THE OCCURRENCE OF CONVERGING PLATES, MUD FLOW VOLCANOES AND ACCRETIONARY PRISM COMPLEXES IN THE MEDITERRANEAN RIDGE. THEIR RELATIONSHIP TO POSSIBLE HYDROCARBON ACCUMULATIONS OFFSHORE CRETE. A NEW RESPECTIVE FOR GREECE'S OIL AND NATURAL GAS RESOURCES.

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Abstract

Evaluation of geological and geochemical data acquired since 1985 from scientists working in the Libyan Sea indicate the possible existence of large hydrocarbon deposits in an area of 80.000 km^2, which is equivalent to the Levantine Basin (combined EEZ of Israel, Lebanon and Syria). These indicators are:

1. The converging plates which host the 20% of the World's Giant Hydrocarbon Fields. Henceforth, the possibility of having large hydrocarbon deposits under Crete should be investigated.
2. A large number of accretionary prisms which are encountered within the Mediterranean Ridge. Accretionary prisms throughout the world- are indicative of hydrocarbon fields. Therefore, the existence of large hydrocarbon deposits underneath Crete should be the subject of intensive research.
3. Throughout the world active mud flow volcanoes are associated with hydrocarbon occurrences. Underneath Crete, there are a large number of active mud flow volcanoes. As a result, a thorough investigation can reveal medium to large oil fields.
4. Geochemical analysis of emitted methane bubbles from active mud flow volcanoes indicate that their origin is thermogenic. Hence, working petroleum systems are encountered at depths.
5. Based upon geological and geophysical data, scientists have identified offshore Crete 2 major anticlines, an abyssal plain and 7 backstop basin-trenches as possible hydrocarbon plays.
6. Based upon the geological similarities and their vast experience in both the Eastern Mediterranean and West Timor Trough, Petroleum Geoservices (PGS) have suggested that the southern basin of Crete is equivalent to the Levantine basin.

Key words: converging plates, accretionary prisms, active mud flow volcanoes, geochemistry of methane bubbles, hydrocarbon potential exploration, offshore Crete

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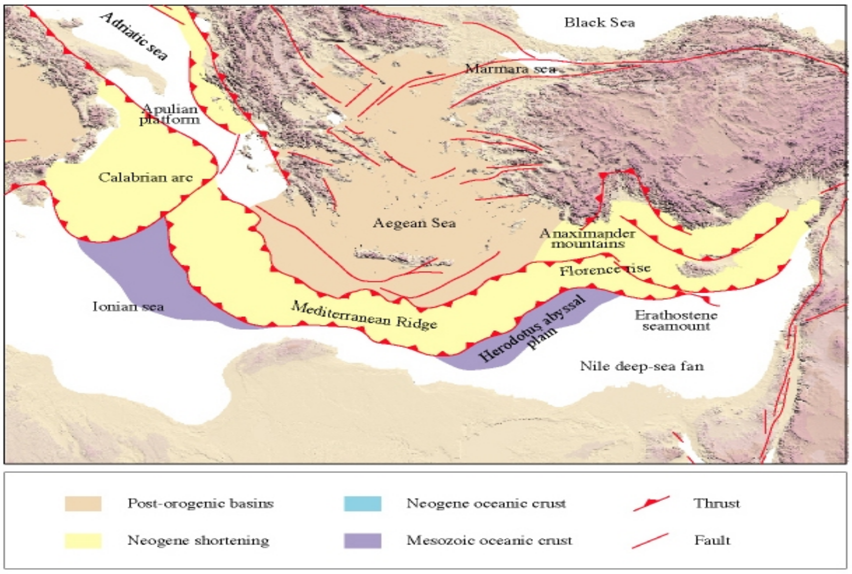
Introduction

In the Libyan Sea, offshore southern Crete, there are 2 areas which may turn out to be of big interest as far as hydrocarbon exploration is concerned. The first one is the Herodotus basin and the other one is the Mediterranean Ridge (Fig. 1).



Tectonic sketch of the Eastern Mediterranean
(adapted from Barrier, E., Chamot-Rooke, N. and Giordano, G., 2004,
Geodynamic Map of the Mediterranean, Commission for The Geological Map of the World, CCGM)

Fig. 1: Tectonic sketch of the Eastern Mediterranean showing:
a) the Mediterranean Ridge and b) the Abyssal Herodotus basin. (Barrier *et al.*, 2004)

The hydrocarbon potential of the Greek portion of the Herodotus basin is already discussed in detail by Bruneton *et al.*, 2011. The geodynamic regime of the Eastern Mediterranean which leads to the evolution of the Mediterranean Ridge is discussed in detail by MacKenzie, 1972, Minster and Jordan, 1978, Le Pichon, 1982, Ryan *et al.*, 1982, Meulenkamp *et al.*, 1988, Jackson, 1994, Oral *et. al.*, 1995, Ten Veen and Mejer, 1998, Cocard *et al.*, 1999, Papazachos, 1999, 2002, McClusky *et al.*, 2000, Knapmayer and Harges, 2000, Huguen *et al.*, 2001, Μουντράκης, 2001, Hollenstein *et al.*, 2002, McClusky *et al.*, 2003, Παπαζάχος και Παπαζάχος, 2003, Ten Veen and Kleinspehn, 2003, Kreemer and Chamot-Rooke, 2004, Reilinger *et al.*, 2004 and Pavlaki, 2006.

The afore-mentioned scientists have indicated that in the wider area of Crete there is an active geodynamic system that is characterized by the motion of two converging plates: the Eurasian and the African. The Arabian plate moving counterclockwise is pushing westward the Anatolian plate which in turn pushes southward the Aegean plate (Fig. 2). It is this interaction of the plates which causes the prerequisites for hydrocarbon accumulation to exist, namely the confluence of reservoirs, source rocks and a way of getting the oil and gas generated from these source rocks into the reservoirs and keeping them there, which is trapping them, (Kanasewich and Havskow, 1978). In converging plates we usually find large hydrocarbon deposits (Thompson, 1976, Carmalt and St. John, 1986).

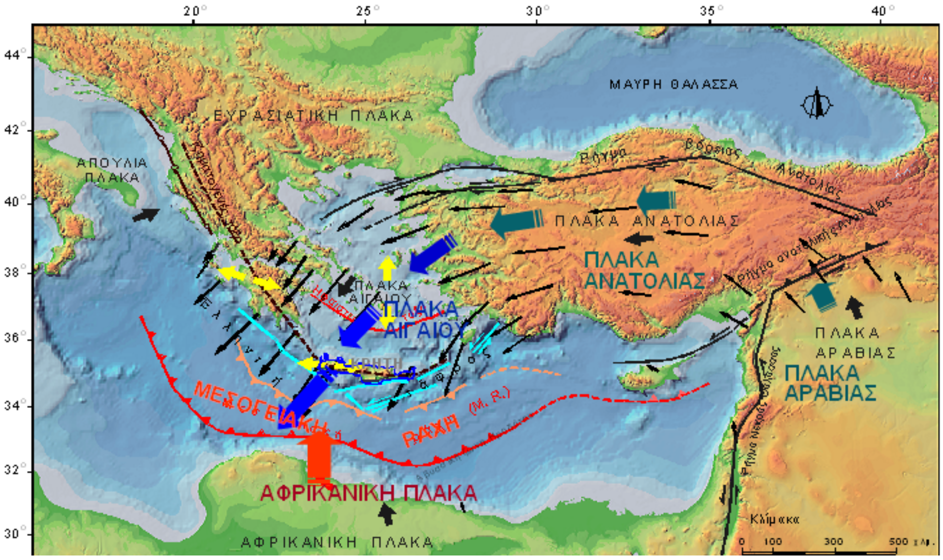


Fig. 2: The geodynamic regime of the wider area of Crete and Eastern Mediterranean.
Arabian plate is pushing counterclockwise the Anatolian plate which in turn pushes sideways the Aegean plate.
The latter overrides the African plate which subducts under the island of Crete. (Pavlaki, 2006)

In the Eastern Mediterranean the compressional forces are also responsible for the formation of an underwater ridge, the so called Mediterranean Ridge (Fig. 3). This ridge is forming an accretionary complex whose rate of increase is the fastest in the world (Kopf *et al.*, 2003).

