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Exploration history and Hydrocarbon Potential of Greece

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Topics

Historical background

- Exploration before 1975
- Exploration from 1975 to 2000
- 1st International Exploration Round 1997-2002

Petroleum system in Greece

Review by area

- Epirus-Aitolokarnania
- NW Peloponessos
- Grevena basin
- W. Thrace, Orestiada & Evros Delta
- Crete, Messara basin & Libyan sea
- Ionian sea and Ionian islands
- Thessaloniki basin - Epanomi area - Thermaikos gulf
- North Aegean sea - Thracian sea
- Hellenic Trench - Mediterranean Ridge

Conclusions

Historical background

Greek Sedimentary Basins



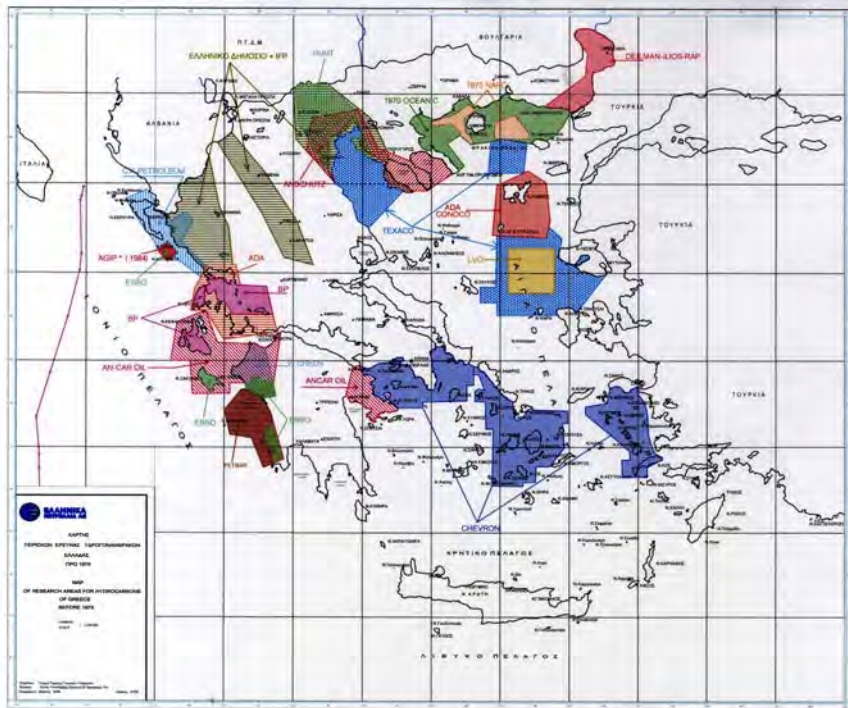
Eastern Greece:

Exploration of the neogene basins

Western Greece:

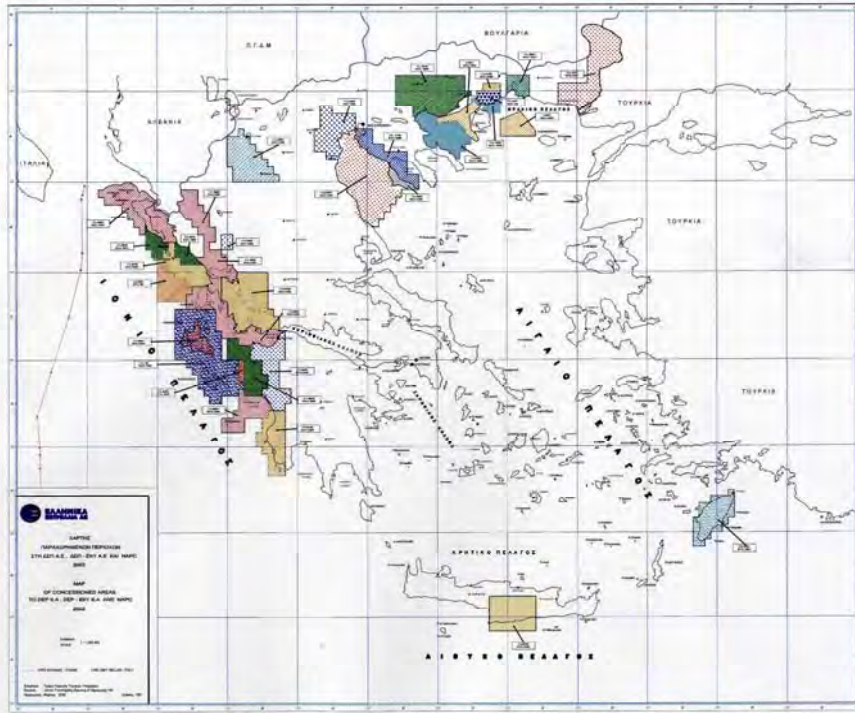
Exploration in the overthrust zone of the external Hellenides and on the foreland.

Exploration activity before 1975



- Concessions were awarded to various, some majors, Oil Companies (ESSO, TEXACO, BP, Oceanic etc)
- Acquisition of about 12,200 Km of seismic lines
- 68 well were drilled with TD varying from a few meters to 4,573m
- Discovery of the Prinos oil field and the South Kavala gas field.
- Significant hydrocarbon shows in many wells (Aitoliko, Zakynthos, Thermaikos etc)
- Some of the of the findings of the deep wells contributed to the overall knowledge of the stratigraphy and the tectonics of Greece

Exploration by DEP/DEP-EKY/HELPE (1/3)



- 6 fully owned and operated seismic crews (3 dynamite, 2 Vibroseis, 1 shallow water telemetric) as well as subcontractors for offshore or onshore seismic acquisition.
- Gravity/magnetic crew.
- Integrated center for processing and interpretation of seismic data.
- Drilling ring (capacity for drilling down to 4.000 m).
- 2 Geological laboratories for evaluation of the results while drilling.
- 1 Geochemical laboratory.

Extensive, self-sufficient and methodical exploration of all basins.

