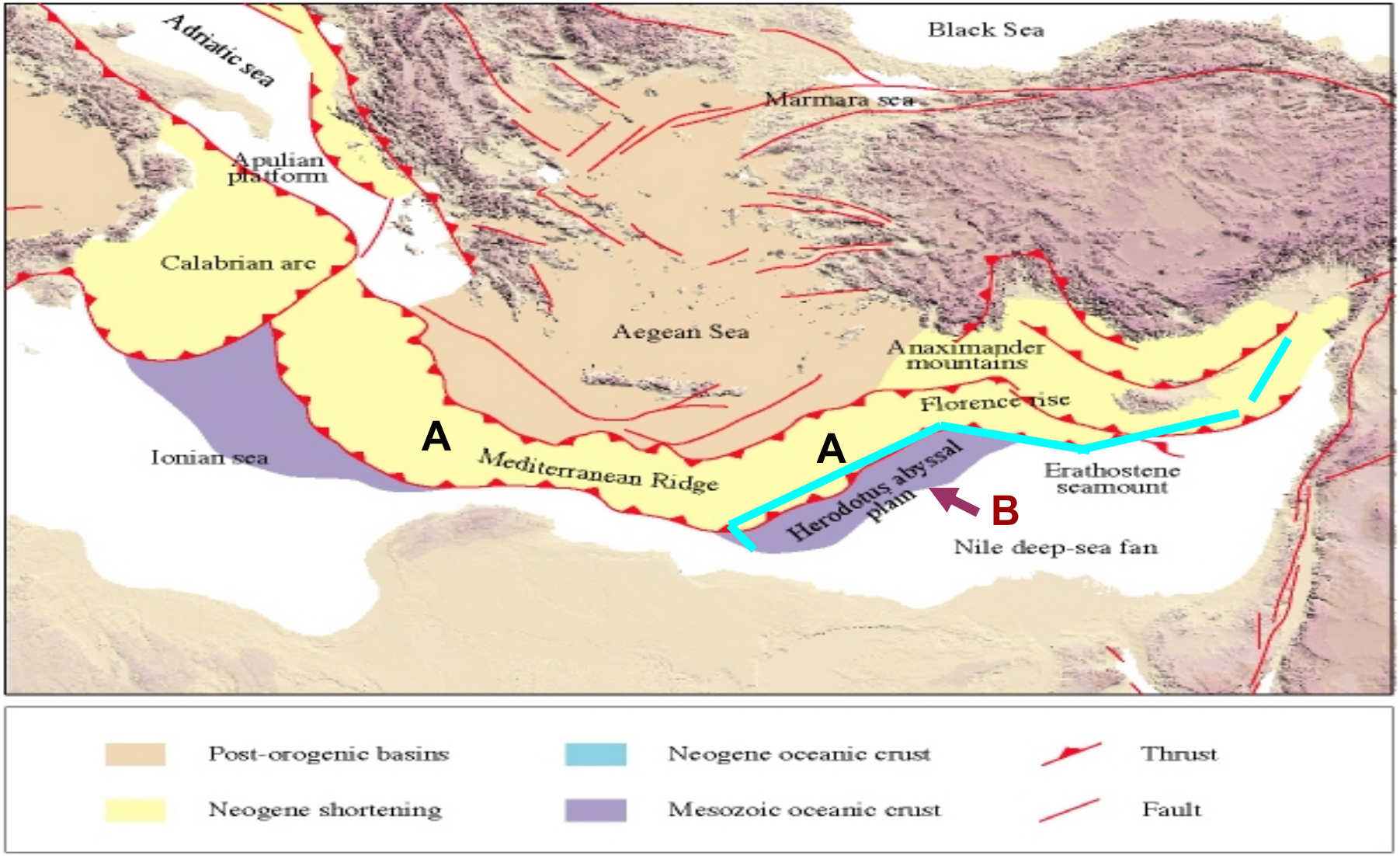
GEOLOGICAL AND GEOCHEMICAL EVIDENCES INDICATING THE EXISTENCE OF LARGE HYDROCARBON DEPOSITS IN THE LIBYAN SEA WITHIN THE GREEK EXCLUSIVE ECONOMIC ZONE (EEZ).

Anthony Foscolos

THEIR ARE 2 AREAS IN SOUTHERN CRETE THAT ARE OF IMMENSE INTEREST AS FAR AS HYDROCARBON EXPLORATION IS CONCERNED. THESE ARE:

A. THE MEDITERRANEAN RIDGE

B. THE HERODOTUS BASIN



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)

Figure 1. Tectonic Sketch of the 2 most important areas for hydrocarbon exploration in the Libyan Sea. A The Mediterranean Ridge and B the abyssal Herodotus Basin, Barrier et al., 2004

IN THE MEDITERRANEAN RIDGE, WHICH EXTENDS FROM WESTERN PELOPONESSE TILL SOUTH OF RHODOS ISLAND, WE HAVE 2 WORLDWIDE INDICATORS THAT BETRAY THE EXISTENCE OF HYDROCARBON DEPOSITS. THESE ARE:

A. MUD FLOW VOLCANOES WITH ACTIVE PETROLEUM SYSTEMS AT DEPTH

B. ACCRETION PRISM COMPLEXES

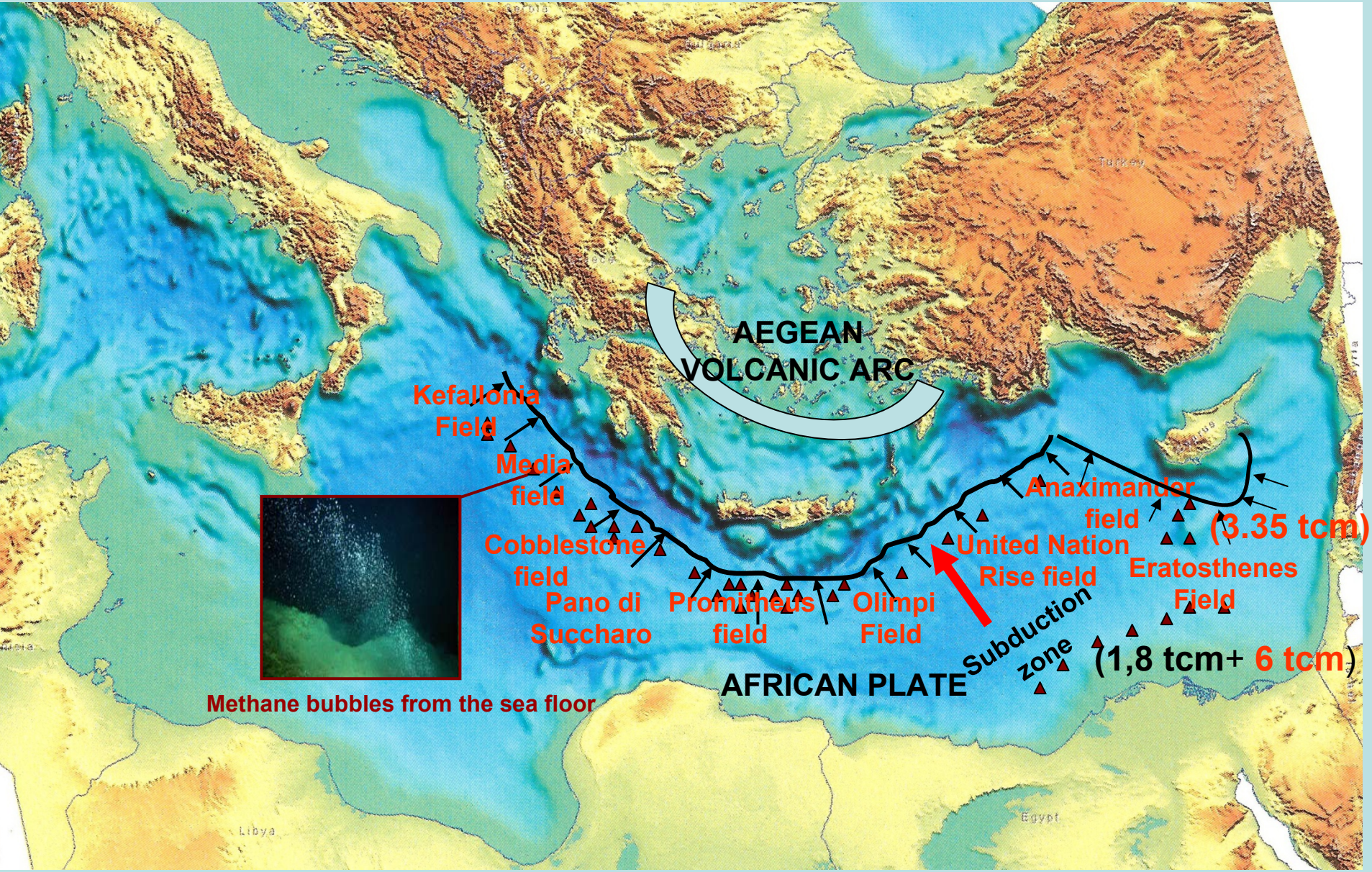


Figure 2. Locations of mud volcanoes along the subduction zone, the Aegean Volcanic Arc and the locations of mud volcanoes along the Cyprus Arc and the Nile Cone. Modified after Dimitrov, 2002

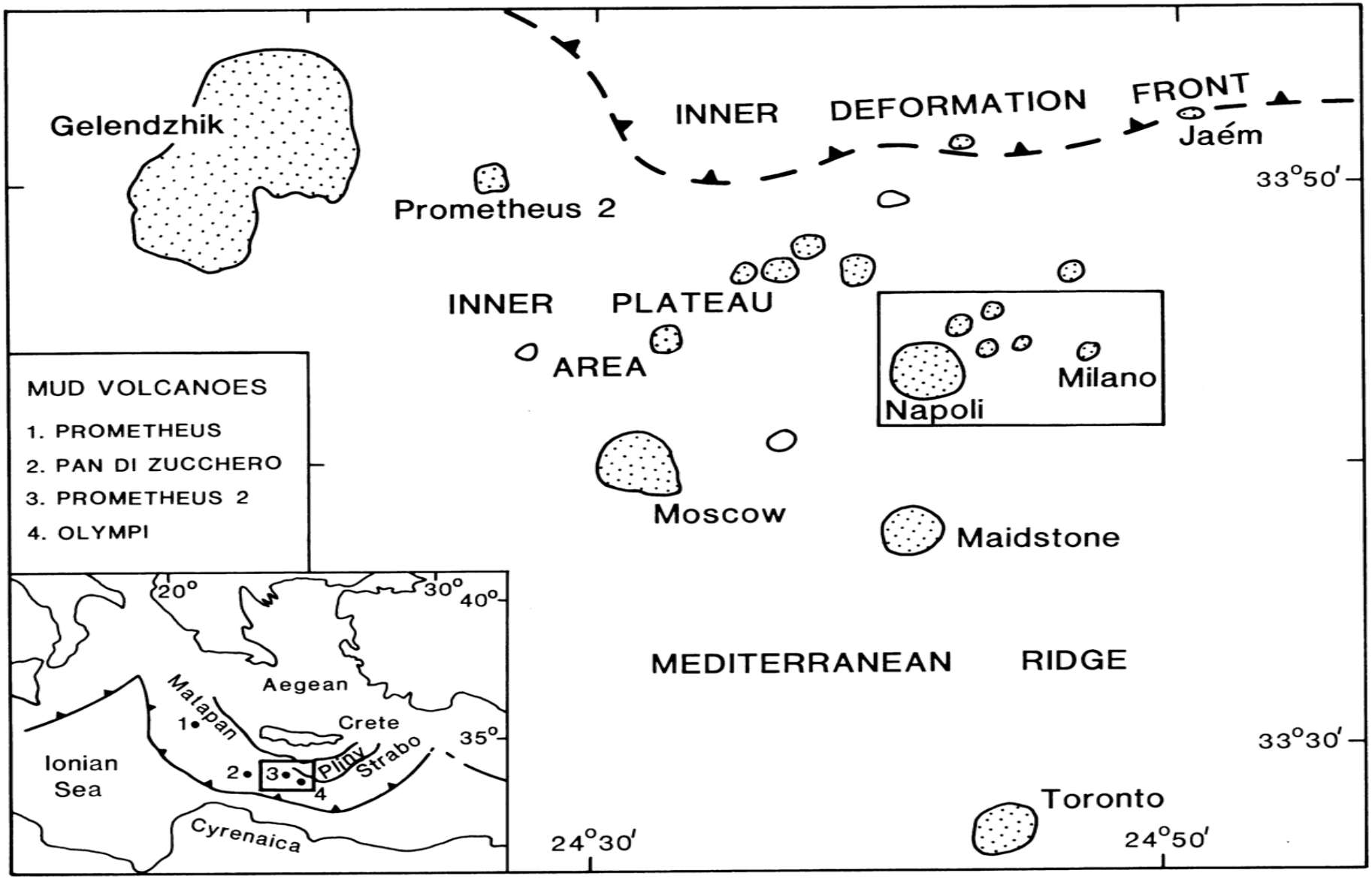


Figure 3. The Olimpi field south of the city of Plakias, Crete. Alastair H.F. Robertson and Achim Kopf 1998 *Proceedings of the Ocean Drilling Program, Scientific Results,* Vol. 160 Robertson, A.H.F., Emeis, K.-C., Richter, C., and Camerlenghi, A. (Eds.), 1998

Figure 4. Methane bubbles from the bottom of the Mediterranean Sea.
www.energybulletin.net/node/51517 **- Cached - Similar**

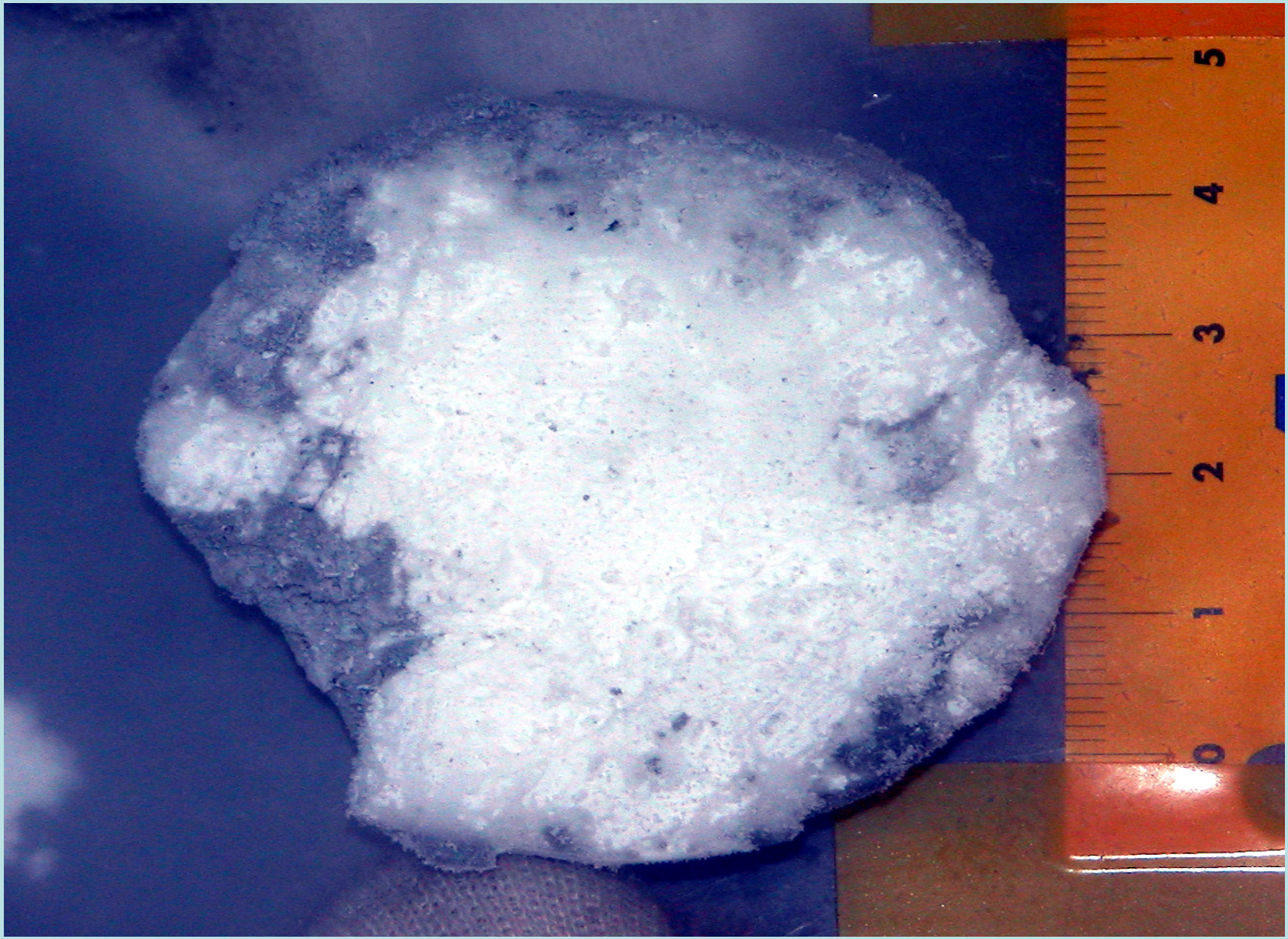


Figure 5. Hydrate lump from the Mud flow volcano Thessaloniki , Anaximander Mountains, East Mediterranean, Lykousis et. al., 2004.

