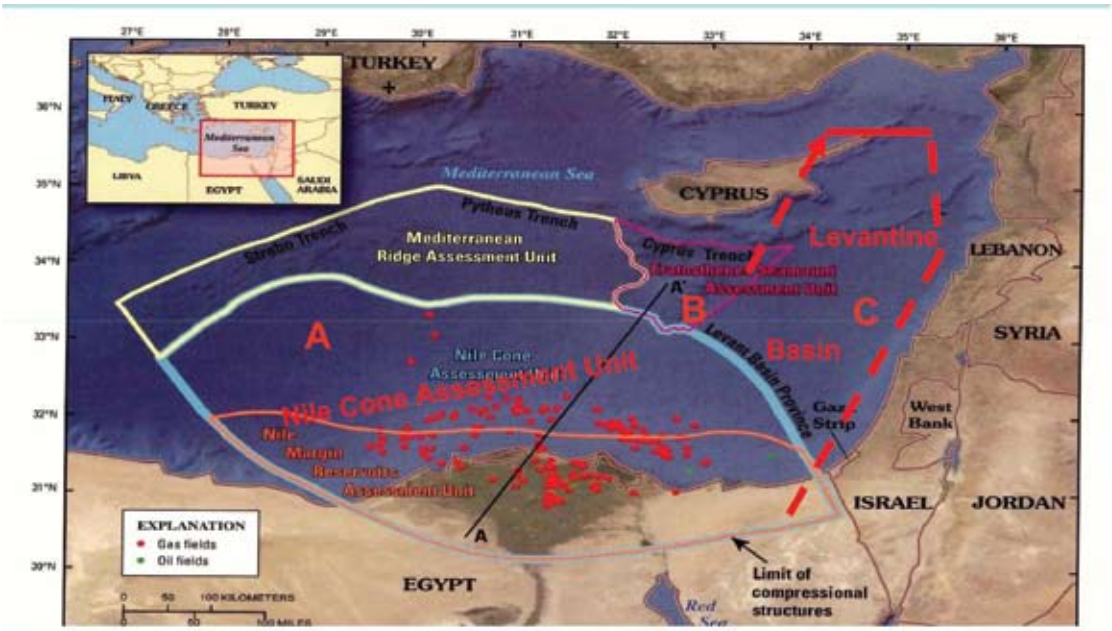


Figure 16. Location of four assessment units in the Nile Delta Basin Province in the eastern Mediterranean. (Map not definitive for political boundaries.) USGS image. A+ B, Potential 223 trillion cubic feet of natural gas(6.31 trillion M^3). C, Potential 122 trillion cubic feet of natural gas (3,45 trillion M^3). USGS Assessment 2010.

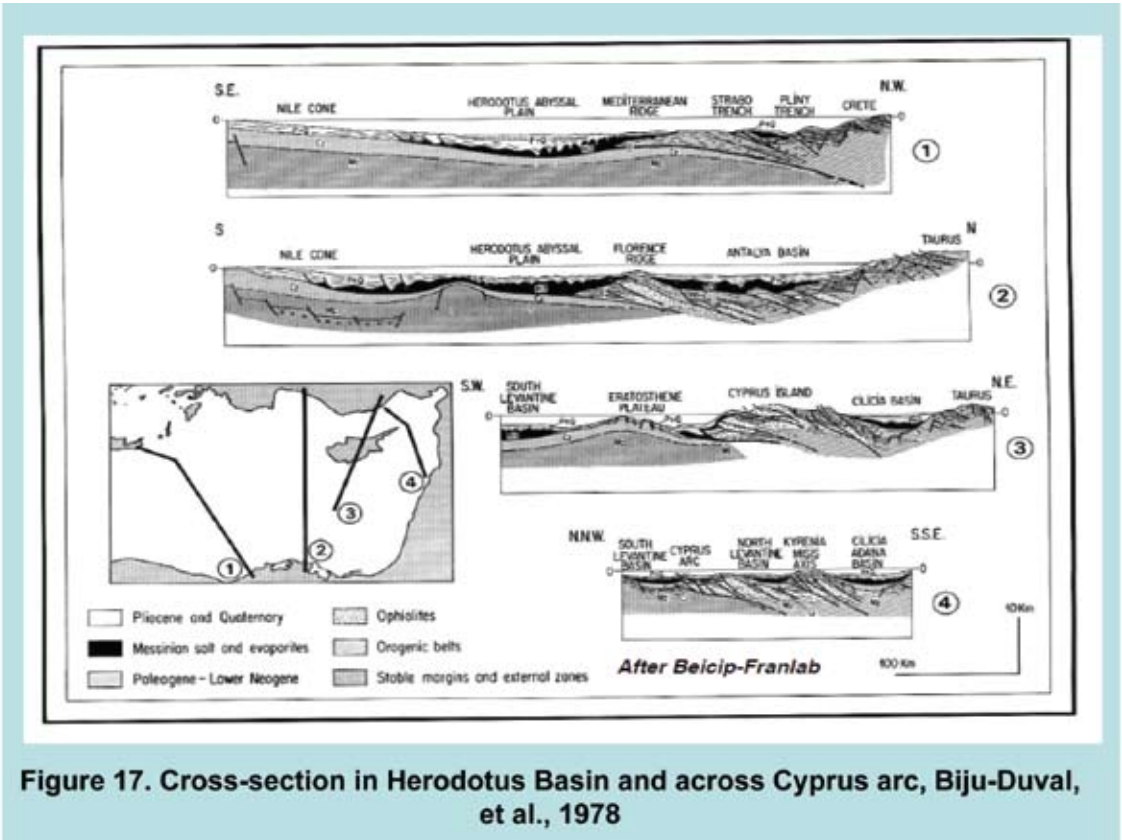


Figure 17. Cross-section in Herodotus Basin and across Cyprus arc, Biju-Duval, et al., 1978

Ireland, Italy, Greece and Spain (PIIGS), de Souza, 2010. The total amount of oil needed per year is more than 4 billion barrels of oil which is equivalent to 620 billion cubic meters of natural gas.

B. Natural Gas. The amount of natural gas consumed every year by the European Union amounts to 500 bcm (Figure 42). Almost half of its consumption is imported from Russia, 160 bcm and 90 bcm are imported from North Africa especially Algeria & Libya (BP Statistical Review of World Energy 2010).

By 2020 the demand for natural gas in Europe will increase by 225 bcm (Fig. 43). Hence, the total energy deficit (oil + gas) of EE, expressed in billion cubic metres of natural gas per year will reach 845 bcm.

This demand in natural gas can not be satisfied by either Russia, (which has 44 trillion cubic meters of natural gas resources and an annual production of 600 billion cubic meters), because 2/3 of the reserves and the production are allocated for domestic uses, nor by Algeria and Libya because the reserves amount to 6.2 tcm (BP Statistical Review of World Energy 2010). However, this extra demand can be satisfied from the newly discovered and the expected natural gas resources in the East Mediterranean and the offshore south of Crete basins as estimated by the U.S. Geological Service and BEICIP / FRANLAB-IFP, France.