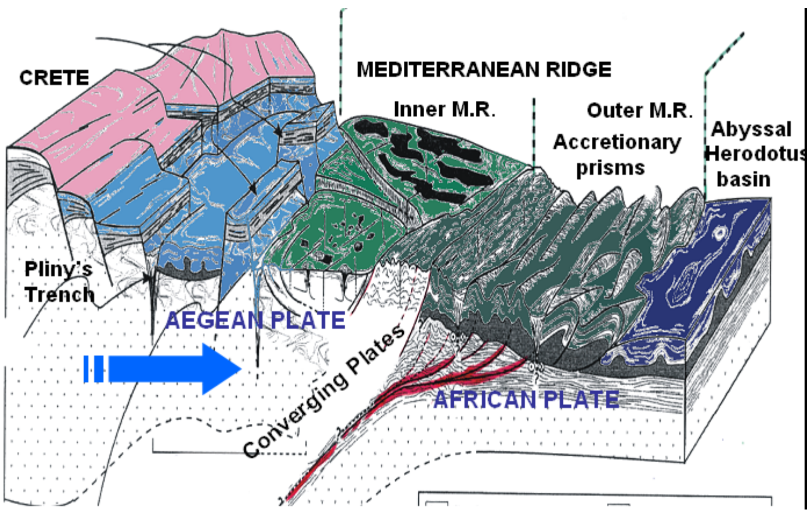


Fig. 3: Conversion of the African plate with the Aegean plate south of Crete
in the region of Eastern Mediterranean. Distortion of the wider sub-Sea region.
Formation of trenches and the Mediterranean Ridge. (Pavlaki, 2006).

Mediterranean Ridge

The Mediterranean Ridge (Fig. 5) starts from the western part of the island of Lefkas in the Ionian Sea, bends around the island of Crete and ends roughly south of the island of Kastellorizo following the subduction of the African Plate underneath the Aegean Plate (Fig. 4).

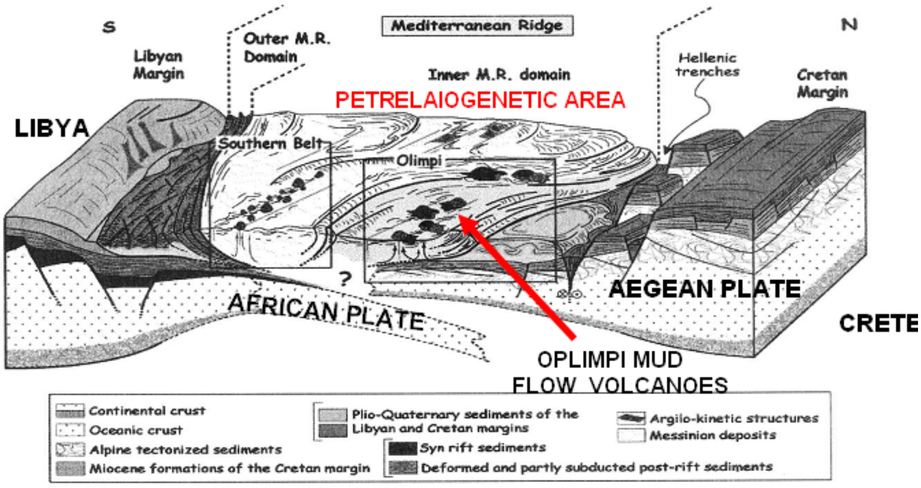


Fig. 4: Interpretative 3D tectonic sketch of the Central Mediterranean Ridge, the Olimpi and the Southern Belt mud fields. Two different source levels are proposed for the two mud fields, the Olimpi field being related to relatively shallow mud formations with high fluid contents and the Southern field being connected to deeper mud sources with lower fluid contents. (Huguen *et al.*, 2005)

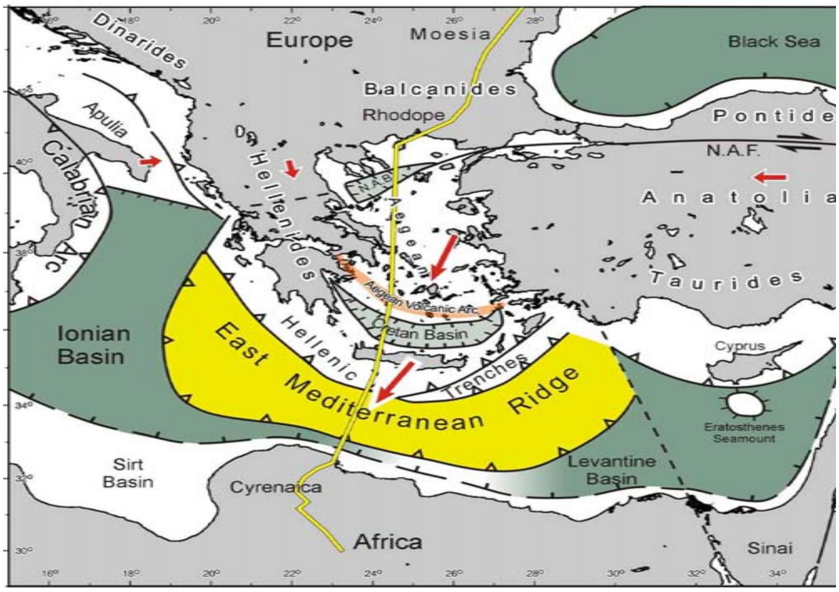


Fig. 5: The Mediterranean Ridge and the main geotectonic features in Eastern Mediterranean and its wider area of the Transmediterranean Section (Transmed. VII), from Moesia till Cyrenaica. (Papanicolaou *et al.*, 2004)

Within this ridge there are 2 possible hydrocarbon indicators. The first is the existence of over 60 mud flow volcanoes along the subduction zone (Fig. 6) and the second is the occurrence of a large number of accretionary prism complexes (Fig. 7, Fig. 8).

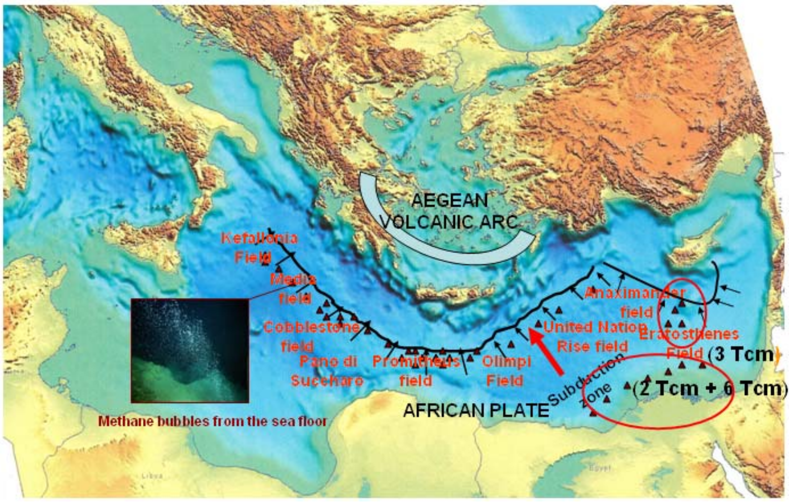


Fig. 6: Location of mud flow volcanoes in the subduction zone along with the location of the Aegean volcanic arc. Location of the mud flow volcanoes in the Nile cone and the EEZ of Cyprus. In parenthesis the anticipated amount of natural gas to be found. (modified after Dimitrov, 2002)

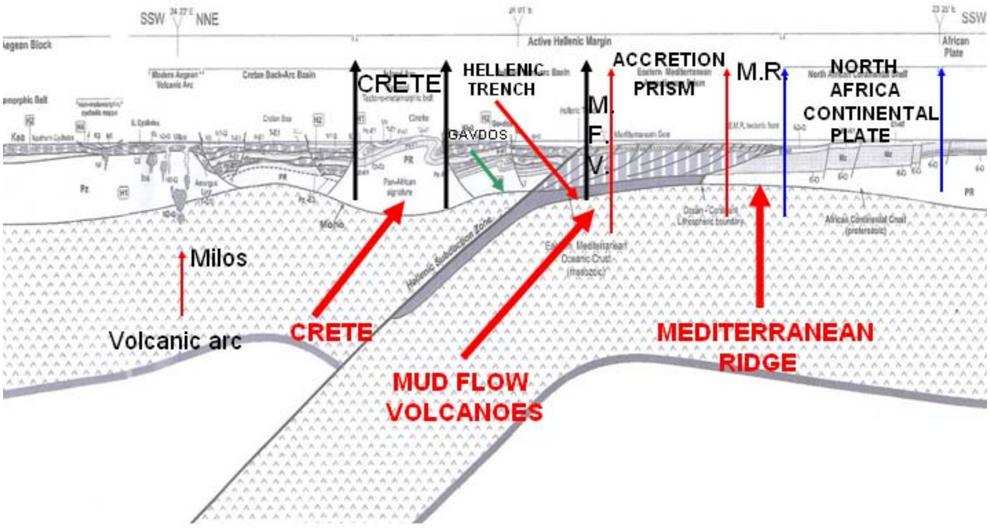


Fig. 7: Portion of the Transmediterranean section (Transmed. VII) starting from Cyrenaica and ending in the Aegean volcanic arc. (Papanicolaou *et al.*, 2004 from Gavazza *et al.*, 2004)