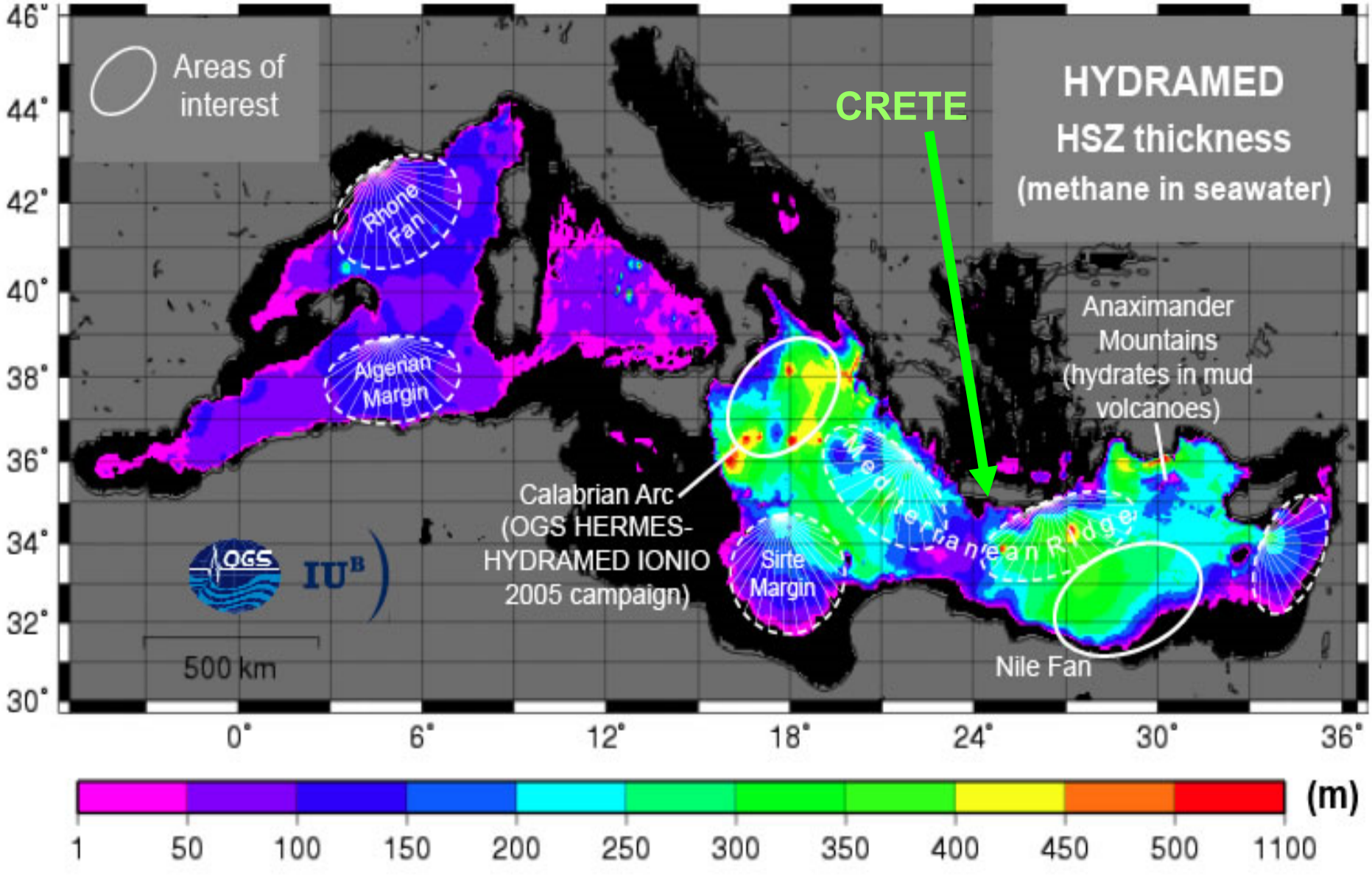


Figure 6. Hydrate thicknesses in the Mediterranean Sea. The biggest thickness is encountered west of Peloponnese and southeast of Crete, Praeg et. al., 2007

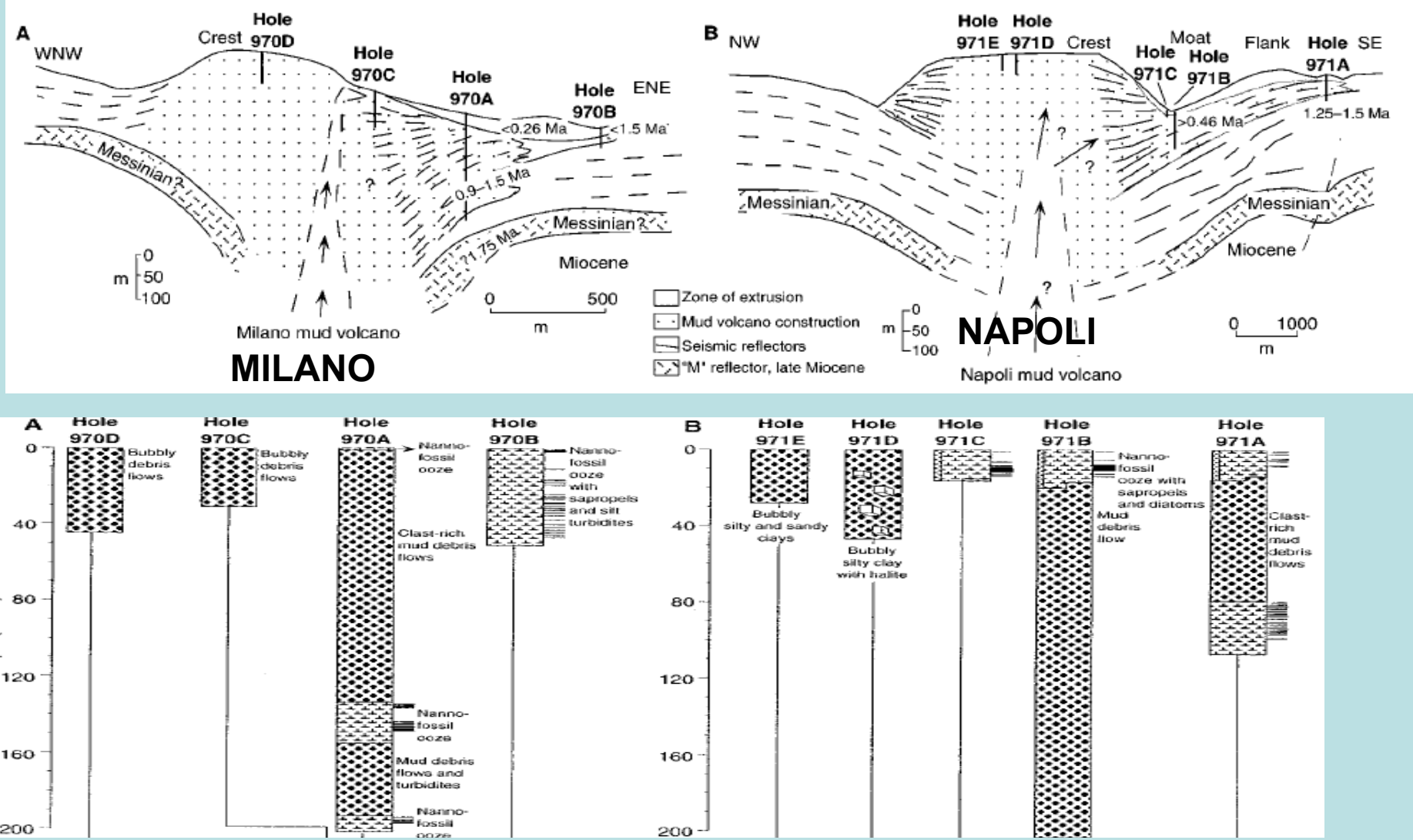


Figure 8. Pockmarks, gas seeps, and the discovery of gas hydrates indicate that the surrounding area is also actively degassing through a vent zone, of which the mud volcanoes are a part. The presence of thermogenic gas is inferred from the ratio of methane to heavier hydrocarbon gases, indicating a deep source of origin, Cronin et al., 1997; Robinson et al., 1996

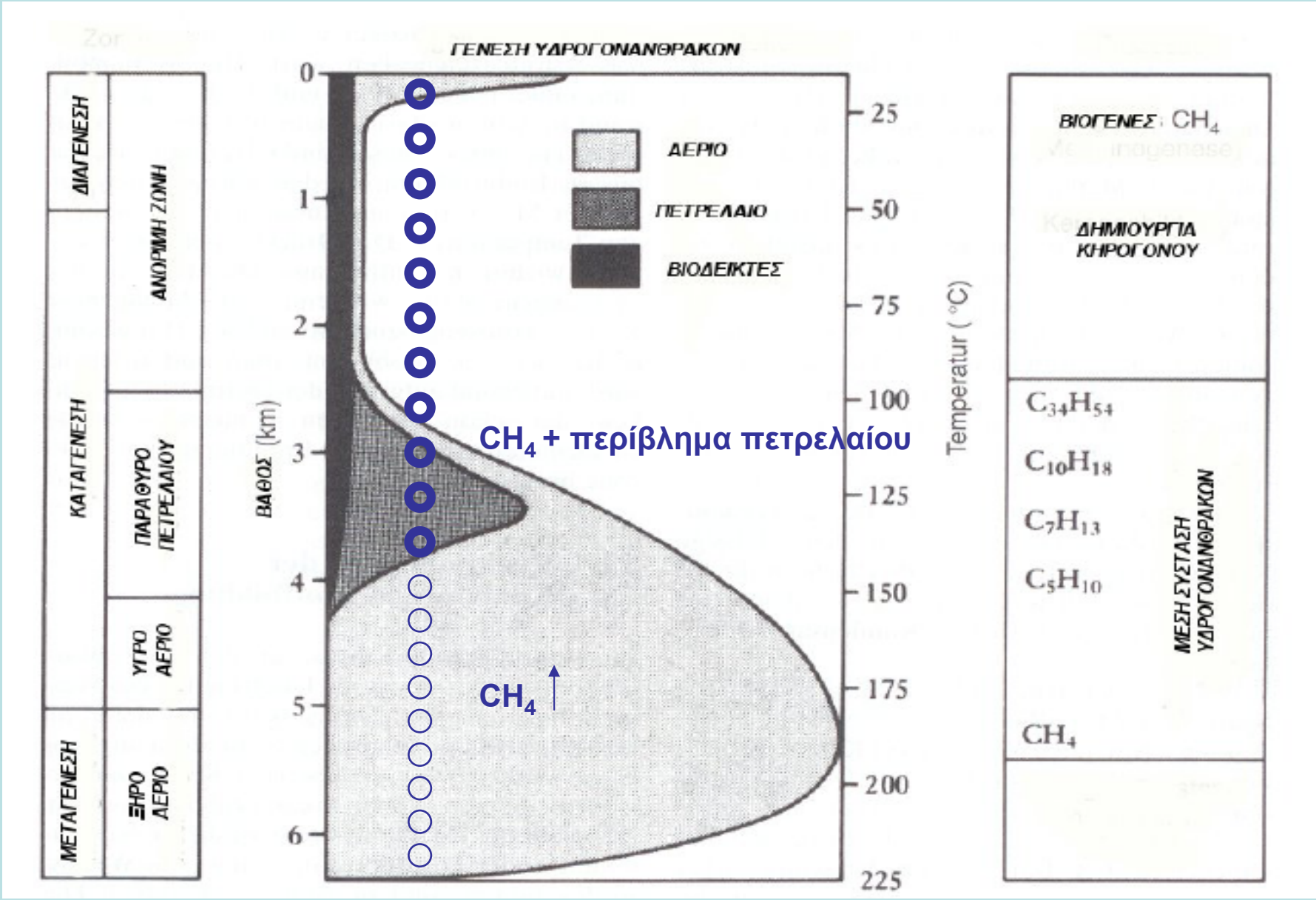


Figure 10. Diagenesis of the organic matter with burial depth. Notes from the Course Organic Geochemistry, Dept. of Mineral Resources Engineering Technical University of Crete, Foscolos and Papanicolaou 2002.

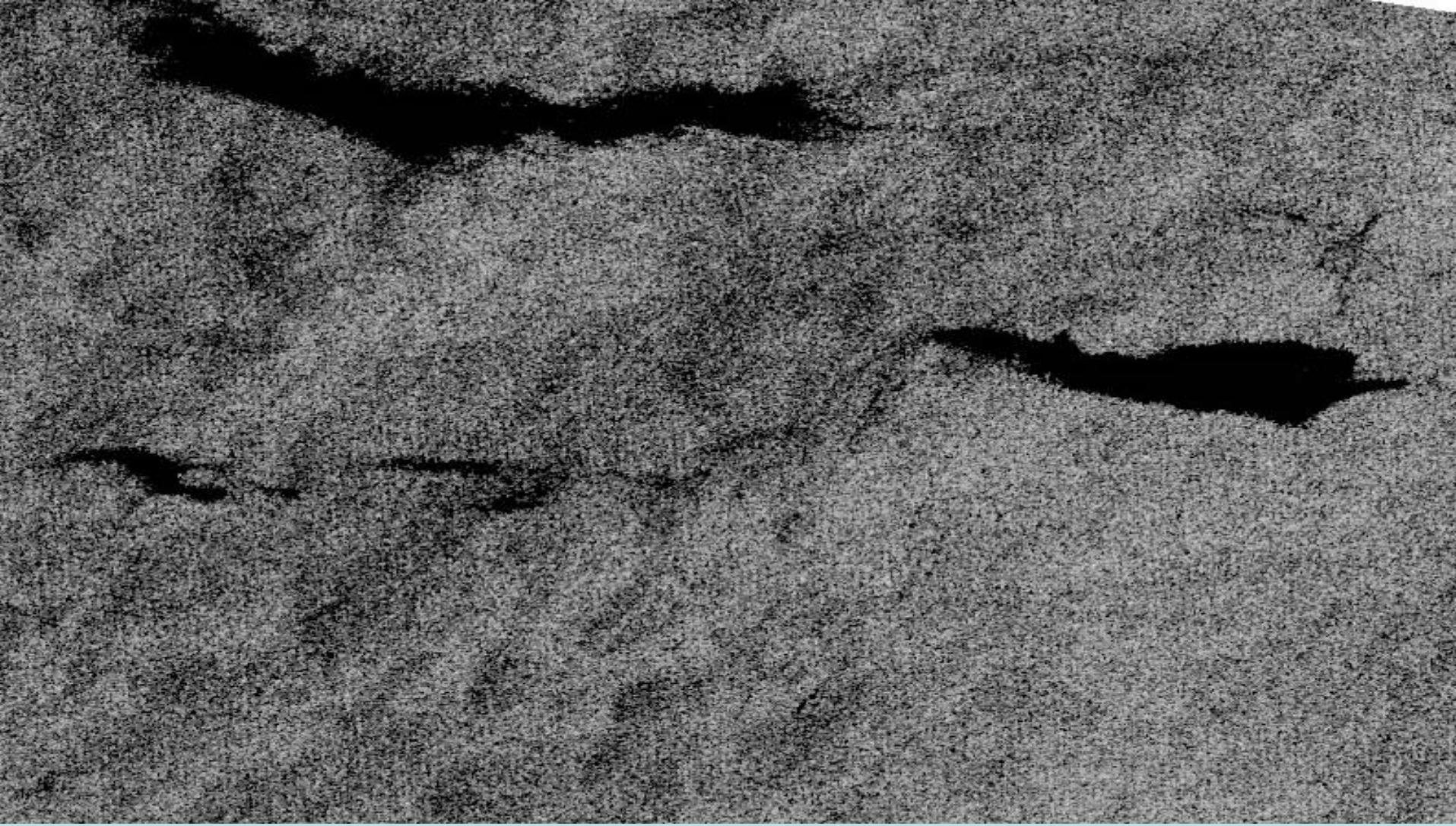


Figure 11. Oil films resulting from escaping gas bubbles which are coated with oil. Gas bubbles are derived from Active Mud Volcanoes. encountered in offshore Nile Cone, Egypt. Picture taken from satellites. Roberts and Peace, 2007

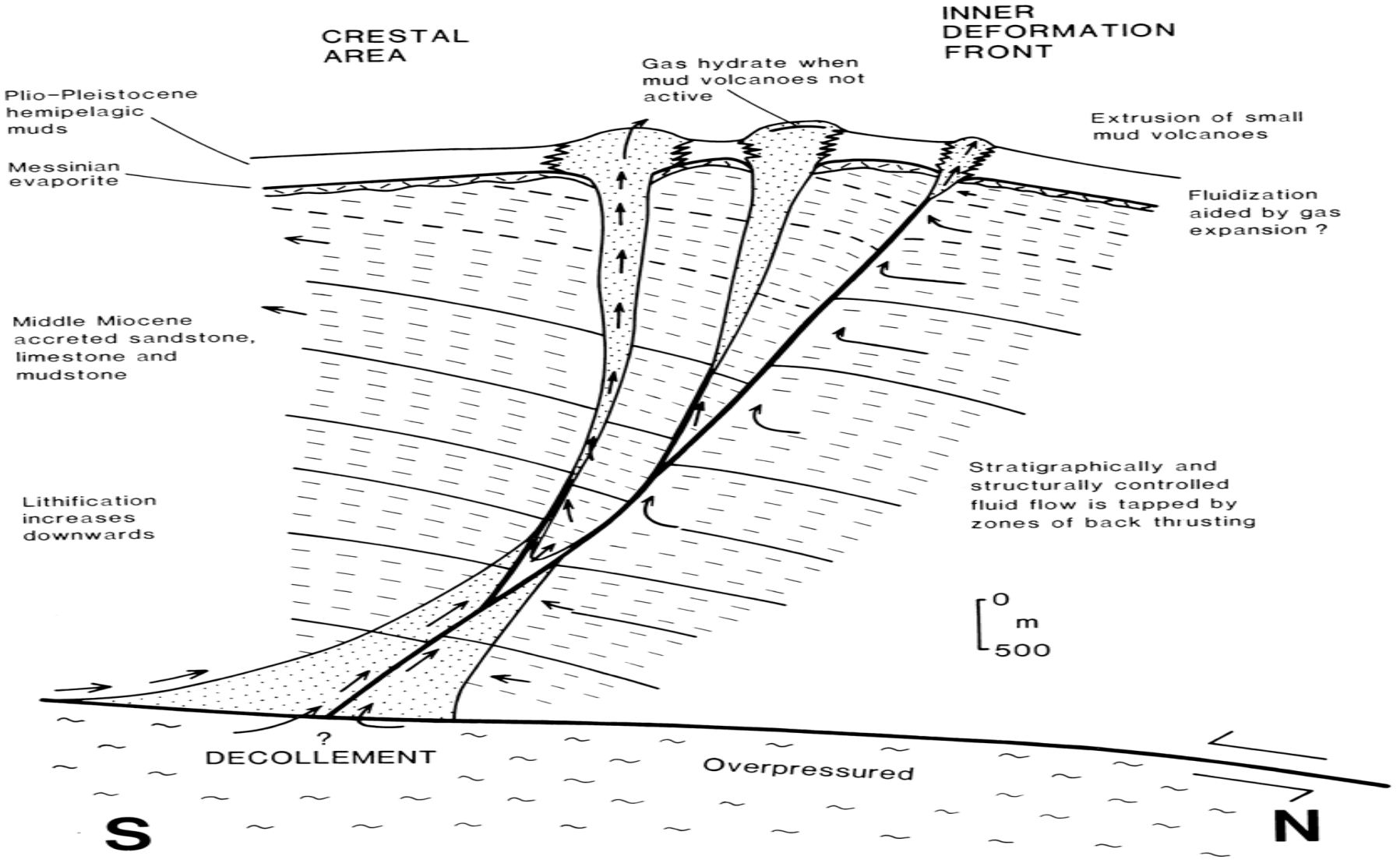


Figure 9. Revised model of mud volcanism on the Mediterranean Ridge Accretionary Complexes supported by petrographic and mineralogical data from Leg 160. Robertson, A., H., F. and Kopf. A. *Proceedings of the Ocean Drilling Program, Scientific,* Vol. 160. Robertson, A.H.F., Emeis, K.-C., Richter, C., and Camerlenghi, A. (Eds.), 1998

Existing Seismic Coverage > Information Package

Limited to Prinos and Sea of Thrace area,

Seismic acquired by unknown companies in the 90's, 00's and most recently 2009.