According to USGS Technical Report 2010, besides the already discovered natural gas deposits in Egypt and Israel, which is around 3 tcm, there is a 50% potential to discover an additional 9.5 tcm of natural gas in the Nile Cone and in the Levantine Basin plus an amount of at least 1.3 tcm of natural gas offshore (Cyprus, Semb, 2009).

This brings the grand total of proven and potential reserves, not counting the probable reserves in the Greek Herodotus Basin and those existing in offshore southern Crete, to over 14 tcm (494 trillion cubic feet) of natural gas. This amount is 12 times more than what Europe expects to have from Azerbaijan (1.2 tcm) via the Nabucco pipeline.

If we subtract 3 tcm in order to satisfy the internal needs of Egypt, Israel and Cyprus over the next 30 years, the remaining amount of 11 tcm could cover E.U. ever increasing needs by 2020 for 35 years.

The export of the southeastern Mediterranean natural gas surplus already found in the region is possible with ships that could carry compressed natural gas (CNG) loading it directly from offshore field floating production systems. The cargo can be unloaded either in Greece and then transfered towards the wider gas European market. In the medium term an onshore gas liquefaction plant (LNG) -for example in Cyprus- could be built allowing ships to transport LNG to Europe. In the long-term following further offshore discoveries in the region, together with a

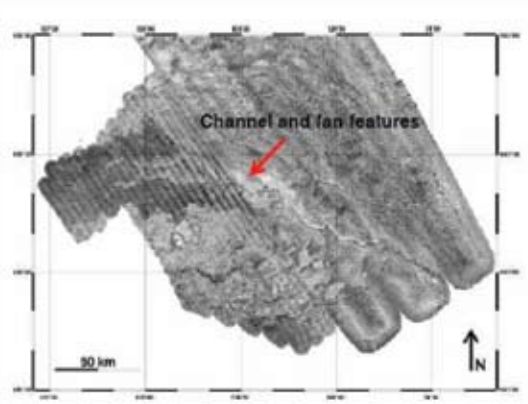


Figure 18a: Simrad EM 300 image from sea bottom

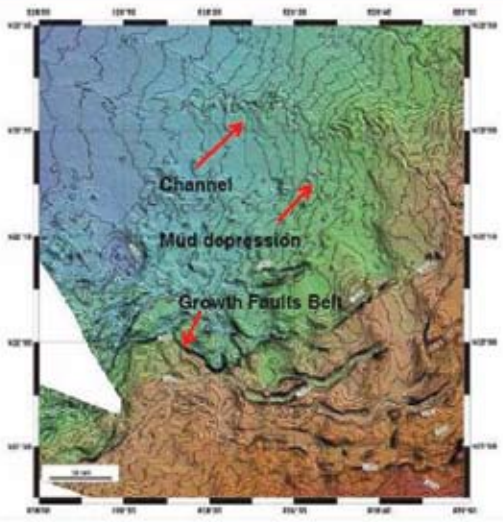
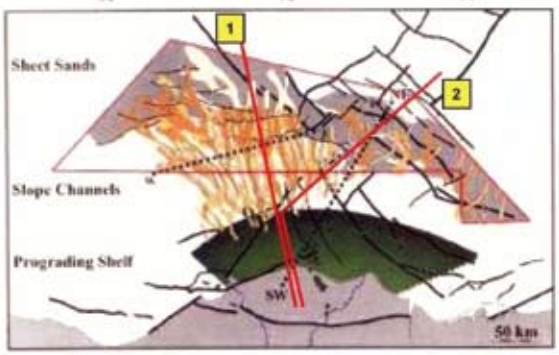


Figure 18b: Color contoured bathymetry showing growth faults belt, channels, mud circular depressions

Figure 18. Sea bottom images from Nile Delta, Mascle, et al,. 2006.

Figure 19a: Pliocene turbiditic system deposition



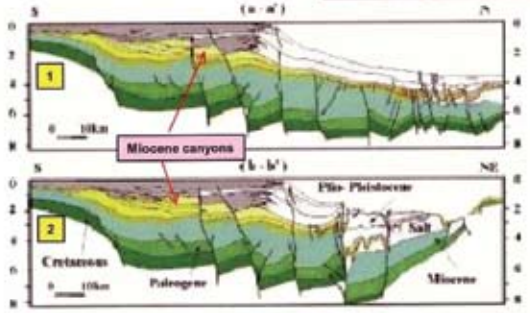


Figure 19b: Messinial canyons and Plio-Pleistocene turbiditic system

Figure 19. A. Pliocene turbidite system deposition and B. Messinian canyons and Plio- Pleistocene turbiditic systems, Abdel Aal, et. al., 2000

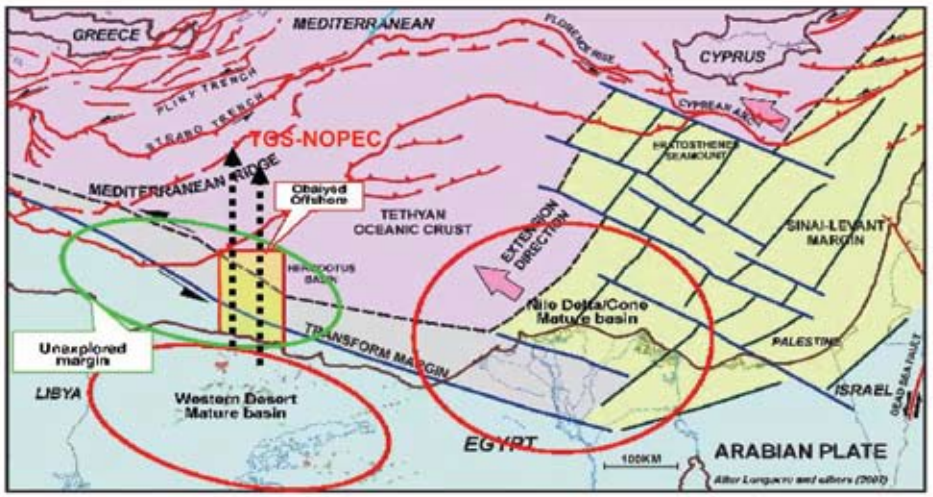


Figure 20. Location of the OMV study (Obaiyed offshore) inside the Greek Herodotus Basin, Dotted arrows are TGS-NOPEC (GR) Lines. Krois, et. al., 2009

