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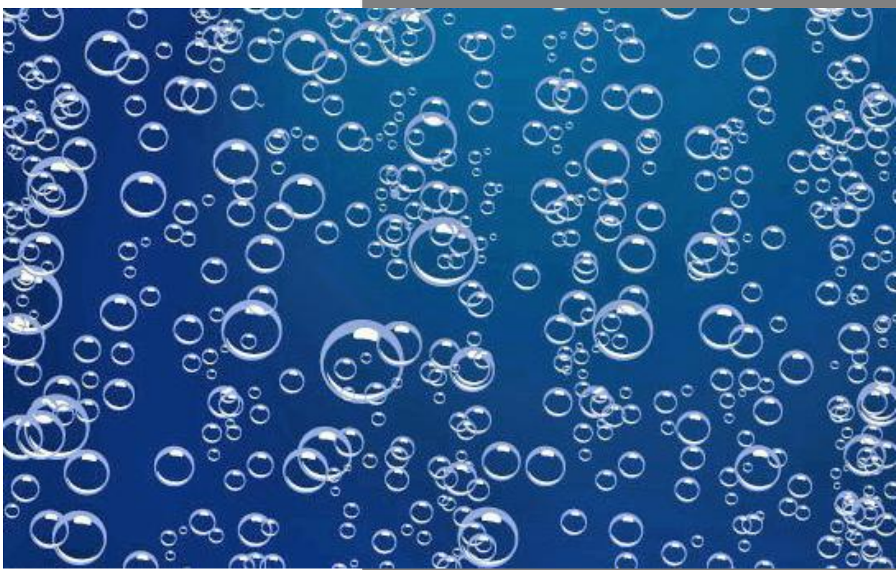
Market
Focus

March 2012

Cretan Gas Fields – A new perspective for Greece's hydrocarbon resources



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Note

The original title for this Paper first published in the Greek language was "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 perspective for Greece's oil and natural gas resources".

Acknowledgement

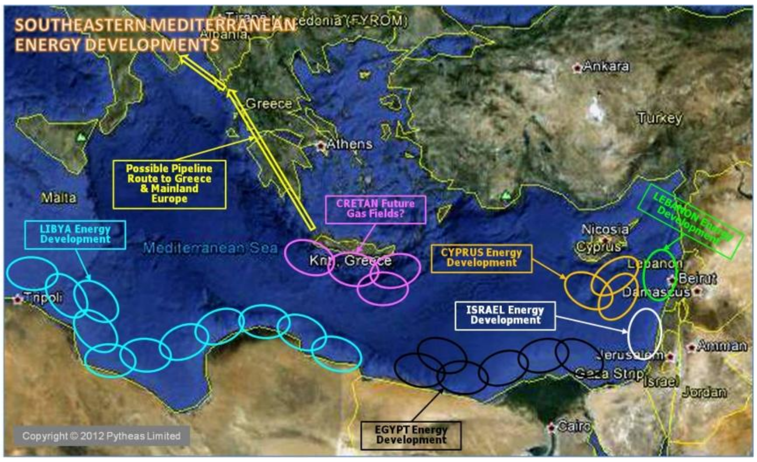
The Authors wish to thank Mrs. Rachel Robinson of the Geological Survey of Canada, Calgary for her help with the English editing of this paper.

Forward

H. A. Samaras

The Greek island of Crete, located in the South-Eastern Mediterranean, about, 300 km north of the African continent, 500 km from the newly discovered gas fields of Cyprus and 800 km from the gas fields of Israel, west of the Middle East and Asian continent, and 600 km east of mainland Europe but 90 km from mainland Greece, is not only in one of Europe's main energy corridors but valid scientific research indicates that significant oil and gas deposits must more than likely occur offshore the island.

It is no coincidence that eight of the world's biggest seismic survey companies (i.e., U.S.-based ION Geophysical, Norway-based TGS-NOPEC, Dolphin Geophysical and Petroleum Geo-Services, France's CGGVeritas, Spec Partners, Spectrum Geo and Fugro Multi Client Services) have expressed interest earlier this month in investing about US$40 million of their own capital for the exploration of hydrocarbons in Greece.



It is our pleasure and honor to publish and host a second paper produced by these world accredited scientists, Mr. Alain Bruneton, Dr. Elias Konofagos and Professor Anthony E. Foscolos. A sequel to their published in January of this year paper with the title, "The Economic and Geopolitical importance of Eastern Mediterranean gas fields for Greece and the EU", this new scientific document attempts to explain why there must be hydrocarbon deposits in the south and southwest of offshore Crete. This new work by Bruneton, Konofagos and Foscolos deducts that the envisaged hydrocarbon deposits in the aforementioned area could be substantial (possibly as substantial as those found in the Levantine Basin) and further investigation ought to be undertaken the soonest possible.

Indeed great news for the much suffering from its worst financial crisis of modern times Greece but also for the ever-starved for fuel Europe.

Pytheas maintains the opinion that Europe is currently confronted with a unique challenge and a remarkable opportunity! **The already confirmed and estimated discoveries of substantial hydrocarbon deposits in the Eastern Mediterranean** – such are those confirmed within the Exclusive Economic Zones (EEZs) of Cyprus and Israel – **along with those discussed in this Paper (which more than likely lie offshore Crete), but also elsewhere within the EEZ of Greece**, such is the area close and adjacent to Hydrocarbon Exploration Block #4 of Cyprus, **signify that for the first time ever in Europe's energy history, the EU may be guaranteed an uninterrupted supply of a traditional energy source!** A most important development (and a pan-European one) that the government of Greece has to set as priority and ensure that an appropriate framework and solid plan are put in place in order to commence investigation as quickly as possible.

The energy strategy that Greece will pursue today in regard to the "Cretan hydrocarbons" is bound to dictate its economic future and not only.

Harris A. Samaras
Chairman & CEO
PYTHEAS

30 March 2012

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, Syria and Southeast Cyprus). These indicators are:

1. Converging plates host 20% of 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 are encountered within the Mediterranean Ridge. Accretionary prisms, throughout the world are indicative of hydrocarbon fields. Therefore, the existence of large hydrocarbon deposits offshore Crete should be the subject of intense research.
3. Throughout the world active mud flow volcanoes are associated with hydrocarbon occurrences. Offshore Crete, there are a large number of active mud flow volcanoes. As a result, a thorough investigation could 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, two major anticlines, an abyssal plain and seven 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 Geo-Services (PGS) have recently suggested that the southern basin of Crete hydrocarbon reserves are equivalent to those of the Levantine basin.

1. Introduction

In the Libyan Sea, offshore southern Crete, there are two 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 is the Mediterranean Ridge (Figure 1).

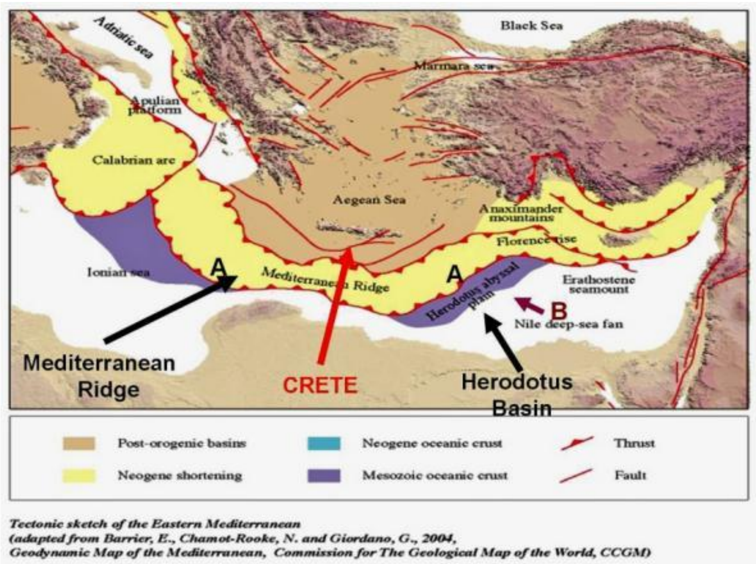


Figure 1. Tectonic sketch of the Eastern Mediterranean: A = The Mediterranean Ridge. B = The Abyssal Herodotus basin, Barrier et. al., 2004.

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 and 2002, McClusky et. al., 2000, Knapmayer and Harges, 2000, Huguen et al., 2001, Mountrakis, 2001, Hollenstein et al., 2002, McClusky et. al., 2003, Papazachos and Papazachos, 2003, Ten Veen and Kleinspehn, 2003, Kreemer and Chamot-Rooke, 2004, Reilinger et. al., 2004 and Pavlaki, 2006.

The aforementioned 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 (Figure 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, trapping them, Kanaswwich and Havskow, 1978. In converging plates we usually find large hydrocarbon deposits, Thompson, 1976, Carmalt and St John, 1986.

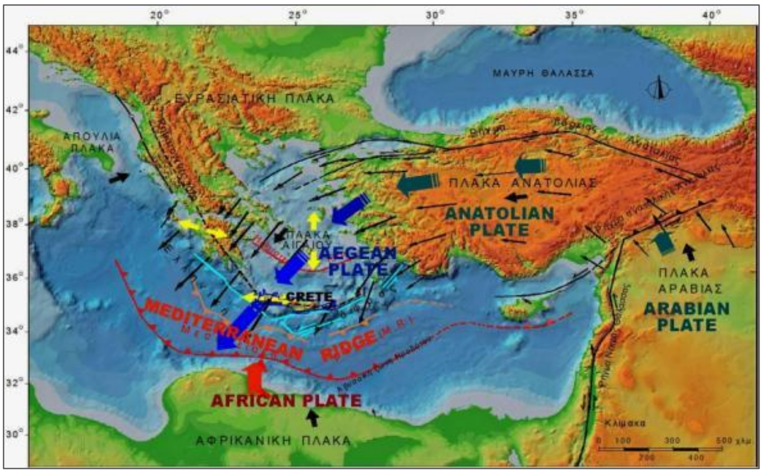


Figure 2. The geodynamic regime of the wider area of Crete and Eastern Mediterranean – The Arabian Plate pushing counterclockwise the Anatolian Plate which in turn pushes sideways the Aegean Plate; the latter overrides the African Plate which sub ducts under the island of Crete, Pavlaki, 2006.

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

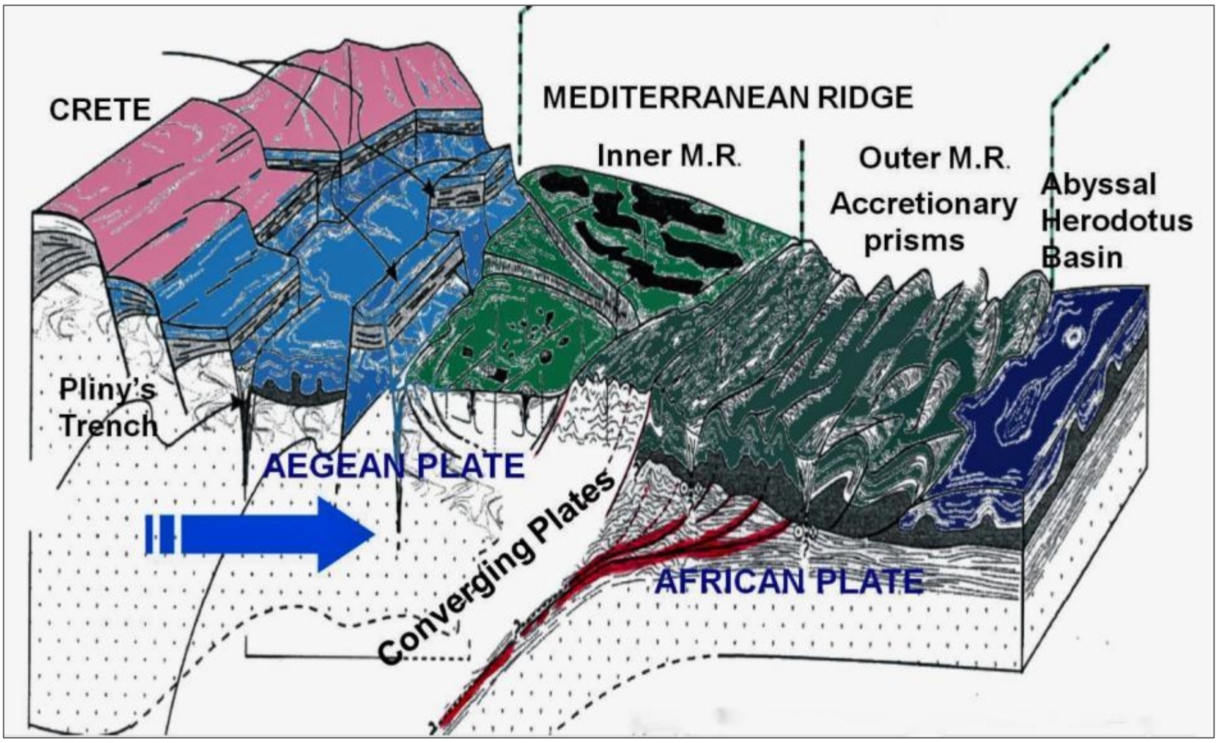


Figure 3. The Conversion of the African Plate with the Aegean Plate south of Crete in the region of Eastern Mediterranean – Distortion of the wider sub-Sea region. Formation of trenches and the Mediterranean Ridge, Pavlaki, 2006.