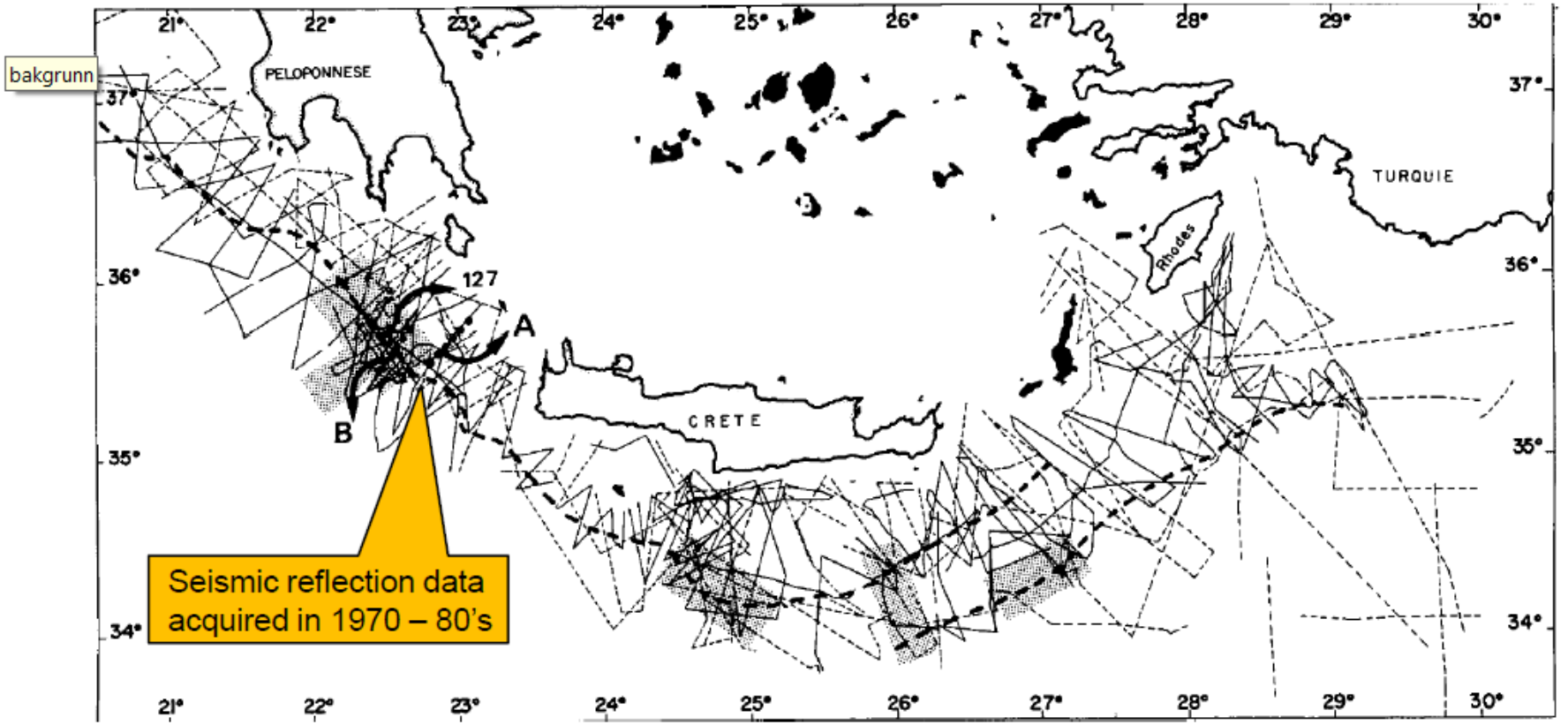


Figure 12. Robinson, J. PGS Multi-Client presentation at Ministry of Energy and Climatic Changes, (YPEKA) Athens Greece, July 2011

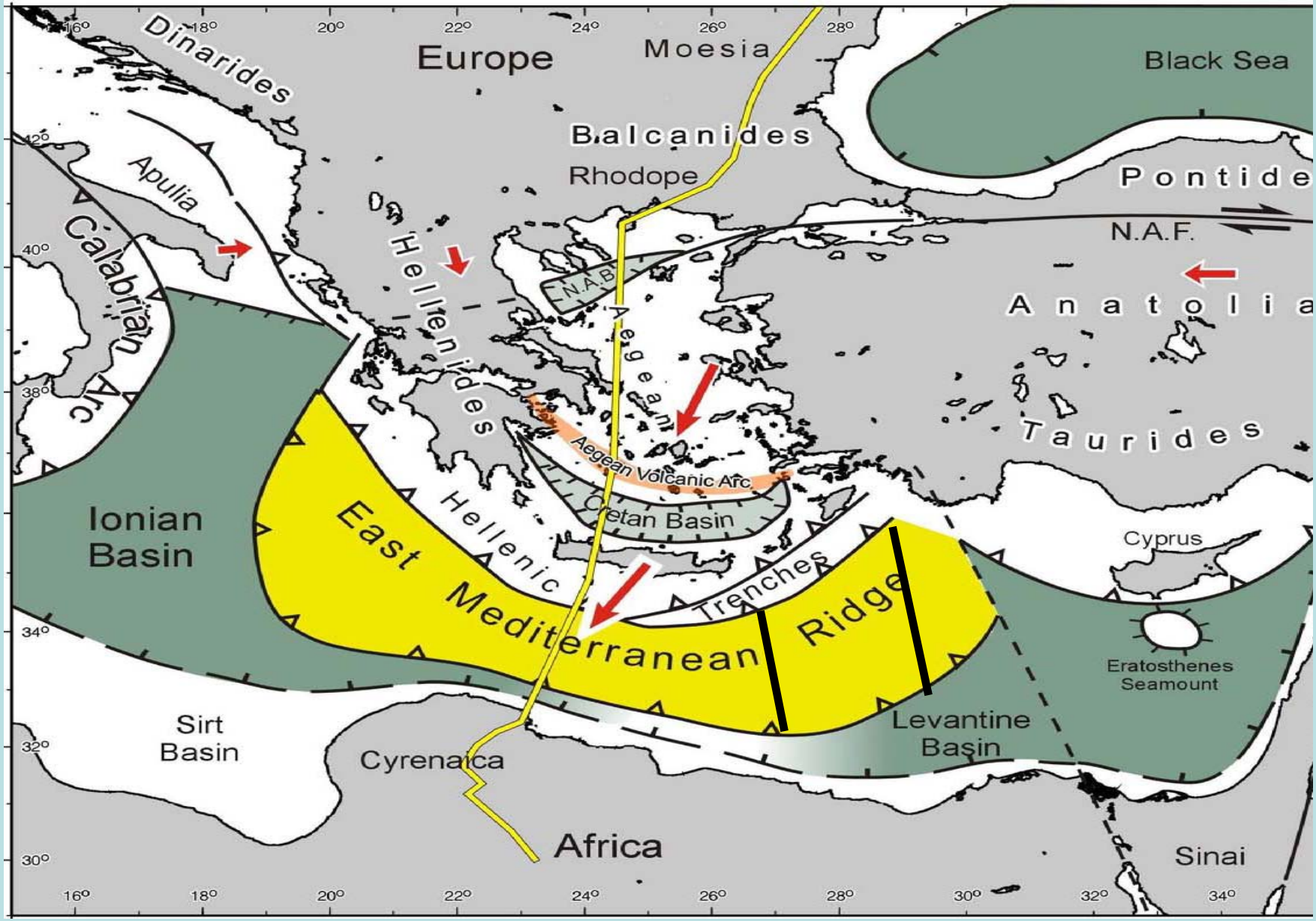
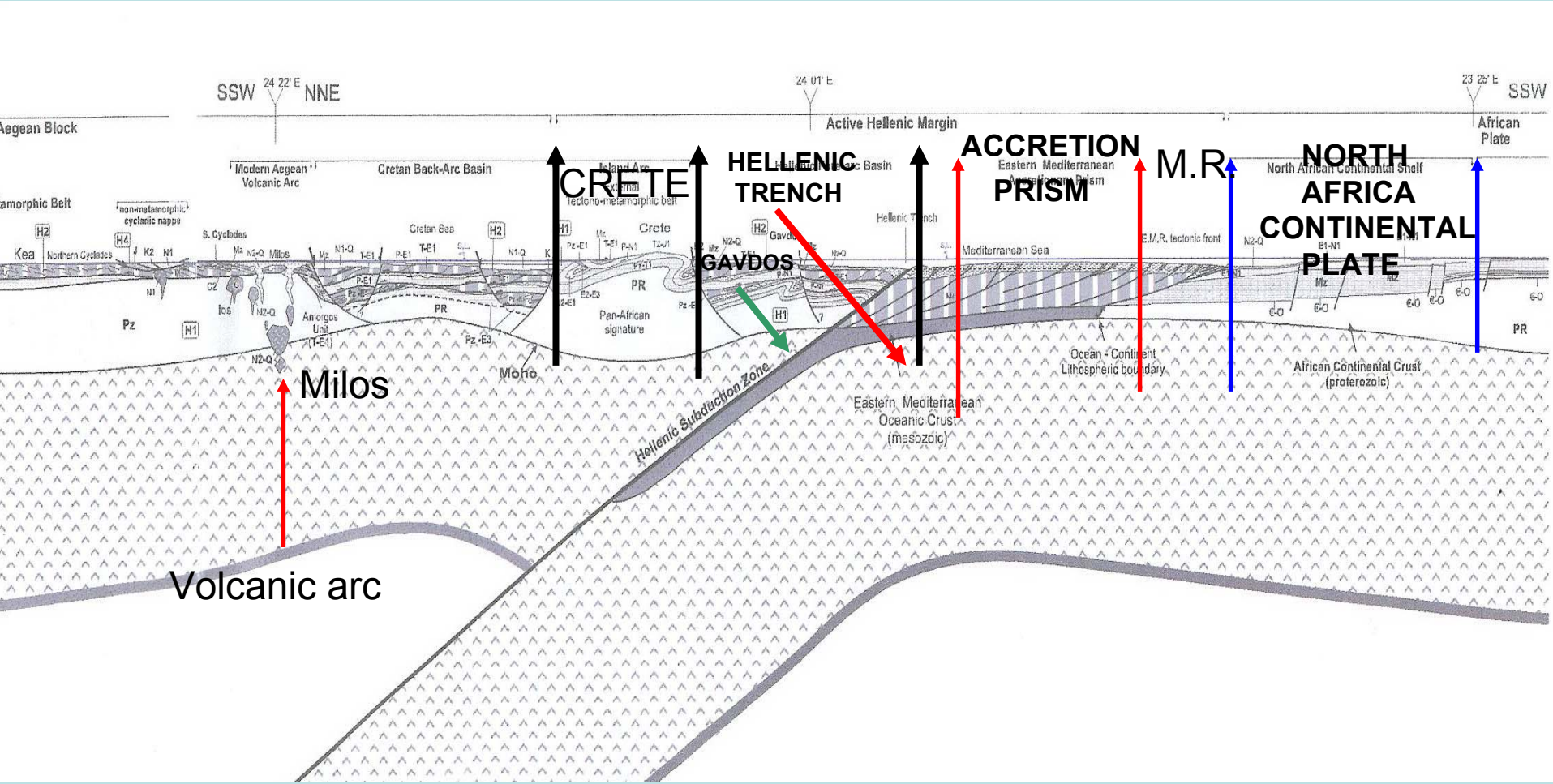


Figure 14. The Mediterranean Ridge and the main geotechtonic elements in the Eastern Mediterranean and the wider area of Transmed VII from Moesia to Cyrenaica, Papanicolaou et. al., 2004



Εικόνα 15. Cross Section of Transmed VII which starts from Cyrenaica and ends at the Aegean Volcanic Arc. The locations of The Mediterranean Ridge (M.R.), the Accretion Prism, Mud Flow Volcanoes (M. F. V.) and the Hellenic Trench are clearly indicated, Papanicolaou et. al., 2004

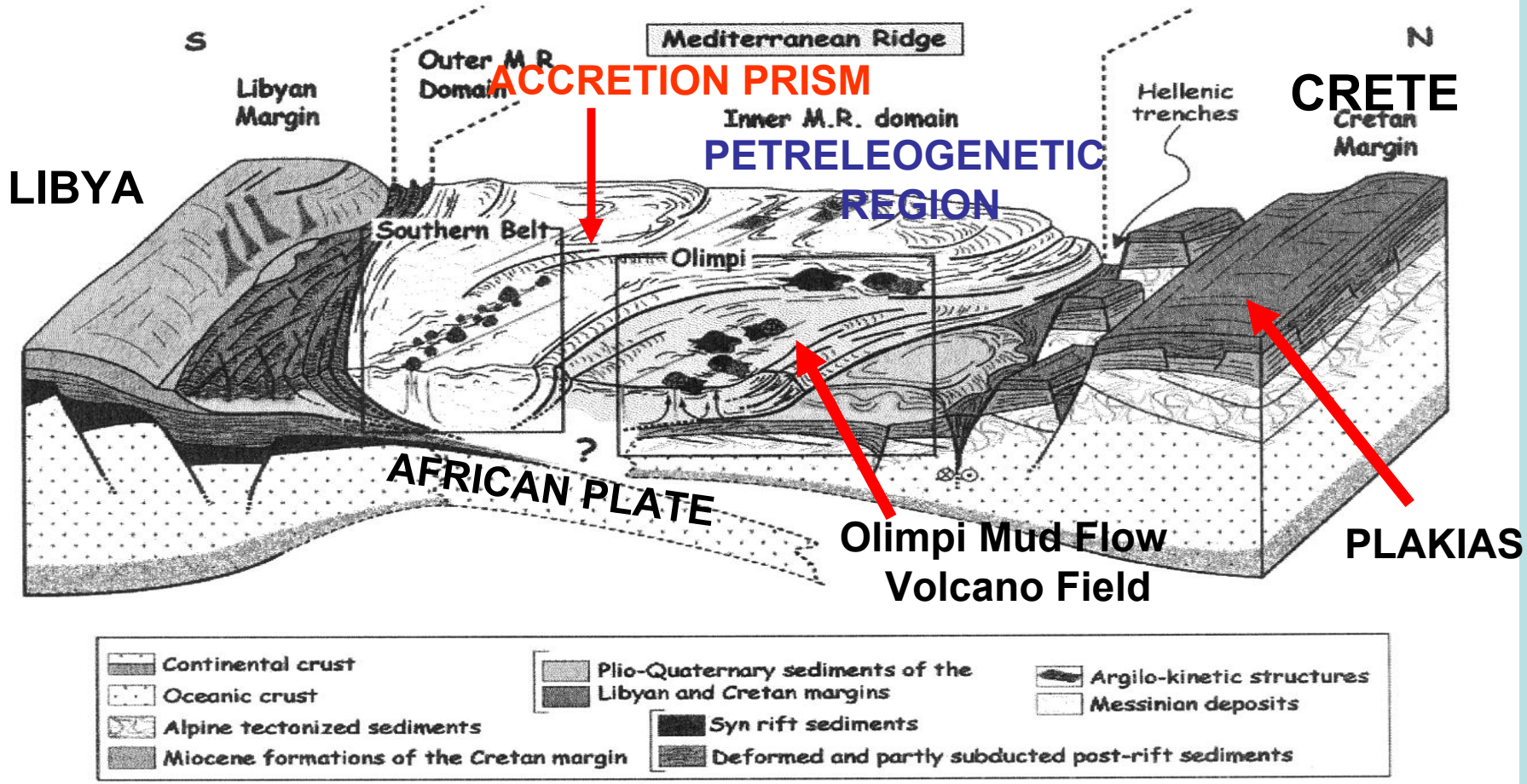


Figure 16. Interpretative 3D tectonic sketch of the Central Mediterranean Ridge and the Olimpi and the Southern Belt mud fields. Two different source levels are proposed for the two mud fields, the Olimpi field being related to relatively shallow mud formations, with high fluid contents and the Southern field being connected to deeper mud sources with lower fluid contents, Huguen, et. al.,2005

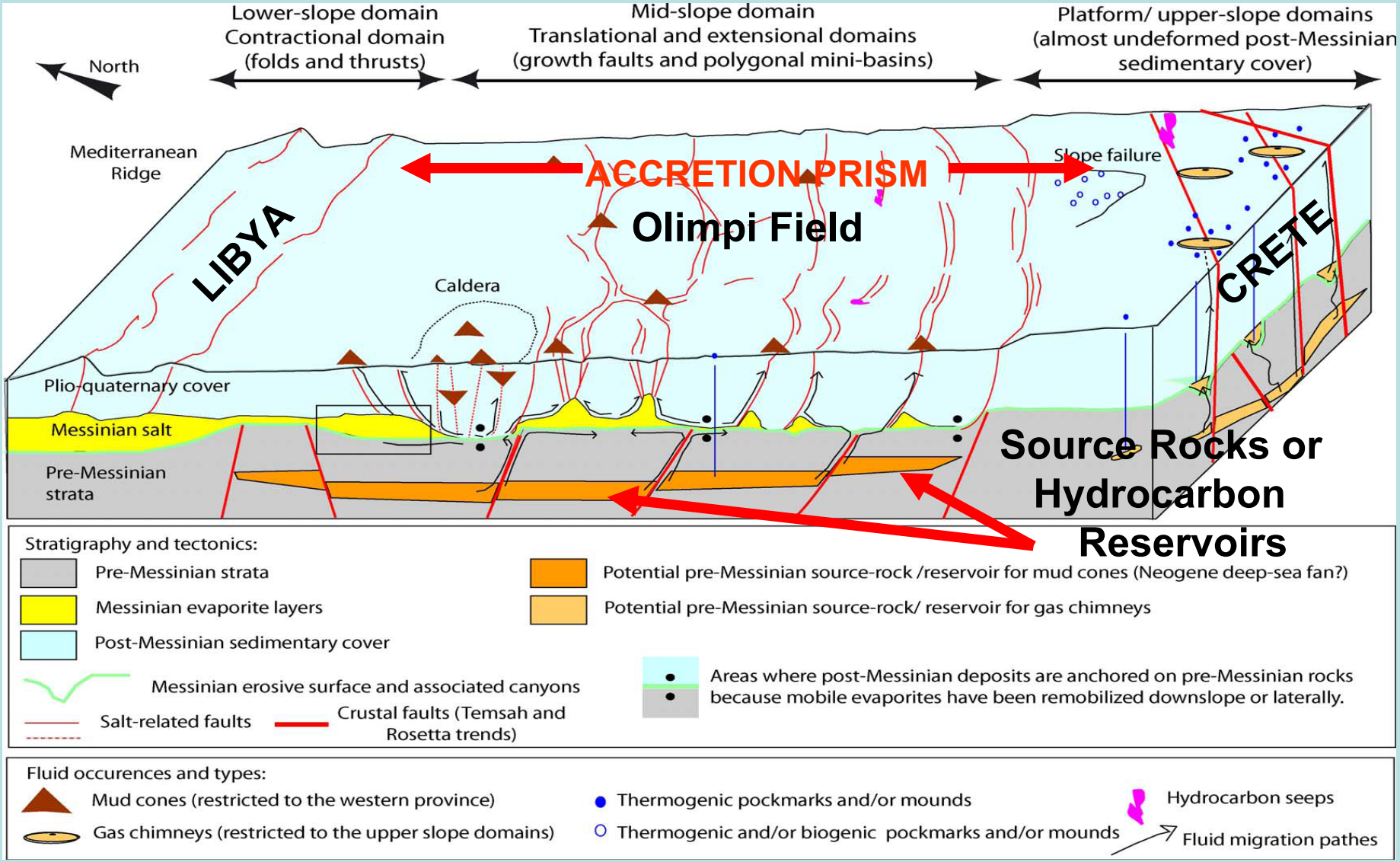


Figure 17. Active Mud Flow Volcanoes (brown triangles), Gas chimneys (brown discs), Thermogenic Pockmarks and Mounds offshore Southern Crete. The pre-Messinian source rocks/ reservoir for the mud cones (brown), are highly visible as well as the reservoir/source for the gas chimneys (light brown), are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