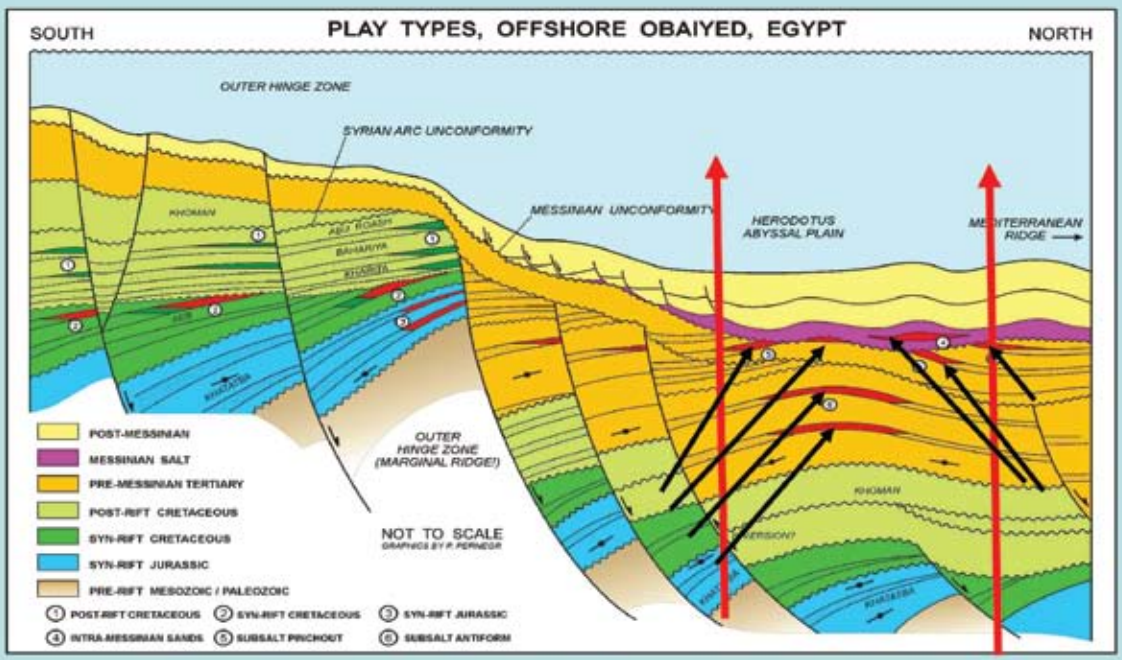


Figure 21. Herodotus Basin with 7 tectonic and structural hydrocarbon traps, Krois et al., 2009

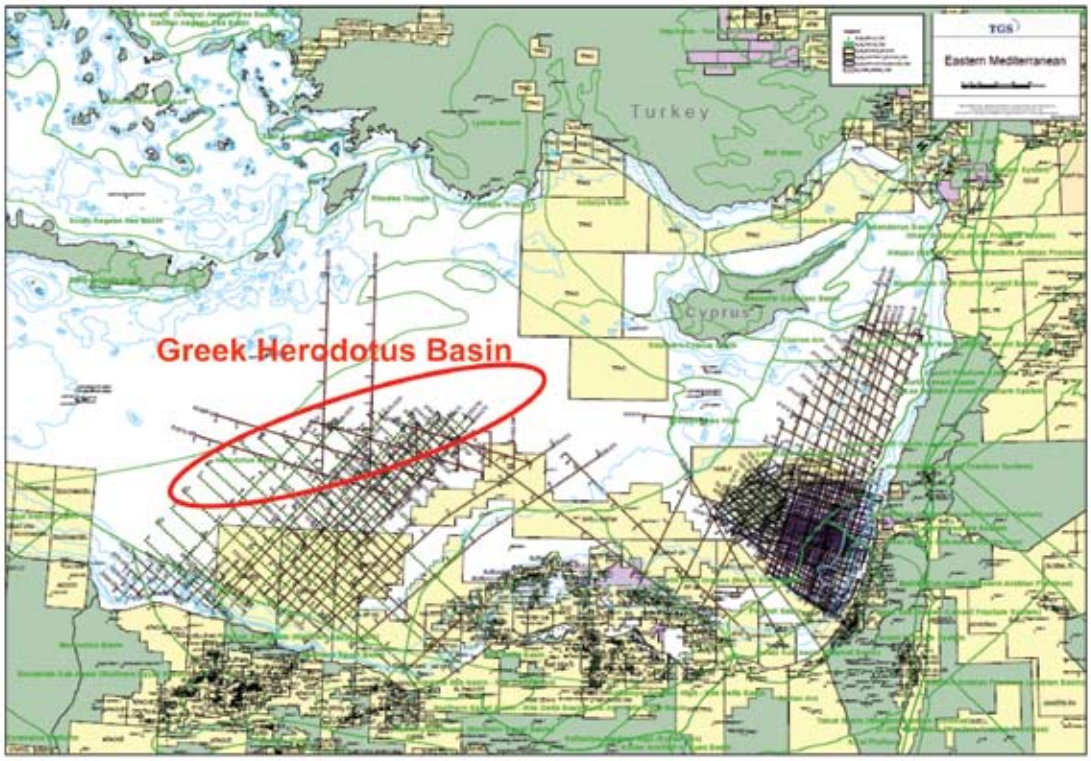


Fig.22: Geophysical survey by TGS-NOPEC, 2010

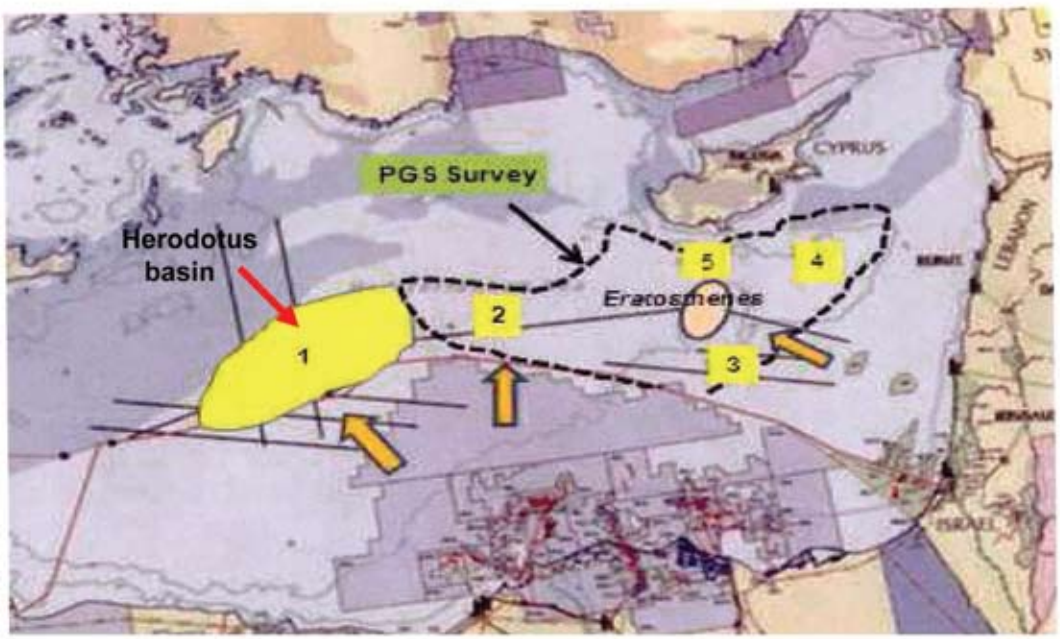


Figure 23. Potential hydrocarbon areas offshore Cyprus and the Greek Herodotus Basin, after IFP (Institute Francais du Petrole), Bruneton et al., 2009??? Overview on the Hydrocarbon potential of the East Mediterranean Deep Offshore: Perpectives for Greek exploration, BEICIP/FRANLAB, 2007.