Excellent technical and scientific personnel

Exploration by DEP/DEP-EKY/HELPE 1975-2000 (2/3)

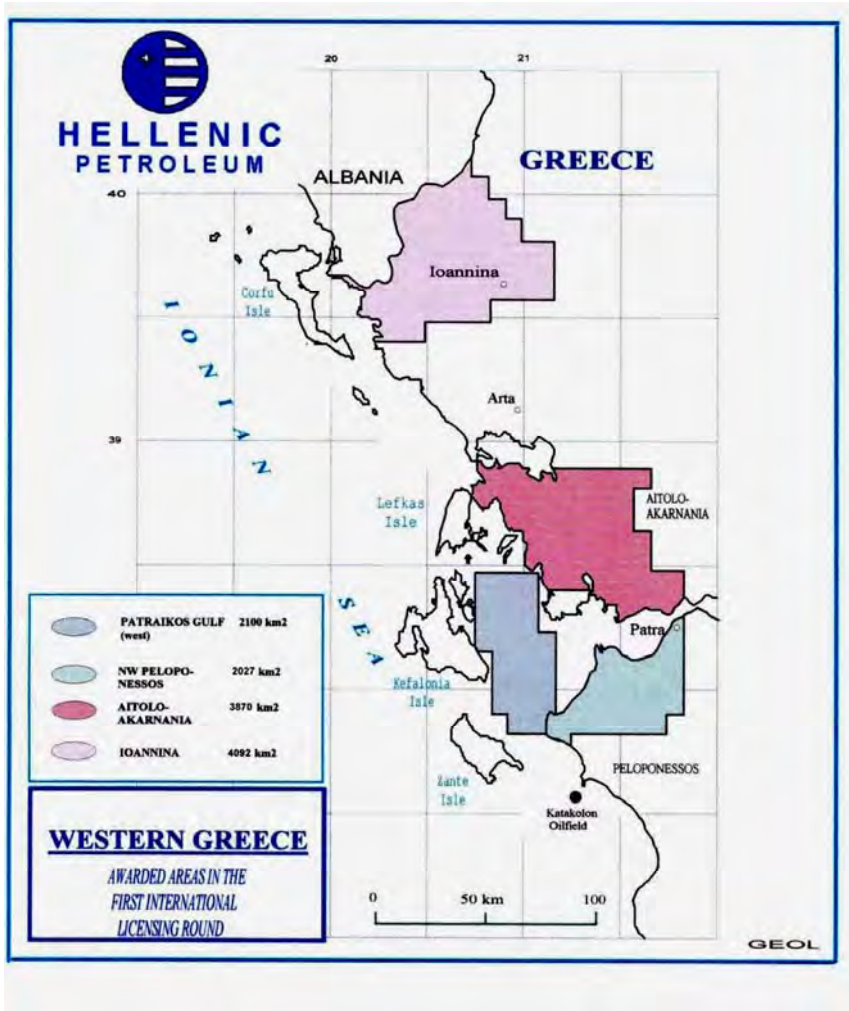
- Evaluation of the hydrocarbon potential not only of the concession areas awarded by the Greek State but of the remaining areas as well.
- Geological studies and mapping.
- Geochemical analyses.
- Acquisition by its own seismic crews or by subcontractors of 12,300 Km onshore 2D Seismic.
- Acquisition by its own Shallow Telemetric crew or by subcontractors 41,600 Km offshore 2D and 3D seismic data.
- Processing of all seismic data either by subcontractors or from 1984 onwards in its own processing center.
- Interpretation of all available geophysical data.
- Selection of the most favorable well location for every prospect to be drilled based on all currently available data.
- Drilling of 75 wells (62 onshore and 13 offshore) with TD ranging from a few hundreds meters to 5,494m.

Exploration by DEP/DEP-EKY/HELPE 1975-2000 (3/3)

RESULTS :

- Evaluation of all significant onshore basins and a lot of the offshore ones.
 - In most basins exploration was limited to the neogene sediments and to the top of carbonates.
 - In offshore areas exploration was restricted to water depths less than 500m but some seismic data were acquired in areas of deeper waters.
- **Discovery of the Katakolo oil field (1981).**
- **Discovery of the Epanomi gas field (1989).**
- **Oil and gas shows in many wells.**
- **Valuation of the hydrocarbon potential of Greece.**

1st International concession round 1997-2002



Ioannina : Enterprise 63.33% (operator), HELPE 16.67% and MOL 20%.

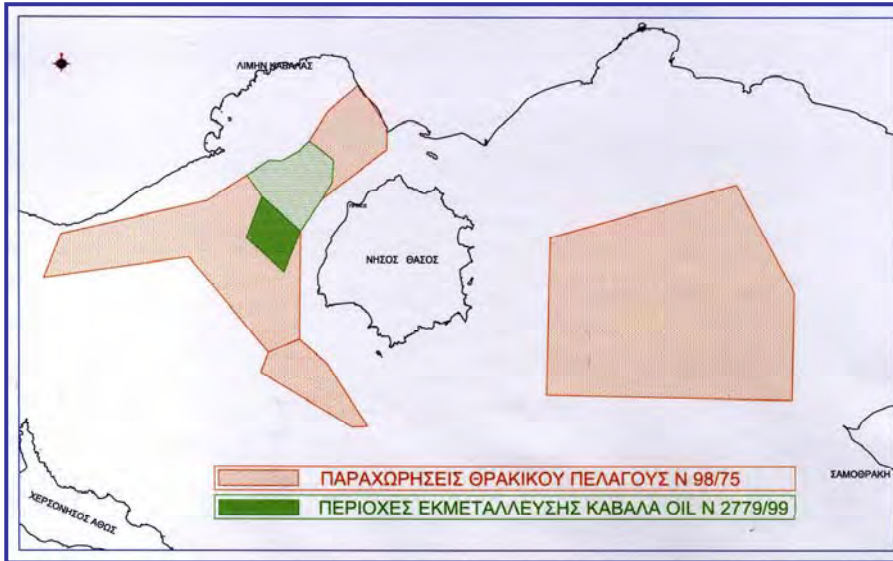
450 Km of new 2D seismic were acquired (200 Km by very expensive heliportable crew). Well Dimitra-1 was abandoned at 3,966 m, without reaching target, due to extremely high pressure.