HYDROCARBON POTENTIAL IN GREECE

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

Πίνακας 1. Source Rocks, Hydrocarbon Reservoirs, Seals, Type of Traps and Type Basin. Worth noticing is the type of basin in the Southern Mediterranean Sea…..LEVANTINE, Robinson, 2011

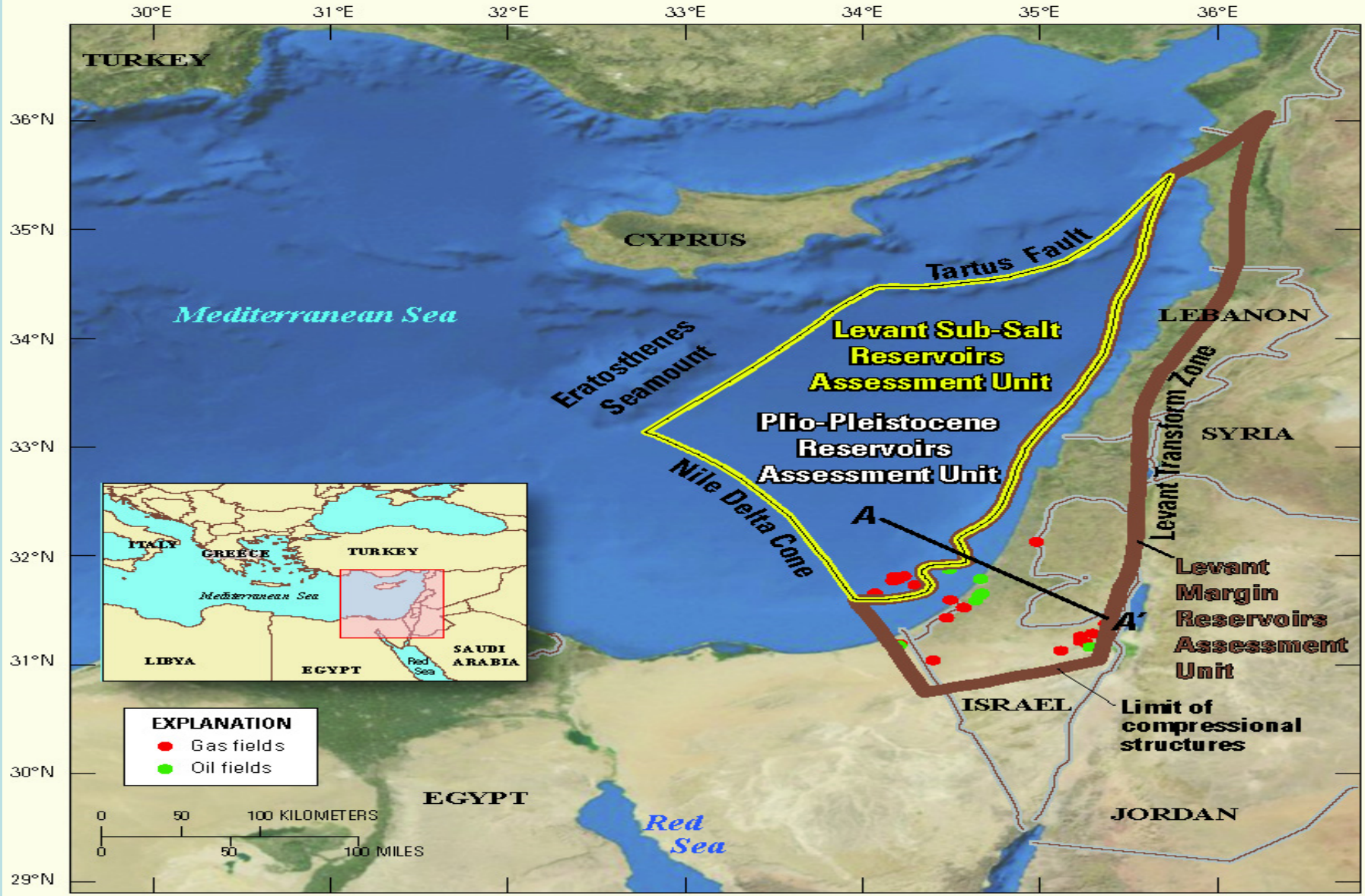


Figure 18. The Levantine basin with its recent hydrocarbon discoveries. Assessed potential for further discoveries of natural gas 122 tcf (3,45 Tcm) and 1,7 billion barrels of oil, USGS Technical Report, 2010

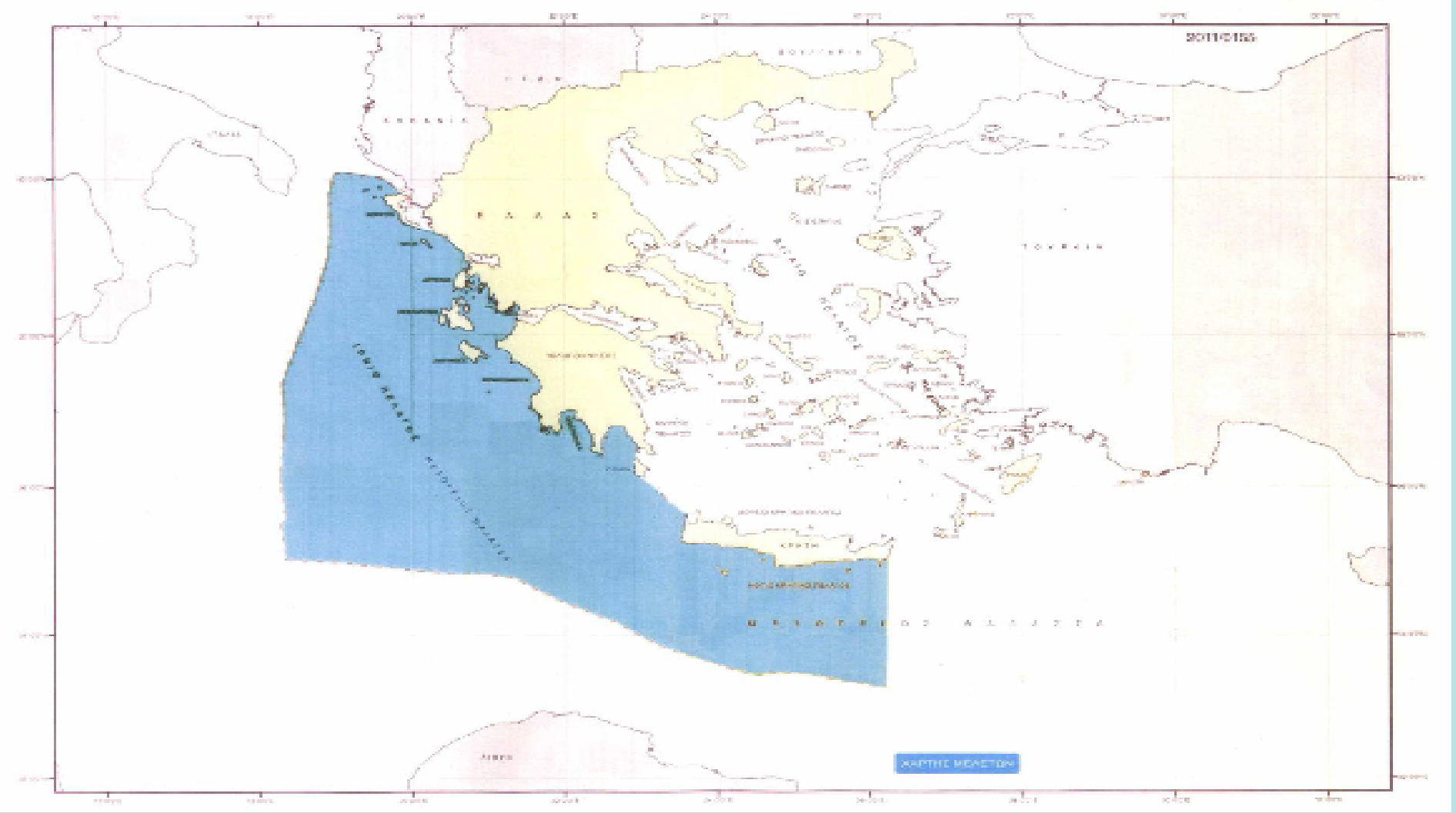


Figure 19. The limits of the area under exploration (seismic survey) are based on the principle of median/equidistance (without considering the Bay of Sirta) line after taking into consideration all territories of the involved states. International Public Invitation for the participation in Non-Exclusive seismic Survey on the Continental shelf of Western and Southern Greece. June 7, 2011, www.maniatisy.gr/index.php?

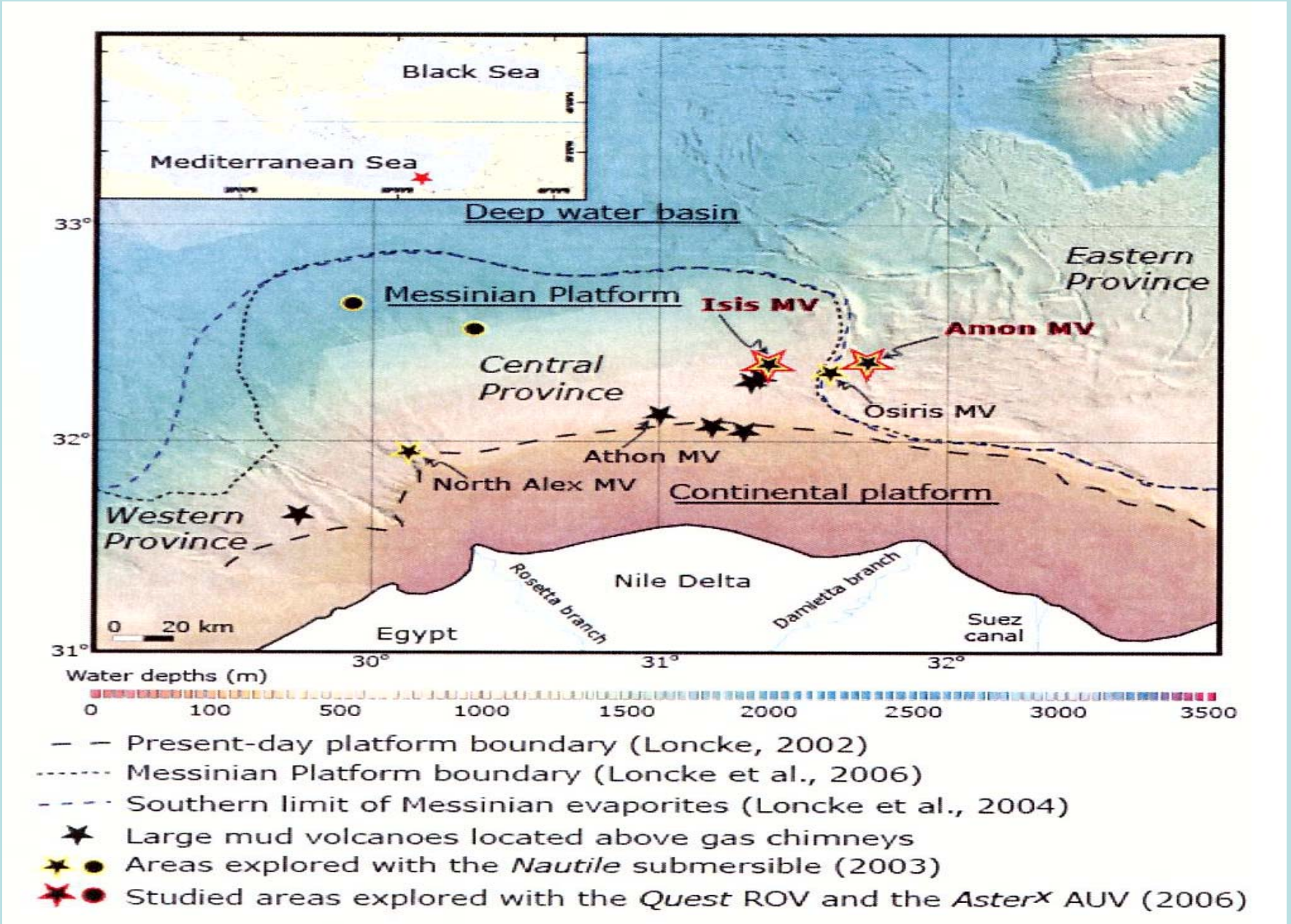


Figure 20. Active Mud Volcanoes in the Nile Cone, Dupre, et. al., 2008

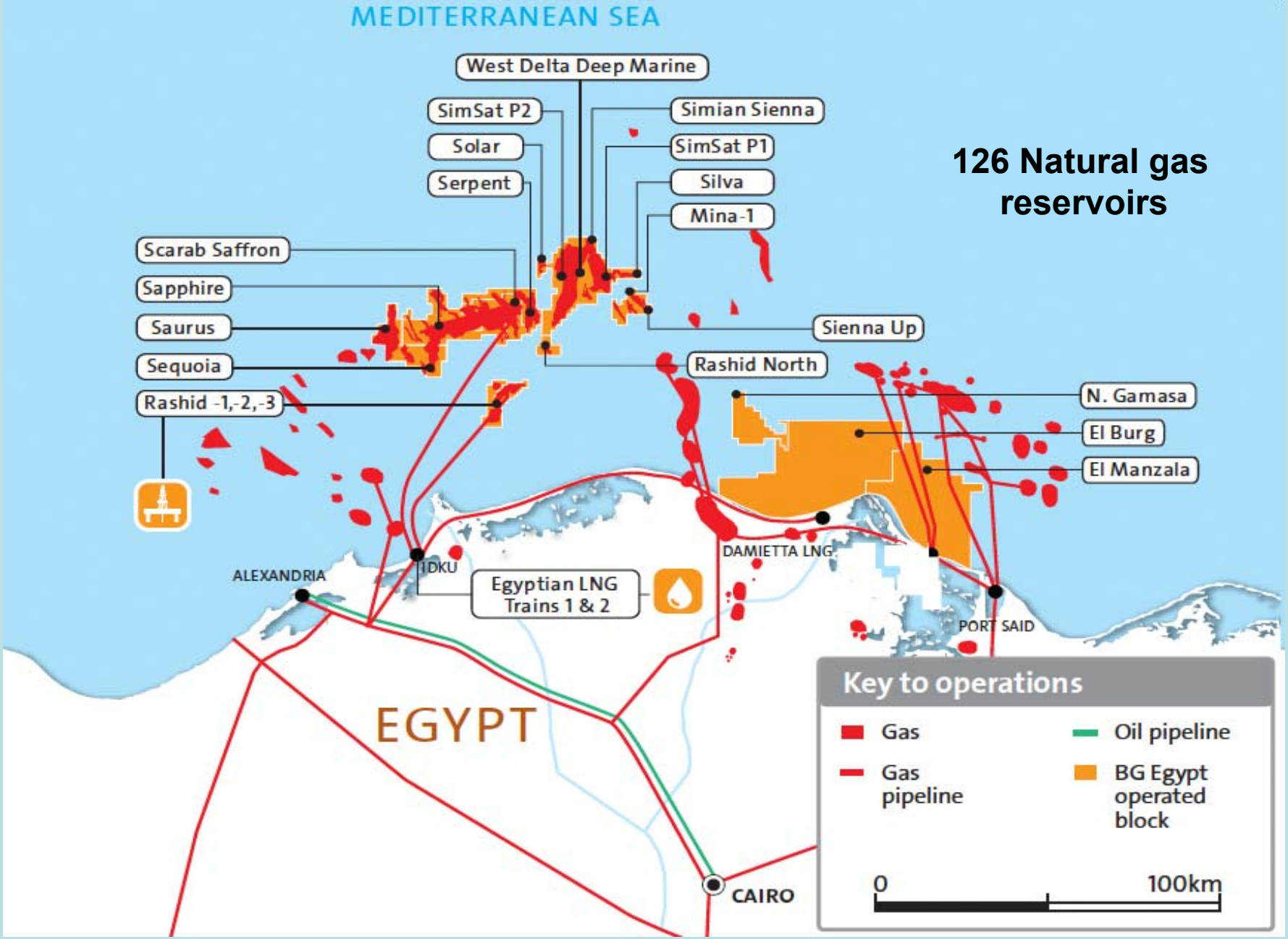


Figure 21. Distribution of natural gas reservoirs offshore Egypt, Neftegaz, EU, 2010 Rigzone, 2010

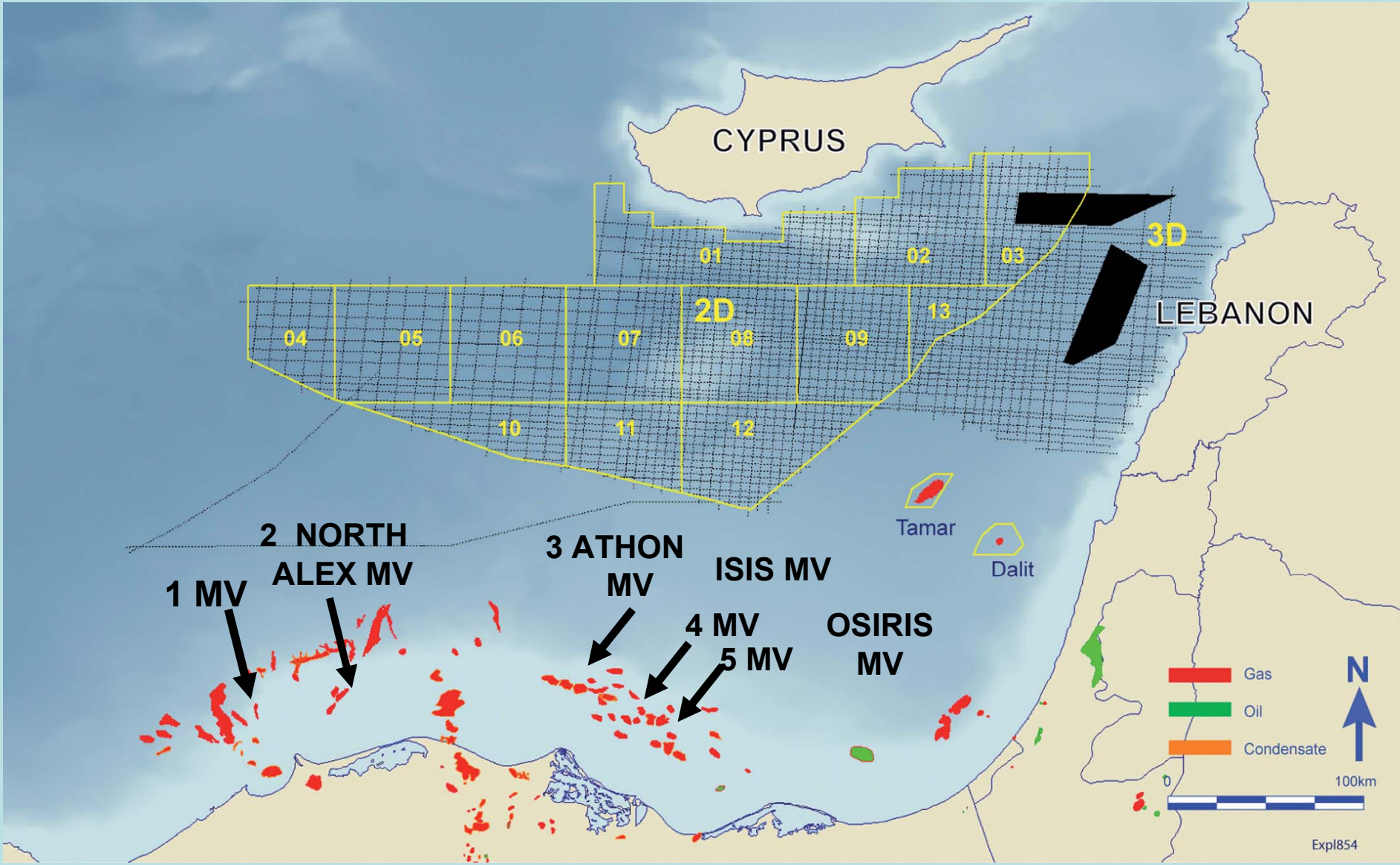


Figure 22. Location of Active Mud Flow Volcanoes (MV) in relation to the natural gas deposits in the Nile Cone. offshore Egypt. Figures 20 and 21 combined.