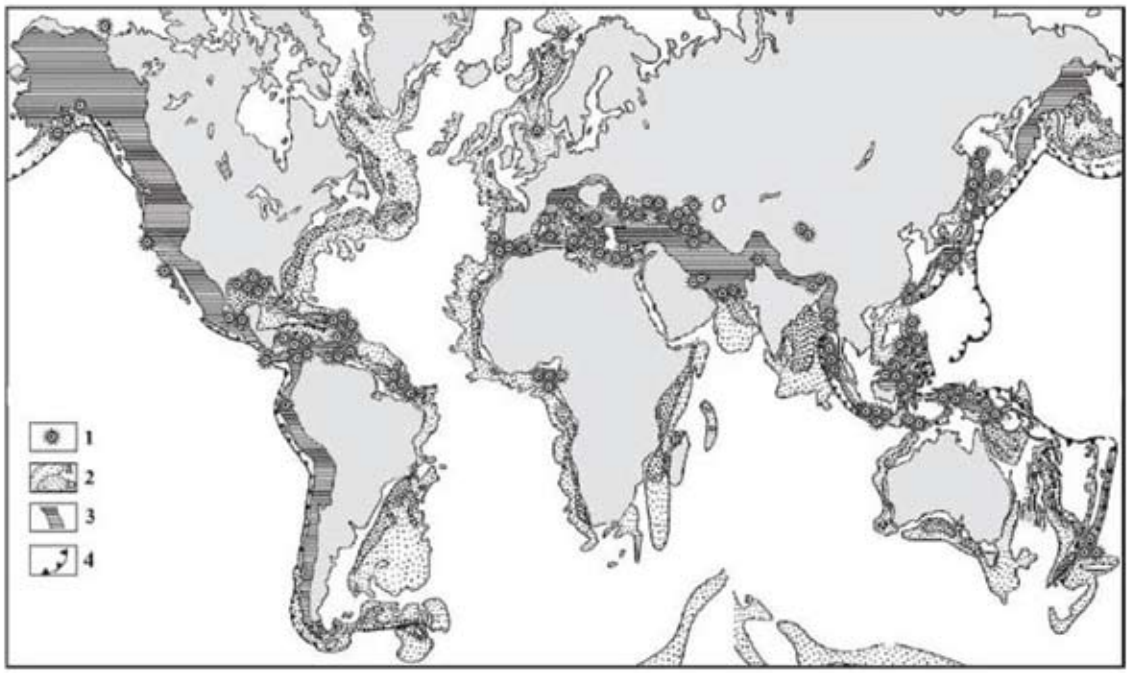


Figure 24. Global distribution of mud volcanoes. 1 Single mud volcanoes, mud volcano belts and separate mud volcano areas. 2. Sediment thickness in the area out of the continental shelves a) 1-4 Km, b) >4Km 3. Active compressional areas 4. Subduction zones. Dimitrov, 2003, Akesson, 2009

possible development of giant shale gas reserves located in the area of Shefla onshore Israel, the ability to build 2 or more pipelines to transport natural pipeline from Haifa, Israel via Cyprus, Crete and the western Greece to Italy & E.U. could easily take place (Fig.44).

4. Conclusions.

4.1 In this paper the existing hydrocarbon resources and exploration activities in the Eastern Mediterranean particularly in the Nile Cone and offshore Israel and Cyprus has been presented.

Further exploration and production opportunities, could follow in offshore areas between Cyprus and Israel, Cyprus and Lebanon, Syria, Egypt, Libya and Crete.

4.2 The Eastern Mediterranean is attracting international interest in hydrocarbon exploration and production investments based on recent giant natural gas discoveries of about 3 Tcm. According to 2010 USGS reports, an additional 9.5 tcm possible natural gas reserves in the Nile Cone and Levant Basin could be present along with another potential of 1,3 tcm offshore Cyprus (Semp, 2009).

4.3. Due to the recent natural gas findings by Shell and BP in areas adjacent to the Greek portion of the Herodotus Basin and the active exploration taking place in the Cypriot portion of the Herodotus basin, as well as the recent publication by Krois et. al., 2009, where cross sections inside the Greek Herodotus basin indicate the presence of hydrocarbon reservoirs, the Greek government should investigate its potential by acquiring from TGS-NOPEC all the geophysical survey lines, tagged as GR lines.

4.4. The existence of active mud volcanoes in southern offshore Crete is a very serious indication of hydrocarbons presence and possible petroleum systems in this region. This is the case throughout the world eg. the Caspian Sea, Gulf of Mexico, Western African Basin, Trinidad-Tobago and the Nile Cone where active mud volcanoes are strongly correlated with the presence of hydrocarbon deposits. The acquisition of exploration data south and around the island of Crete is absolutely necessary and urgent in order to further evaluate the presence of a working petroleum system with reservoirs, seals and structures in the region.

4.5 The necessity to export surplus natural gas to Europe requires either the building of CNG or LNG ships or the construction of a pipeline(s) which will start from Haifa, Israel or Limassol Cyprus (Transeuropean Natural Gas Pipeline). Due to the expected possible enormous quantities of natural gas to be discovered in Eastern Mediterranean this pipeline(s) could be more economical than the proposed Nabucco pipeline which will carry Azeri natural gas, (around 1 tcm), to Europe. This development will benefit Greece immensely