NW Peloponnessos: Enterprise 54,99% (operator), HELPE 26,83% and MOL 18,88%. Based on pre-existing seismic and 360 Km new ones, 2 dry well were drilled.

W. Patraikos: Triton 88% (operator), HELPE 12%. Based on pre-existing seismic as well as 1136 Km of new ones, some very promising prospects were identified.

Aitolioakarnania: Triton 88% (operator), HELPE 12%. Based on pre-existing seismic, 220 Km new seismic, gravity aeromagnetic and MT data, 2 shallow dry well were drilled.

Currently active Concessions in Greece



Concession of the production area of Prinos and S Kavala (N2779/99):

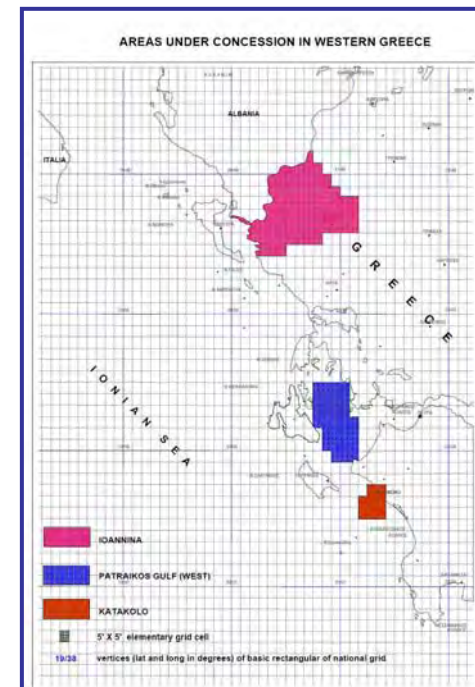
Energiean Oil & Gas S.A. 100%

Concession of Thracian Sea (N98/75):

Calfrac 75%, HELPE 25% .

An “open door” round is currently open for 3 areas:

- Katakolo
- W. Patraikos gulf
- Ionnina



Hydrocarbon system in Greece

Petroleum System 1/5

WESTERN GREECE

Lithology	Geologic Time	Formation	Basin Evolution	Source Rocks	Reservoir	Seal
	L. Miocene					
	Oligocene	Flysch Claystone & Sandstone				
	U. Cretaceous-Eocene	Breccias Limestone				
	L. Cretaceous	Vigla: Pelagic Limestones with Cherts & Marls Intercalations	Post-rift sequence			
	Dogger-Malm	Posidonia Beds	Syn-rift			
	Lias	Shallow water Limestones & Dolomites	Pre-rift sequence			
	Upper Triassic	Evaporites -Breccias Anhydrites & salt with intercalations of dolomite, limestone & shales				

EASTERN GREECE

Lithology	Geologic Time	Formation	Source Rocks	Reservoir	Seal
	Pliocene	Shallow marine - lacustrine			
	Miocene	Shallow neritic marine - lacustrine Lignite horizons are potential source rocks for gaseous hydrocarbons			
	Eocene - Oligocene	Pelagic to neritic environment Significant source rock horizons capable to generate mainly gas and minor oil			
		Reefal Limestones			
	Mesozoic	Katsika Lst/barrier carbonates deposited at shoreline			
		Intrusive basement			

Petroleum system 2/5

SOURCE ROCK

WESTERN GREECE: the main source rock are the Posidonia beds of early Jurassic age

EASTERN GREECE: Miocene – Oligocene shales



Posidonia
beds

Dragopsa



Petroleum system 3/5

Reservoir

WESTERN GREECE: Limestone with low primary porosity but in many cases with improved secondary one. High porosity Neogene sandstone.

EASTERN GREECE: Sandstone with high porosity and low porosity limestone.



Limestone breccias of Upper Cretaceous

Dolomitised Cretaceous limestone

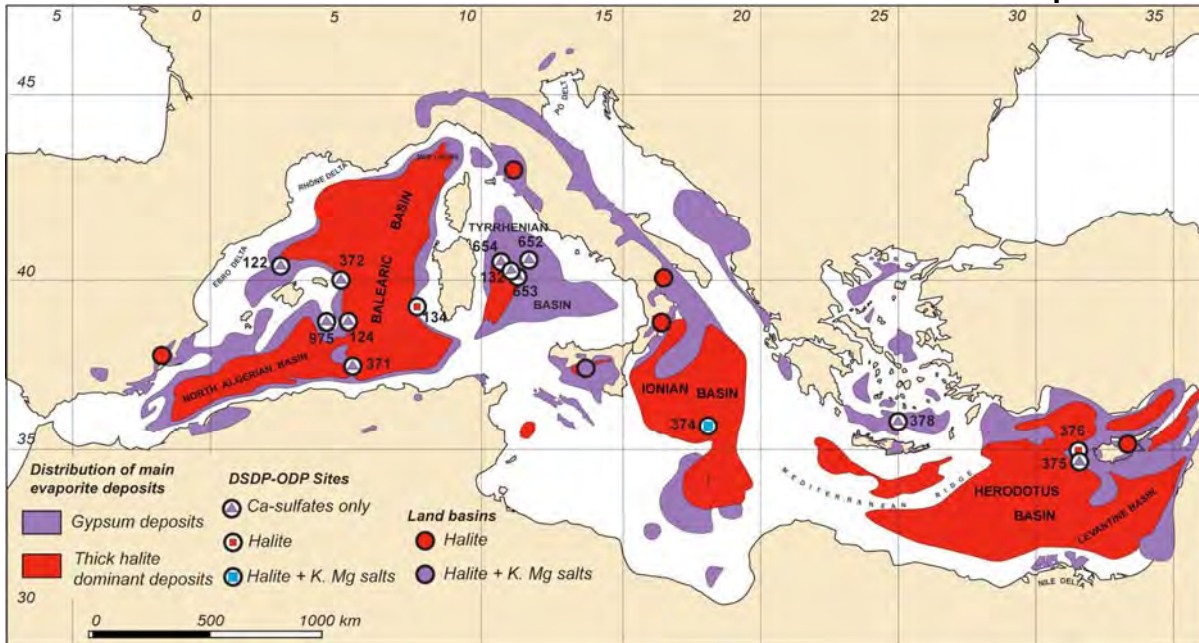


Petroleum system 4/5

Seal

WESTERN GREECE: Neogene shales, Flysh or evaporites (Miocene or Triassic)