2. The Mediterranean Ridge

The Mediterranean Ridge (Figure 5), starts from the western part of the island of Lefkas in the Ionian Sea, it bends around the island of Crete and ends roughly south of the island of

Kastellorizo, while following the subduction of the African Plate underneath the Aegean Plate (Figure 4). Within this ridge there are two possible hydrocarbon indicators. The first is the existence of over 60 mud flow volcanoes, along the subduction zone (Figure 6). The second is the occurrence of a large number of accretionary prism complexes (Figures 7 and 8).

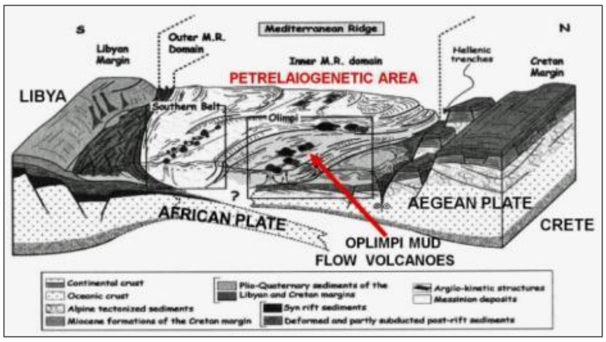


Figure 4. Interpretative 3D tectonic sketch of the Central Mediterranean Ridge and the Olimpi and the Southern Belt mud fields. Two different source levels are proposed for the two mud fields, the Olimpi field being related to relatively shallow mud formations, with high fluid contents and the Southern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

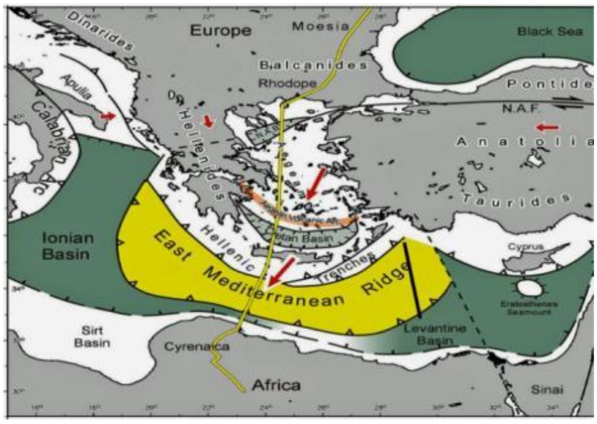


Figure 5. The Mediterranean Ridge and the main geotectonic features in Eastern Mediterranean and its wider area of the Trans-Mediterranean section (Transmed). VII0 from Moesia to Cyrenaica, Papanicolaou et. al., 2004.

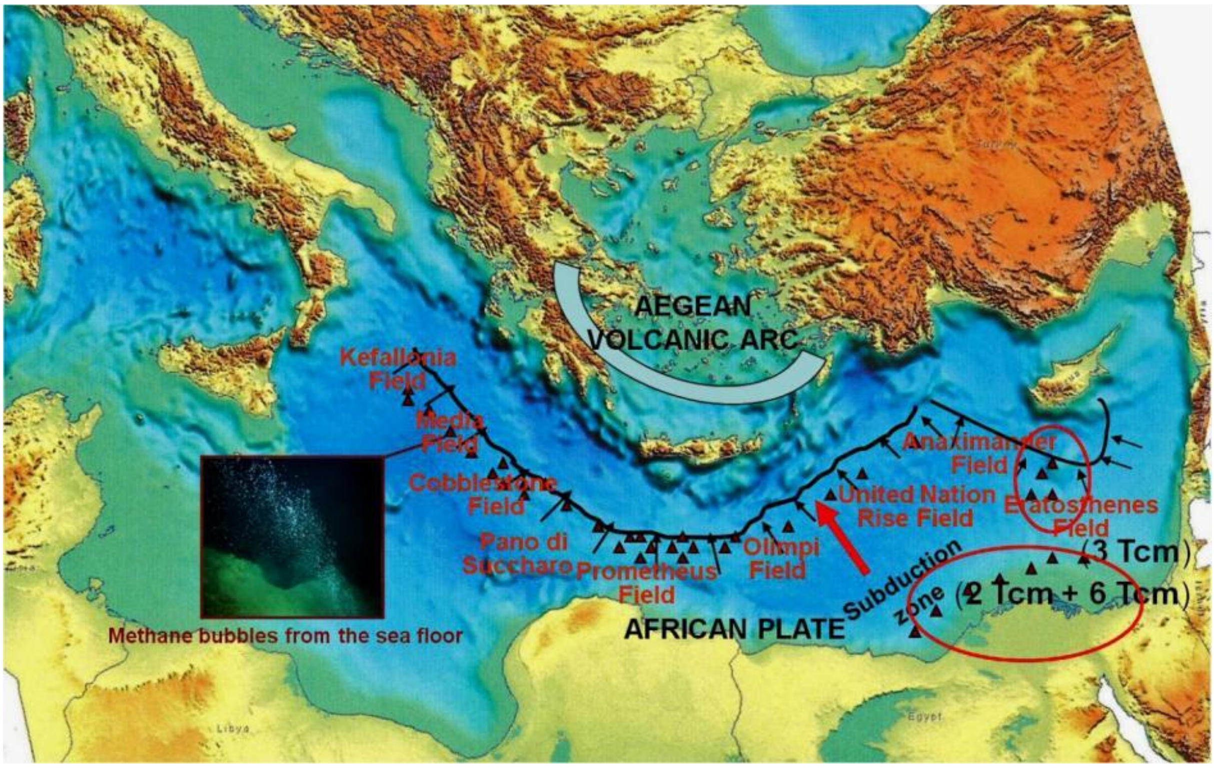


Figure 6. Location of mud flow volcanoes in the subduction zone along with the location of the Aegean Volcanic Arc – Location of the mud flow volcanoes in the Nile Cone and the Exclusive Economic Zone (EEZ) of Cyprus; within parenthesis the anticipated amount of natural gas to be found (modified after Dimitov, 2002).

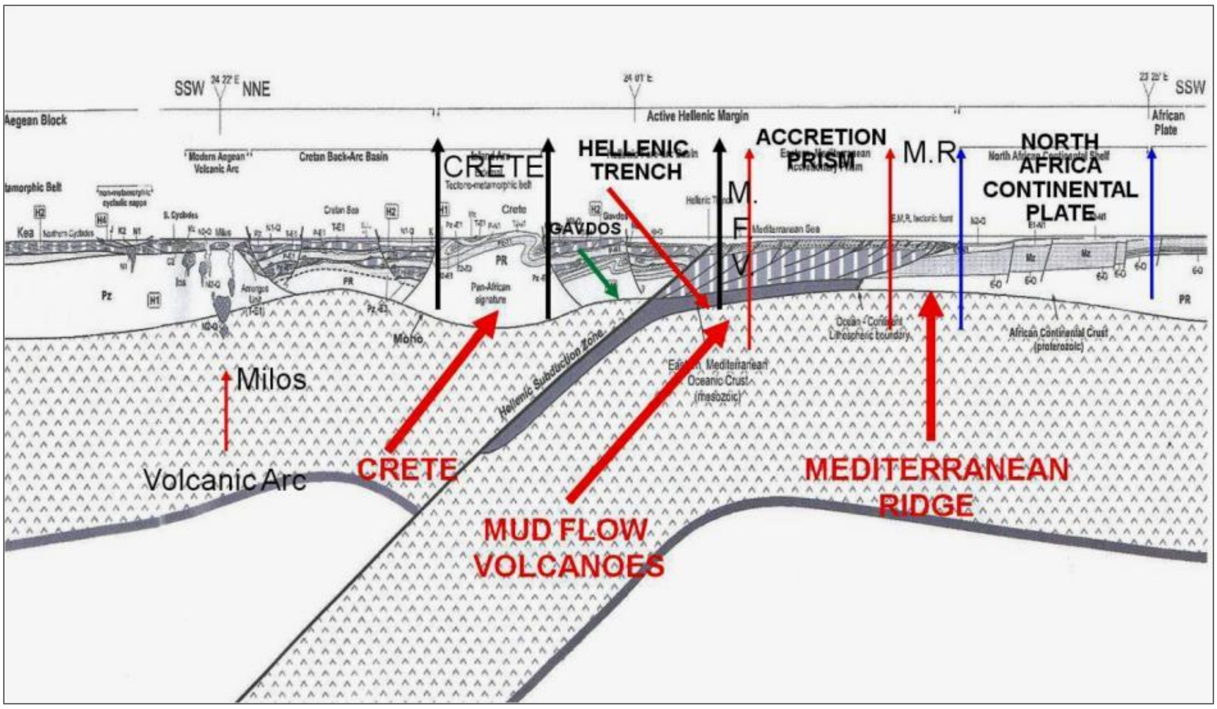


Figure 7. Portion of the Trans-Mediterranean section (Transmed VII), starting from Cyrenaica and ending in the Aegean Volcanic Arc. Papanicolaou et. al., 2004 from Gavazza et. al., 2004.

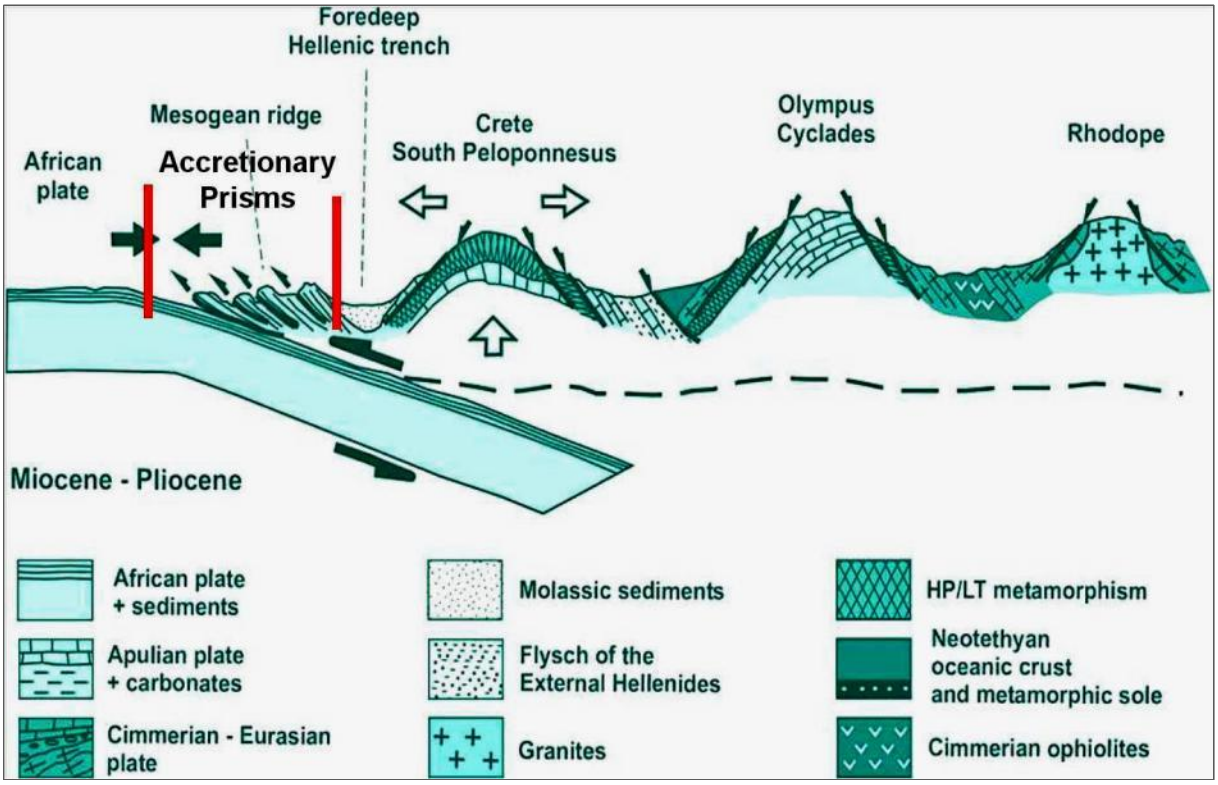


Figure 8. Schematic representation of the geodynamic process which created the Hellenides during the Mediterranean Orogenesis and its tectonic migration impact which affected the new subduction zone underneath Crete, Mountrakis 2001, Pavlaki 2006.