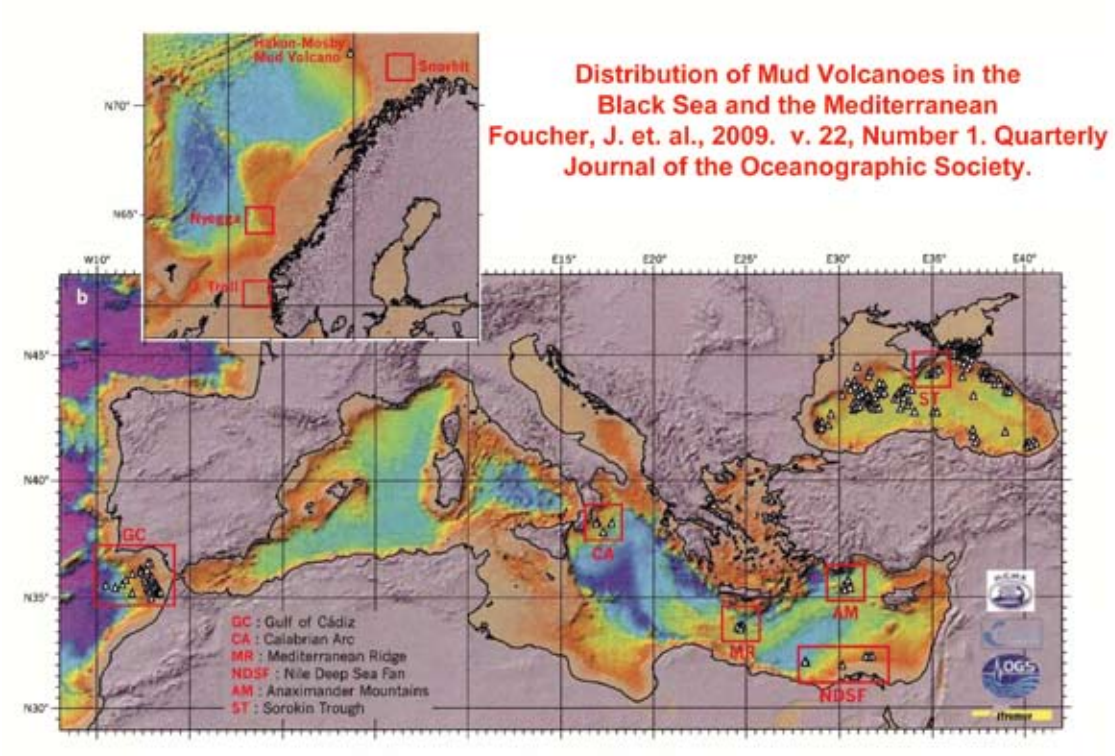


Figure 25. Distribution of Mud Volcanoes on the Black Sea anf the Mediterranean, Foucher, et. al., 2009

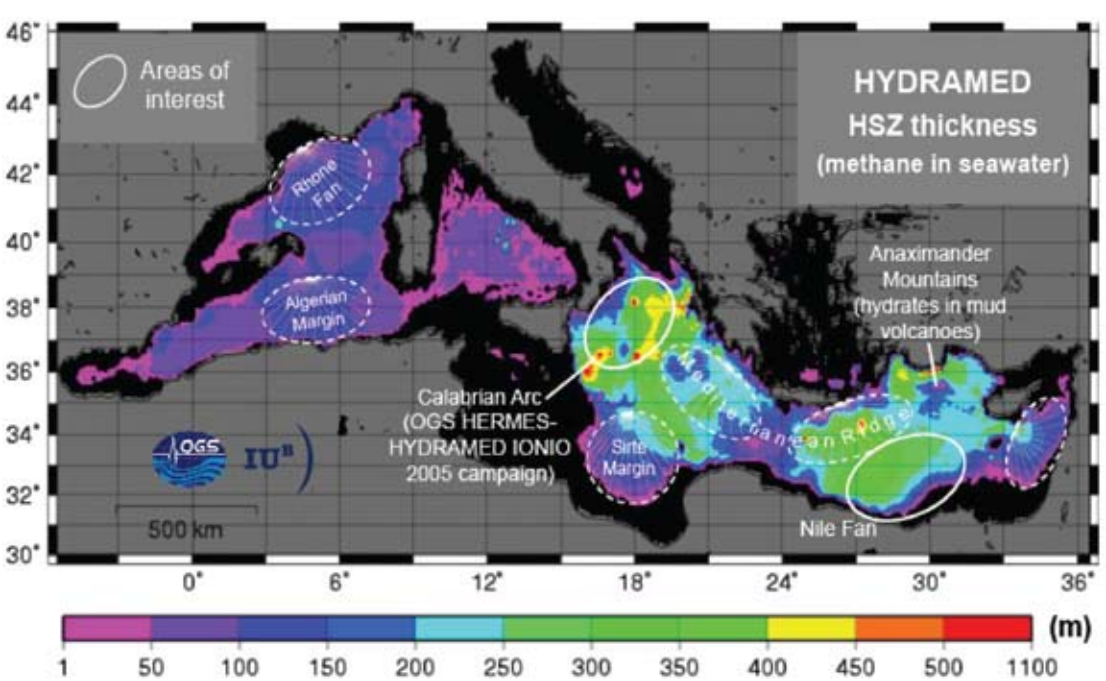


Figure 26. Hydrate thicknesses in the Mediterranean Sea, Praeg et. al., 2007

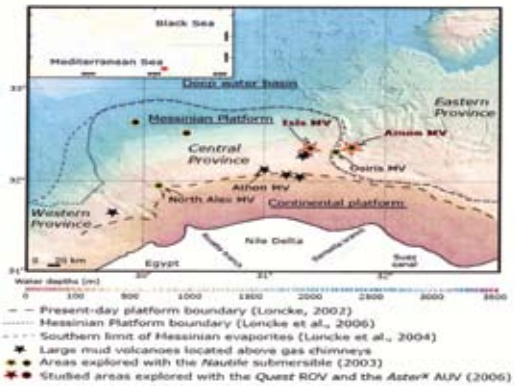


Figure 27. Active Mud Volcanoes in the Nile Cone, Dupre, et. al., 2008

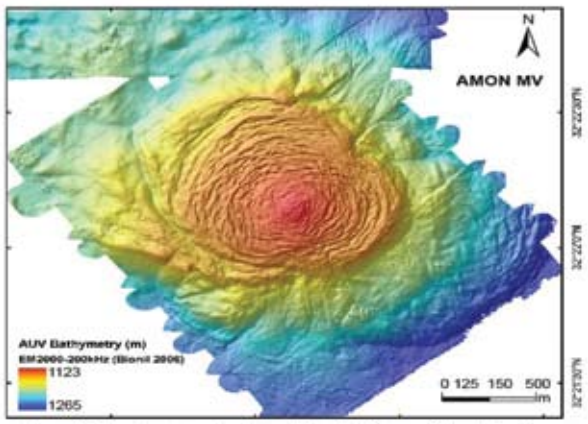


Figure 28. The Amon mud volcano in the Nile Cone, offshore Egypt , Dupre, et. al., 2008

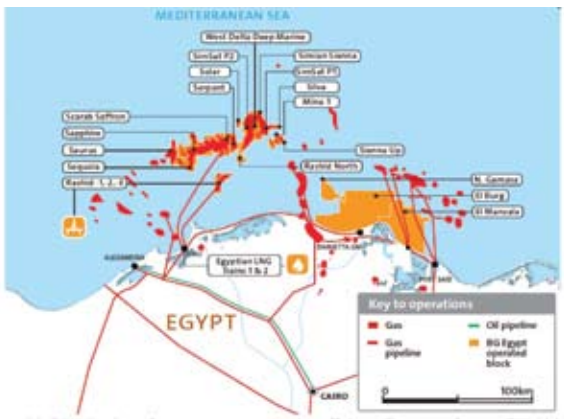


Figure 29. Distribution of natural gas reservoirs offshore Egypt, Neftegaz, EU, 2010 Rigzone, 2010