EASTERN GREECE: shales and Messinian evaporites



Deposition of Messinian evaporites in Mediterranean sea. (Roushy, 2000)

Evaporites are the best seal but their deposition may not fully cover Eastern Mediterranean

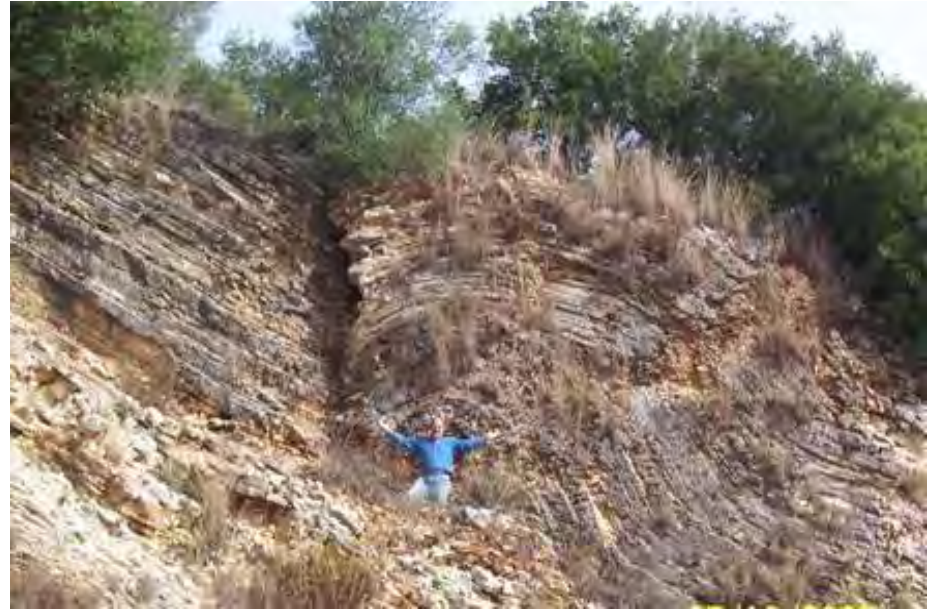
Petroleum system 5/5

Traps

WESTERN GREECE: mostly tectonic

EASTERN GREECE: tectonic and stratigraphic ones

Good quality seismic are essential for mapping possible traps (3D necessary for mapping the stratigraphic ones).



Migration

Based on all available data hydrocarbon maturation and migration occurred at the right geological moment.

Review by Area

Epirus-Aitoloakarnania 1/3

1960-1966:

7 wells in Epirus (Greek State)
2 wells in Aitoloakarnania (BP)

1979-1990: DEP/DEP-EKY

2D seismic surveys, gravity, magnetic and MT
7 exploration wells

1997-2002: ENTERPRISE/HELPE

2D seismic surveys, Passive seismic, MT
1 well

1997-2002: TRITON/HELPE

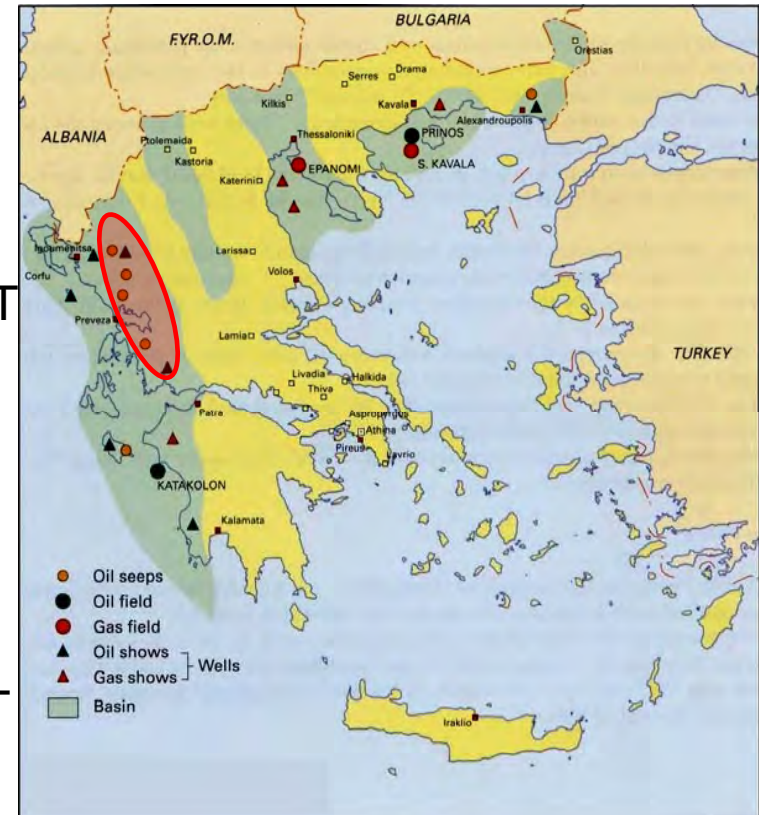
2D seismic survey, gravity, aeromagnetic, MT
2 wells