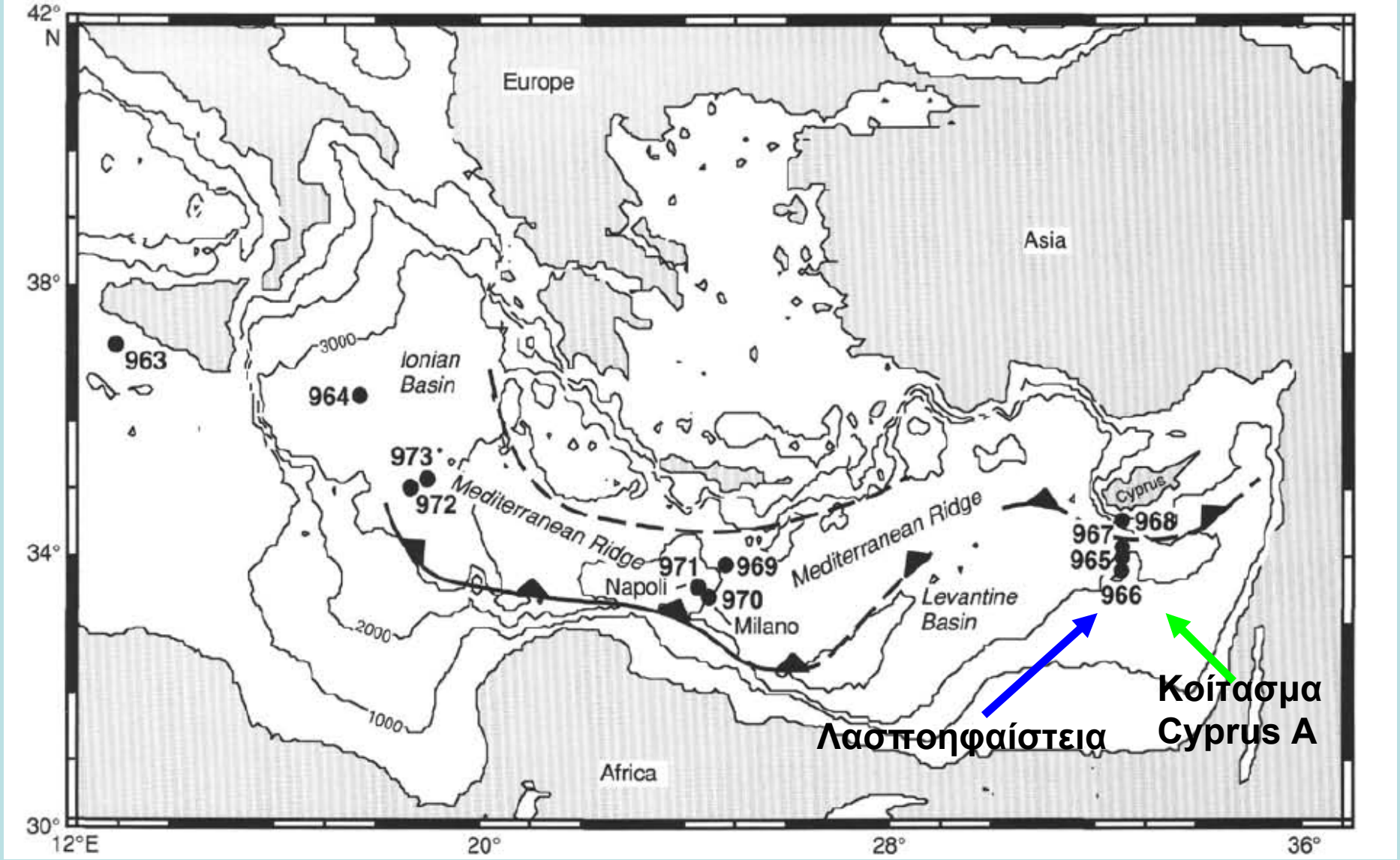


Figure 23. Outline map of the Eastern Mediterranean Ridge showing the location of the Milano (site 970), Napoli (site 971) and Eratosthenes (sites 965, 966, 967 and 968) mud volcanoes drilled during ODP Leg 160. Robertson and Shipboard Scientific Party, 1996.

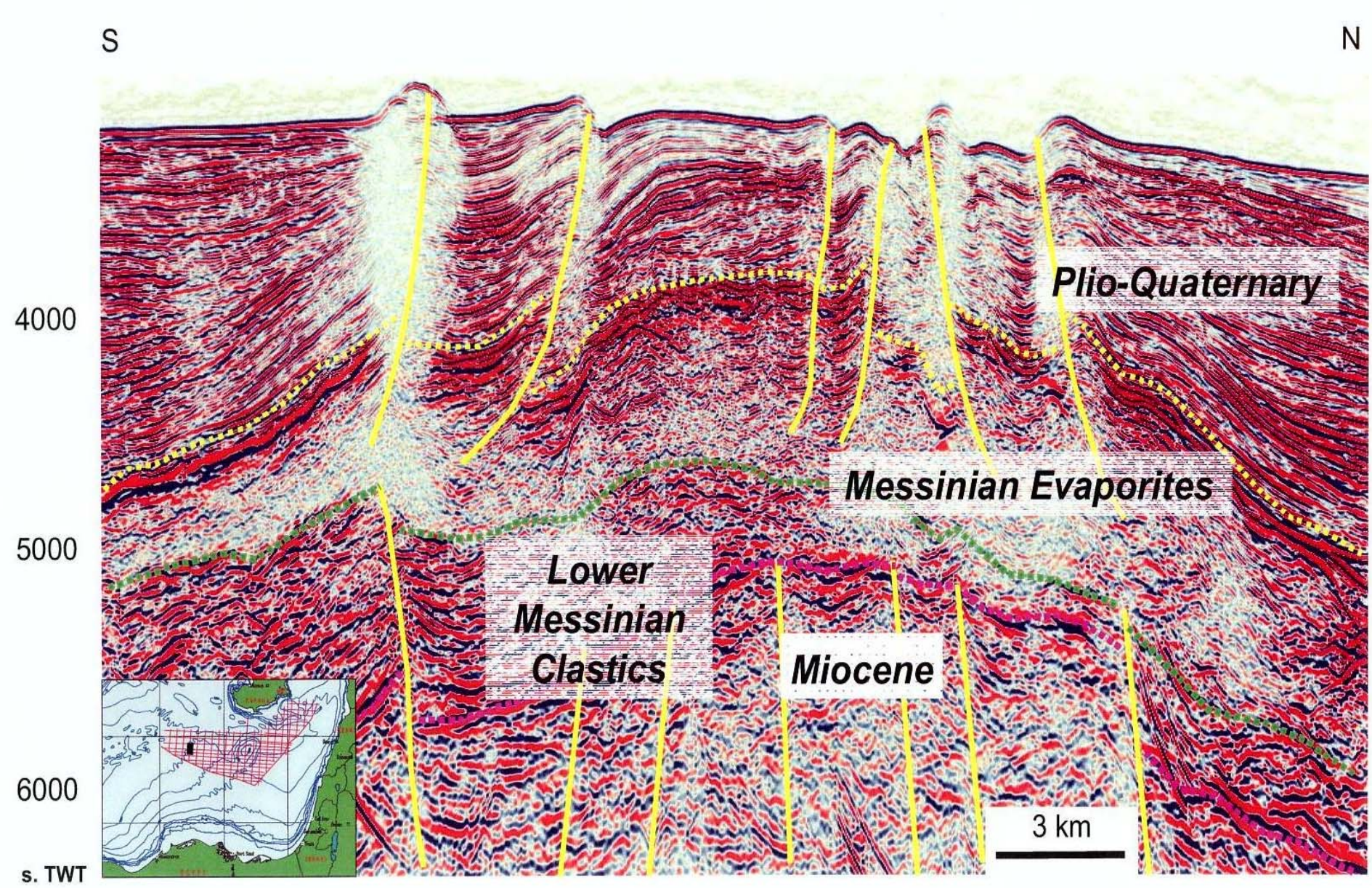


Figure 12. Large anticline on the toe of deep Nile delta fan with Messinian low-stand delta clastic sand faulted pre-Messinian. Gas chimneys are highly visible, Montadert and Nikolaides, 2010.

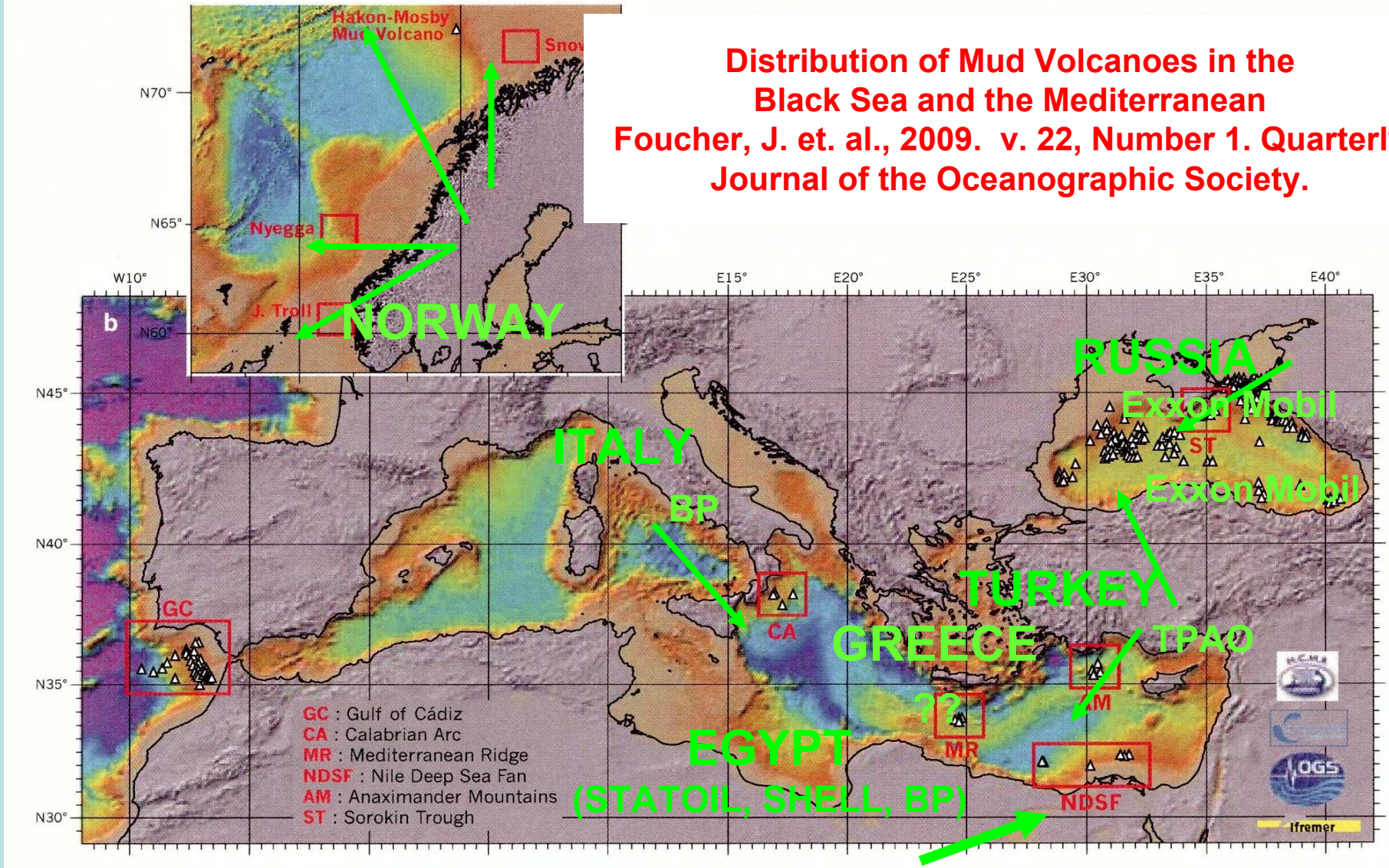


Figure 24. Distribution of mud flow volcanoes in the North Sea, Black Sea and the Mediterranean Sea, Foucher, et. al., 2009. Green arrows indicate the exploration areas of oil and gas around the mud flow volcano fields

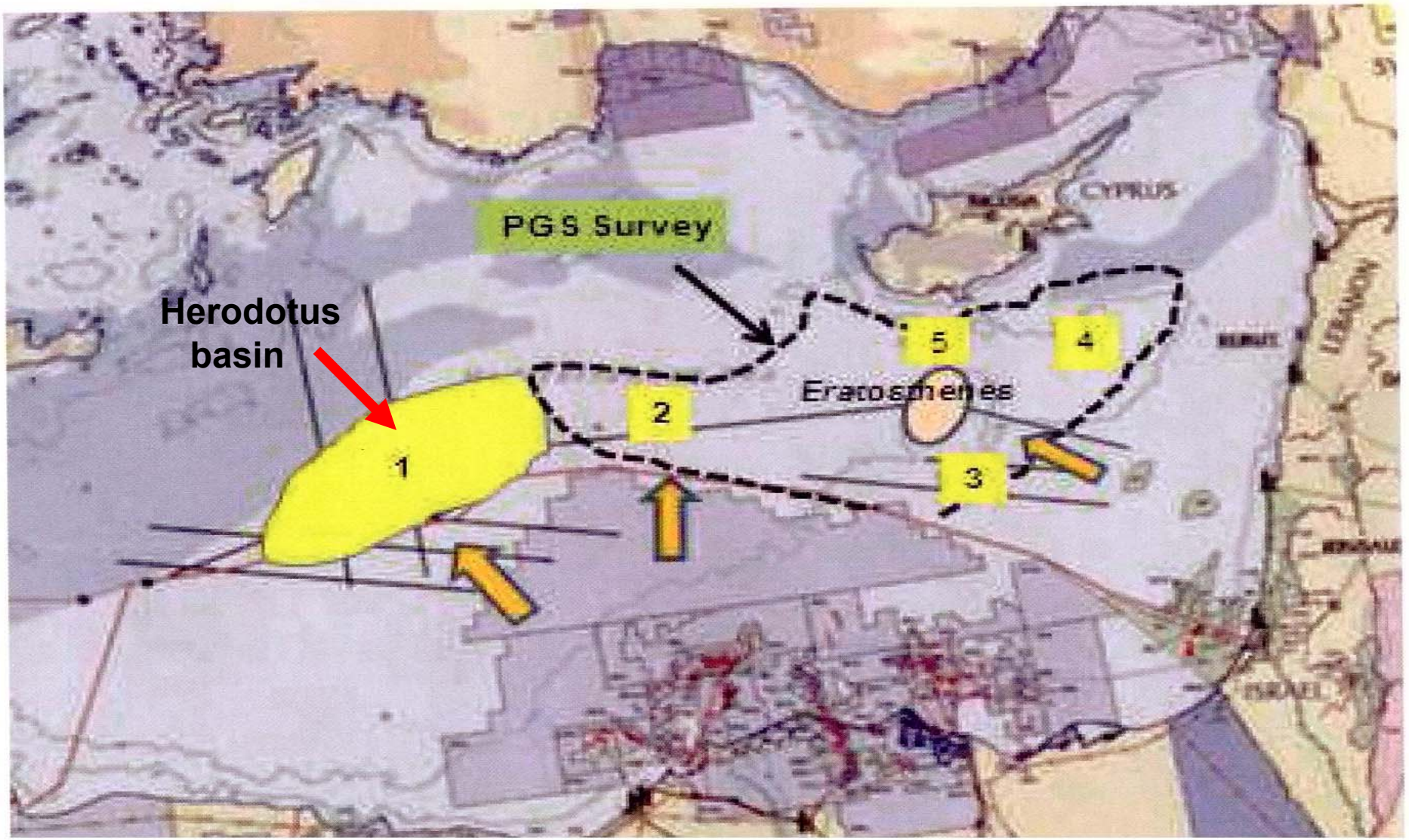


Figure 25. Potential hydrocarbon areas offshore Cyprus and the Greek Herodotus Basin, after IFP (Institute Francais du Petrole), Bruneton et al., 2010 Overview on the Hydrocarbon potential of the East Mediterranean Deep Offshore: Perpectives for Greek exploration, BEICIP/FRANLAB, 2007.