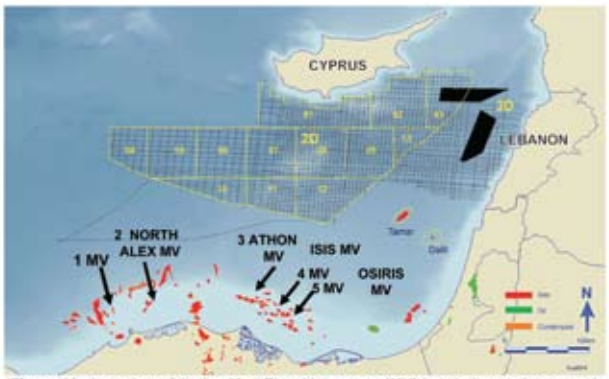


Figure 30. Location of Active Mud Flow Volcanoes (MV) in relation to the natural gas deposits in the Nile Cone. offshore Egypt. Figures 27 and 29 combined.

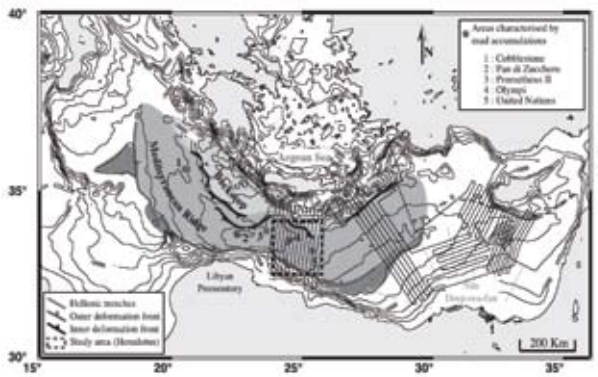


Figure 31. Morphostructural sketch of the Mediterranean Ridge (MR) (modified from Chaumillon et al., 1996; Robertson and Shipboard Scientific Party, 1996; Cronin et al., 1997). Locations of the Prismed 2 (February 1998) track map and of the study area are indicated. Huguen et. al., 2004 Marine Geology

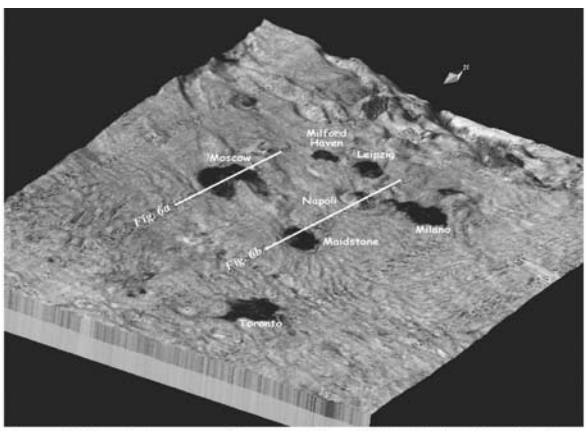


Figure 32. Mud Volcanoes offshore Southern Crete. Backscatter data 7 superimposed on 3D seafloor relief view of the Eastern Olimpi field. Huguen et al., 2004, Marine Geology 209: 245-263

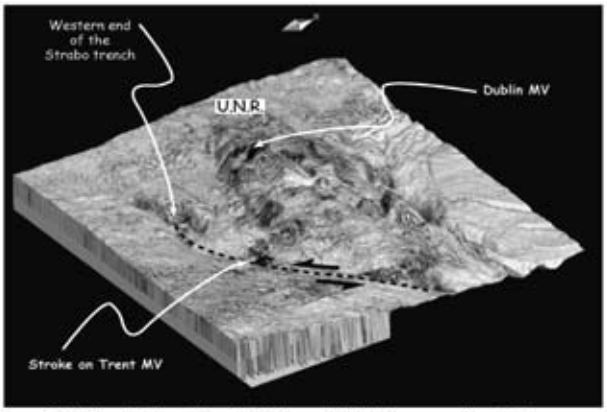


Figure 33. United Nations Rise Mud Volcano field offshore southern Crete. Backscatter data superimposed on oblique 3D bathymetry seafloor relief of the United Nations Rise field.

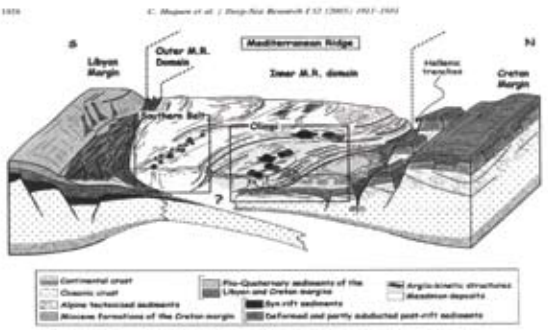


Figure 34. Interpretative 3D tectonic sketch of the Central Mediterranean Ridge and the Olimpi and the Southern Belt mud fields. Two different source levels are proposed for the two mud fields, the Olimpi field being related to relatively shallow mud formations, with high fluid contents and the Southern field being connected to deeper mud sources with lower fluid contents, Huguen, et. al., 2005

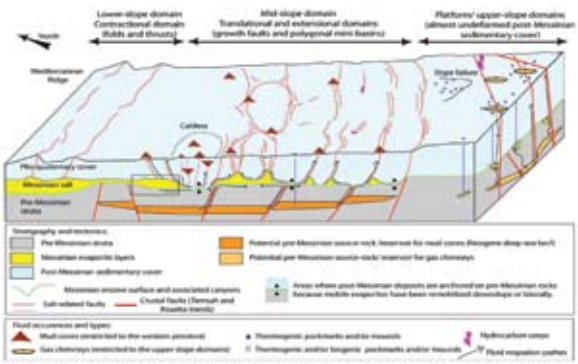


Figure 35. Active Mud Flow Volcanoes (brown triangles), Gas chimneys (brown discs), Thermogenic Pockmarks and Mounds offshore Southern Crete. The pre-Messinian source rocks/ reservoir for the mud cones (brown), are highly visible as well as the reservoir/source for the gas chimneys (light brown), are also visible, Loncke et al., 2004,

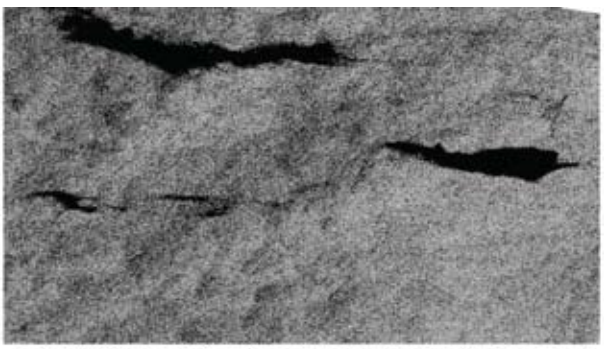


Figure 36. Oil films resulting from escaping gas bubbles which are coated with oil. Gas bubbles are derived from Active Mud Volcanoes. in offshore Nile Cone, Egypt. Picture taken from satellites. Roberts and Peace, 2007

Figure 37. Areas for hydrocarbon exploration west and south of Crete.