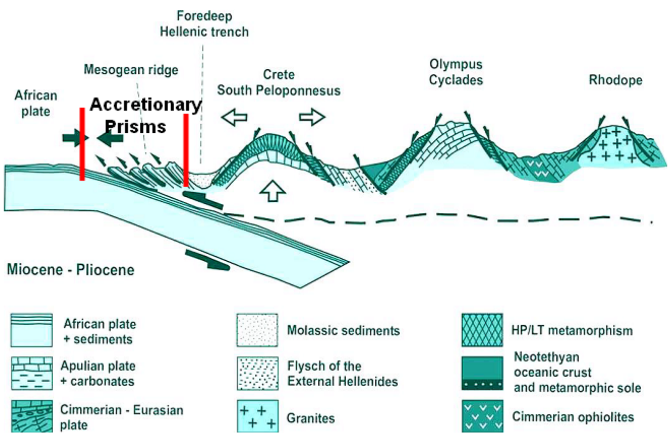


Fig. 8: Schematic representation of the geodynamic process which created the Hellenides during the Mediterranean orogenesis and its tectonic migration impact which affected the new subduction zone underneath Crete. (Mountrakis, 2001, Pavlaki, 2006)

Mud Flow Volcanoes

Mud flow volcanoes within the Greek Exclusive Economic Zone (EEZ) have been and still are emitting natural gas bubbles for more than 1 million years. A portion of these gases, after travelling through the sea water, are lost in the air (Fig. 9). Another portion is converted to gas hydrates (Fig. 10) and another small fraction is consumed by methane bacteria.

Fig. 9: Methane bubbles from the bottom of the Mediterranean Sea. (www.energybulletin.net/node/51517 - Cached - Similar)

Fig. 10: Hydrate from the Thessaloniki mud flow volcano of Anaximander mountains, Eastern Mediterranean. (Lykousis *et al.*, 2004)

The area covered by the gas hydrates is close to 200,000 Km^2 and the volume is roughly calculated at 30 trillion m^3 (assuming an average thickness of 150 meters) (Fig. 11). Roughly, 1% of this volume are hydrates, that is 0.30 trillion m^3. This value should be multiplied by 170 m^3 of natural gas / 1m^3 of hydrate in order to equate it to the conventional natural gas value (Massari, 2009). This implies that we have the equivalent of 51 trillion m^3 of natural gas which is a huge amount.

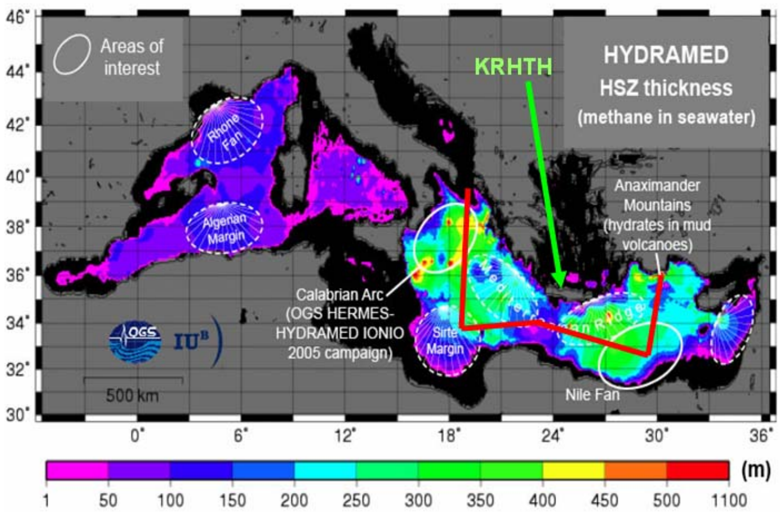


Fig. 11: Hydrate thicknesses in the Mediterranean Sea (red line denotes Greece's EEZ). (Praeg *et al.*, 2007).

Geochemical analysis of the bubbles, which takes into account the ratio of methane/ethane$^+$, have indicated that the origin of these bubbles is due to the pyrolysis of hydrocarbons that reside at depth. If the ratio of $C1/C2^+$ is far less than 100, then this is considered as strong evidence that the gas is thermogenic in origin, whereas if the same ratio is far in excess of 100, the gas is considered biogenic microbial in origin (Robinson *et al.*, 1996, Cronin *et al.*, 1997, Robertson and Kopf, 1998, Deyhle and Kopf, 2012) (Fig. 12, Fig. 13).

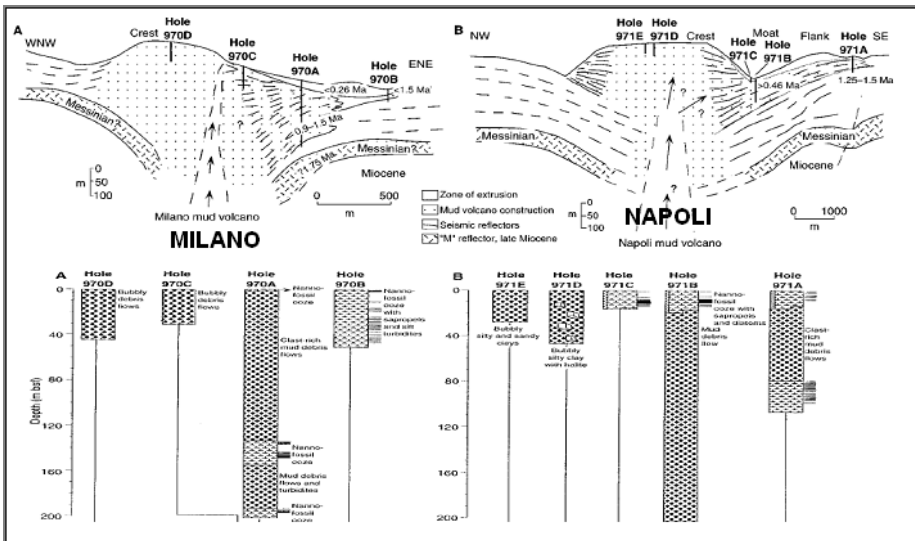


Fig. 12: Pockmarks, gas seeps and the discovery of gas hydrates indicate that the surrounding area is also actively degassing through a vent zone, of which the mud volcanoes are a part. The presence of thermogenic gas is inferred from the ratio of methane to heavier hydrocarbon gases indicating a deep source of origin.
(Cronin *et al.*, 1997, Robinson *et al.*, 1996)

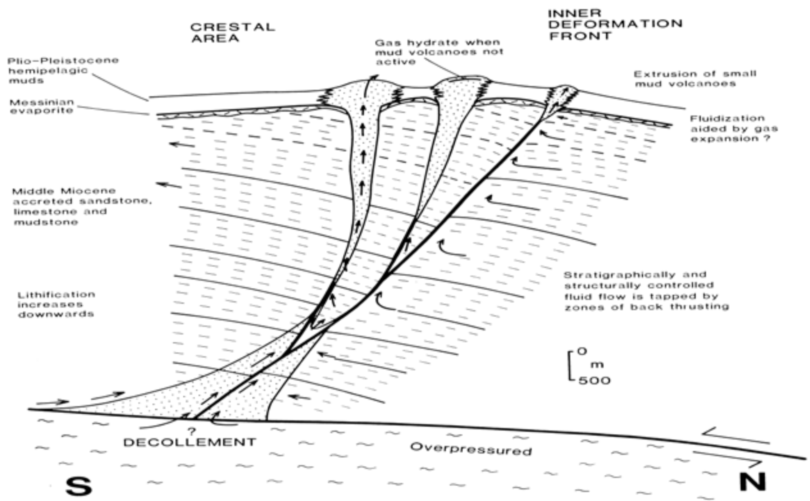


Fig. 13: Revised model of mud volcanism on the Mediterranean Ridge accretionary complex, supported by petrographic and mineralogic data from Leg.160. Mud volcanism was initiated >1 Ma ago, following collision of the to the Mediterranean ridge accretionary complex with a promontory of the North African passive continental margin. (Robertson and Kopf, 1998)

Gas hydrate analysis in shallow deposits of the Amsterdam mud volcano, Anaximander Mountains, Northeastern Mediterranean Sea showed also a prevalence of thermogenic light hydrocarbons as inferred from C_1/C_{2+} ratios <35 and $\delta^{13}C$-CH_4 values of -50,60/00 (Pape *et al.*, 2010) (Fig. 14, Fig. 15).