Total seismic coverage about 3.100 Km

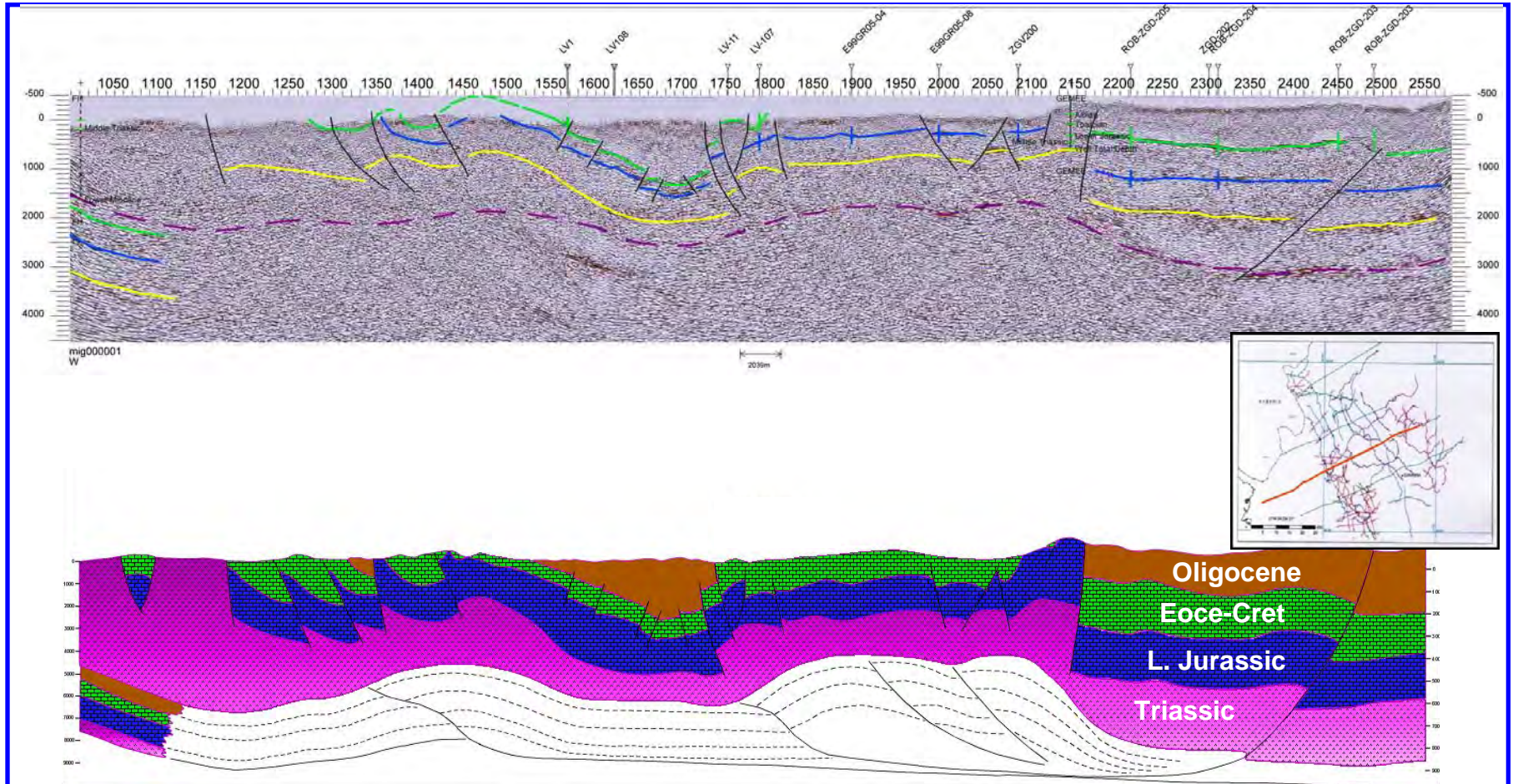
The area is part of the folded belt of external Hellenides.

Although considerable hydrocarbon fields have been found in similar environment, both areas are consider to be high risk - high reward ones.

Seismic exploration is rather expensive due to the morphology of the terrain.



Epirus-Aitolokarnania 2/3



ΕΛΠΕ, ΛΑΡΓ, ΑΘΗΝΑ 2007

Sub-evaporite plays

Epirus-Aitolokarnania 3/3

- Many wells have encountered significant oil and gas shows.
- **The Petroleum System is proved.**
 - Source rock
 - reservoir
 - Traps and seal
- “Shallow” or “deep targets” have been identified.
- Shallow targets (down to 2.500m) within the neogene sediments or at the top of the carbonate series (some of them have been already drilled) are considered to be of limited interest due to:
 - The small size of the structures resulting from the intensive tectonism
 - The small geological probability of success
- Structures below the evaporites (>4.500m) are quite interesting due to:
 - Expected size of the prospects based on the size of the structures

But seismics of very good quality are required in order to identify reflections below the evaporite.

NW Peloponessos 1/2

1939-1954, 1962:

11 wells 1939-1954

4 wells 1962

1979-1987: DEP/DEP-EKY

Seismic surveys + gravity /magnetic, MT measurements

7 wells

2001-2002: ENTERPRISE/HELPE

Seismic survey, surface geochemical study
2 wells

2.750 Km seismic 2D in total



NW Peloponessos 2/2

- Significant hydrocarbon shows in many wells.
- **Proven Petroleum System.**
- Shallow targets to the top of the limestone are of small interest.
- There is no seismic coverage in the eastern flag of the Olympia basin, therefore the structure and the prospectivity need to be studied farther.
- Deeper targets (within the limestone or bellow the evapotite) have not been explored in full. Therefore the hydrocarbon potential bellow the Triassic evapotites is open to farther investigation.
- Small local scale exploitation of the biogenic gas pockets could be feasible for greenhouses or other local small scale consumption.