A. 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 (Figure 9). Another portion is converted to gas hydrates (Figure 10), and another small fraction is consumed by methane bacteria. 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 (Figure 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.

Figure 9. Methane bubbles from the bottom of the Mediterranean Sea.

Figure 10. Hydrate from the Thessaloniki mud flow volcano of Anaximander Mountains, Eastern Mediterranean, Lykousis et. al., 2004.

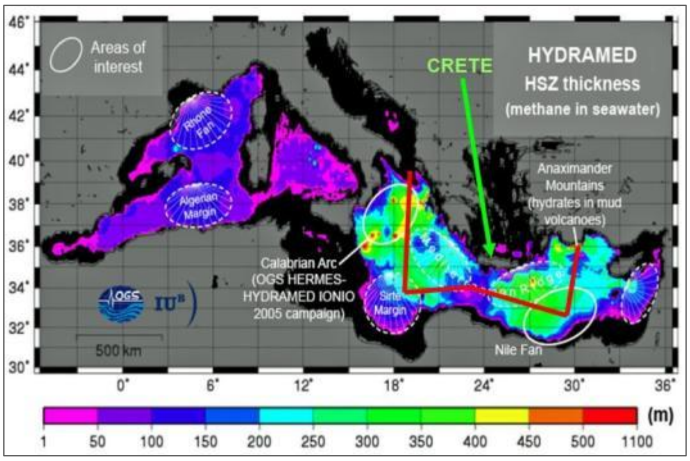


Figure 11. Hydrate thicknesses in the Mediterranean Sea, Praeg et. al., 2007. Red line denotes Greece's EEZ.

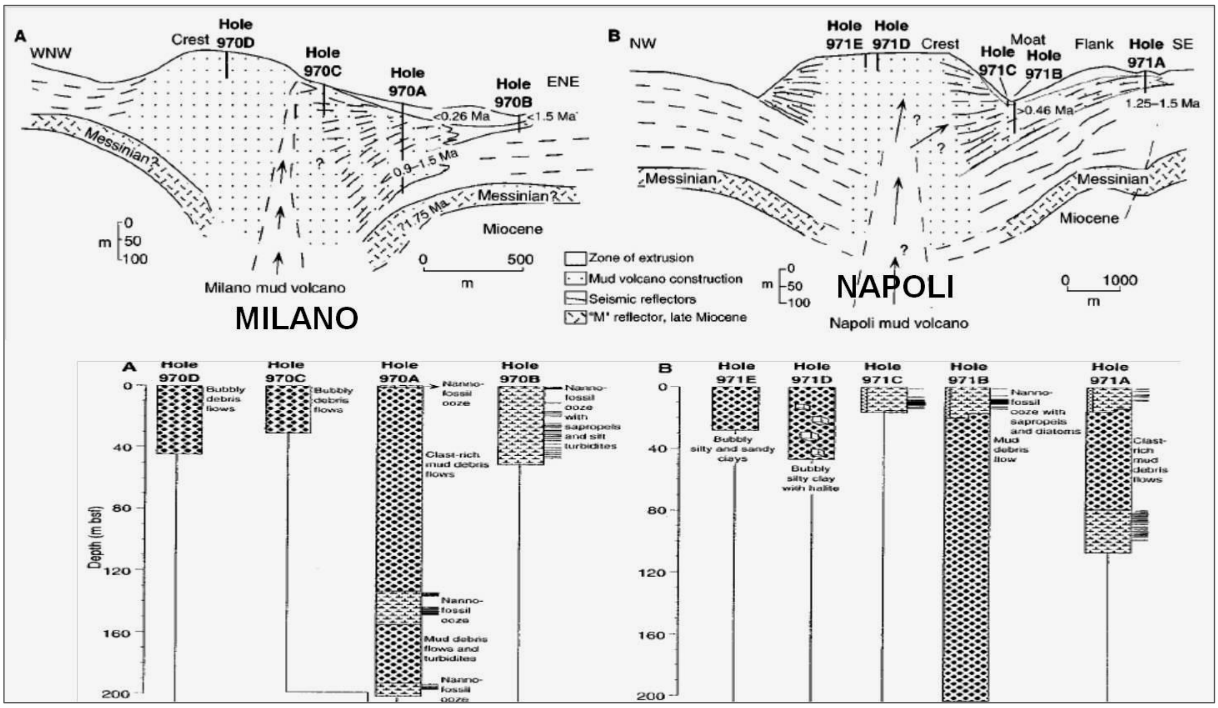


Figure 12. Pockmarks, gas seeps, and the discovery of gas hydrates indicate that the surrounding area is also actively degassing through a vent zone, of which the mud volcanoes are a part. The presence of thermogenic gas is inferred from the ratio of methane to heavier hydrocarbon gases, indicating a deep_source of origin_Cronin et al., 1997; Robinson et al., 1996.

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 (Figure 12 above), Robertson and Kopf, 1998 (Figure 13), Deyhle and Kopf, 2012. Gas hydrate analysis in shallow deposits of the Amsterdam mud volcano, Anaximander Mountains, North-Eastern Mediterranean Sea showed, also, a prevalence of thermogenic light hydrocarbons as inferred from C1/C2+ ratios < 35 and δ^{13}C- CH_4 values of -50,6$^{0}/_{00}$, Pape et al., 2010 (Figures 14 and 15).

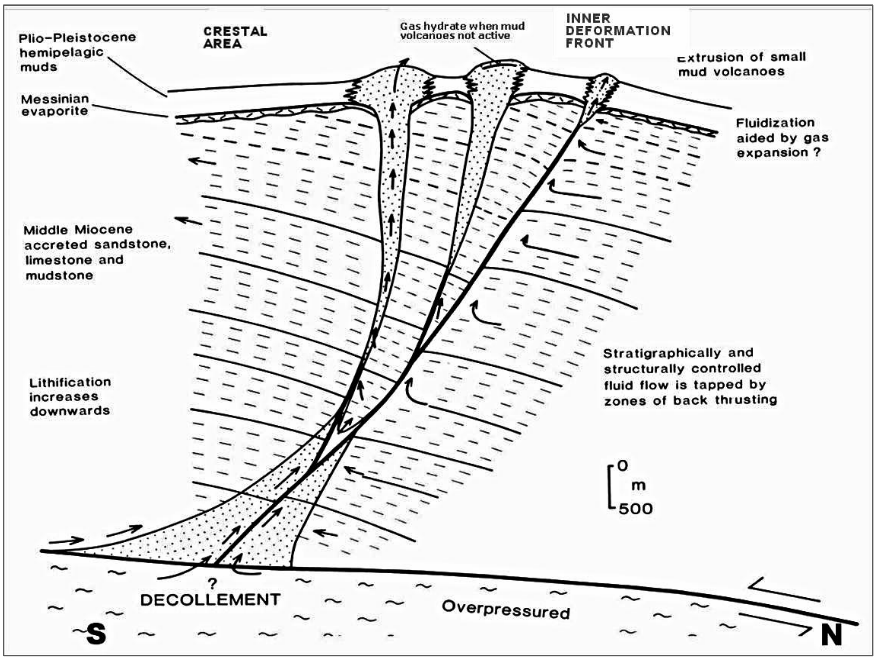


Figure 13. Revised model of mud volcanism on the Mediterranean Ridge accretionary complex, supported by petrographic and mineralogic data from Leg. 160. Mud volcanism was initiated >1 Ma ago, following collision of the to the Mediterranean Ridge accretionary complex with a promontory of the North African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

Active mud flow volcanoes are associated, throughout the world, with hydrocarbon occurrences. Offshore Crete, at the point where the African plate submerges there is a large number of active mud flow volcanoes, pockmarks and pipenecks emitting methane for thousands of years. fields

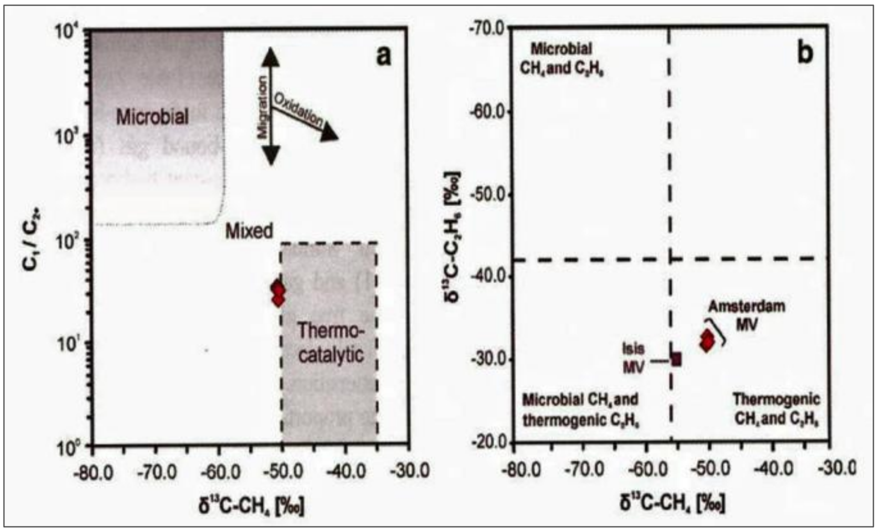


Figure 14. The relation of C_1/C_{2+} vs δ^{13}C-CH_4 ($^{0}/_{00}$) and δ^{13}C-C_2H_6 ($^{0}/_{00}$) vs δ^{13}C-CH_4 ($^{0}/_{00}$) in the Amsterdam Mud Flow Volcano, Anaximander Mountain, indicating the thermogenic origin of methane bubbles, Pape et. al., 2010.

Hydrocarbon analysis offshore Crete on mud samples around mud flow volcanoes taken during the Ocean Drilling Program indicates again the presence of an active hydrocarbon system at depth

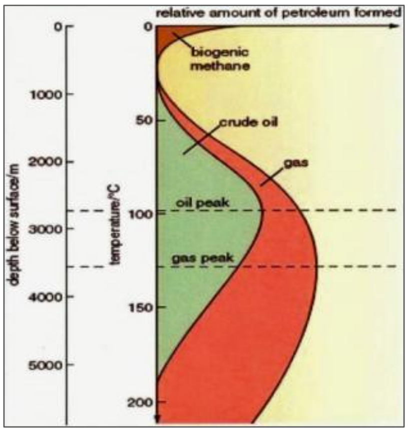


Figure 15. Generation of gases from organic matter with increasing temperature, Buruss, and Laughrey, 2009.

Also using the isotope signature of hydrocarbon gases, $\delta^{13}C_{CH4} < \delta^{13}C_{C2H8}$ along with the ratio of CH_4/C_2H_6 Toki et. al., 2006, it is established that the origin of hydrocarbons in the Sagara oil field in central Japan is thermogenic.

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, 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 (Figure 16), Roberts and Peace 2007; these analyses, along with the occurrence of oil slicks, leads to the existence of working petroleum systems at depth. Pyrolysis of saturates and/or aromatics of oil occur at 180^0C. A geothermal gradient of 33^0C/1000 meters implies that oil petroleum systems occur at a depth of around 5,000 to 5,500 meters, Loncke, 2004 (Figure 17). The same is observed also in Exploration Block # 5 of the Cyprus EEZ (Figure 18).

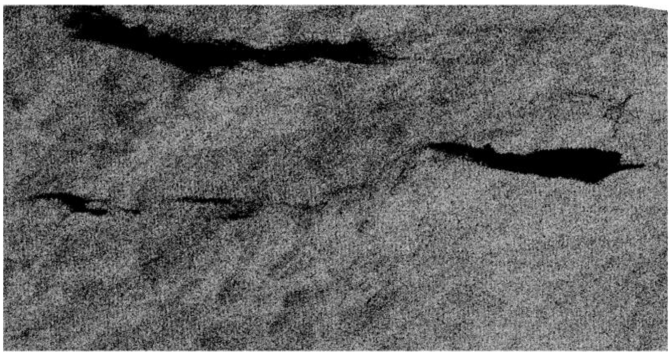


Figure 16. Oil films resulting from escaping gas bubbles which are coated with oil – Gas bubbles are derived from Active Mud Volcanoes in offshore Nile Cone, Egypt. Picture taken from satellites, Roberts and Peace, 2007.