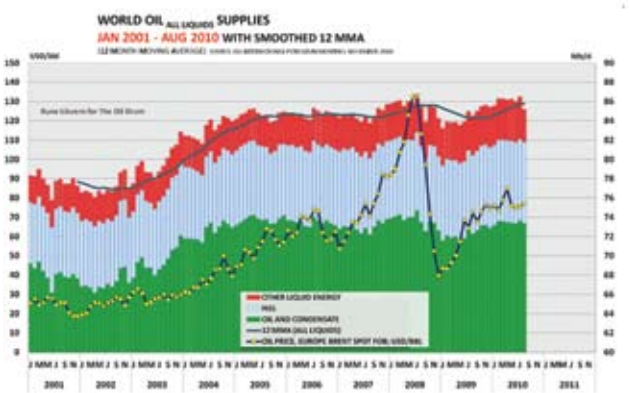


Figure 38. Global Oil Supplies as reported by EIA's International Petroleum Monthly, by Likvern, R., November 2010 Oil Drum, Europe

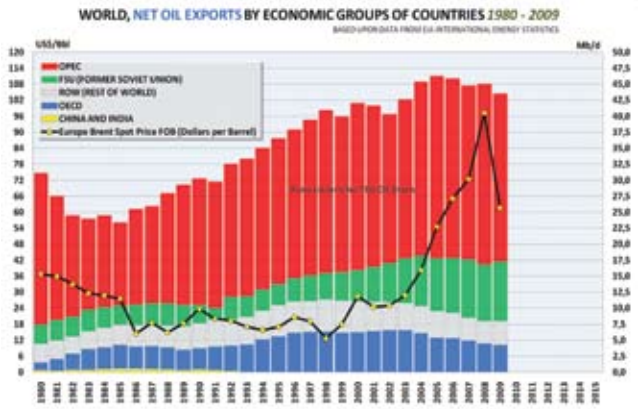


Figure 39. Trends in World Oil Supply/ Consumption and Net Exports/Imports, Likvern, R., September 2010 Oil Drum Europe

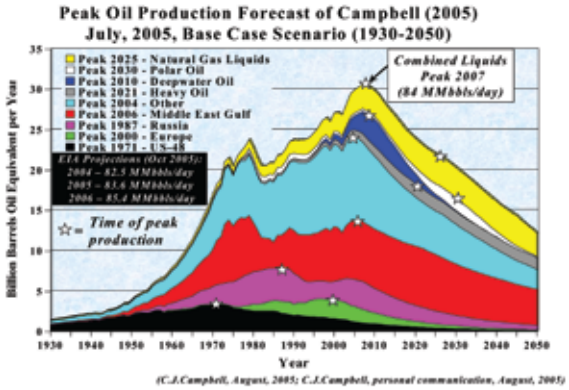


Figure 40. Peak oil Production, C.J. Campbell, 2005. www.hubbertpeak.com/campbell/-Cashed-Similar

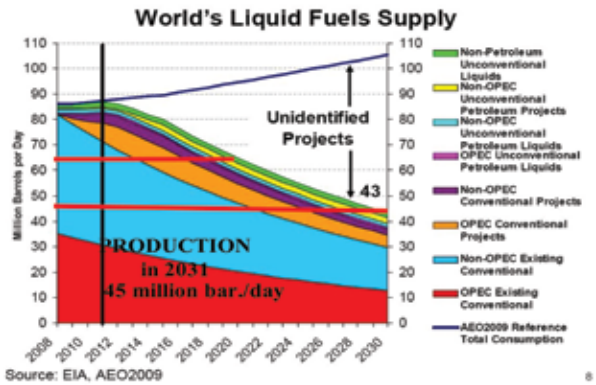


Figure 41. World's Liquid Fuels Supply by EIA, 2009

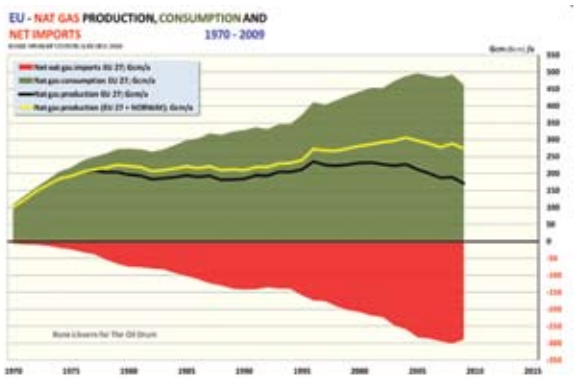


Figure 42. Natural Gas Production, Consumption and Net Imports of the European Union, Likvern, R., August 2010. www.energybulletin.net/node/53656- Cashed and in August 3, 2010 the Oil Drum

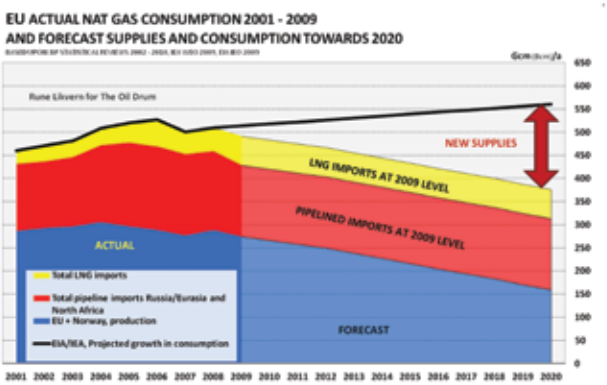


Figure 43. Actual Natural Gas Consumption between 2001 and 2009 of the European Union. Forecast Supplies and Consumptiom towards 2020, Likvern, R. August 2010. www.energybulletin.net/node/53656- Cashed and in August 3, 2010 the Oil Drum

Figure 44. Transeuropean gas pipeline which could carry the already discovered and the about to be discovered natural gas from eastern Mediterranean from either Haifa or Limassol to Europe through Greece and Italy

and could open the way for starting hydrocarbon exploration in Southern Crete, the Western Greece and the Ionian Sea.