Grevena basin 1/2

1966-1967:

2 wells

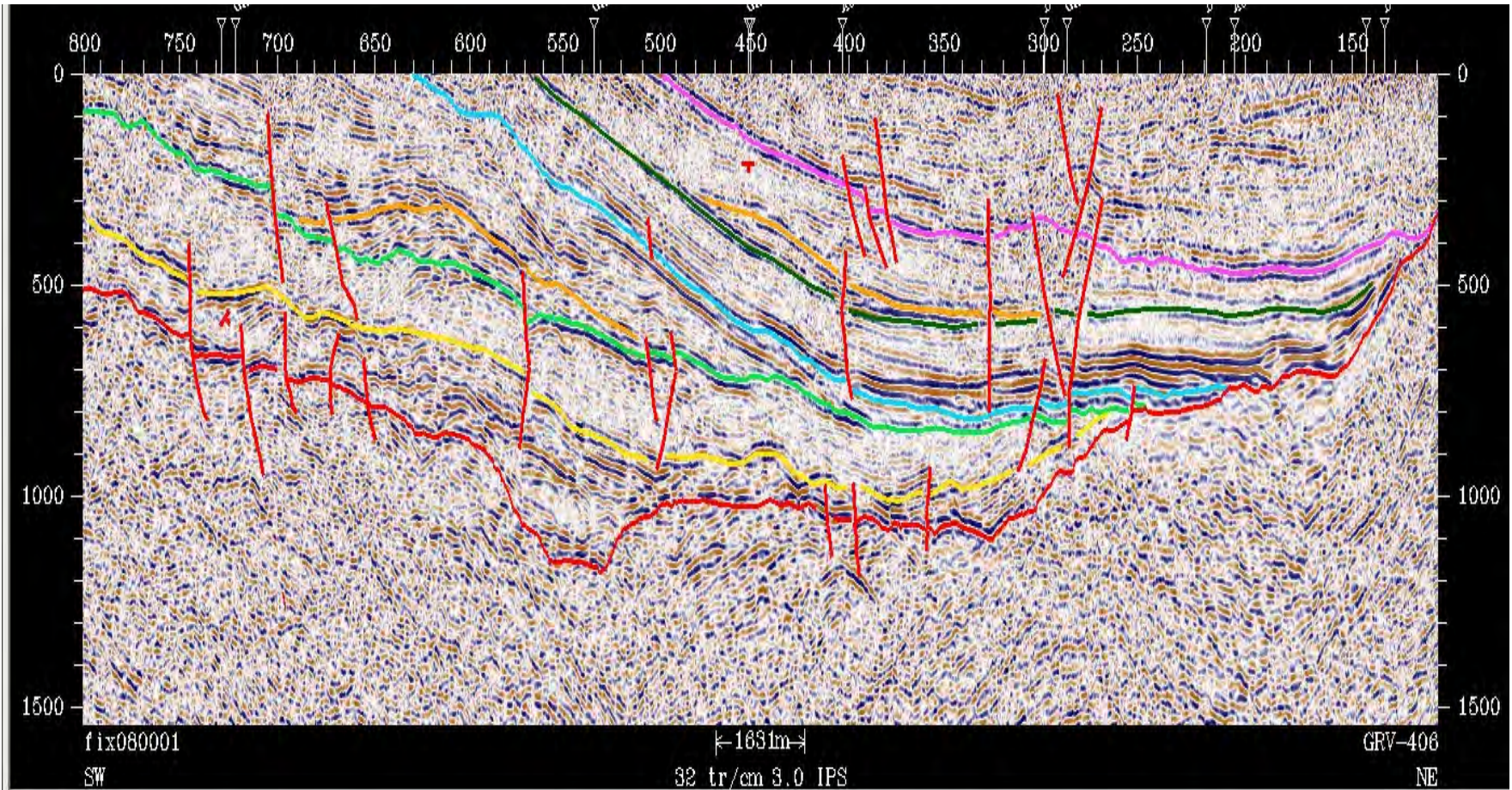
1979-1997: DEP/DEP-EKY

1055 Km of 2D seismic, gravity/magnetic measurements

- Hydrocarbon promising, considered as frontier area
- Difficulty in mapping the stratigraphic traps expected (deltaic fans, channels etc).
- 3D seismic required but such acquisition is extremely expensive due to terrain restrictions



Grevena basin 2/2



N. Kontopoulos et al, Marine and Petroleum Geology, 1999

W. Thrace, Orestiada & Evros' delta

1938-1962:

10 wells

Oil and gas shows

1979-1988: DEP/DEP-EKY

1470 Km of 2D seismics

7 wells

Oil and gas shows

- Western margin of Thrace basin.
Producing gas fields exist in the eastern, Turkish, part (proven petroleum system).
- Seismic data from the 80's
- Faulted zones drilled in the past with no success (but with hydrocarbon shows) could be revisited.
- The size of the expected fields can not be very large.



Crete, Messara basin & Libyan Sea

1982-1983: DEP/DEP-EKY

56 Km onshore seismics

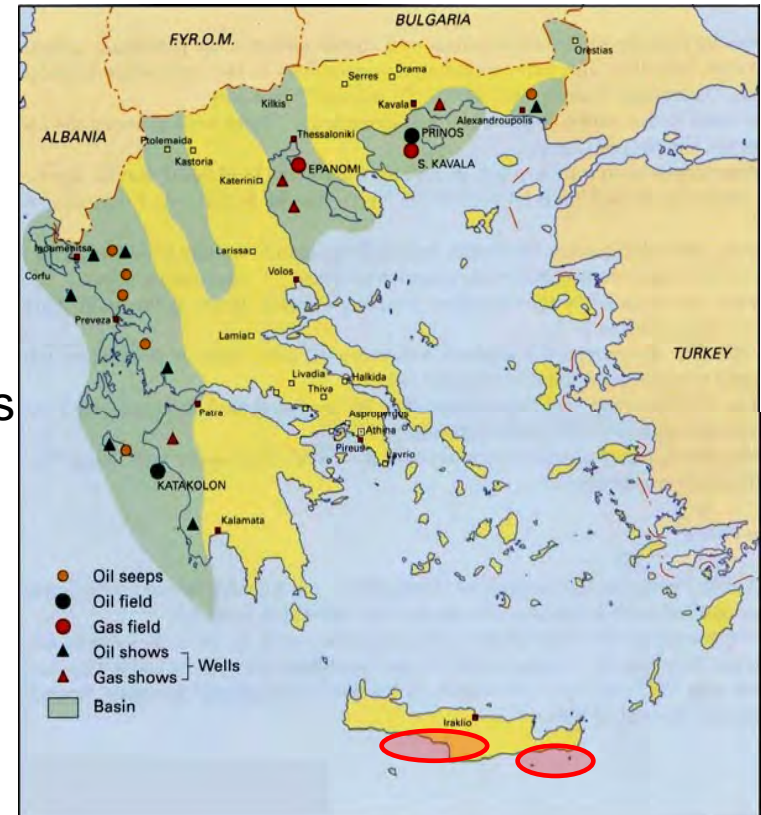
2050 Km offshore seismics

Messara basin

- Small thickness of the neogene sediments
- Small traps with biogenic gas have been observed