Also using the isotope signature of hydrocarbon gases, $\delta^{13}C$-CH_4 < $\delta^{13}C$-C_2H_8 along with the ratio of CH_4/C_2H_6, Toki *et al.* (2006) have established that the origin of hydrocarbons in the Sagara oil field in central Japan is thermogenic.

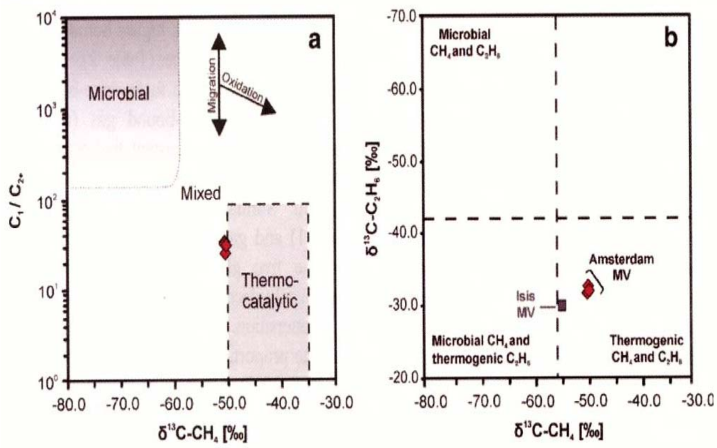


Fig. 14: The relation of C_1/C_{2+} vs $\delta^{13}C\text{-}CH_4$ ($^0/_{00}$) and $\delta^{13}C\text{-}C_2H_6$ ($^0/_{00}$) vs $\delta^{13}C\text{-}CH_4$ ($^0/_{00}$) in Amsterdam Mud Flow Volcano, Anaximander Mountain, indicating the thermogenic origin of methane bubbles. (Pape *et al.*, 2010)

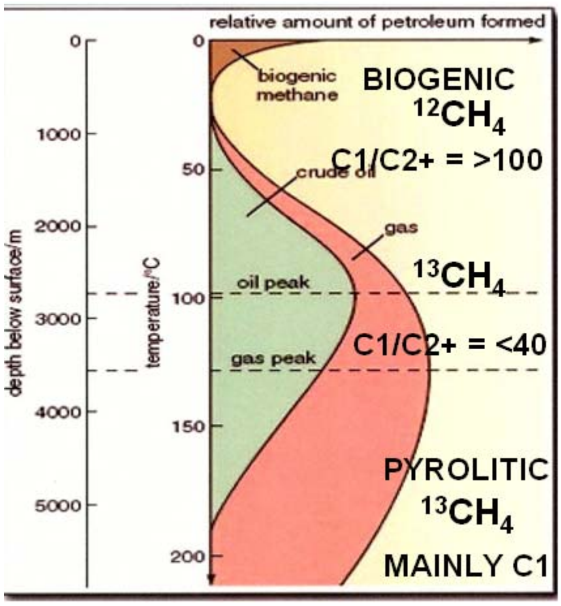


Fig. 15: Generation of gases from organic matter with increasing temperature. (Buruss and Laughrey, 2009)

Ranges of gas composition corresponding to (i) bacterial gas, (ii) thermogenic oil-associated gas, (iii) dry post–mature thermogenic gas and (iv) gas of mixed biogenic/thermogenic origin have been defined, facilitating the interpretation of gas compositional data by Schoell 1983, 1988, Faber *et al.*, 1992, Whiticar, 1994 and Buruss and Laughrey, 2009.

Some thermogenic bubbles are covered with a liquid hydrocarbon sleeve and upon their arrival on the water surface they explode and leave an oil slick. This slick grows when similar bubbles arrive at the water surface. This phenomenon is visible from satellites (Roberts and Peace 2007) (Fig. 16). These analyses, along with the occurrence of oil slicks, lead to the existence of working petroleum systems at depth. Pyrolysis of saturates and/or aromatics of oil occur at 180°C. A geothermal gradient of 33°C/1000 meters implies that oil petroleum systems occur at a depth of around 3500 to 4500 meters (Loncke *et al.*, 2004) (Fig. 17). The same is observed also in block 05 of Cyprus EEZ (Fig. 18).

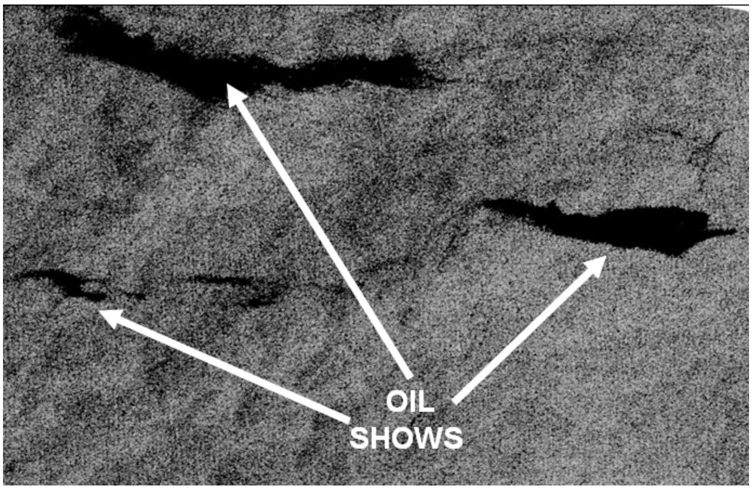


Fig. 16: Oil films resulting from escaping gas bubbles which are coated with oil. Gas bubbles are derived from Active Mud Volcanoes in offshore Nile Cone, Egypt. Picture is taken from satellites. (Roberts and Peace, 2007)

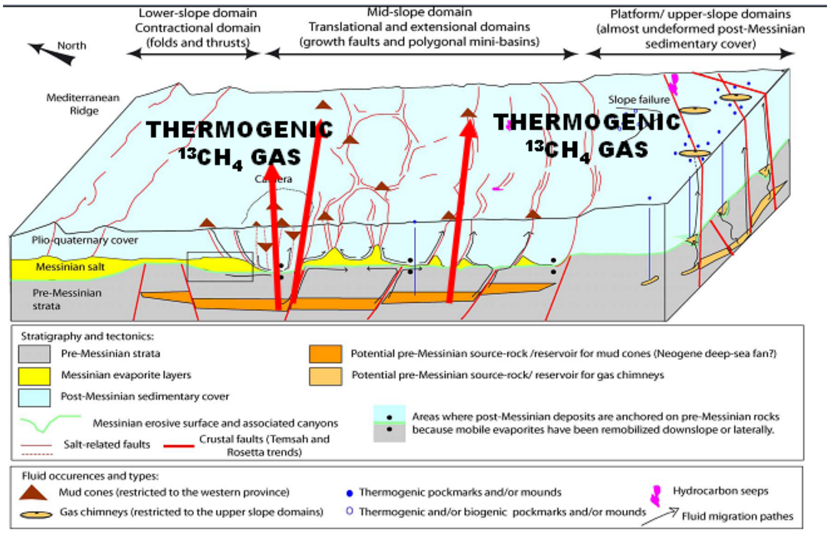


Fig. 17: Active Mud Flow Volcanoes (brown triangles), Gas chimneys (brown discs), Thermogenic Pockmarks and Mounds offshore Southern Crete. The pre-Messinian source rocks/reservoir for the mud cones (brown) are highly visible as well as the reservoir/source for the gas chimneys (light brown) are also visible.
(Loncke *et al.*, 2004)

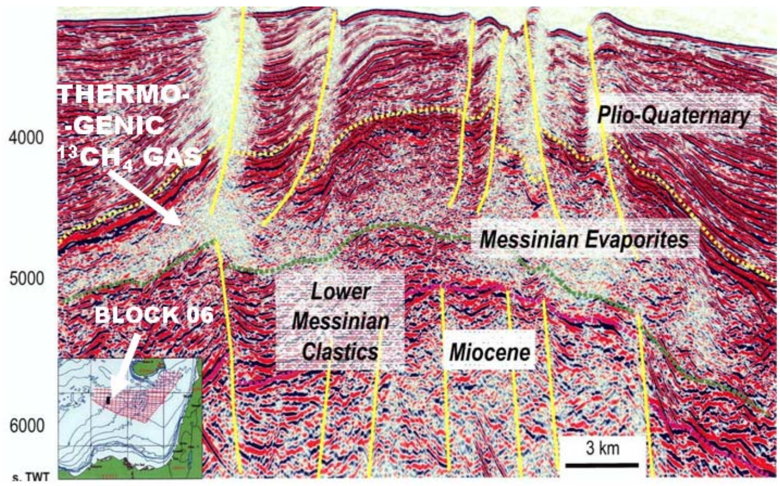


Fig. 18: Large anticline on the toe of deep Nile delta fan with Messinian low-stand delta clastic sand faulted pre-Messinian. Gas chimneys are highly visible. (Montadert and Nikolaides, 2010)

Hydrocarbon analysis on mud samples around mud flow volcanoes taken during the ODP (Ocean Drilling Program, Leg 160) indicates the presence of an active hydrocarbon system at depth (Robertson and Kopf 1998).