Visible from satellites, offshore Crete, a phenomenon of thermogenic bubbles covered with liquid hydrocarbon sleeve explode leaving an oil slick..., indicating the existence of petroleum systems

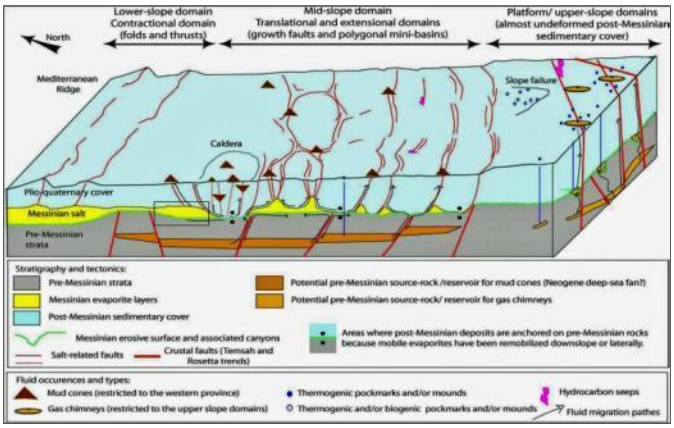


Figure 17. Active Mud Flow Volcanoes (brown triangles), Gas chimneys (brown discs), and Thermogenic Pockmarks and Mounds offshore Southern Crete. The pre-Messinian source rocks/ reservoir for the mud cones (brown), are highly visible as well as the reservoir/source for the gas chimneys (light brown),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

A geothermal gradient of 33^0C/1000 meters implies that oil petroleum systems occur offshore Crete at a depth of around 5,000 to 5,500 meters

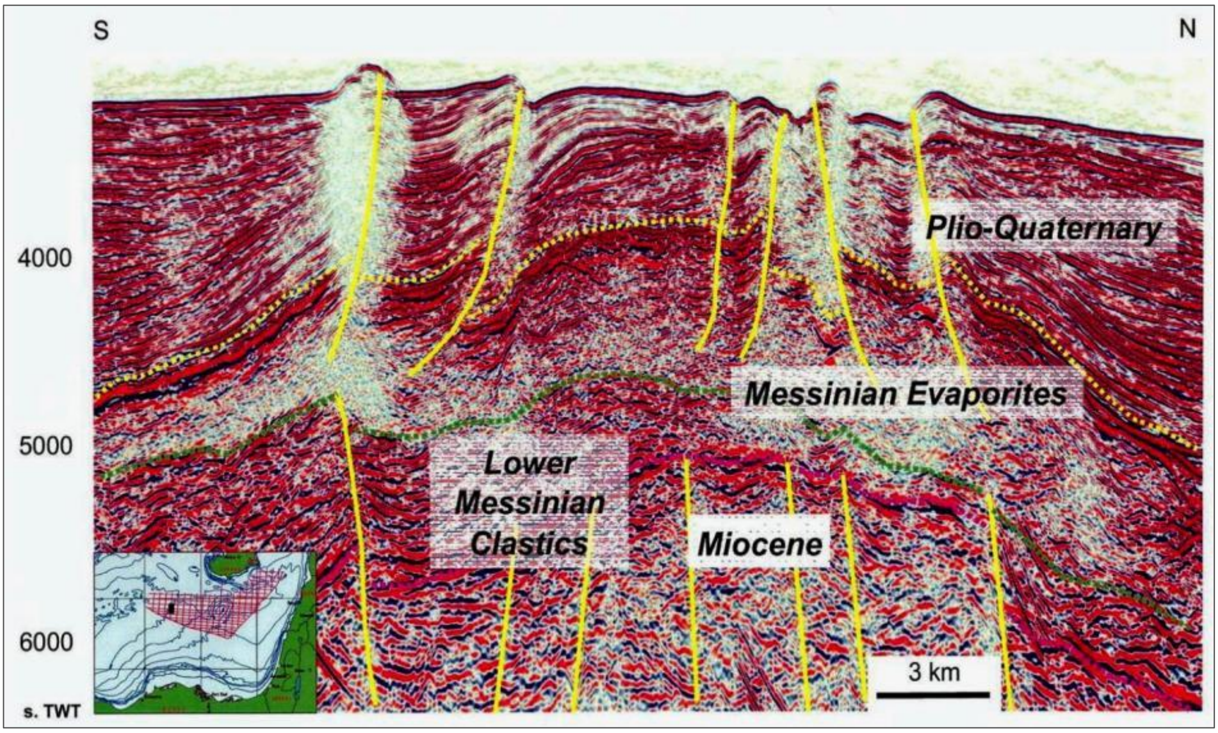


Figure 18. Large anticline on the toe of deep Nile Delta Fan with Messinian low-stand Delta clastic sand faulted pre-Messinian. Gas chimneys are highly visible, Montadert and Nikolaides, 2010.

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

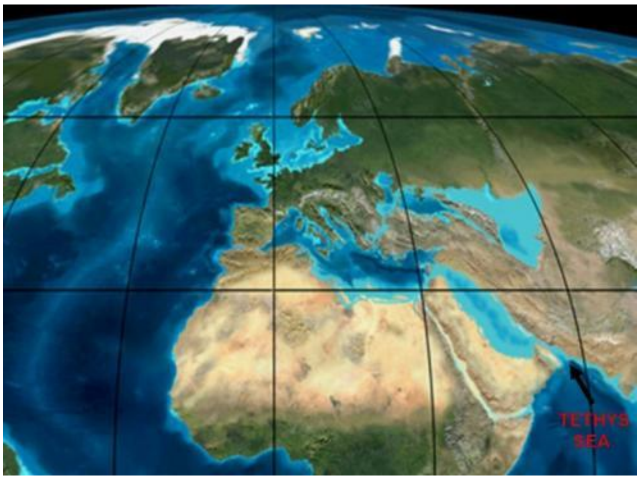


Figure 19. The geology of North Africa and Southern Europe during Mid Miocene, Scotese, 2000.

The geochemical data along with the immense volumes of hydrates that lie in the bottom of the Mediterranean Sea (50 trilion 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 5,000 meters in order to produce pyrolitic methane. Thus, the origin of methane gases cannot be attributed to post-Messinian sediments. The huge amounts of organic matter is most likely phytoplankton accumulated since the creation of the Tethys Sea, that is, since the end of the Jurassic, beginning of the Cretaceous, some165 million years ago. Tethys during the mid-Messinian was a shallow sea (Figure 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.

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 (Figures 20 and 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.

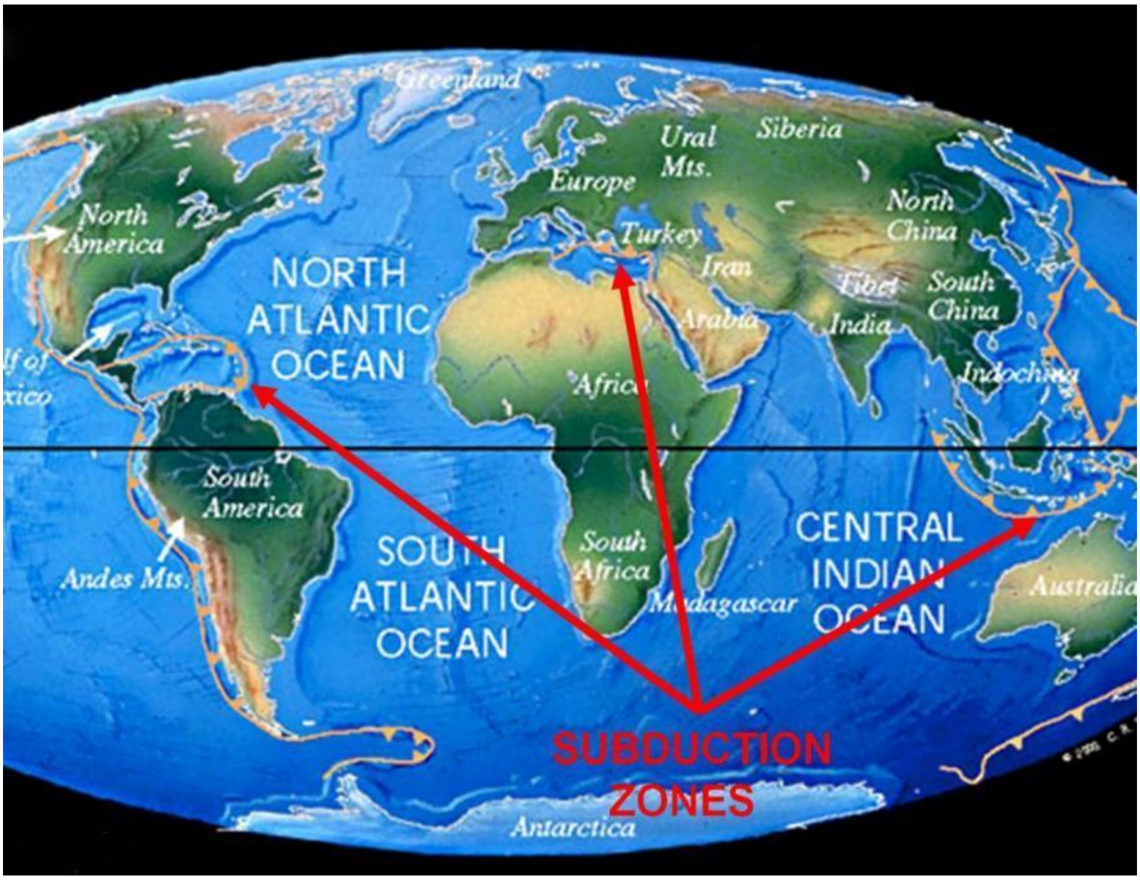


Figure 20. Modern world, Scotese 2000.

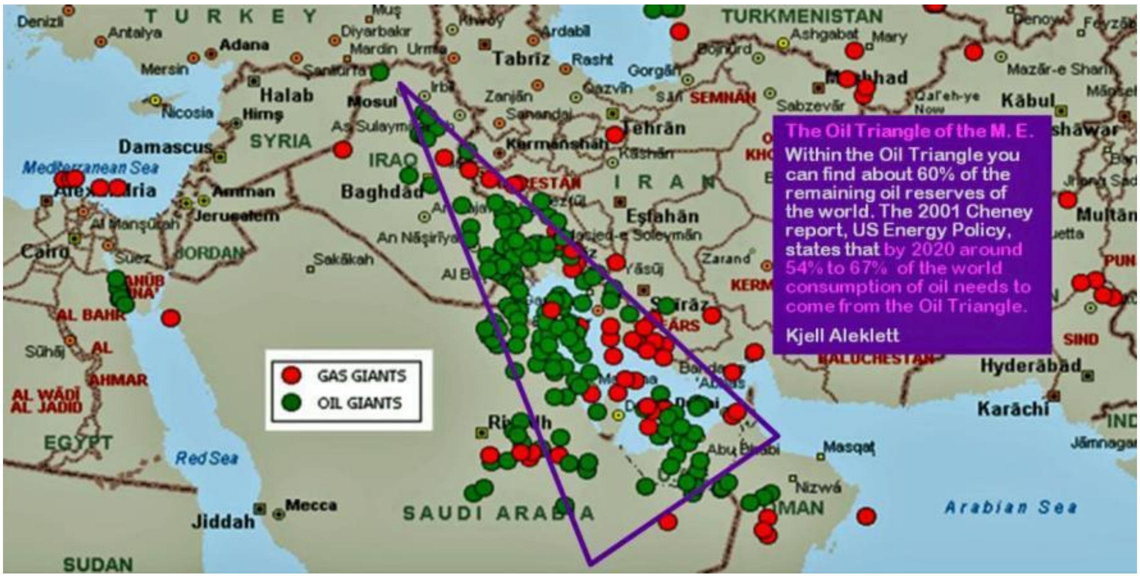


Figure 21. The Middle East Oil Triangle, Aleklett 2004.

The correlation between mud flow volcanoes and hydrocarbon discoveries can be seen in both the Egyptian and the Cypriot EEZ (Figures 22 and 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.