Offshore area south of Crete

- Seismics from the 80's
- Small thickness of Pliocene is expected
- We are not certain about the extension and the thickness of the Messinian evaporites
- Existing seismic are not adequate to map the possible stratigraphic traps



Ionian Sea & Ionian islands 1/4

North Ionian:

2 wells in Paxoi island,
 ESSO 1962 , AGIP 1983
 4 wells by DEP 1978-82
 Oil and gas shows

Patraikos gulf and South Ionian:

9 wells by DEP 1978-82
 Oil and gas shows
 Discovery of West Katakolo oil field

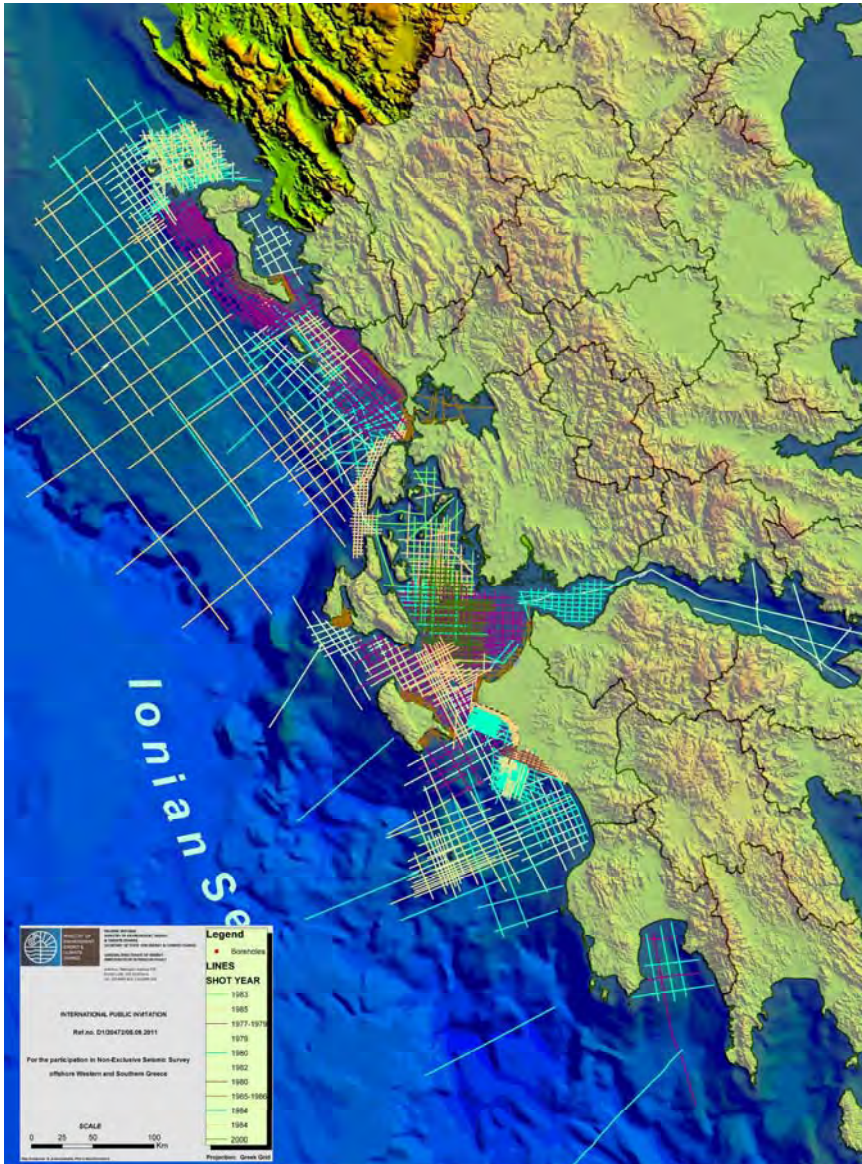
Zakynthos island:

12 wells 1957-73
 7 wells by DEP 1983-86
 Oil shows
 A non economic asphalt field discovery

Total 3.100 Km offshore seismic 2D before DEP
 23.200 Km offshore seismic 2D by DEP
 1 3D seismic survey
 400 Km onshore seismic by DEP