The geochemical data along with the immense volumes of hydrates that lie in the bottom of the Mediterranean sea (50 trillion m^3 of natural gas is equivalent to 328 billion barrels of oil) raises the question of how much organic matter was imbedded in the sediments in order to be converted through diagenesis to kerogen, subsequently to oil and finally upon pyrolysis to methane bubbles. This organic matter, probably phytoplankton, was buried in pre-Messinian sediments at depths of more than 5000 meters in order to produce pyrolytic methane**,** $^{13}CH_4$. Thus, the origin of methane gases can not be attributed to post Messinian sediments. The huge amounts of organic matter is most likely phytoplankton accumulated since the creation of Tethys Sea, that is, since the end of the Jurassic, beginning of the Cretaceous, some 165 million years ago. Tethys during the mid-Messinian was a shallow sea (Fig. 19) with temperatures similar to tropical ones. This type of climate was responsible for the production of large quantities of organic matter which upon burial and diagenesis generated huge amounts of oil and gas.

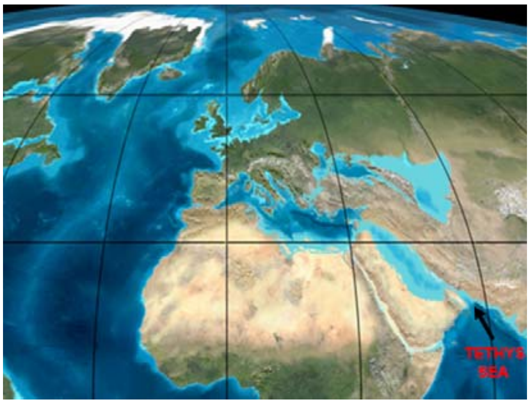


Fig. 19: The geology of North Africa and Southern Europe during Mid Miocene. (Scotese, 2000)

Hydrocarbon generating conditions in offshore Crete and the Eastern Mediterranean were akin to those of Saudi Arabia and all the states of the Persian Gulf (Fig. 20, Fig. 21). One has to remember that during the Cretaceous era the Persian Gulf was the inlet of the Tethys Sea passing through the Mediterranean to meet the Atlantic Ocean.

Fig. 20: Modern world. (Scotese, 2000)

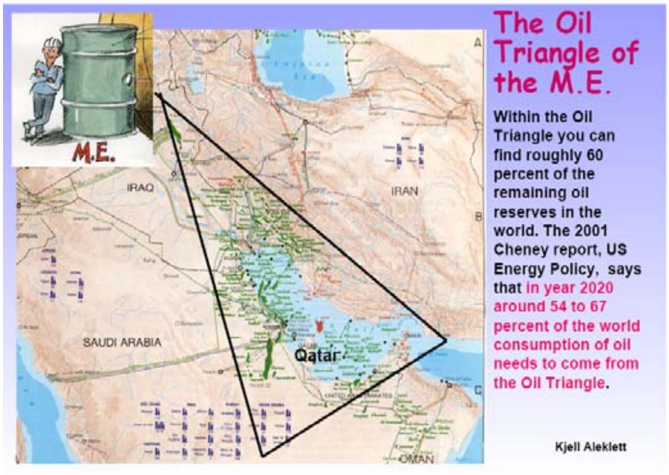


Fig. 21: The Middle East Oil Triangle. (Aleklett. 2004)

Another source of organic matter which upon diagenesis can generate hydrocarbons are sponges, Hahn et. al.,1988. Very large colonies of fossilized sponges are encountered in the metamorphosed plattenkalk of Outer Hellenides which are present in Peloponnese and Crete, Μανούτσογλου, 2004.

The correlation between mud flow volcanoes and hydrocarbon discoveries can be seen in both the Egyptian and the Cypriot EEZ, Fig. 22 and Fig. 23 respectively. More correlations are reported by Bruneton *et al.* (2011). Also, the role of mud volcanoes in petroleum systems can be easily seen in Timor, South Caspian and the Caribbean Seas (Ware and Ichram, 1997).

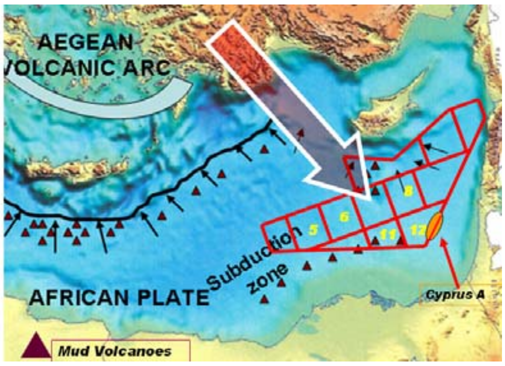


Fig. 22: Occurrence of mud flow volcanoes and hydrocarbon reservoirs in the Nile Cone and EEZ of Cyprus. (Modified by E. Konophagos from Dupre *et al.*, 2008 and Robertson, 1996)

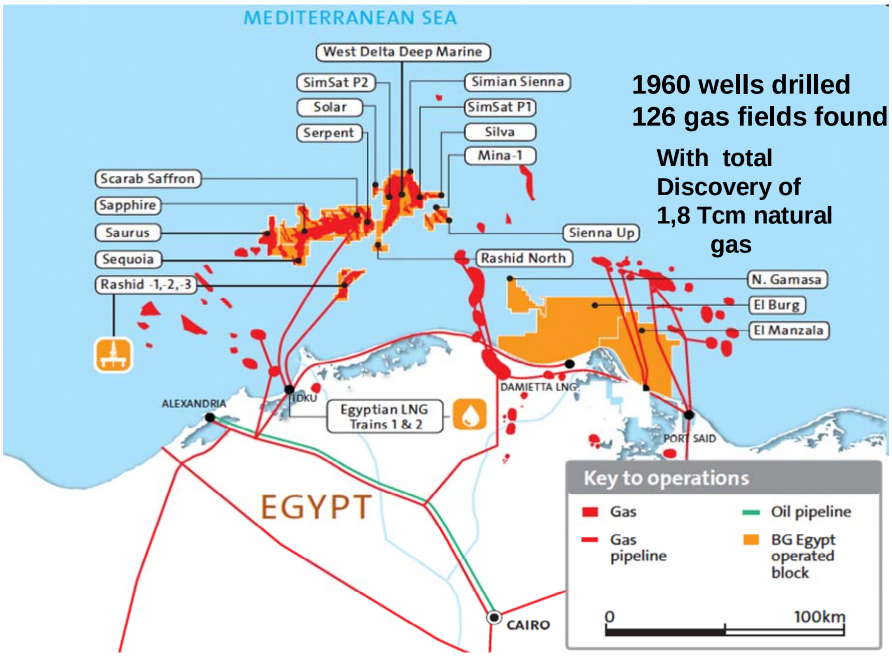


Fig. 23: Distribution of natural gas reservoirs offshore Egypt. (Neftgaz-EU, 2010, Rigzone, 2010)

Accretionary prism complexes

An accretionary prism is an individual structure which can have one oil or gas field. In extremely compressed areas, faulting defines individual structures and individual oil and gas fields. The compression shape does not provide us with giant gas fields. However, the total accumulated reserves in all structures can be enormous. A different situation can exist in places with less compressional stresses or extensional areas[1]. Accretionary prisms are underexplored for hydrocarbons and may hold large quantities of hydrocarbon reserves (Barbados accretionary prism in Dolan *et al.*, 2004, Escalona *et al.*, 2008, Persad, 2008), (Makran accretionary prism, Pakistan in Ellouz-Zimmerman *et al.*, 2007, Hairms *et al.*, 1982), (Peru margin characterized by oceanic/continental plate collision with accretionary prisms in Klein *et al.*, 2011), (West Timor trough in Jones *et al.*, 2011), (Irrawaddy-Andaman accretionary prism in Wandrey, 2006). In the Mediterranean Ridge, accretionary prism complexes occupy an area of over 80.000 km^2 (Fig. 24) and starts offshore west of the island of Kefallinia, travels along western Peloponnese, goes underneath Crete ending offshore the island of Cyprus. This area is worth exploring for hydrocarbon deposits since out of 877 giant oil and gas fields which exist on land and offshore, while 71 are encountered within the accretionarry prisms (Mann *et al.*, 2003).