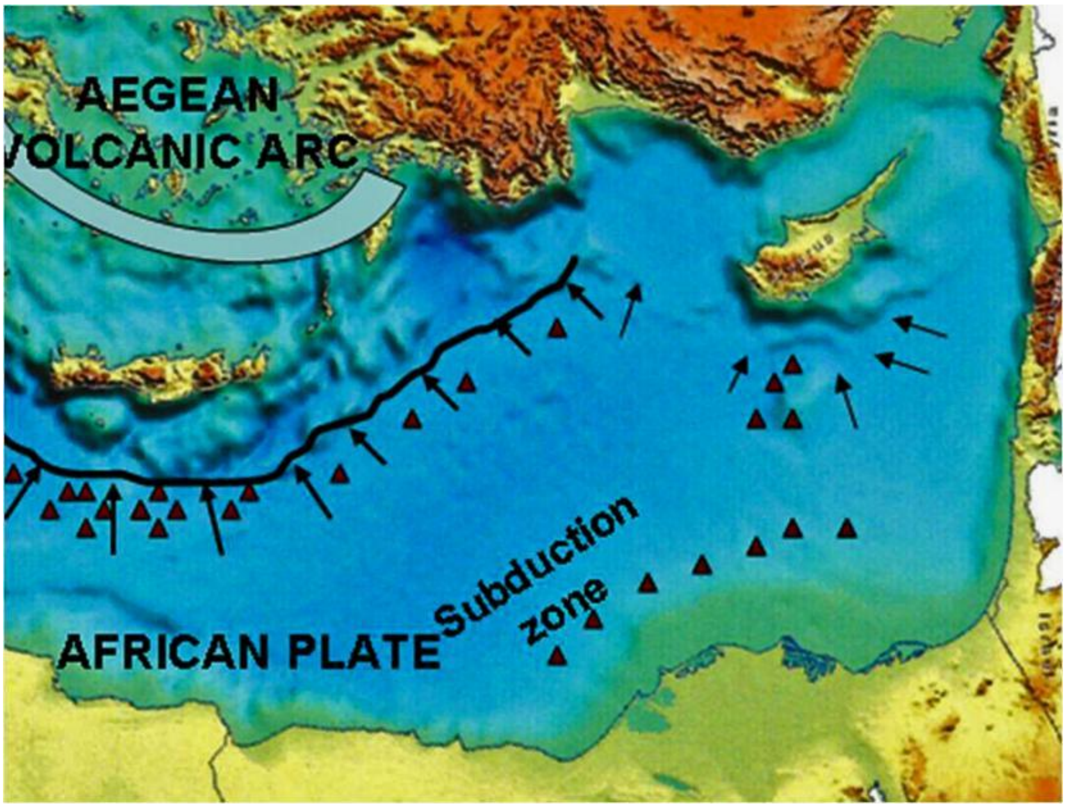


Figure 22. Occurrence of mud flow volcanoes and hydrocarbon reservoirs in the Nile Cone and EEZ of Cyprus. Modified by E. Konophagos from Dupre et. al., 2008 and Robertson, 1996.

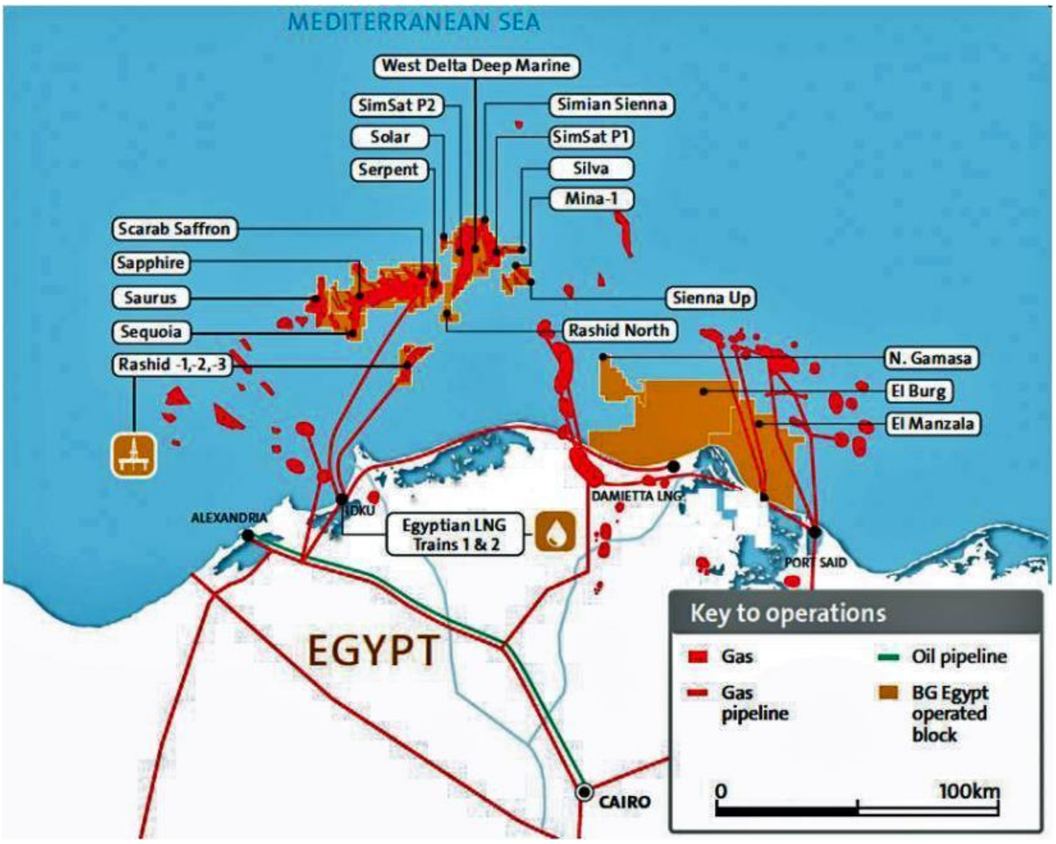


Figure 23. Distribution of natural gas reservoirs offshore Egypt, Neftegaz, EU 2010, Rigzone, 2010.

B. 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 (As per personal communiqué with Lucien Montadert, petroleum geologist BEICIP/FRANLAB) structures can be enormous. A different situation can exist in places with less compressional stresses or extensional areas (As per personal communiqué with Lucien Montadert, petroleum geologist BEICIP/FRANLAB)

Accretionary prisms are underexplored for hydrocarbons and may hold large quantities of hydrocarbon reserves, Dolan et. al., 2004, (Barbados accretionary prism), Escalona et. al., 2008, (Barbados accretionary prism), Persad, 2008, (Barbados accretionary prism), Ellouz-Zimmerman et,al., 2007, (Makran accretionary prism, Pakistan) Hairms et. al., 1982, (Makran accretionary prism, Pakistan), Klein et al., 2011 (Peru margin characterized by oceanic/ continental plate collision with accretionary prisms), Jones et. al., 2011 (West Timor Trough,) Wandrey, 2006, (Irrawaddy-Andaman accretionary prism).

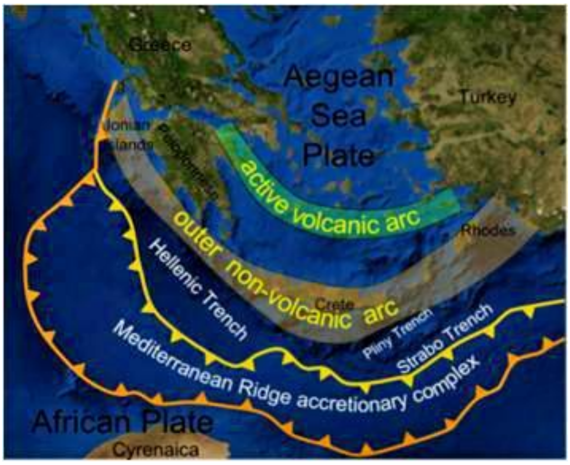


Figure 24. The area covered by the Mediterranean Ridge accretionary prisms. Its implication for potential hydrocarbon reserves, en. Wikipedia org/…./Mediterranean Ridge.

In the Mediterranean Ridge accretionary prism complexes occupy an area of over 80,000 Km^2 (Figure 24), and starts offshore west of the island of Kefallinia, travels along western Peloponnese, goes underneath Crete ending offshore the island of Cyprus (occupying an area of over 80,000 Km^2). 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.

3. Hydrocarbon potential within the Mediterranean Ridge

Though there is substantial geophysical information concerning the offshore geology of Crete, Astrium, EADS Co. (Figure 25) and PGS information (Figure 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. The possible areas are two major anticlines and an abyssal plain, while another seven backstop basins-trenches represent possible hydrocarbon plays (Figures 27, 28, and 29). Also, Robinson 2011 of Petroleum Geo-Services (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 the Levantine basin (Figures 30 and 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 favourable climate for hydrocarbon exploration in offshore Crete. Zelilidis, 2011, and Maravelias 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.

A large number of accretionary prisms encountered within the Mediterranean Ridge, offshore Crete, whose length is over 1,000 Km, indicate the existence of large to giant hydrocarbon deposits

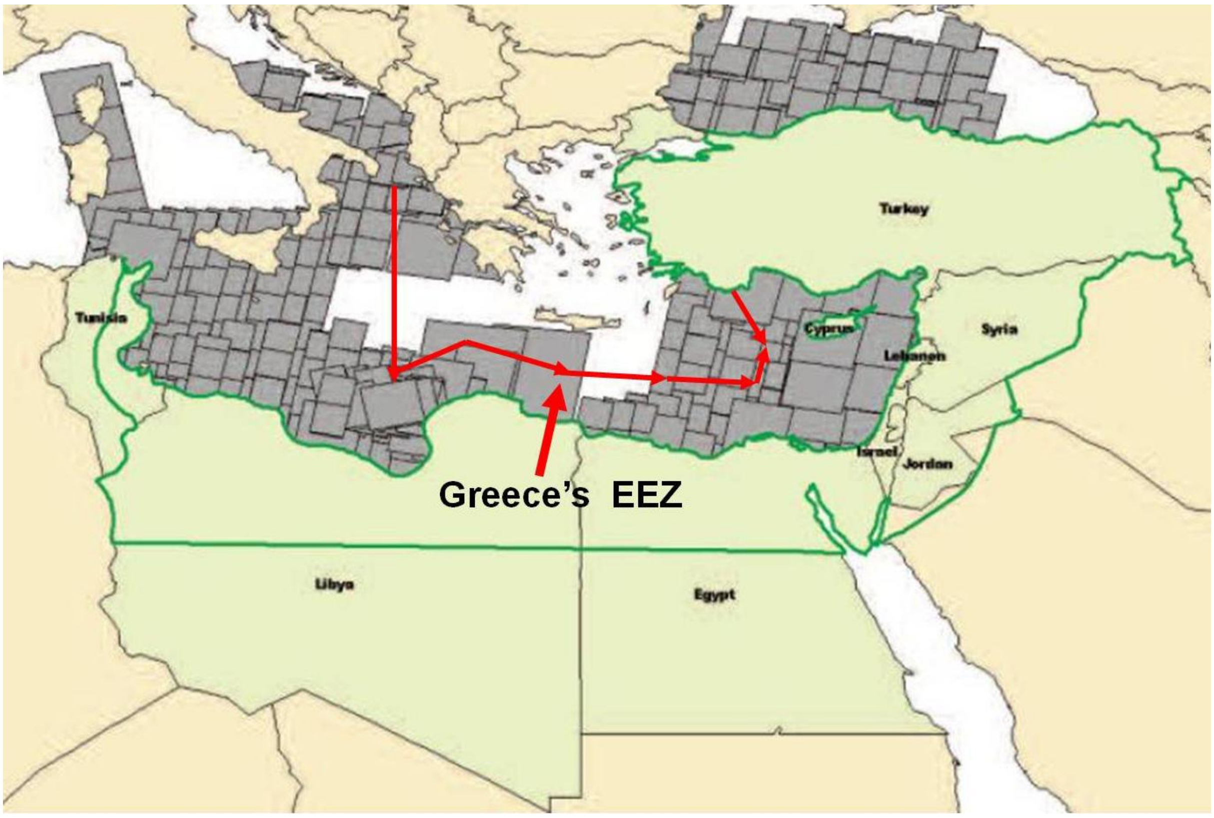


Figure 25. Geological and geophysical data maps by ASTRIUM, an EADS Co.