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ΟΙΚΟΝΟΜΙΚΗ & ΓΕΩΠΟΛΙΤΙΚΗ ΣΗΜΑΣΙΑ ΤΩΝ ΚΟΙΤΑΣΜΑΤΩΝ ΦΥΣΙΚΟΥ ΑΕΡΙΟΥ ΤΗΣ ΑΝΑΤΟΛΙΚΗΣ ΜΕΣΟΓΕΙΟΥ ΓΙΑ ΤΗΝ ΕΛΛΑΔΑ ΚΑΙ ΤΗΝ Ε.Ε. – ΕΜΦΑΣΗ ΣΤΑ ΑΝΑΜΕΝΟΜΕΝΑ ΚΟΙΤΑΣΜΑΤΑ ΤΟΥ ΛΙΒΥΚΟΥ ΠΕΛΑΓΟΥΣ ΠΟΥ ΒΡΙΣΚΟΝΤΑΙ ΕΝΤΟΣ ΤΗΣ ΕΛΛΗΝΙΚΗΣ ΑΠΟΚΛΕΙΣΤΙΚΗΣ ΟΙΚΟΝΟΜΙΚΗΣ ΖΩΝΗΣ (Α.Ο.Ζ.)

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ΠΕΡΙΛΗΨΗ

Με βάση την υπάρχουσα τεχνογνωσία η εκτίμηση των πιθανών αποθεμάτων φυσικού αερίου της λεκάνης του Λεβάντε ανέρχεται, κατά την Γεωλογική Υπηρεσία των ΗΠΑ, σε περίπου 3,5 Τρις Μ3. Ήδη στην Αποκλειστική Οικονομική Ζώνη (ΑΟΖ) του Ισραήλ μια ποσότητα των 800 Δις Μ3 φυσικού αερίου έχει ανακαλυφθεί στα πεδία Marie B, Gaza Marine, Yam ½, Levathian, Dalit και Tamar. Σύντομα, στο Κυπριακό τμήμα της λεκάνης του Λεβάντε θα γίνει μία γεώτρηση για την ανακάλυψη και την εκμετάλλευση του στόχου στο αντίκλινο Cyprus A. Λόγω της γεωλογικής ομοιότητας με το γειτονικό πεδίο φυσικού αερίου Tamar, εκτιμάται ότι θα μπορούσε να περικλείει απόθεμα φυσικού αερίου της τάξης, τουλάχιστον, των 300 Δις Μ3 και ύπαρξης αποθέματος αργού πετρελαίου, με πιθανότητα 17%, της τάξης των 3 Δις βαρελιών

Επίσης, κατά το U.S.G.S., τα πιθανά και τεχνικώς απολήψιμα, με τις σημερινές τεχνολογίες, αποθέματα φυσικού αερίου της Κυπριακής λεκάνης του Ηροδότου και του κώνου του Νείλου εκτιμήθηκαν, σε 6.3 Τρις Μ3, πέραν των βεβαιωμένων κοιτασμάτων φυσικού αερίου, της Αιγύπτου, που ανέρχονται σε 2.2 Τρις Μ3 και του αργού πετρελαίου που ανέρχονται σε 1.7 Δις. βαρέλια. Επιπροσθέτως, στην ίδια περιοχή εκτιμάται, κατά το U.S.G.S., ότι υπάρχουν αποθέματα αργού πετρελαίου της τάξης των 1,7 Δις βαρελιών και συμπυκνώματα αέριων υδρογονανθράκων της τάξης των 6 Δις βαρελιών. Τα πιθανά και τεχνικώς απολήψιμα με τις σημερινές τεχνολογίες αποθέματα φυσικού αερίου που υπάρχουν στην Κυπριακή Αποκλειστική Οικονομική Ζώνη, ανέρχονται σύμφωνα με την BEICIP/ FRANLAB και το IFP (Institut Francais du Petrole) σε περίπου 3 Τρις Μ3.

Τα πιθανά, και τεχνικώς απολήψιμα με τις σημερινές τεχνολογίες, αποθέματα φυσικού αερίου που ευρίσκονται στο τμήμα της λεκάνης του Ηροδότου που εντοπίζεται εντός της ατακτοποίητης ακόμη Ελληνικής Αποκλειστικής Οικονομικής Ζώνης (Ε.Α.Ο.Ζ.) εκτιμώνται, από το IFP -λόγω της γεωλογικής ομοιότητας με τα τμήματα της λεκάνης του Ηροδότου που βρίσκονται στην Κυπριακή & την Αιγυπτιακή Αποκλειστική Οικονομική Ζώνη- σε 1 έως & 3 Τρις Μ3. Τα πιθανά και τεχνικώς απολήψιμα με τις σημερινές τεχνολογίες αποθέματα φυσικού αερίου που ευρίσκονται νοτίως και νοτιοδυτικά της Κρήτης και εντός της Ε.Α.Ο.Ζ., όπου υπάρχει πλήθος λασποηφαιστείων που εκλύουν φυσικό αέριο με ταυτόχρονη παρουσία στο βυθό υδριτών στα σημεία συμβολής της Αφρικανικής Πλάκας με την Ελληνική, δεν έχουν ακόμη εκτιμηθεί. Σημειώνουμε ότι στον Κώνο του Νείλου η ύπαρξη 7 λασποηφαιστείων συνοδεύεται από ήδη ανακαλυφθέντα 126 κοιτάσματα φυσικού αερίου με αποδεδειγμένα αποθέματα προς εκμετάλλευση 1,8 Τρις Μ3. Με βάση αυτή την αναλογία λασποηφαιστείων/φυσικού αερίου ένα απόθεμα της τάξης των 1,5 Τρις Μ3 φυσικού αερίου γύρω από τα λασποηφαίστεια της Κρήτης είναι πολύ πιθανόν. Με δεδομένη δε αυτή την πραγματικότητα θα έπρεπε ήδη η Ελλάδα να είχε προχωρήσει σε ενέργειες που θα επέτρεπαν την πραγματοποίηση εκτεταμένων γεωφυσικών και γεωλογικών μελετών του Λιβυκού Πελάγους (νότια, νοτιοανατολικά & νοτιοδυτικά της Κρήτης) τα στοιχεία των οποίων θα μπορούσαν να αξιολογηθούν άμεσα από ξένα η/και Ελληνικά Ιδρύματα.

Αυτά τα πολύ μεγάλα αποθέματα υδρογονανθράκων, κυρίως φυσικού αερίου, που υπάρχουν στην Ανατολική Μεσόγειο μπορούν τελικά μέσομακροπρόθεσμα να λύσουν το τεράστιο ενεργειακό έλλειμμα σε αργό πετρέλαιο και φυσικό αέριο που υπάρχει και προβλέπεται σύντομα να αντιμετωπίσει η Ευρωπαϊκή Ένωση πριν το 2020.

Λέξεις Κλειδιά : Υδρογονάνθρακες, λασποηφαίστεια, Κρήτη, Ανατολική Μεσόγειος

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