[1] Personal communiqué with Lucien Montadert, petroleum geologist BEICIP/FRANLAB

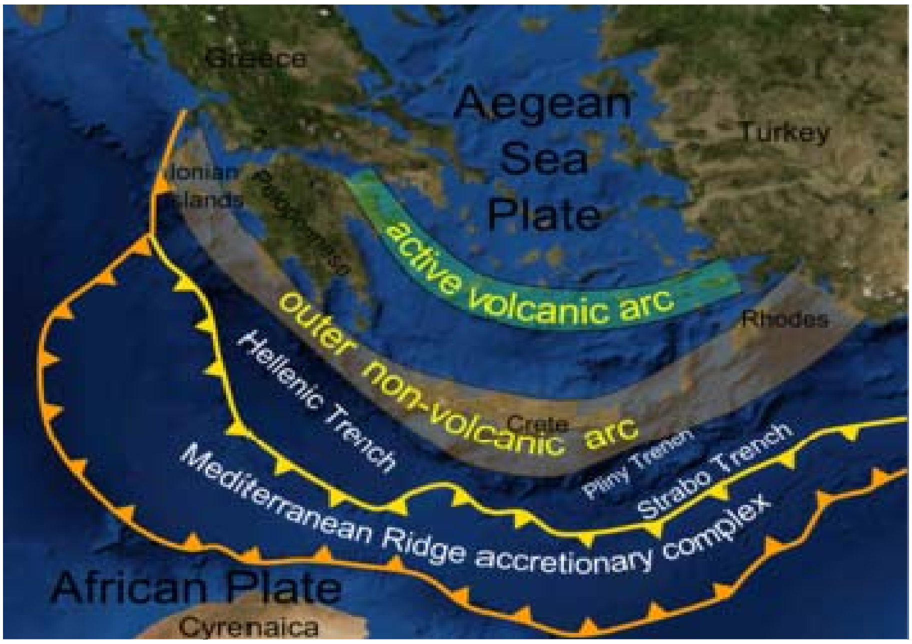


Fig. 24: The area covered by the Mediterranean Ridge accretionary prisms. Its implication for potential hydrocarbon reserves. (en. Wikipedia org/…./Mediterranean Rid…)

Hydrocarbon Potential within the Mediterranean Ridge

Though there is substantial geophysical information concerning the offshore geology of Crete (Astrium, EADS Co. in Fig. 25, PGS information in Fig. 26), these data are unavailable to Greek scientists. However, Zelilidis (2011) and Maravelis *et al.* (2012) using data from Leite and Mascle (1982), Truffert *et al.* (1993) and Kokinou *et al.* (2006) have identified the stratigraphy, the geological evolutionary stages and basin configurations offshore Crete which lead to possible hydrocarbon fields consisting mainly of gas.

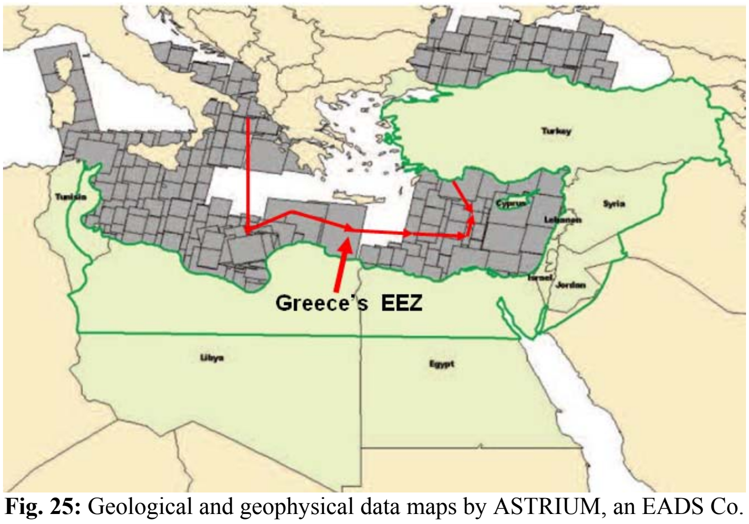


Fig. 25: Geological and geophysical data maps by ASTRIUM, an EADS Co. (https://webmail.isc.tuc.gr/exchweb/bin/redir.asp?URL=http://www.astrium-geo.com/en/222-east-mediteranean)

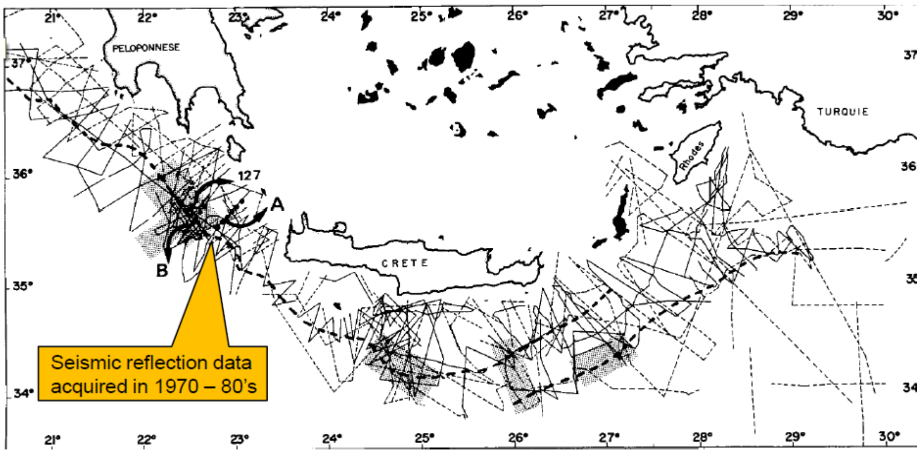


Fig. 26: Robinson, J. PGS Multi-Client presentation at Ministry of Energy and Climatic Changes. (YPEKA, Athens, Greece, July 2011).

The possible areas are 2 major anticlines and an abyssal plain, while another 7 backstop basins-trenches represent possible hydrocarbon plays (Fig. 27, Fig. 28 and Fig. 29). Also, Robinson (2011) of Petroleum Geoservices (PGS), during his oral presentation at the Department of Energy and Climatic Changes (YPEKA), showed from the point of hydrocarbon prospectivity that the southern basin of Crete is very similar to the West Timor Trough (Jones et al., 2011) as well as to the Levantine basin (Fig. 30, Fig. 31). PGS is very familiar with Levantine basin. The fact that USGS (Technical Report 2010) has assessed the Levantine Basin to have, on 50% chance, 123 trillion cubic feet of natural gas and 1,7 billion barrels of gas condensate creates a very favorable climate for hydrocarbon exploration in offshore Crete. Zelilidis (2011) and Maravelis *et al.* (2012) have also concluded that there are several potential hydrocarbon plays as well as structural and stratigraphic traps. The same belief is shared also by Robinson (2011).

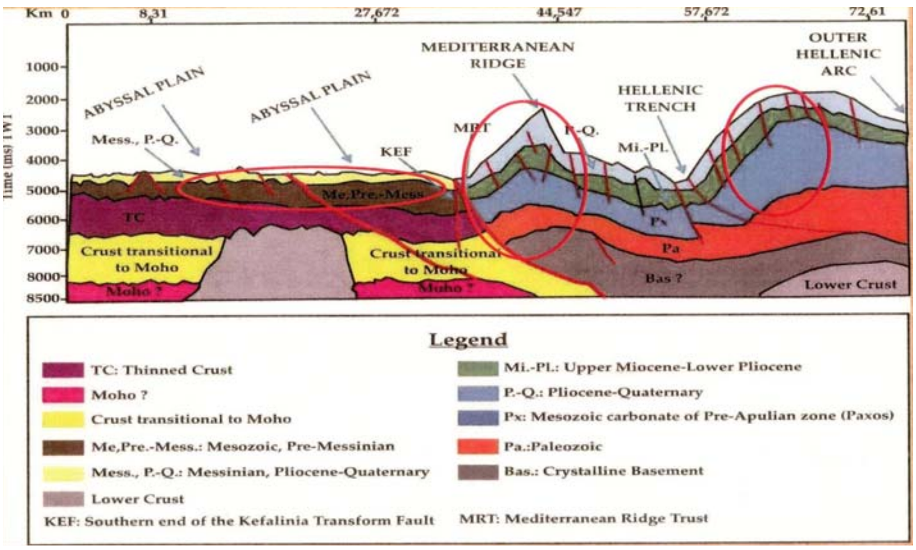


Fig. 27: Possible hydrocarbon plays offshore southern Crete: a) two major anticlines (ellipsoidal red circles) and the Hellenic trench, 2 km below sea level, b) abyssal plain (oval red circle). (Zelilidis, 2011)