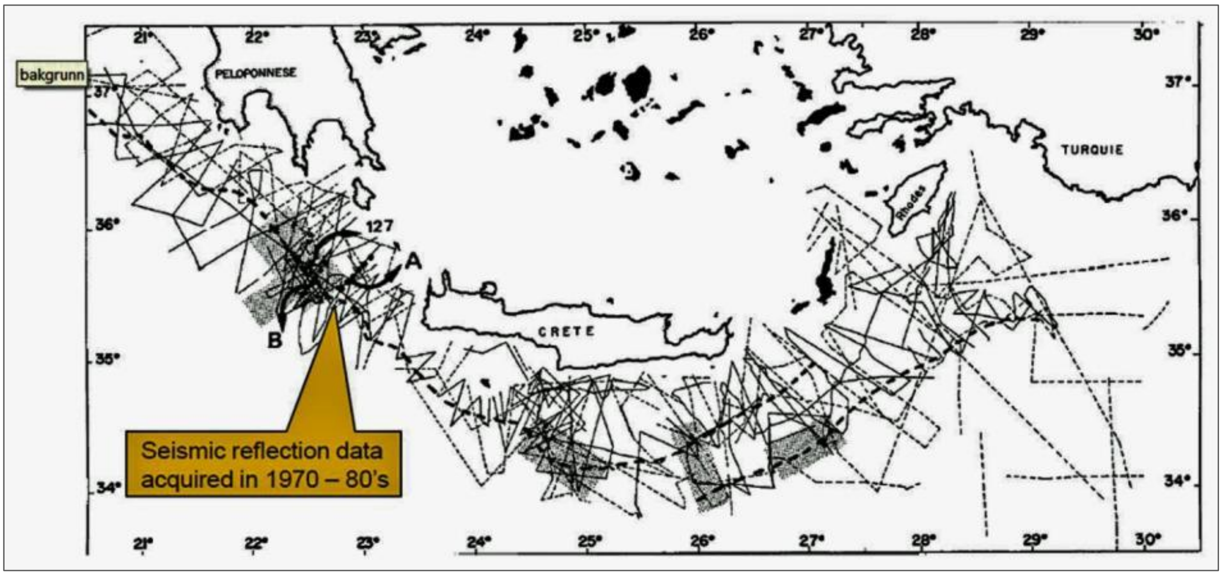


Figure 26. Existing seismic coverage information package limited to Prinos and Sea of Thrace area (seismic data acquired by unknown companies in the 90's, 00's and 2009). Robinson, J. PGS multi-client presentation at Ministry of Energy and Climatic Changes, (YPEKA) Athens, Greece, July 2011.

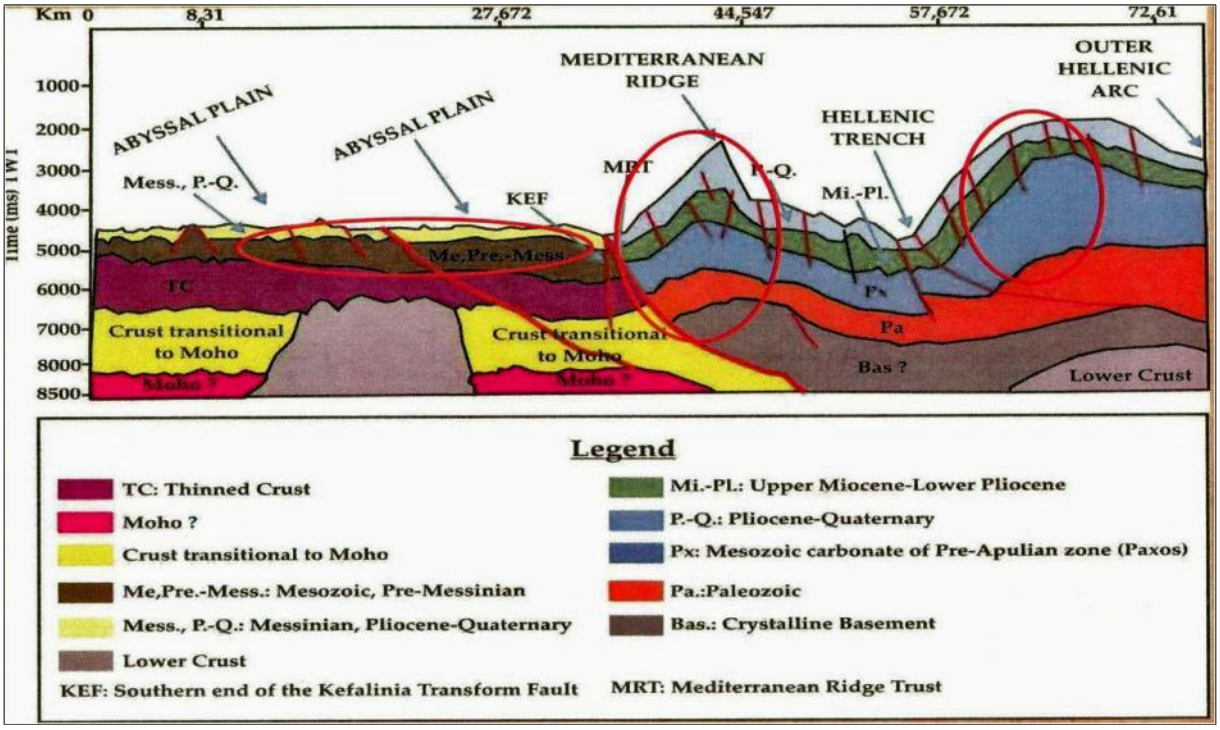


Figure 27. Possible hydrocarbon plays offshore southern Crete. Two major anticlines (ellipsoidal red circles) and the Hellenic trench, 2 Km below sea level. Also, Abyssal Plain (Oval red Circle). Zelilidis, 2011.

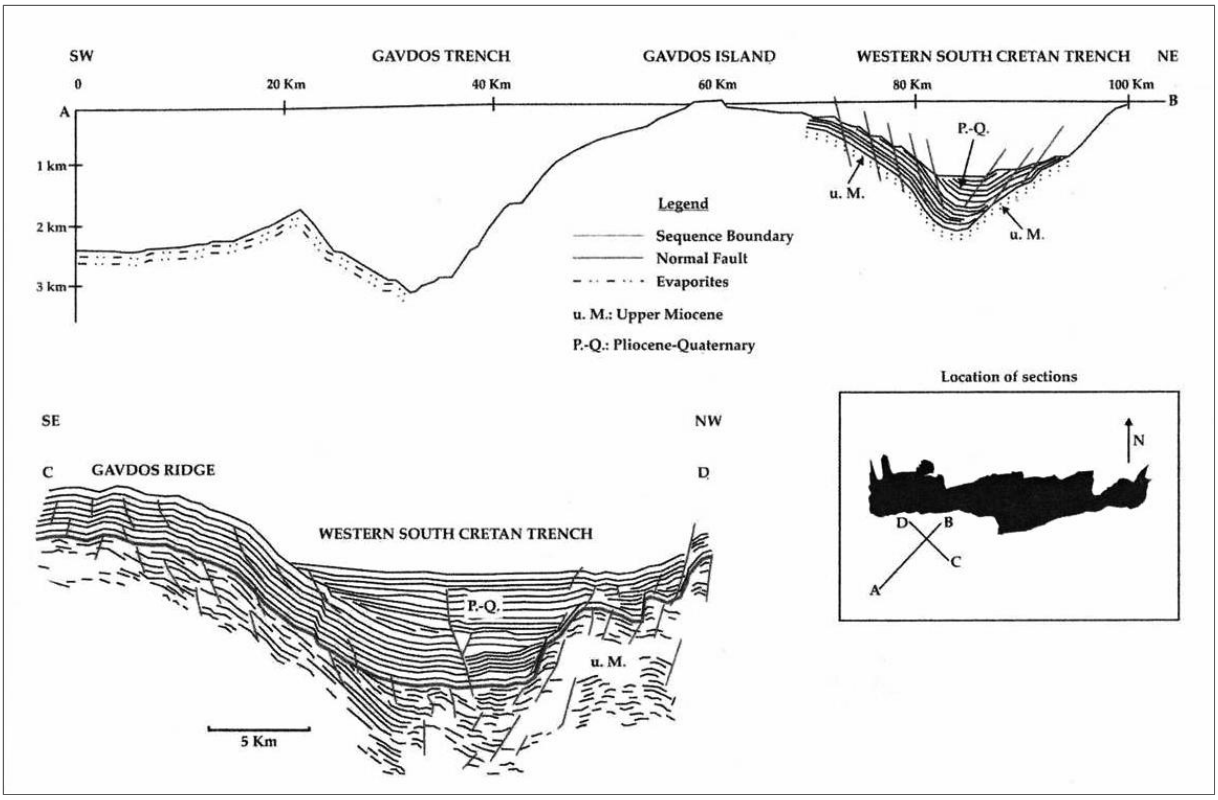


Figure 28. Example from the six backstop basins southward of Crete (Gavdos, Gortys, Poseidon, Ptolemeus, Pliny and Stravon trenches). Interpretation of seismic reflection profiles across the western south Cretan Trench. P.Q. recent sedimentary cover. uM, Miocene evaporite and related tectonics, Maravelis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

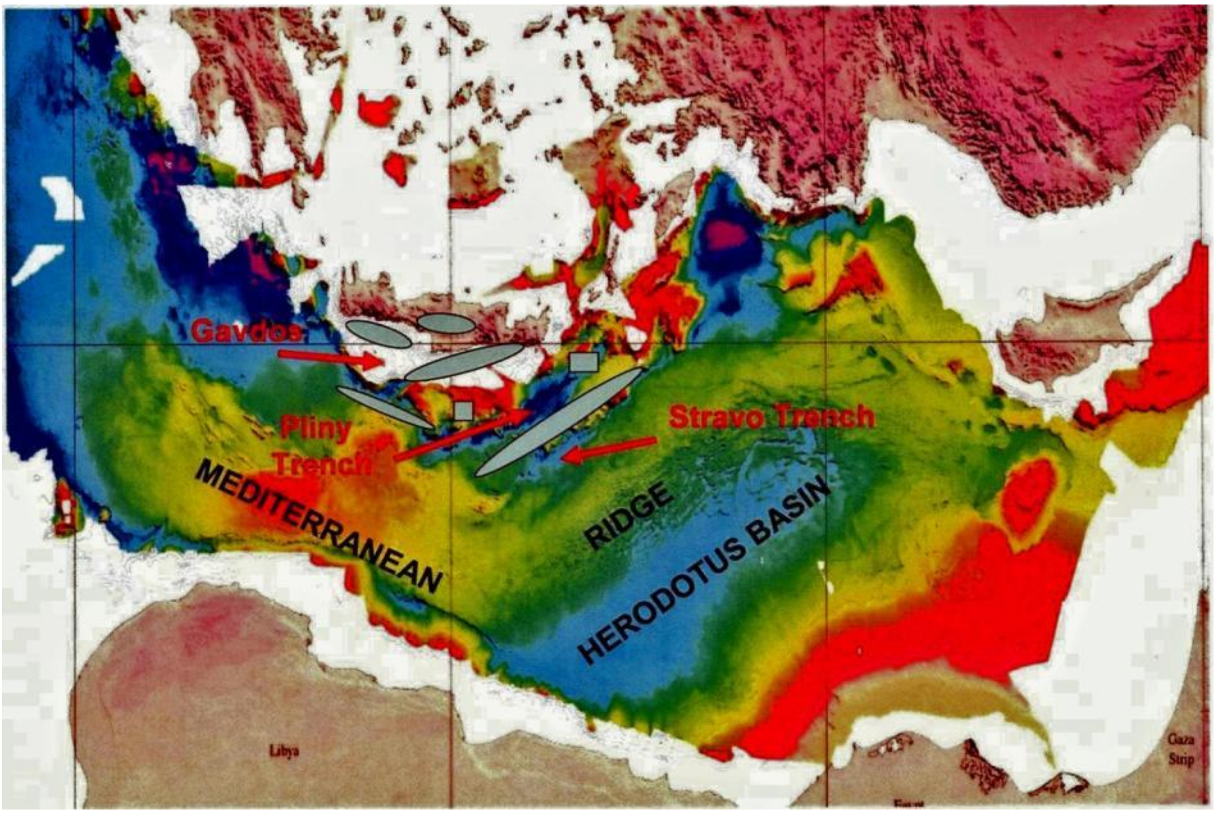


Figure 29. Hydrocarbon Fields, pale blue oval circles, offshore Crete according to Maravelis et. al., 2012.

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 3.45 TCM?	Cretan

Figure 29. Hydrocarbon potential in Greece. Source rocks, Reservoirs, Seals Traps and Type basin. Presentation of PGS by J. Robinson at the ministry of Energy and Climatic Changes, Athens, Greece (ΥΠΕΚΑ), 2011.