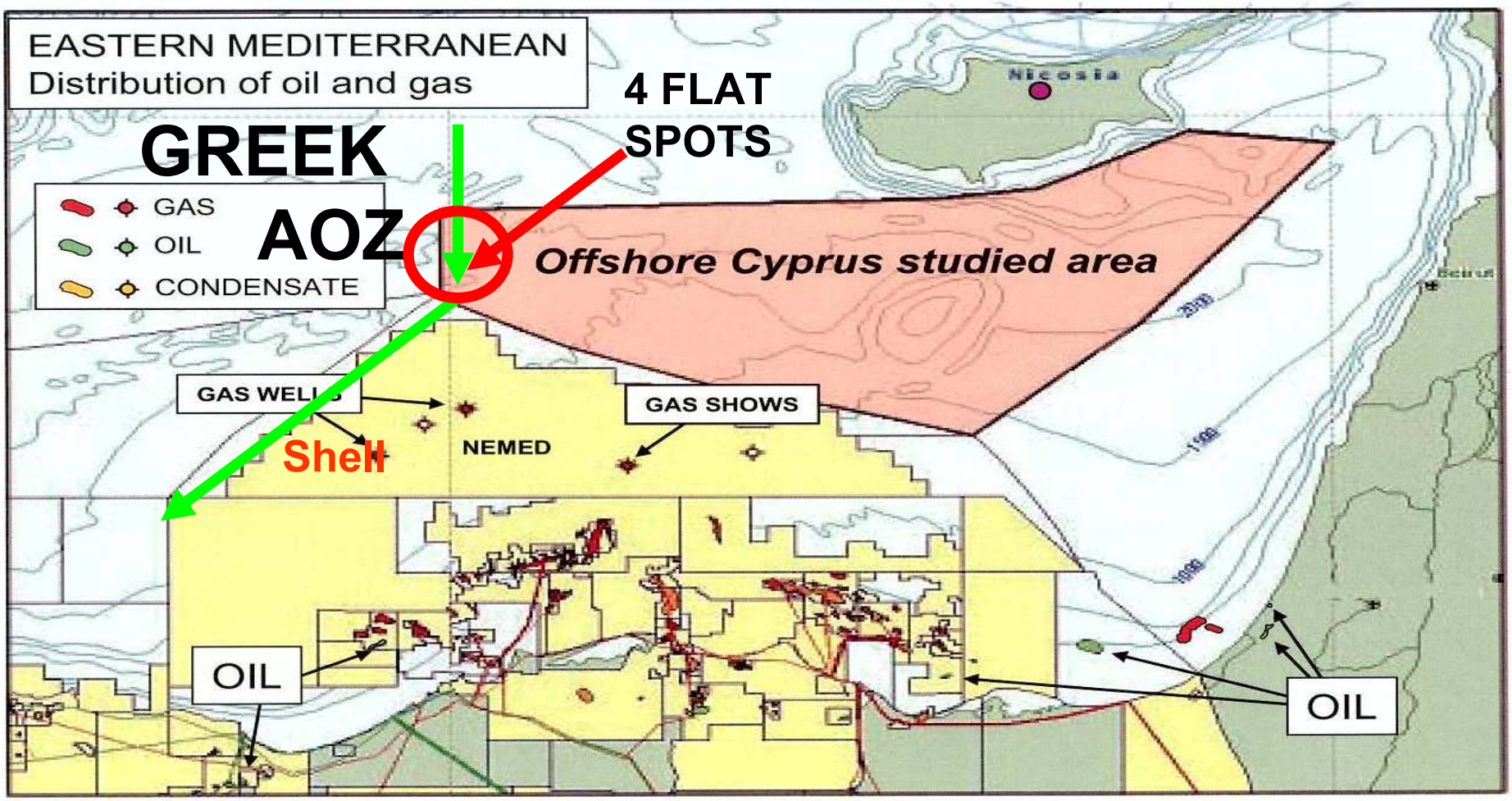


Figure 28. Distribution of oil and gas Fields and Discoveries in Eastern Mediterranean. Of interest are the 2 gas fields discovered by Shell, due to their proximity to the Greek and Cypriot Herodotus Basin. BEICIP/FRANLAB, 2007

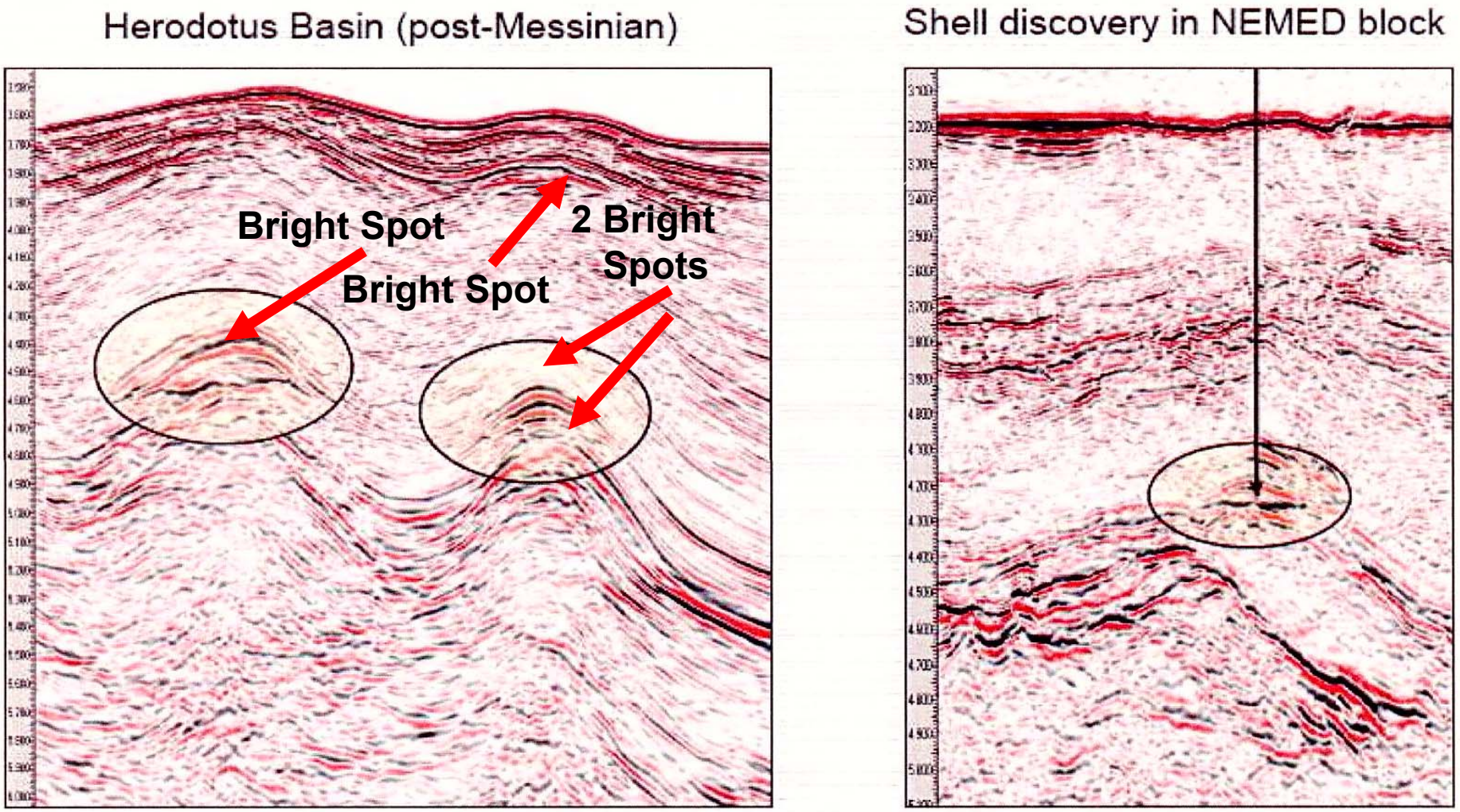


Figure 18. Correlation between Bright spots (DHI) detected by PGS in the Herodotus Basin belonging to Cyprus and the bright spot which lead to the successful Shell discovery in NEMED Block, Kassinis, 2008, Semb, 2009

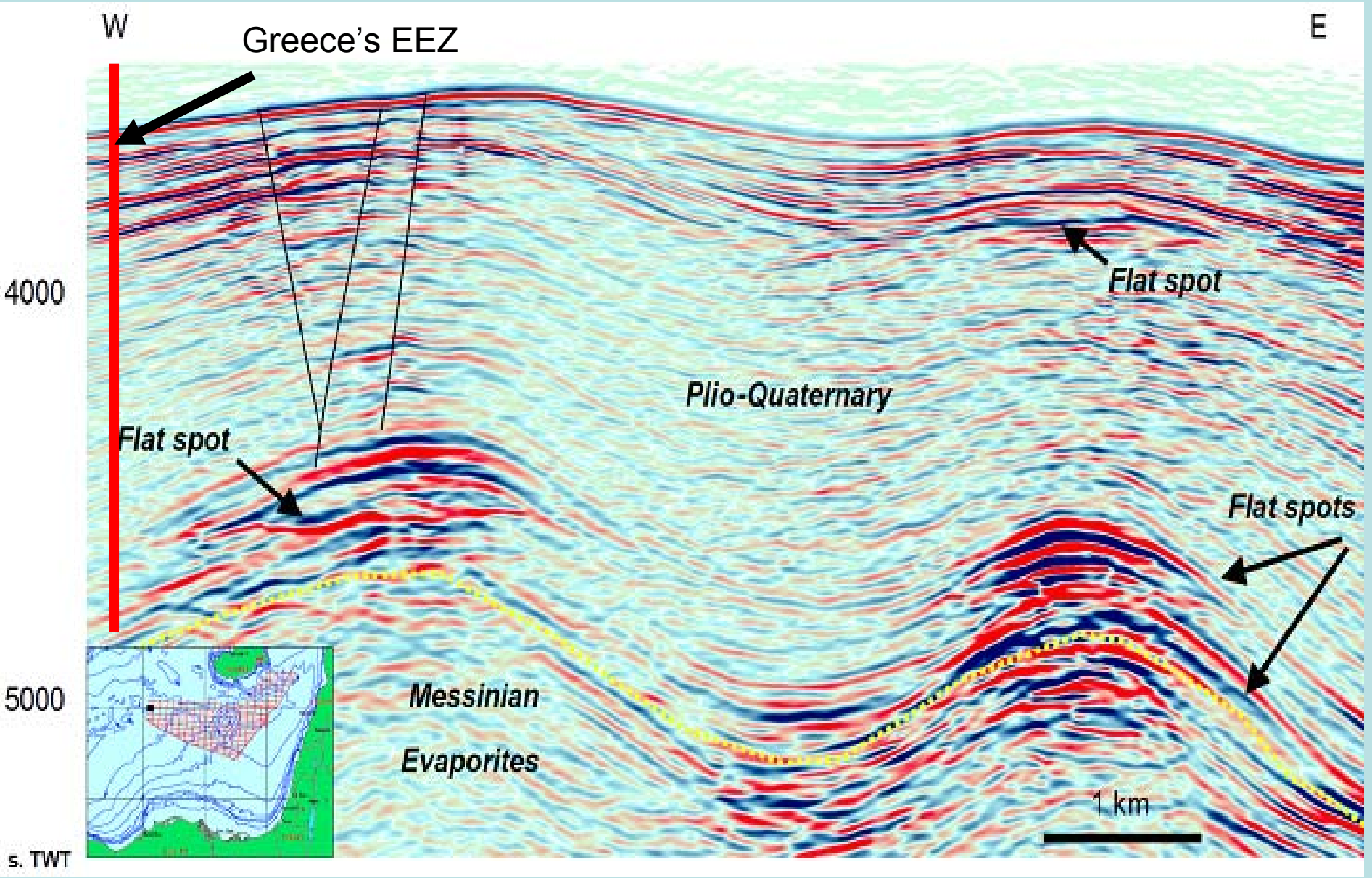


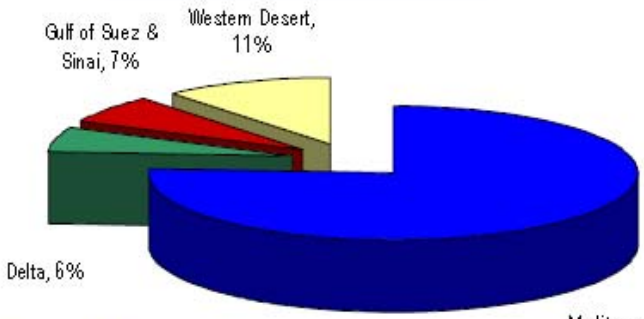
Figure 26. Plio-Pleistcene salt related anticlines with the 4 flat spots which are indicators of natural gas occurrence inside in the Herodotus basin Montadert, et. al., 2010.

Regional Hydrocarbon System

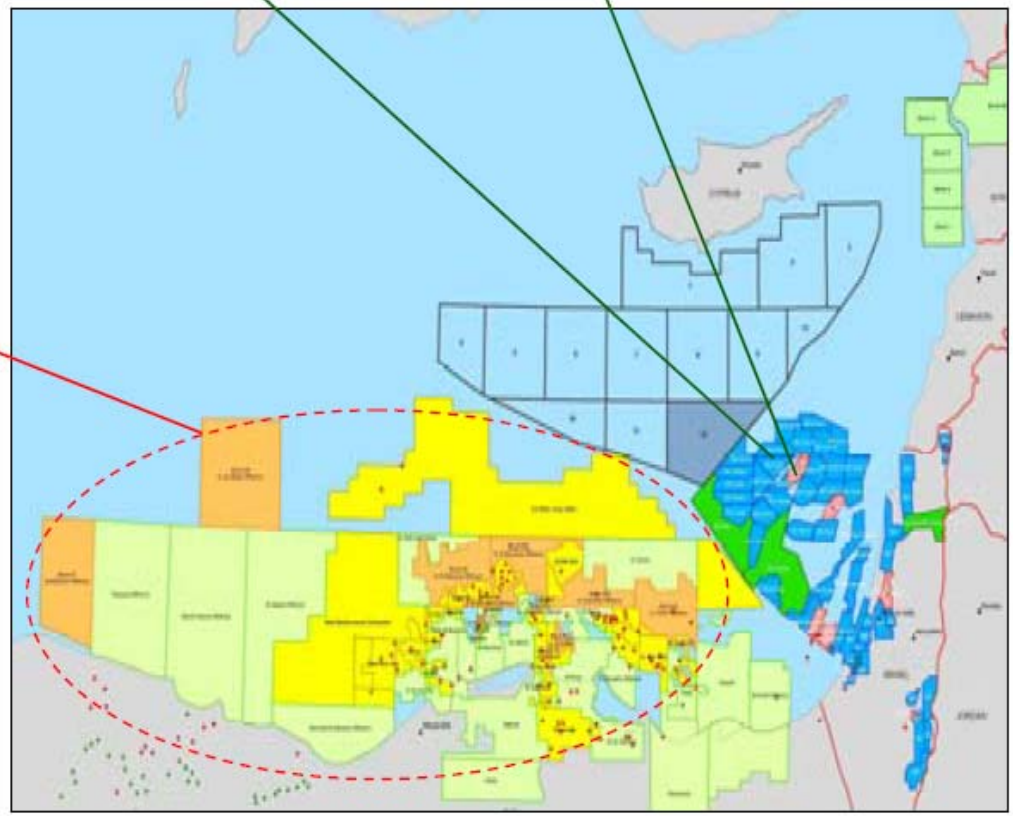
Leviathan Discovery
Resources/Estimation: 16 Tcf

Tamar Discovery
Total depth: 16,076 feet
Total Recoverable Resources: 8.4 Tcf
First Phase Production: early 2013

Egypt: Gas Reserves



Source: EGAS



Discoveries show that petroleum systems are active in the very thick Levantine and Herodotus basins