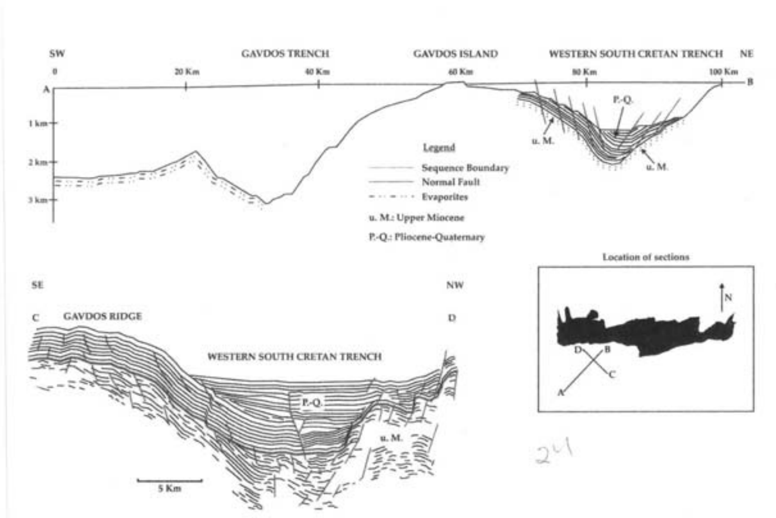


Fig. 28: Example from the six backstop basins southward of Crete (Gavdos, Gortys, Poseidon, Ptolemeus, Pliny and Stravon trenches). Interpretation of seismic reflection profiles across the western south Cretan trench, P.Q. recent sedimentary cover, u.M. Miocene evaporite and related tectonics. (Maravelis *et al.*, 2012)

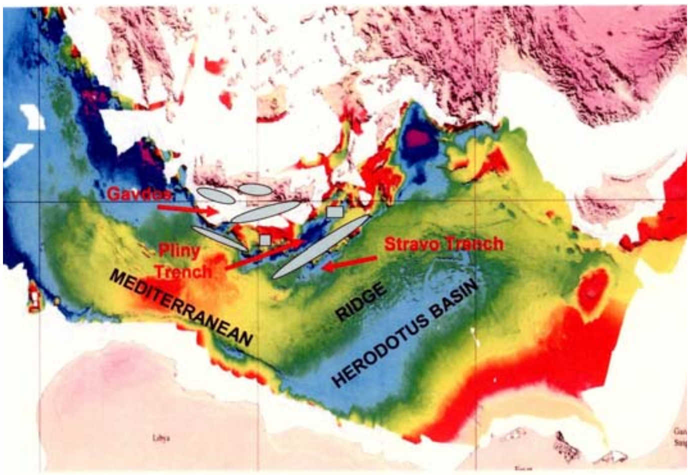


Fig. 29: Hydrocarbon Fields (pale blue schemes) offshore Crete, according to Maravelis *et al.*, 2012.

Play Name	Prinos	Ionian	S. Mediter.	Cretan Sea
Source	Miocene Shale	Neogene Shales	Cretaceous – Palaeogene Shales	Miocene Shale
Reservoir	Miocene Turbidites	Pliocene Turbidites	Miocene – Pliocene Turbidites	Miocene Deltaics
Seal	Miocene Evaporites	Pliocene Shales	Miocene Evaporites	Miocene Evaporites / Pliocene Shales
Trap	Structural	Stratigraphic	Stratigraphic	Combination
Type Basin	Prinos	Ionian	Levantine	Cretan

Fig. 30: Source rocks, Reservoirs, Seals, Traps and Type basins. Presentation of PGS by J. Robinson at the ministry of Energy and Climatic Changes, Athens, Greece (YPEKA), 2011.

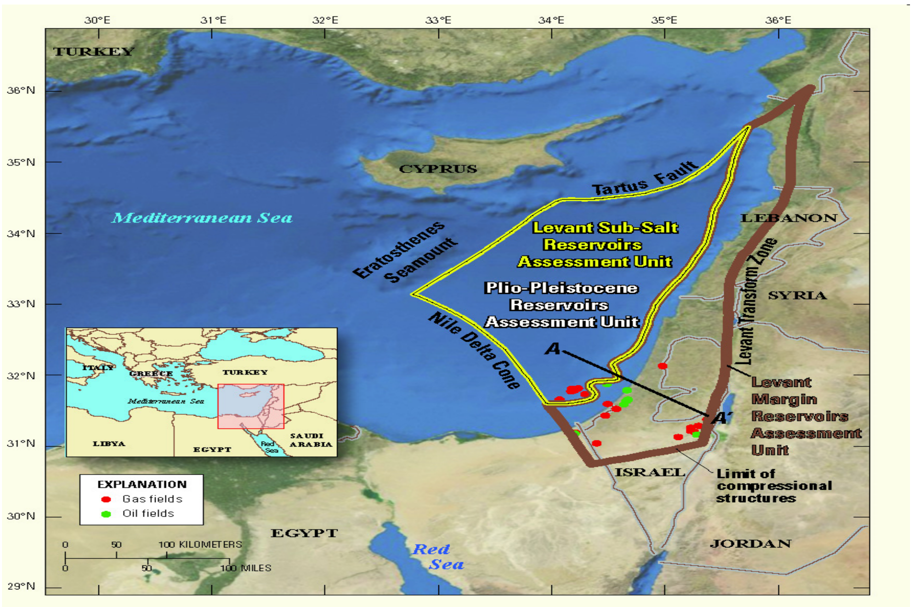


Fig. 31: The Levantine Basin with its recent oil and gas discoveries. Assessed potential for further discoveries of natural gas 122 tcf (3,45 tcm) and oil 1,7 billion barrels. (USGS Technical Report, 2010)

Conclusions

1. Converging plates host large hydrocarbon fields. In the Eastern Mediterranean, the Aegean plate overrides the African plate underneath the island of Crete. Henceforth, the possibility of having large hydrocarbon deposits should be investigated by carrying high quality 2D but specifically 3D geophysical surveys in order to determine the depth and size of the hydrocarbon fields
2. Accretionary prisms, throughout the world (Barbados, Makran, Irrawaddy-Andaman, West Timor trough) are indicative of giant hydrocarbon deposits. A large number of accretionary prisms are encountered within the Mediterranean Ridge whose length is over 1000 km. Hence, the existence of large to giant hydrocarbon deposits should be the subject of intense exploration research by carrying high quality 2D but specifically 3D geophysical surveys in order to determine the depth and size of the hydrocarbon fields
3. Active mud flow volcanoes are associated, throughout the world, with hydrocarbon occurrences (Timor, South Caspian Sea, the Caribbean Sea, Egypt and Cyprus). Underneath Crete, at the point where the African plate submerges, there are a large number of active mud flow volcanoes, pockmarks and pipenecks emitting methane for thousands of years. As a result a thorough investigation could reveal giant oil fields.
4. Geochemical analysis of emitted methane bubbles from active mud flow volcanoes indicates that their origin is thermogenic. This implies that pyrolysis or better thermal cracking of hydrocarbons takes place at depth where temperatures are 160^{o}C to 180^{o}C. Based upon a geothermal gradient of 33^{o}C/1000 meters, pyrolysis should take place at a depth between 5000 to 5500 meters. Hence, working petroleum systems are encountered at depth while the thickness of the sediments, below sea level, is over 5000 meters.

5. Hydrocarbon analysis on mud samples around mud flow volcanoes taken during the Ocean Drilling Program (ODP) indicates again the presence of an active hydrocarbon system at depth.
6. Based upon geological and geophysical data, Greek scientists have identified offshore Crete within the Mediterranean Ridge 2 major anticlines, an abyssal plain and 7 backstop basin-trenches as possible hydrocarbon plays.
7. Based upon the geological similarities and their vast experience in both the Eastern Mediterranean and the West Timor trough, Petroleum Geoservices (PGS) have suggested that the Southern basin of Crete is equivalent to the Levantine basin. This result implies that the potential to discover natural gas and oil in offshore Crete is very strong.