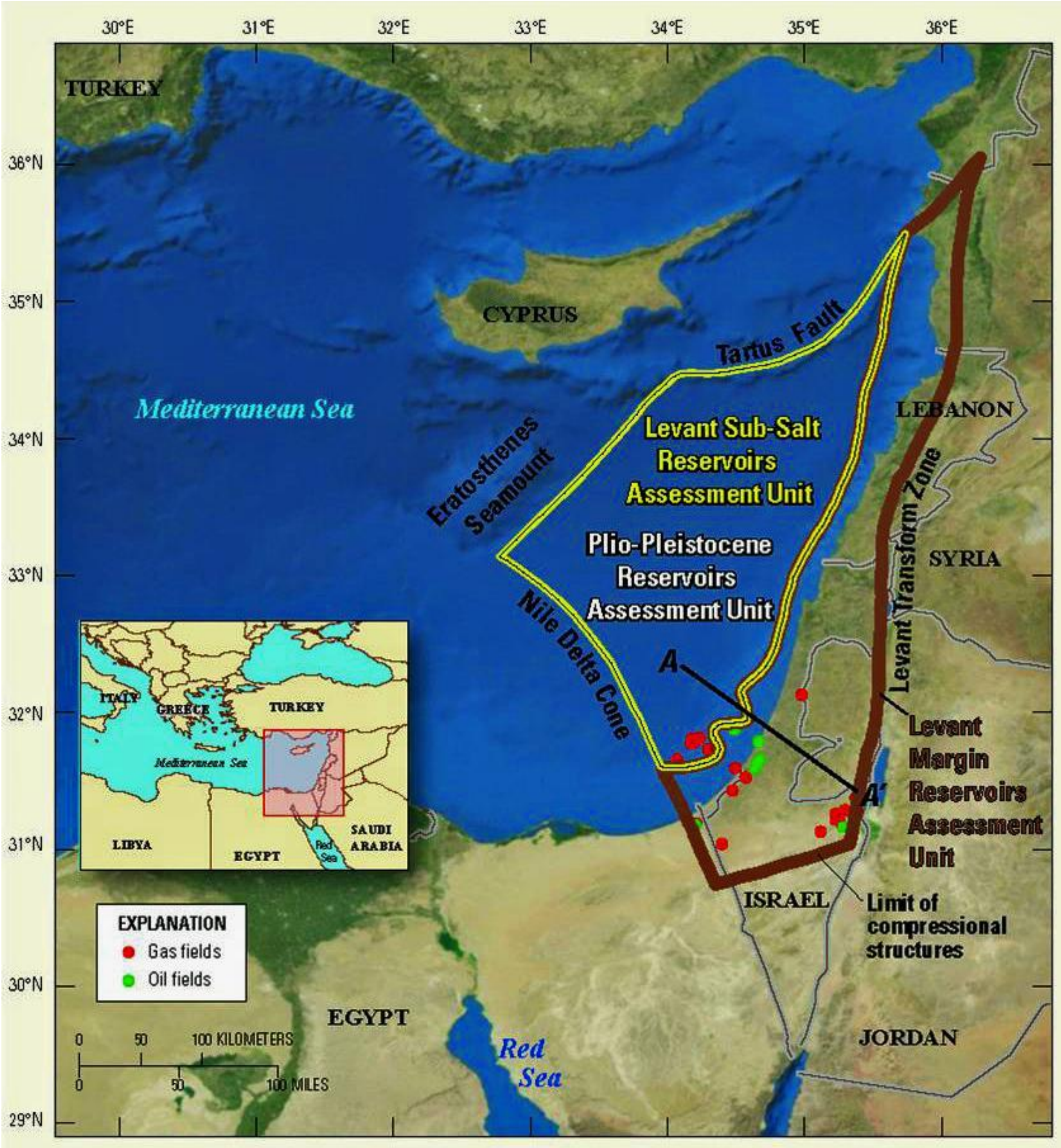


Figure 31. The Levantine Basin with its recent oil and gas discoveries. Assessed potential for further discoveries of natural gas 122 tcf (3.45 tcm) and oil 1.7 billion barrels, USGS Technical Report, 2010.

4. 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.
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 1,000 Km, Hence, the existence of large to giant hydrocarbon deposits should be the subject of intense exploration research.
3. Active mud flow volcanoes are associated, throughout the world, with hydrocarbon occurrences (Timor, South Caspian Sea, the Caribbean, Egypt and Cyprus). Underneath Crete, at the point where the African plate submerges there is 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 160^0C to 180^0C. Based upon a geothermal gradient of 33^0C/1000 meters, pyrolysis should take place at a depth between 5,000 to 5,500 meters. Hence, working petroleum systems are encountered at depth while the thickness of the sediments, below sea level, is over 5,000 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 two major anticlines, an abyssal plain and seven 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 Geo-Services (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.

The conclusions of the Paper in the Greek language:

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

Συμπεράσματα

1. **Το 20% των γιγαντιαίων κοιτασμάτων υδρογονανθράκων απαντάται στα σημεία σύγκλισης των λιθοσφαιρικών πλακών. Άρα η ύπαρξη κοιτασμάτων υδρογονανθράκων στην υπεράκτιο Νότια Κρήτη θα πρέπει να διερευνηθεί.**

2. **Τα Πρίσματα Επαύξησης σε όλο τον κόσμο, (Barbados, Makran, Irrawaddy – Andaman, West Timor Trough) είναι δείκτες ύπαρξης γιγαντιαίων κοιτασμάτων υδρογονανθράκων. Επομένως, η ύπαρξη κοιτασμάτων υδρογονανθράκων στην υπεράκτιο Νότια Κρήτη θα πρέπει να διερευνηθεί δεδομένου ότι τα επαυξητικά πρίσματα βρίσκονται στην Μεσογειακή Ράχη που έχει μήκος πάνω από 1,000 χιλιόμετρα.**

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 Νότια Κρήτη θα πρέπει να διερευνηθεί.**

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. Επομένως, η ύπαρξη κοιτασμάτων υδρογονανθράκων στην υπεράκτιο Νότια Κρήτη θα πρέπει να διερευνηθεί.**

5. **Σε δείγματα ιλύος που λήφθησαν 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 (the 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 στην διάθεσή τους ορισμένοι μόνον Έλληνες Πανεπιστημιακοί, ότι στην υπεράκτιο υπάρχουν στην Νότια Κρήτη και εντός της Μεσογειακής Ράχης δύο (2) μεγάλα αντίκλινα, μία (1) αβυσσική λεκάνη και επτά (7) οπισθοτάφροι που μπορούν να αποτελέσουν πεδία έρευνας για τον εντοπισμό κοιτασμάτων υδρογονανθράκων.**

7. **Η Νορβηγική εταιρεία γεωφυσικών ερευνών Petroleum Geo-Services (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 Κύπρου, Ισραήλ, Συρίας και Λιβάνου) η οποία θεωρείται από την Γεωλογική Υπηρεσία των ΗΠΑ (USGS) ότι έχει τουλάχιστον 3.45 τρις. m^3 φυσικού αερίου και 1,7 δισ. βαρέλια αργού πετρελαίου. Άρα επιβάλλεται η έρευνα για τον εντοπισμό κοιτασμάτων υδρογονανθράκων νοτίως της Κρήτης.**

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Sources and Bibliography (Alphabetically)

- **Aleklet**, K. 2006. The Swedish plan for independence on oil. Pisa, Italy, July 2006.
- **Barrier**, E., Chamot-Rooke, N., Giordano, G. 2004. Geotectonic Map of the Mediterranean, sheet 1, (Tectonics and Kinematics), Commission for the Geological Map of the World (CCGM)/CGMW), Edition, Paris, France.
- **Bruneton**, A., Konofagos, E., Foscolos, A. 2011. Economic and Geopolitical Importance of Eastern Mediterranean gas fields for Greece and the EU. Emphasis on the Probable Natural Gas Deposits Occurring in the Libyan Sea within the Exclusive Economic Zone of Greece. Mineral Wealth, v 160 pp.7-22.
- **Buruss**, R. C., Laughrey, C.D. 2009. Covariation of carbon and hydrogen isotopic composition in natural gas: Separating biogenic, thermogenic and Abiotic (inorganic CO2 reduction) source USGS.
- **Carmalt**, S. W., St John, B. 1986. Future Petroleum Provinces of the World. Giant oil and gas fields. AAPG Special Volumes, volume M 40. pp 11-53.
- **Cocard** M., Kahle H-G., Peter Y., Geiger A., Veis G., Felekis S., Paradisis D. and Billiris H. 1999: "New constraints on the rapid crystal motion of the Aegean region: recent results inferred from GPS measurements (1993-1998) across the West Hellenic Arc, Greece". Earth and Planetary Science Letters, 172, 39-47.
- **Cronin**, B.T., Ivanov, M.K., Limonov, A. F., Egorou, A., Akhmanov, G.G., Akhmetjanov A.M., Kozlova. E. 1997. TTR Shipboard Scientific Party 1997. New discoveries of mud volcanoes on the Eastern Mediterranean Ridge. Journal of the Geological Society of London 154 (2) pp. 173-182.
- **Deyhle**, A., Kopf, A. 2012. Deep fluids and ancient pore waters at the backstop: Stable isotope systematics (B, C, O) of mud-volcano deposits on the Mediterranean Ridge accretionary wedge. Geology 2001; 1031-1034 doi : 10.1130/0091-7613 (2001)029<1031: DFAAPW>2.0.CO; 2.
- **Dimitrov**, L. 2002. Mud volcanoes, the most important pathway for degassing deeply buried sediments. Earth Science Reviews 59, pp 47-76.
- **Dolan**, P., Burggraf, D,. Soofi, K., Fitzsimmons, R., Aydemir, E., Senneseth, O., Strickland, L. 2004. Challenges to exploration in frontier basins-The Barbados accretionary prism. AAPG International Conference, October 24-27, Cancun, Mexico.
- **Dupre**, S., Buffet, G., Mascle, J., Foucher, J-P., Gauger, S, Boetius, A., Marfia. C., The AsterX AUV Team, The Quest ROV Team and The BIONIL scientific party. 2008. High-resolution mapping of large gas emitting mud volcanoes on the Egyptian continental margin (Nile Deep Sea Fan) by AYV surveys. Marine Geophysical Researches, v.29, No. 4, pp. 275-290.
- **Ellouz-Zimmerman**, N., Deville., E. Muller, C, 2007. Thrust belts and foreland basins : from kinematics to hydrocarbon. Books.google.gr/pp471 books? ISBN=3540694250. Publishers, Olivier Lacombe, Societe Geologique de France and Sociedad, Geologica de Espagna.
- **Faber**, E. W., Stahl, J., Whiticar, M.J. 1992. Distinction of bacterial and themogenic hydrocarbon gases, in R. Vially, ed., Bacterial Gas, Paris Editions Technip, pp.63-74.
- **Escalona**, A., Mann, P., Bingham, L. 2008. Hydrocarbon exploration plays in the Great Caribbean region and neighboring provinces. 2008. AAPG Annual Convention, San Antonio Texas April 20-23. Search and Discovery Article # 10047. Posted July, 2008.
- **Gavazza**, W., Roure, F., Spackman, W., Stampfli,G., Ziegler, P (Eds), 2004. The Mediterranean Region from Crust to Mantle. The Transmed Atlas. Geological and Geophysical Framework of the Mediterranean and the Surrounding Areas. A publication of the Mediterranean Consortium for the 32nd International Geological Congress, Florence, Italy, August, 20-28, 2004.
- **Hollenstein** Ch., Kahle H.-G., Cocard M., Veis G., Paradissis D., Felekis S. and Billiris H. 2002: "CGPS data in Greece: Time Series of Crystal Motion and Error Analysis". Proc: WEGENER conference 2002, Eleventh General Assembly, Athens, 12-14 June, p.4.
- **Jackson** J. 1994: "Active tectonics of the Aegean region". Annual Reviews of Earth and Planetary Sciences 22, 239-271.
- **Jones**, W., Tripathi, A., Rajagopal, R., Williams, A. 2011. Accretionary prisms-plate tectonics-Hydrocarbons. Petroleum prospectivity of the West Timor trough (www.pnronline.com.au/article.php/127/150).
- **Hairms**, J., S. Cappel, H., N. Francis, D., C 1982. Geology and petroleum potential of the Makran coast, Pakistan. Society of Petroleum Engineers. ISBN: 978-1-55563674-6, DOI: 102118/10423-MS.
- **Huguen** C., Mascle J., Chaumillon E., Woodside J.M., Benkhelil J., Kopf A. and Volokonskaia A. 2001: "Deformation styles of the eastern Mediterranean Ridge and surroundings from combined swatch mapping and seismic reflection profiling". Tectonophysics, 343, 21-47.
- **Huguen**, C., Mascle, J., Woodside, J. M., Zitter, T. 2005. An in situ and near- bottom study of Mud Volcanoes in the Eastern Mediterranean Pre-Collisionnal Setting. Deep Sea Res. I 52, 1911-1931.
- **Klein**, G.D., Zuniga-Rivero, J., Hay-Roe, H., Alvarez-Calderon, E., 2011. Mesozoic/Cenozoic tectonic evolution, basin fairways and play opportunities, Peru. Sipes Houston Chapter Meeting, Septeptember 15. 2011.
- **Kanasewich**, E. R., Havskov, J. 1978. Plate tectonics and the location of oil fields.
- **Kokinou**, E., Papadimitriou, E., Karakostas, V., Kamberis, E. and Vallianatos, F. 2006. The Kefalonia Transform Zone (offshore Western Greece) with special emphasis to its prolongation towards the Ionian Abyssal Plain. Marine Geophysical Research 27:241-252.
- **Knapmeyer** M. and Harjes H-P., 2000: "Imaging crystal discontinuities and the down going slab beneath western Crete". Geophys. J. Int., 143, 1-21.
- **Kopf** A., Mascle J. and Klaeschen D. 2003: "The Mediterranean Ridge: A mass balance across the fastest growing accretionary complex on Earth". Journal of Geophys. Research, Vol. 108, No B8, 2372, doi: 10.1029/2001JB000473.