Εικόνα 29. Offshore Cyprus: A Frontier Exploration Area by Solon Kassinis, 2011

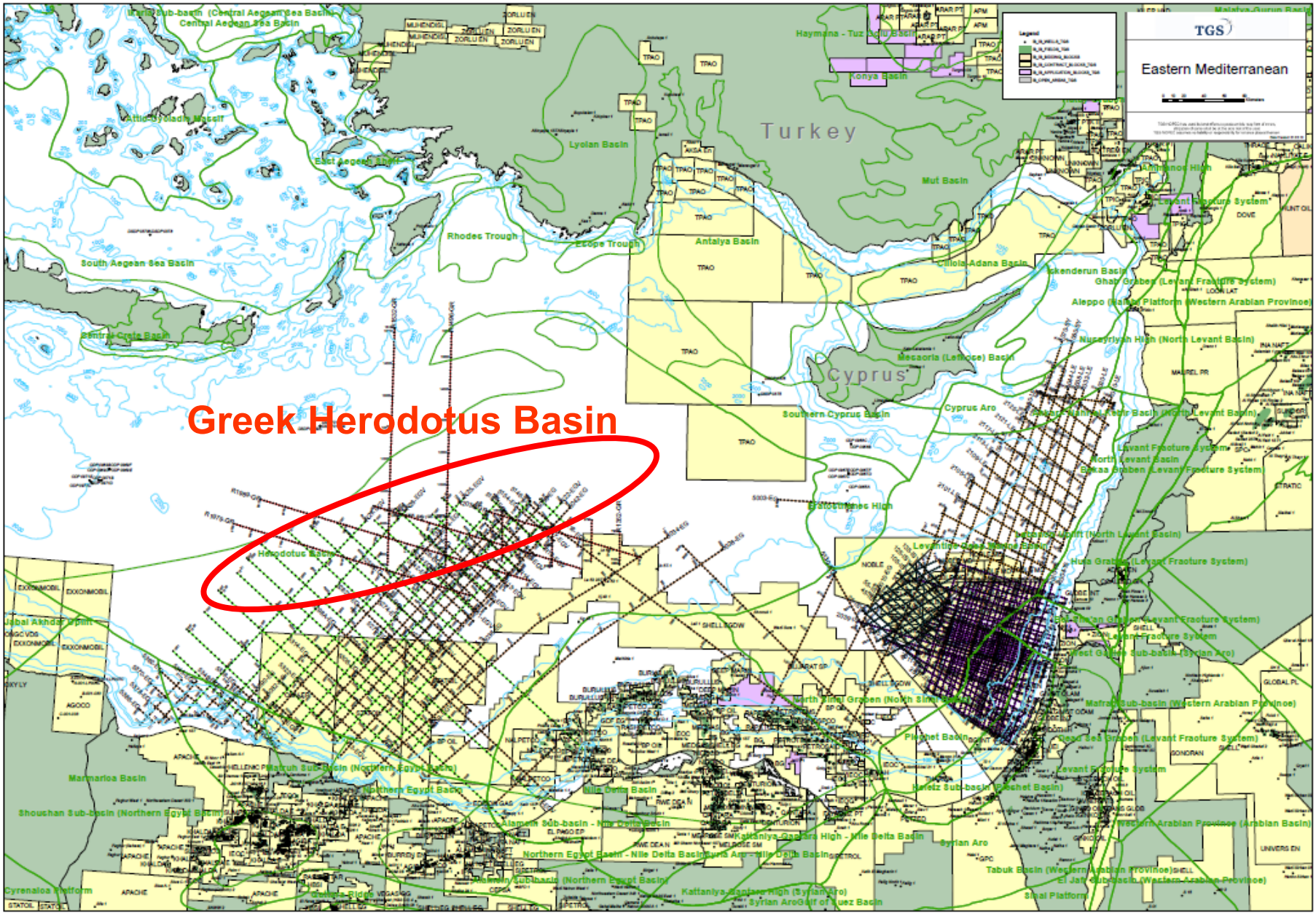


Figure 30. Geophysical survey by TGS-NOPEC, 2010

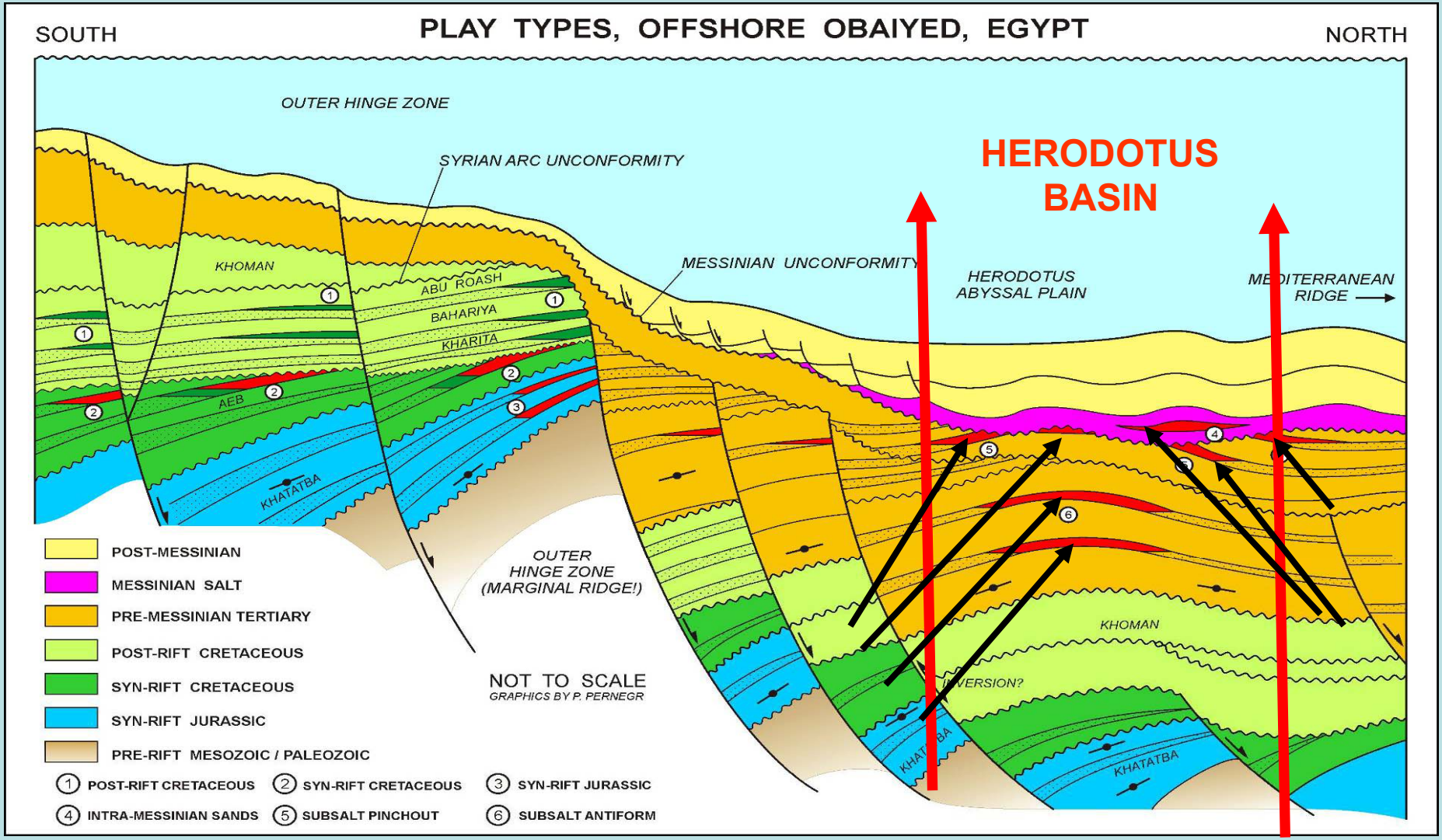


Figure 31. Herodotus Basin with 7 tectonic and structural hydrocarbon traps, Krois et al., 2009

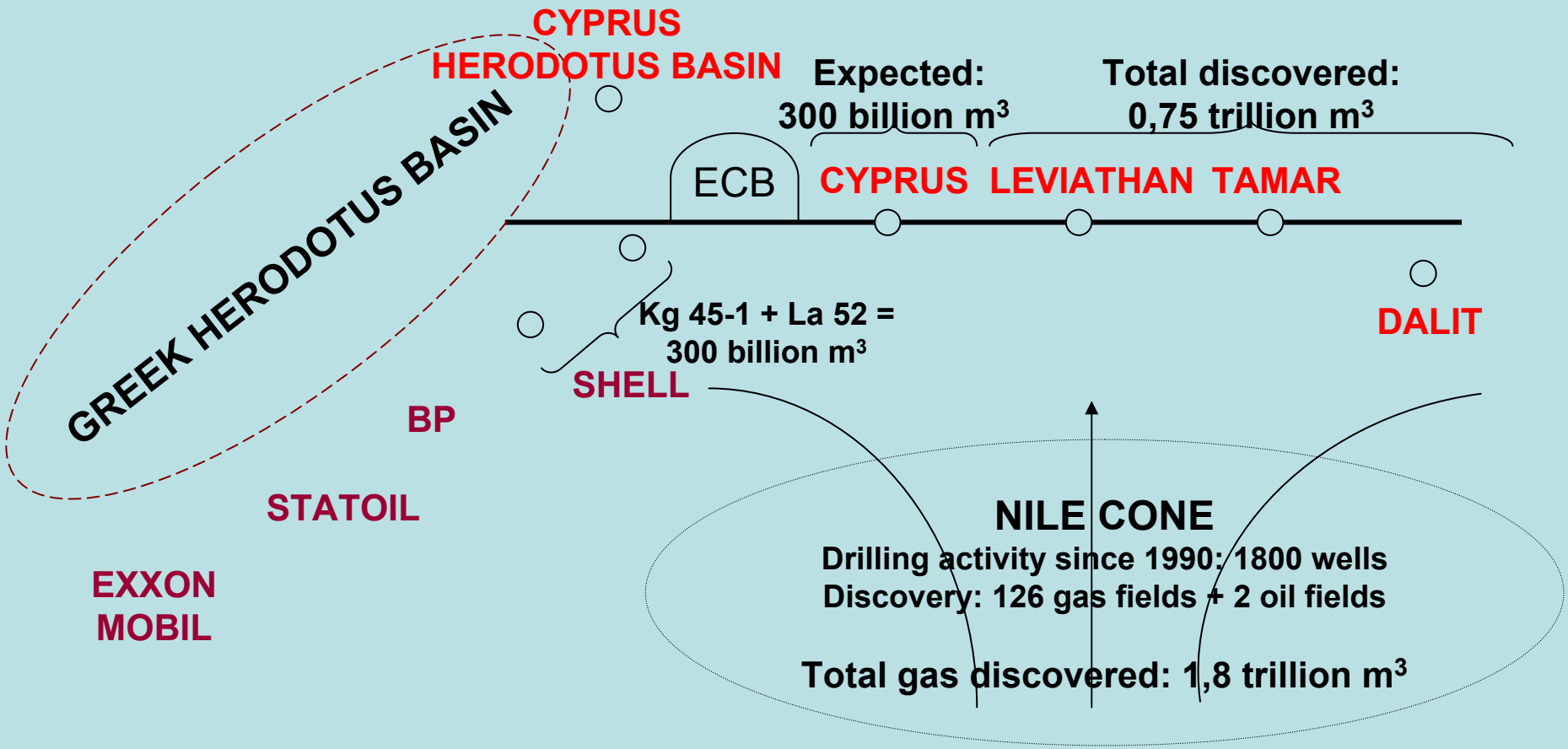


Figure 5. Oil Companies Exploring and Exploiting around the Greek Herodotus Basin. Blue dots indicate discovered natural gas fields

Figure 32. 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 M3). C, Potential 122 trillion cubic feet of natural gas (3,45 trillion M3). USGS Assessment, Technical Report, 2010.

PROVEN, HIGHLY PROBABLE AND PROBABLE CONVENTIONAL NATURAL GAS RESERVES OF EASTERN MEDITERRANEAN

IN TRILLION CUBIC METERS (1 Tcm = 6.44 X 10 $^{=3}$ boe)

EEZ OF COUNTRIES	PROVEN	HIGHLY PROBABLE	50% PROBABLE
EGYPT	1.8		6.3[1]
ISRAEL	0.9		1.8[1]
CYPRUS		0.3	2.0[2]
SYRIA+ LEBANON			1.2[1]
GREECE/CRETE			3.5[3]—5.5[4]
TOTAL	2.7	0.3	14.8 – 17.8

[1] USGS Technical Report, 2010. [2] BEICIP/F3.RANLAB and PGS [3] Relating similar natural gas findings with number of MVF and similarities of the Herodotus basin portions belonging to Egypt and Cyprus to the one belonging to Greece.
[4] If we equate the basin south of Crete to the Levanyine according to recent statements by PGS
CONVERSION FACTORS = 1 boe = 5,487 cubic feet = 155.373 cubic meters of natural gas.

CONCLUSIONS

Since we have thick sedimentary sequences, working petroleum systems at depth, source rocks and caps or seals there is no need to question the occurrence of hydrocarbons in the Libyan Sea

BUT

TO LOCATE the traps. Henceforth, we need high quality geophysical surveys above and below the Messinian Evaporites to identify them, though substantial geophysical survey work has been carried out for more than 19 years around the Mud Flow Volcanoes.


THANK YOU
DO WE HAVE IN CRETE AN EQUIVALENT TO AMALTHIA?
ZEUS DRINKING MILK FROM AMALTHIA IN PSILORITIS MOUNTAIN

REASONS FOR EXPLORATION IN SOUTHERN CRETE. PRESENTATION BY PGS AT MANIATIS OFFICE

1. *Hydrocarbon seeps have been recorded* adjacent to mud volcanoes

2. *Hydrocarbon analyses* of mud from ODP cores *suggests the presence of an active hydrocarbon system at depth*

REASONS FOR EXPLORATION IN SOUTHERN CRETE. PRESENTATION BY PGS AT MANIATIS OFFICE

3. ***Interpretation of deep seismic data suggests not only the presence of Messinian salt, however also pre-Messinian sediment***

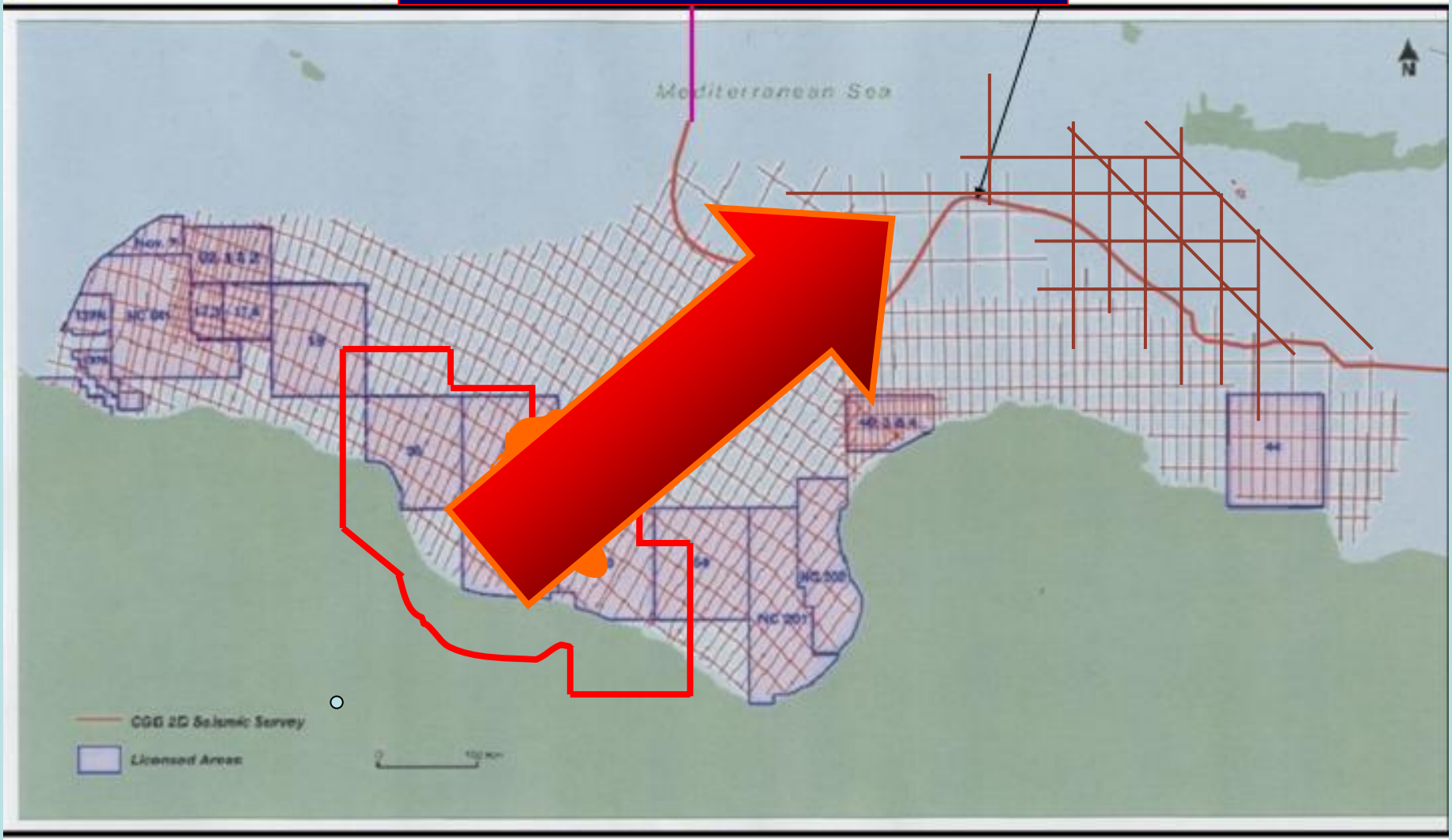
4. **Potential (Hydrocarbon) analogues to the Messinian facies exist in Libya and across the Mediterranean.**

5. **Accretionary prisms are productive across the world i.e. (Barbados, Makran, Andaman Oceanic Island Arc system)**

CGG-Seimic Lines Libya

Μη Αποκλειστικα Σεισμικα Λιβύης - 2003

Ορια Οικονομικών Ζωνών



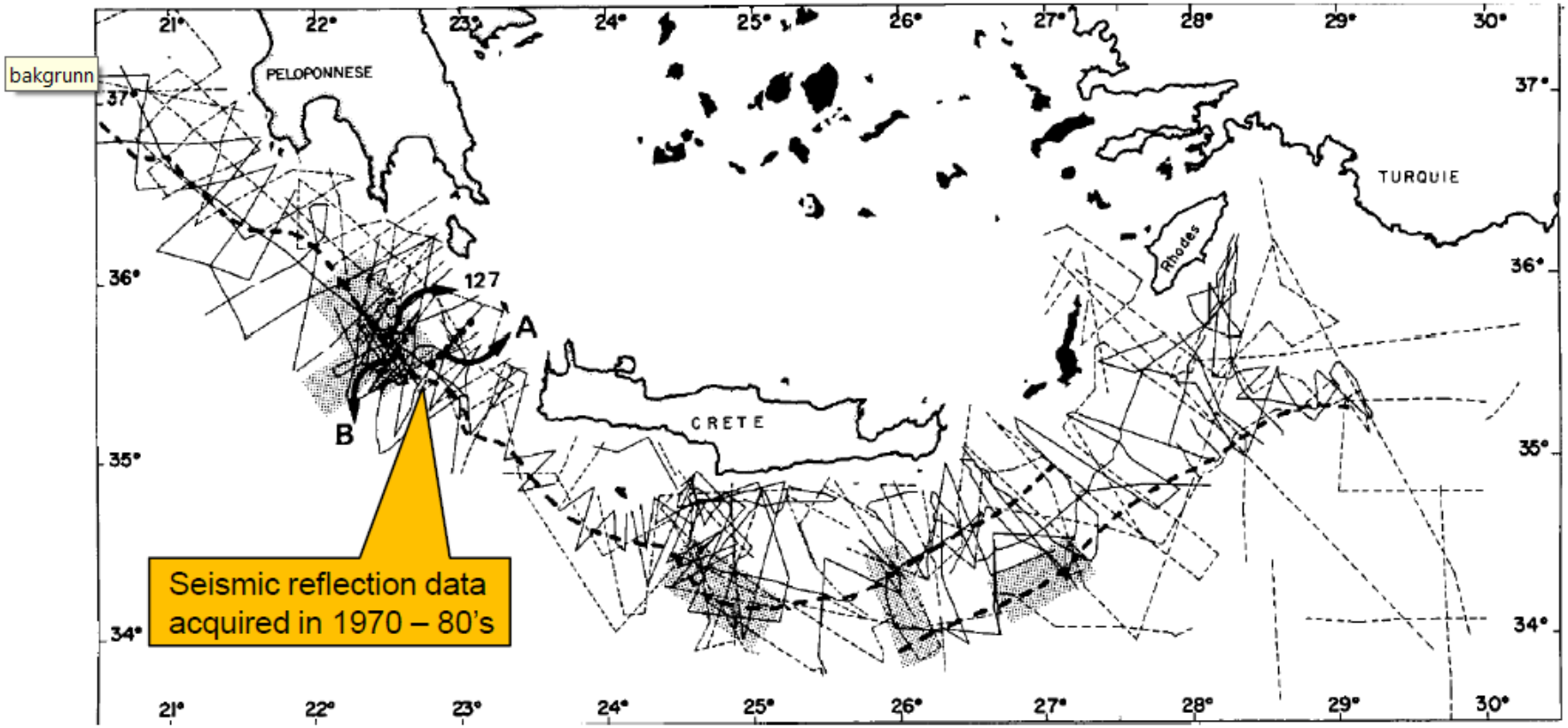
Εικόνα 34. CGG Veritas geophysical company Compagnie General de Geophysique, France

OIL SEARCH LIMITED

SIPETROL

HELLENIC PETROLEUM

Existing Seismic Coverage > Information Package
Seismic acquired by unknown companies in the 90's, 00's and most recently 2009.