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ΟΙ ΣΥΓΚΛΙΝΟΥΣΕΣ ΛΙΘΟΣΦΑΙΡΙΚΕΣ ΠΛΑΚΕΣ ΚΑΙ Η ΤΑΥΤΟΧΡΟΝΗ ΥΠΑΡΞΗ ΠΡΙΣΜΑΤΩΝ ΠΡΟΣΑΥΞΗΣΗΣ ΚΑΙ ΛΑΣΠΟΗΦΑΙΣΤΕΙΩΝ ΣΤΗΝ ΜΕΣΟΓΕΙΑΚΗ ΡΑΧΗ ΩΣ ΔΕΙΚΤΕΣ ΥΠΑΡΞΗΣ ΚΟΙΤΑΣΜΑΤΩΝ ΥΔΡΟΓΟΝΑΝΘΡΑΚΩΝ ΣΤΗΝ ΠΑΡΑΚΤΙΑ ΝΟΤΙΑ ΚΡΗΤΗ. ΝΕΕΣ ΠΡΟΟΠΤΙΚΕΣ ΕΝΤΟΠΙΣΜΟΥ ΚΟΙΤΑΣΜΑΤΩΝ ΥΔΡΟΓΟΝΑΝΘΡΑΚΩΝ ΣΤΗΝ ΕΛΛΑΔΑ.

ΦΩΣΚΟΛΟΣ, Α.[1], ΚΟΝΟΦΑΓΟΣ, Η.[2], BRUNETON, A.[3]

Περίληψη

1. Στα σημεία σύγκλισης των λιθοσφαιρικών πλακών υπάρχουν γιγαντιαία κοιτάσματα υδρογονανθράκων π.χ. στην κατάδυση της δυτικής λιθοσφαιρικής πλάκας του Βόρειου Ατλαντικού κάτω από την Βόρειο Αμερική (Καναδάς, ΗΠΑ) και της ανατολικής κάτω από την Ευρασιατική, στην κατάδυση της δυτικής λιθοσφαιρικής πλάκας του νότιου Ατλαντικού κάτω από την Νότια Αμερική (Βραζιλία) και της ανατολικής κάτω από την Δυτική Αφρική (Νιγηρία, Αγκόλα). Το ίδιο συμβαίνει και με τις λιθοσφαιρικές πλάκες του Ειρηνικού Ωκεανού και του Ινδικού Ωκεανού. Στην Ανατολική Μεσόγειο η σύγκλιση της Αιγιακής πλάκας με την Αφρικανική λαμβάνει χώρα κάτω από την Κρήτη. Άρα η ύπαρξη κοιτασμάτων υδρογονανθράκων στην υπεράκτιο νότιο Κρήτη θα πρέπει να διερευνηθεί με την χρήση δισδιάστατων, 2D, η καλλίτερα τρισδιάστατων, 3D, γεωφυσικών απεικονίσεων υψηλής ευκρίνειας για να προσδιορισθούν το βάθος και τα πεδία των υδρογονανθράκων

2. Τα πρίσματα προσαύξησης σε όλο τον κόσμο, (Barbados, Makran, Irrawaddy- Andaman, West Timor trough) είναι δείκτες ύπαρξης γιγαντιαίων κοιτασμάτων υδρογονανθράκων. Επομένως, η ύπαρξη κοιτασμάτων υδρογονανθράκων στην υπεράκτιο νότιο Κρήτη θα πρέπει να διερευνηθεί με την χρήση δισδιάστατων, 2D, η καλλίτερα τρισδιάστατων, 3D, γεωφυσικών απεικονίσεων υψηλής ευκρίνειας για να προσδιορισθούν το βάθος και τα πεδία των υδρογονανθράκων δεδομένου ότι τα προσαυξητικά πρίσματα βρίσκονται στην Μεσογειακή Ράχη που έχει μήκος πάνω από 1000 χιλιόμετρα εισερχόμενη και στην Κυπριακή ΑΟΖ

3. Ενεργά λασποηφαίστεια σε όλο τον κόσμο προδίδουν την ύπαρξη γιγαντιαίων κοιτασμάτων υδρογονανθράκων (Timor, Καραϊβική θάλασσα, Νότια Κασπία θάλασσα ήτοι Αζερμπαϊτζάν, Ιράν, Μαύρη θάλασσα, ήτοι Ρουμανία, Ρωσία και Τουρκία, Ανατολική Μεσόγειος, ήτοι Αίγυπτος, Κύπρος και Τουρκία). Επομένως, η ύπαρξη κοιτασμάτων υδρογονανθράκων στην υπεράκτιο νότιο Κρήτη θα πρέπει να διερευνηθεί δεδομένου ότι ενεργά λασποηφαίστεια βρίσκονται στην Μεσογειακή Ράχη και κατά μήκος της καταδυόμενης Αφρικανικής Πλάκας κάτω από την Αιγιακή. Μερικά από αυτά τα λασποηφαίστεια εκλύουν επί εκατοντάδες χιλιάδες χρόνια μεθάνιο με αποτέλεσμα να συσσωρευτούν 30 τρισεκ. m^3 στερεοποιημένου μεθανίου (υδρίτες) στον πυθμένα της θάλασσας που βρίσκεται εντός της Ελληνικής ΑΟΖ.
4. Γεωχημικές αναλύσεις των φυσαλίδων του μεθανίου που εκλύονται από τα ενεργά λασποηφαίστεια τα οποία απαντώνται στον υποθαλάσσιο χώρο της Κρήτης δείχνουν με σαφήνεια ότι η προέλευσή τους δεν είναι βιογενετική αλλά θερμογενετική/πυρολυτική. Αυτό σημαίνει ύπαρξη κοιτασμάτων αργού πετρελαίου του οποίου οι αλειφατικές και αρωματικές ενώσεις διασπώνται από υψηλές θερμοκρασίες με αποτέλεσμα να δημιουργείται καταγενετικό μεθάνιο. Με βάση την γεωθερμική βαθμίδα των 33^oC/1000 μέτρα, και δεδομένου ότι η πυρόλυση λαμβάνει χώρα μεταξύ 160^oC και 180^oC, τα κοιτάσματα αργού πετρελαίου πρέπει να βρίσκονται μεταξύ 5000 μέτρων και 5500 μέτρων βάθους κάτω από την επιφάνεια του βυθού της θάλασσας. Αυτά τα κοιτάσματα πρέπει να είναι όχι γιγαντιαία αλλά υπερ-γιγαντιαία για να δικαιολογήσουν το υπέρμετρο γιγαντιαίο ποσό των 30 τρις. m^3 στερεοποιημένου μεθανίου, δηλαδή των υδριτών που βρίσκεται εντός της Ελληνικής ΑΟΖ. Επομένως, η ύπαρξη κοιτασμάτων υδρογονανθράκων στην υπεράκτιο νότιο Κρήτη θα πρέπει να διερευνηθεί.

5. Σε δείγματα ιλύος που ελήφθησαν κατά την διάρκεια του προγράμματος Ocean Drilling Program (ODP) γύρω από τα ενεργά λασποηφαίστεια της Κρήτης πιστοποιήθηκε η ύπαρξη υγρών υδρογονανθράκων στα δείγματα. Και αυτή η ένδειξη μας υποδεικνύει την ύπαρξη συστήματος πετρελαιογένεσης σε μεγάλα βάθη (presence of an active hydrocarbon system at depth).

6. Με βάση τα γεωλογικά και γεωχημικά δεδομένα όπως επίσης τα πολύ λίγα γεωφυσικά στοιχεία που έχουν ορισμένοι Έλληνες καθηγητές των Πανεπιστημίων, υποδεικνύεται ότι στην υπεράκτιο νότιο Κρήτη και εντός της Μεσογειακής Ράχης υπάρχουν δύο (2) μεγάλα αντίκλινα, μία (1) αβυσσική

7. Η Νορβηγική εταιρεία γεωφυσικών ερευνών Petroleum Geoservices (PGS) με βάση τις μελέτες που έχουν γίνει νότια της Κρήτης, εν αγνοία των ελληνικών κυβερνήσεων, διαπίστωσε από την εμπειρία της με τις μελέτες που έκανε στην Ανατολική Μεσόγειο ότι υπάρχουν τεράστιες γεωλογικές ομοιότητες με την λεκάνη της Λεβαντίνης, (ΑΟΖ Ισραήλ, Συρίας και Λιβάνου) η οποία θεωρείται από την Γεωλογική Υπηρεσία των ΗΠΑ (USGS) ότι έχει 3,45 τρις. m^3 φυσικού αερίου και 1,7 δισεκ. βαρέλια αργού πετρελαίου. Άρα επιβάλλεται η έρευνα για τον εντοπισμό κοιτασμάτων υδρογονανθράκων νοτίως της Κρήτης.

Λέξεις Κλειδιά: Συγκλίνουσες λιθοσφαιρικές πλάκες, πρίσματα προσαύξης, ενεργά λασποηφαίστεια, γεωχημεία των φυσαλίδων μεθανίου, πιθανά αποθέματα υδρογονανθράκων, υπεράκτια Κρήτη.

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