- **Kreemer** C. and Chamot - Rooke 2004: "Contemporary kinematics of the Southern Aegean and the Mediterranean Ridge". Geophys, J. Int., 157, 1377-1392.
- **Leite**, O., Mascle, L. 1982. Geological structure of the south Cretan continental margin and Hellenic trench. Marine Geology, v. 49 pp. 199-223.
- **Le Pichon** 1982: "Land-locked oceanic basins and continental collision: The Eastern Mediterranean as a case example". In: Hsu, K. (ed) Mountain Building Processes. Academic Press, London, 201-211.
- **Loncke**, L., Mascle, J., Fanil Scientific Parties. 2004. Mud volcanoes, gas chimneys, pockmarks and mounds in the Nile deep-sea fan (Eastern Mediterranean): Geophysical evidence. Marine and Petroleum Geology v.21. pp. 669-689.
- **Lykousis**, V, Alexandri, S., Woodside,, J., Nomikou, P. Perissoratis, C, Sakelllariou, D., de Lange, G., Dahlmann, A, Casas, D. Rousakis, G., Ballas, D, Ioakim, C.2004. New evidence of extensive active mud volcanism in the Anaximander Mountains (Eastern Mediterranean). The "ATHINA" mud volcano. Environmental Geology 46, 1030–1037.
- **Mann**, P., Galagan, L., Gordon. M.P. 2003 Tectonic settings of the world's giant oil and gas fields. AAPG Special Volume. Memoir 78: Giant oil and gas fields of the decade 1990-1999, pp. 15-105.
- **MacKenzie** D. P. 1972: "Active tectonics of the Mediterranean region". Geophys. Journal of the Royal Astronom. Society, 30, 109-185.
- **Massari**, S. 2009. Technical feasibility for the exploitation of methane hydrates. J. Commodity Sci. Technol. Quality 2009, 48 (II), 121-138.
- **Maravelis**, A., Manutsoglu, E.,Konstantopoulos, P., Pantopoulos,G., Makrodimitras, G., Zampouli, E.,Zelilidis, A. 2012. Hydrocarbon plays and prospectivity of the Mediterranean Ridge. Energy Sources, Accepted and In press.
- **McLusky** S. et al 2000: "Global Position System constraints on plate kinematics and dynamics in the eastern Mediterranean and Caucasus". Journal of Geophysical Research, 105, 5695-5719.
- **McLusky**, Reilinger R., Mahmoud S., Ben Sari D., and Tealeb A. 2003: "GPS constraints on Africa (Nubia) and Arabia plate motions". Geophys. J. Int. 155, 126-138.
- **Meulenkamp** J.E., Wortel M.J.R., VanWamel W.A., Spakman W. and Hoogerduyn Strating E. 1988: "On the Hellenic subduction zone and the geodynamic evolution of Crete since the late Middle Miocene". Tectonophysics, 146, 203-215.
- **Montadert**, L., Nikolaides, S. 2007. The Geological structure of the Eratosthenes Continental Block and its Margins with the Levantine and Herodotus Basins (Eastern Mediterranean) from New Seismic Reflection Data. AAPG Search and Discovery Article # 90072. AAPG and AAPG European Region Conference, Athens, Greece.
- **Μουντράκης** Δ., 2001: "Τεκτονική εξέλιξη του Ελληνικού Ορογενούς. Γεωμετρία και κινηματική της παραμόρφωσης". Πρακτ. 9ου Διεθν. Συνεδρ. Ελλην. Γεωλ. Εταιρ., Αθήνα, Δελτ., Τομ. XXXIV/6, 2113-2126.
- Minster J.B. and Jordan T.H. 1978: "Present day plate motions". Journal of Geophy-sical Research, 83, 5331- 5334.
- **Nefregaz**. RU. Oil and gas worldwide, 2010. Offshore oil treasures in East Mediterranean sea.
- Oral M.B., Reilinger R.E., Toskoz M.N., King R.W., Barka A.A., Kiniki J. and Lenk D. 1995: "Global Positioning System offers evidence of plate motions in Eastern Mediterranean". EOS, 76, 9-11.
- **Papanicolaou**, D.,Barghati, H., Dabroski, C., Dimitriou, R., El-Hawat, A., Joane, D., Kranis. H., Obeidi, A., Gale, G., Seghed, A., Zagorchev, I. 2004. Transect VII. East European Craton-Scythian Platform-Dobrogea-Balkanides-Rhodope Massif-Hellenides-East Mediterranean. The Transmed Atlas. Geological and Geophysical Framework of the Mediterranean and the Surrounding Areas. A publication of the Mediterranean Consortium for the 32nd International Geological Congress, Florence, Italy, August, 20-28, 2004.
- **Papazachos** C.B. 1999: "Seismological and GPS evidence for the Aegean-Anatolia interaction". Geophys. Res. Lett., 26, 2653-2656.
- **Papazachos** C.B. 2002: "A tecto-Kinematic model for the Aegean using seismological and GPS data". Proc., 11th Gen. Ass. WEGENER, 12-14 June, 2002.
- **Παπαζάχος** Β. Κ. και Παπαζάχου Κ. Β. 2003: "Οι σεισμοί της Ελλάδας". Εκδόσεις Ζήτη, γ΄ έκδοση, Θεσσαλονίκη, σελ. 286.
- **Pape**, T., Kasten, S., Zabel, M., Bahr, A., Abegg, F., Hohnerg, H-J., Bohrmann, G. 2010. Gas hydrates in shallow deposits of the Amsterdam mud volcano, Anaximander Mountains, Northeastern Mediterranean Sea.Geo-Mar Lett. V. 30, pp 187-206. DOI 10.1007/s00367-010-0197-8.
- **Pavlaki** Cath, 2006: "Engineering geology conditions at Chania Prefecture". PhD Thesis, Aristotle University of Thessaloniki - Department of Civil Engineering, p. 540.
- **Παυλάκη** Αικ. 2006. "Τεχνικές Γεωλογικές Συνθήκες στο Νομό Χανίων". Διδακτορική διατριβή, Τμήμα Πολ. Μηχ/κών - Αριστοτέλειο Πανεπιστήμιο Θεσσαλονίκης, σελ. 540.
- **Persad**, K.M. 2008. Petroleum geology and prospects of Trinidad and Tobago. 100 years of petroleum in Trinidad and Tobago (www.energy.gov.tt/content/Centenery_Pub_Krishna_Persad.pdf).
- **Praeg**, D., Unnithan, V., Camerlenghi, A. 2007. PROJECT: HYDRAMED. Gas hydrate stability and prospectivity in the Mediterranean sea (www.dur.ac.uk/ey.go/general_public/AAPG_Newsletter_June.pdf).
- **Reilinger** R., McClusky S. and Vernant Ph. 2004: "GPS constraints on continental deformation in the eastern Mediterranean and Caucasus region. (1988-2004)". E. Mediterranean and Caucasus GPS Consortium, Centre for the Observation and Modeling of Earthquakes and Tectonics.
- **Roberts**, G., Peace, D. 2007. Hydrocarbon plays and prospectivity of the Levantine Basin, offshore Lebanon and Syria from modern seismic data. Geoarabia, v.12. No 1, pp. 99-124.
- **Robertson**, A., H., F. and Kopf. A. 1998 Proceedings of the Ocean Drilling Program, Scientific Results, Vol. 160 Robertson, A.H.F., Emeis, K.-C., Richter, C., and Camerlenghi, A. (Eds.), 1998.

- **Robertson**, A.H.F. and Shipboard Scientific Party, 1996. 18 Mud Volcanism on the Mediterranean Ridge. Emeis, K.-C, Robertson, A.H.F., Richter, C, et al., 1996 Proceedings of the Ocean Drilling Program. Initial Report, vol. 160.
- **Robinson**, A.G., Rudat, J.H., Banks, C. J., Wiles, R., L., F. 1996. Petroleum Geology of Black Sea. Mar. Petr. Geol.13, pp.195-223.
- **Robinson**, J. 2011. PGS Multi Client Power Point Presentation at the Ministry of Energy and Climatic Changes, Athens, Greece, July 2011.
- **RIGZONE**, 2010. Analysis: Egypt's waters hold significant untapped gas reserves. http//www.rigzone.com/news/article.asp?a_id=96194.
- Ryan W.B.F., Kastens K.A. and Cita M. 1982: "Geological evidence concerning compressionnal tectonics in the Eastern Mediterranean". Tectonophysics 86, 213-242.
- **Scotese**, R. C. 2000. Paleomap Project, Earth History (www.scotese.com).
- **Schoell**, M. 1983. Genetic characterization of natural gases. AAPG, Bulletin, v. 67, pp 2225-2238.
- **Schoell**, M. 1988. Multiple origins of methane in the earth. Chemical Geology, v. 71, pp. 1-10.
- **Ten Veen** J.H. and Meijer P.Th 1998: "Late Miocene to Recent tectonic evolution of Crete (Greece): geological observations and model analysis". Tectonophysics 298, 191-208.
- **Ten Veen** J.H. and Kleinspehn K.L. 2003: "Incipient continental collision and plate-boundary curvature: Late Pliocene - Holocene transtensional Hellenic forearc, Crete, Greece". Journal of the Geological Society, London, Vol. 160, 161-181.
- **Thompson**, L. 1976. Plate Tectonics in Petroleum Exploration of Convergent Continental Margins: Hydrocarbons. AAPG Special Volumes. Volume M 25: Circum-Pacific Energy and Mineral Resources, Pages 177 – 188.
- **Truffert**, C., Chamot-Rooke, N., Lallemant,S., de Voogd, B., Huchon, P., Le Pichon,X. 1993. The Crust of the Western Mediterranean Ridge From Deep Seismic Data and Gravity Modeling. Geoph. J. Intern, v.114, issue 2, pp. 360–372.
- **Toki**, T., Gamo, T., Tsunogai, U. 2006. Origins of hydrocarbons in the Sagara oil field, central Japan. Island Arc, v. 15 pp. 285-291.
- **United States Geological Survey (USGS) 2010**. Assessment of undiscovered oil and gas resources of the Levant Basin Province, Eastern Mediterranean. Fact Sheet 2010-3014, March 2010.
- **Wandrey**, C., J. 2006.Eocene to Miocene composite total petroleum system, Irrawadsy-Andaman and north Burma geologic provinces, Myamar. U S Geological Survey Bulletin 220B-E, U S Department of Interior, U S Geological Survey, p 26.
- **Ware**, P., Ichram, L.,O. 1997. The role of mud volcanoes in petroleum systems: Examples from Timor, the south Caspian Sea and the Caribbean. Indonesian Petroleum Association. Proceedings of an International Conference on Petroleum Systems of SE Asia and Australia, 1997. IPA 2006 pp. 995-998.
- **Whiticar**, M., J. 1994. Correlation of natural gases with their resources. In L. B. Magoon and W. G. Dow eds. The Petroleum System, frm Source to Trap. AAPG Bulletin pp. 261-263.
- **Zelilidis**, A. 2011. Hydrocarbons in SE Mediterranean. Fourth Energy Summit Sustainable, Competitive and Secure Energy in Europe. Conference organized by the Economist, Nicosia Cyprus, Monday, 14th of November, 2011. Power Point Presentation (www.hazliseconomist.com/uploads/speeches/CyprusEnergy2011/Zelilidis.pdf and www.rsijournal.eu/ARTICLES/Journal_dece_2010/GEOPOLITICS%20OF%20ENERGY%20IN%20THE%20KASTELORIZO%20%20CYPRUS%20MIDDLE%20EAST%20COMPLEX%20BASED%20ON%20THE%20EXISTING.pdf).

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