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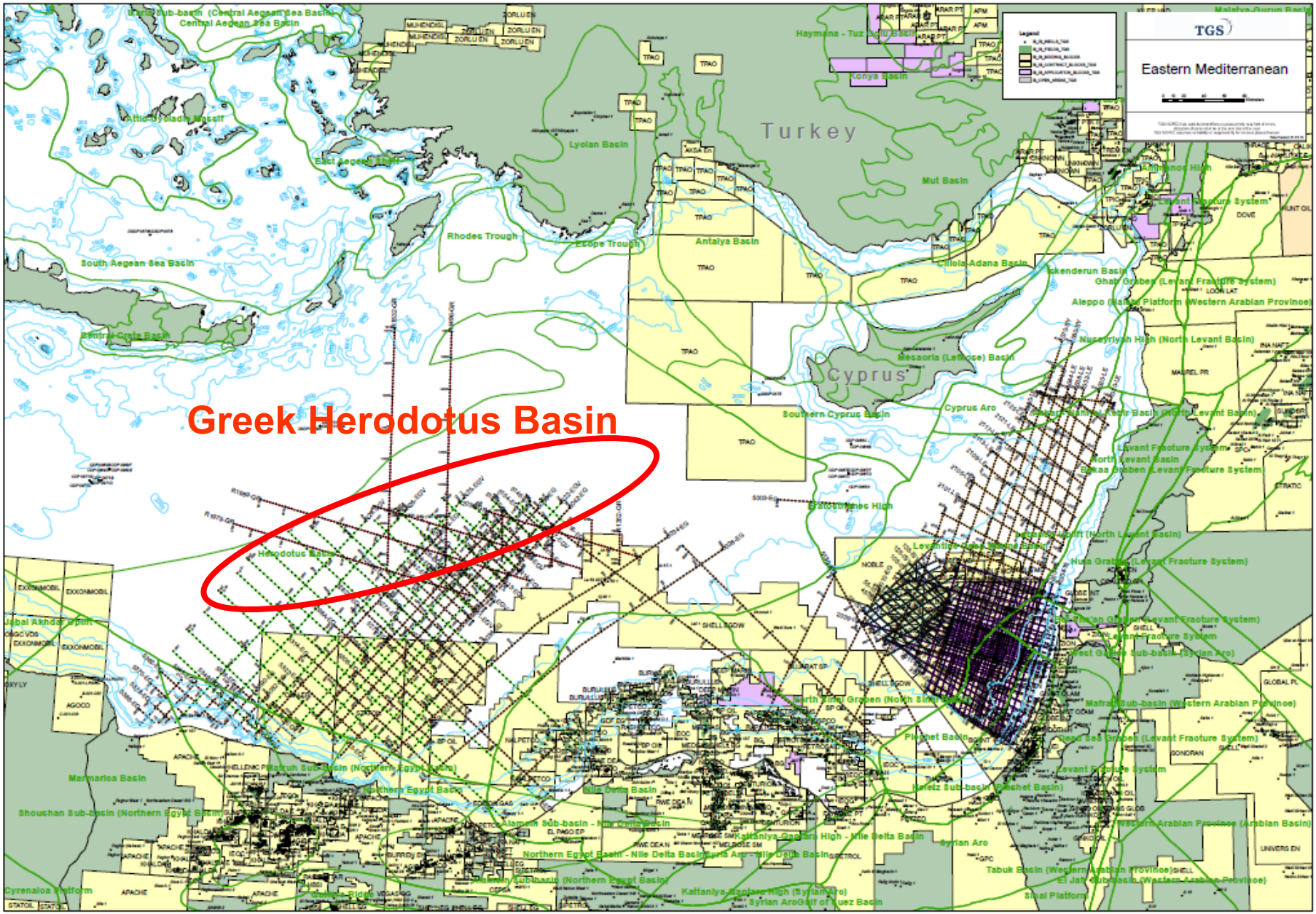


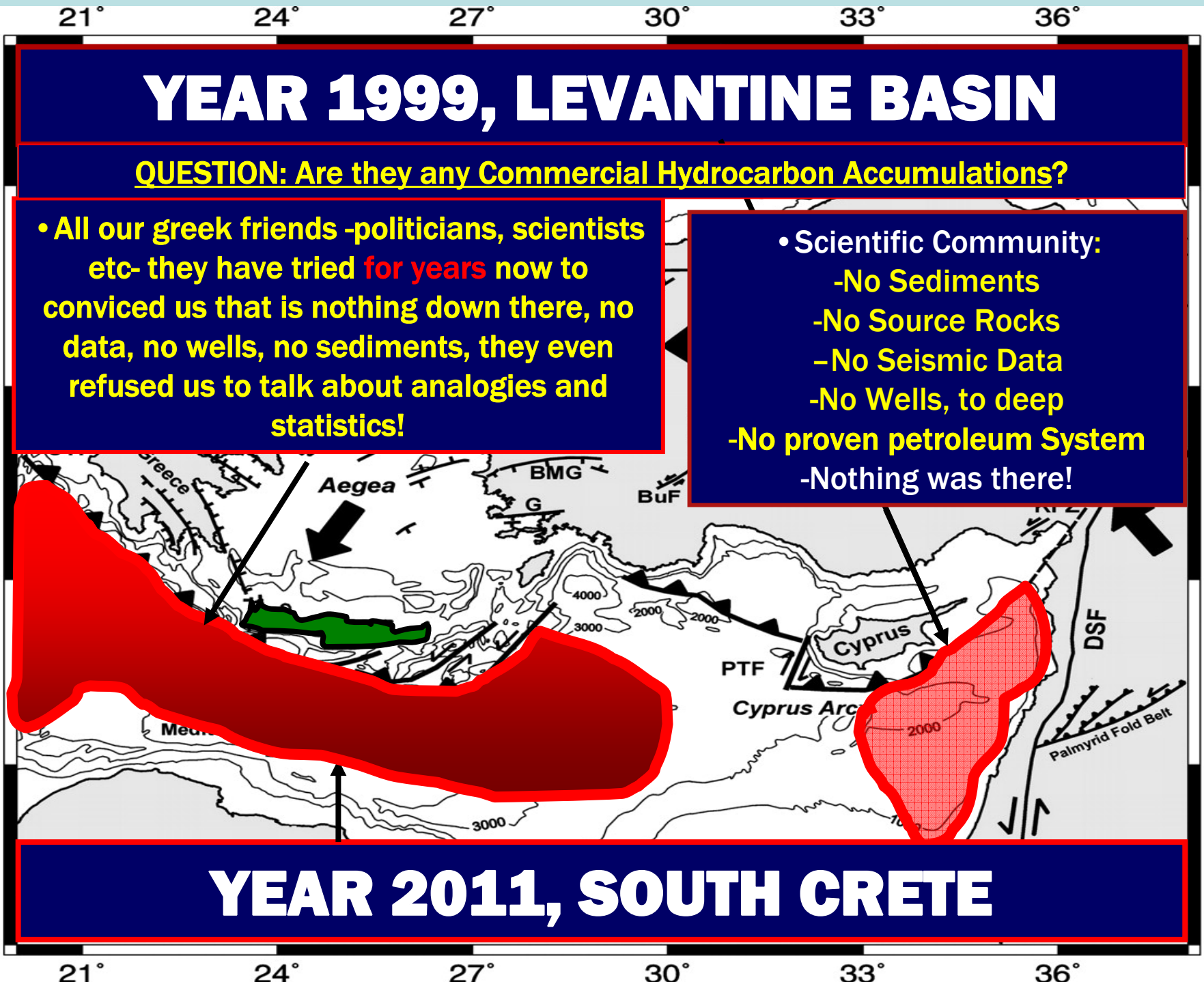
Figure 31. Geophysical survey by TGS-NOPEC, 2010

YEAR 1999, LEVANTINE BASIN

QUESTION: Are they any Commercial Hydrocarbon Accumulations?

- All our greek friends -politicians, scientists etc- they have tried for years now to conviced us that is nothing down there, no data, no wells, no sediments, they even refused us to talk about analogies and statistics!

- Scientific Community:
  - -No Sediments
  - -No Source Rocks
  - –No Seismic Data
  - -No Wells, to deep
  - -No proven petroleum System
  - -Nothing was there!



YEAR 2011, SOUTH CRETE

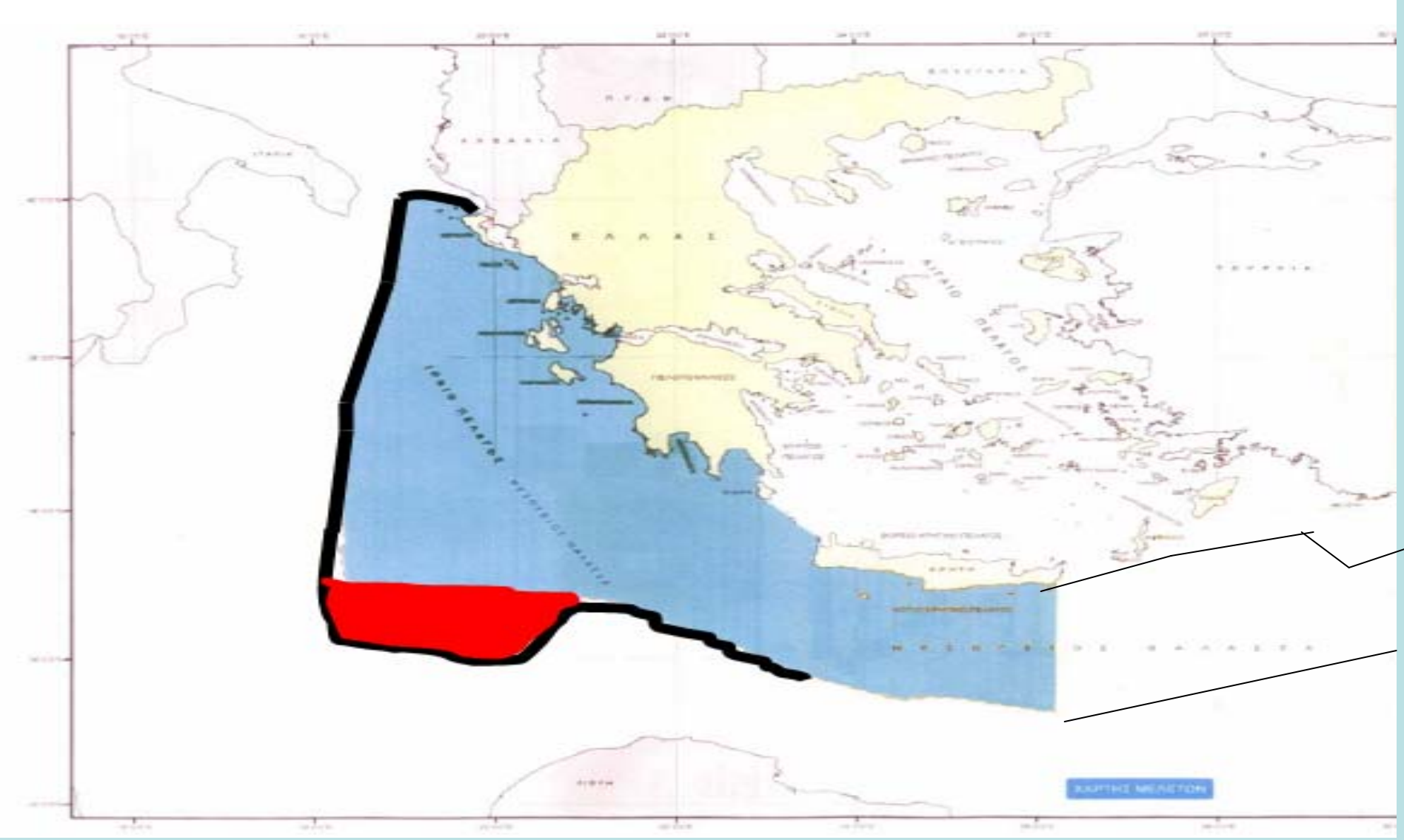
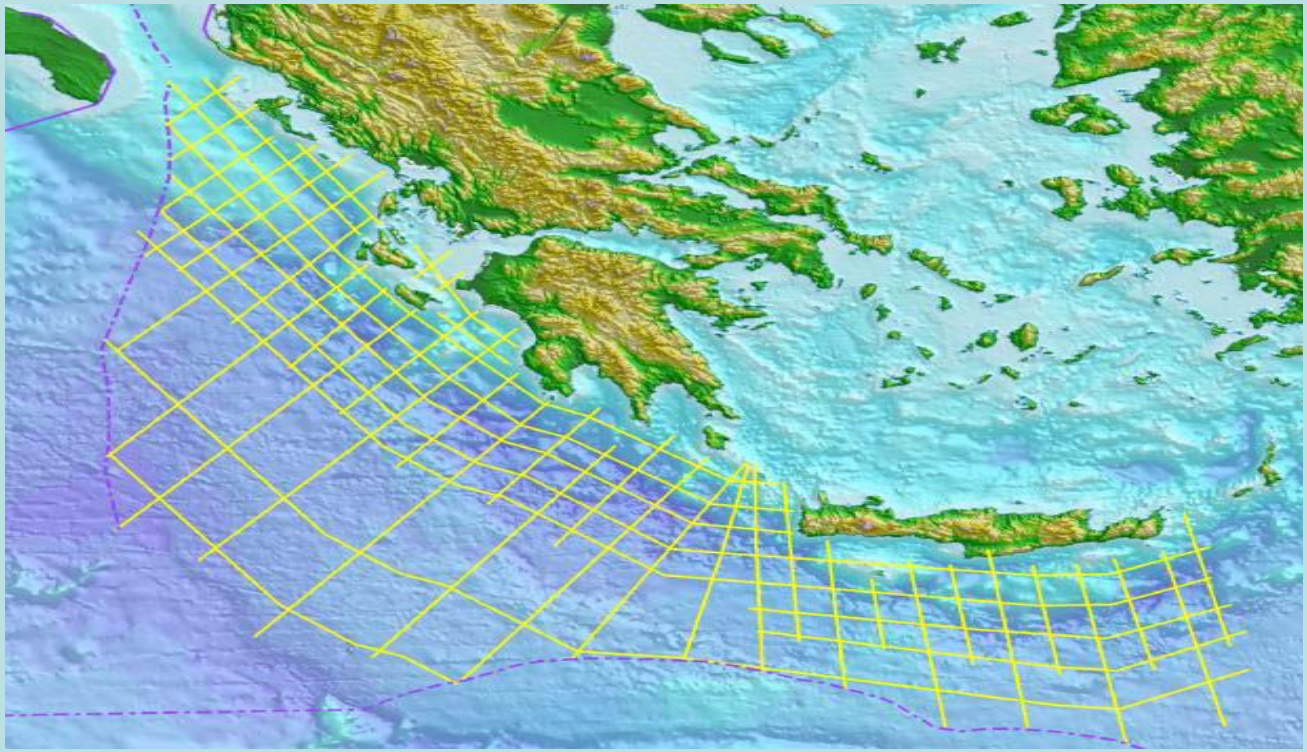


Figure 19.The limits of the area under exploration (seismic survey) are based on the principle of median/equidistance (including the Bay of Sirta) line after taking into consideration all territories of the involved states. Red Zone is a gift to Libya. Black lines delineate the area that belongs to Greek EEZ. Therefore, seismic surveys should have been extended to include this area

Survey Proposal –Working with the Ministry

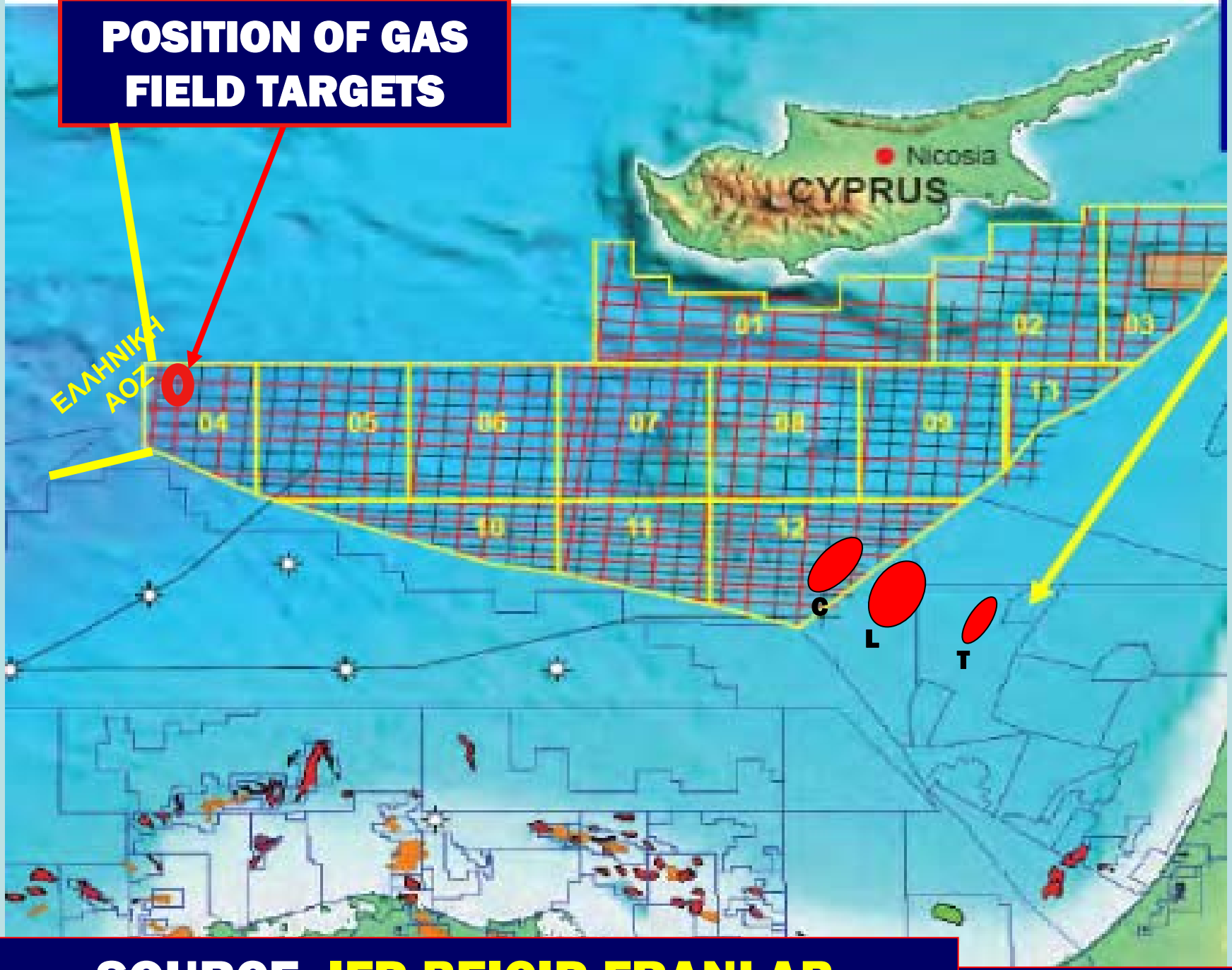


Geophysics Excellence•

2D GeoStreamer GS Seismic •

Time and Depth imaging •Marine Gravity •Marine Magnetic

Figure 20. Survey proposal of geophysical lines by PGS, Robinson, 2011



SOURCE: IFP-BEICIP-FRANLAB

Figure 13. THE MEDITERRANEAN REGION FROM CRUST TO MANTLE TRANSMED ATLAS, Gavazza et. al., 2004