Ionian Sea & Ionian islands 2/4



Offshore seismics in Western Greece

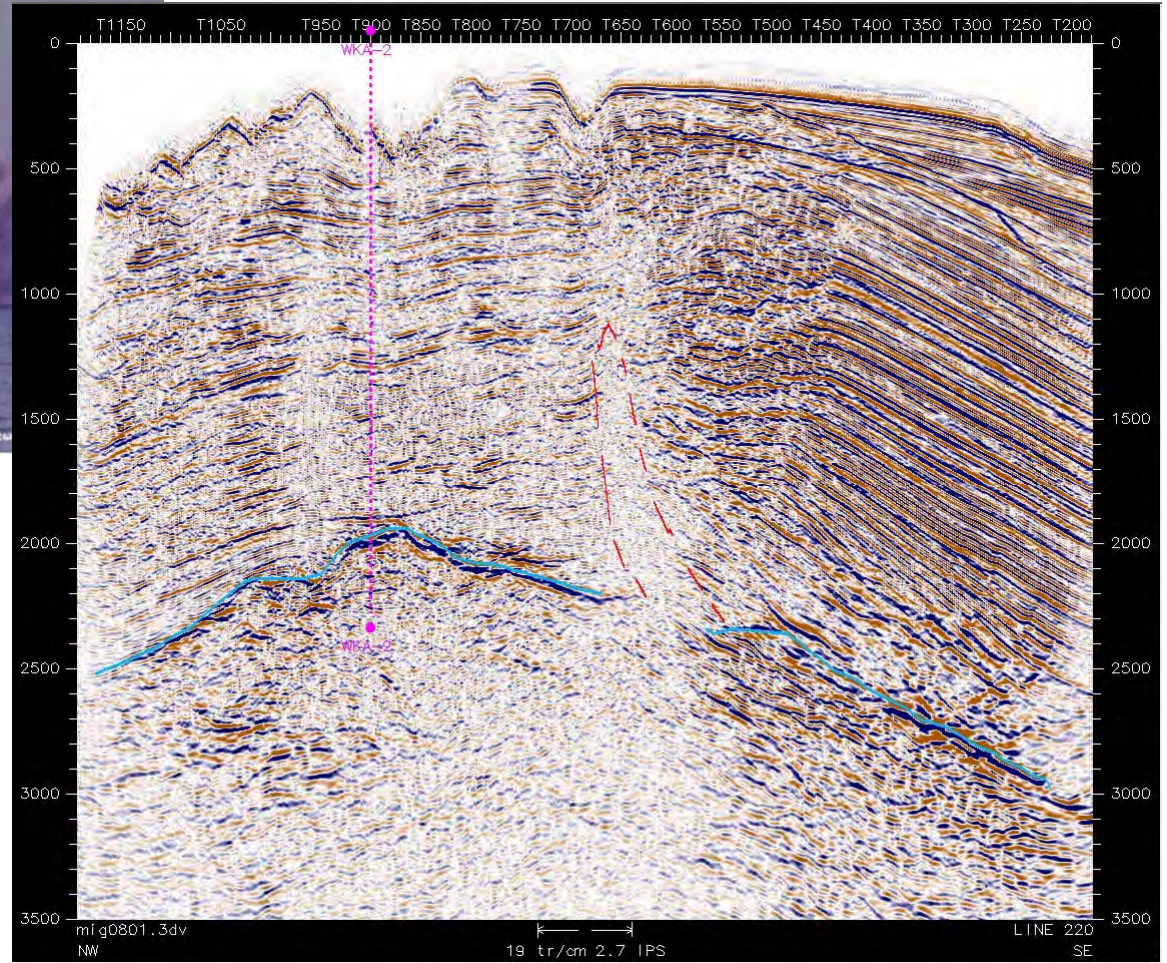
Legend			
LINES			
SHOT YEAR	Km	Source	Fold
1983	568	AIRGUN	48
1985	4050	AIRGUN	48
1977-1979	4330	VAPOURCHOC	48
1979	3181	MAXIPULSE	48
1980	4254	MAXIPULSE	48
1982	3769	AIRGUN	48
1980	491	VARIUS	12-24
1985-1986	780	AIRGUN	24
1984	100 Km ²	AIGUN	24
1984	365	AIRGUN	24
2000	1136	AIRGUN	162

Ionian Sea & Ionian islands 3/4



The Katakolo field was discovered in 1981/82.

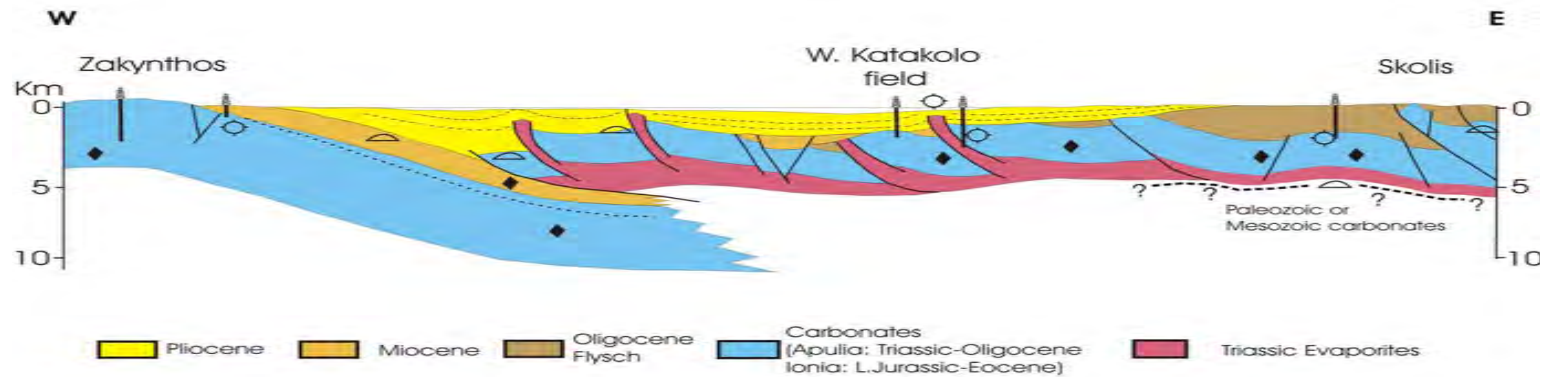
Recoverable reserves are estimated to 3 MMbbbls



Ch. Armoutidis and M. Kapnistos, 3rd EC Symposium, 1988

Ionian Sea & Ionian islands 4/4

SYNTHETIC CROSS SECTION



HELPE, AAPG, AΘHNA 2007

- **Proven Petroleum System**
- Discovery of W. Katakolo field.
- Additional prospects ready to be drilled in rather shallow water depths (200-300m) or in deeper ones (around or more than 1000m).
- Dense coverage with seismics from the 70's and 80's (and a few from 00's) in areas with water depths less than 500m. Very limited coverage in areas with deeper waters.
- Sea depth is greater than 2000m in the south part.
- Modern seismic may reveal additional targets (stratigraphic traps, pinch outs etc)

Thessaloniki basin - Epanomi - Thermaikos gulf 1/2

before DEP:

Some onshore seismic & 740 Km offshore seismic

10 onshore wells, 1961-74
2 offshore wells, 1970

DEP:

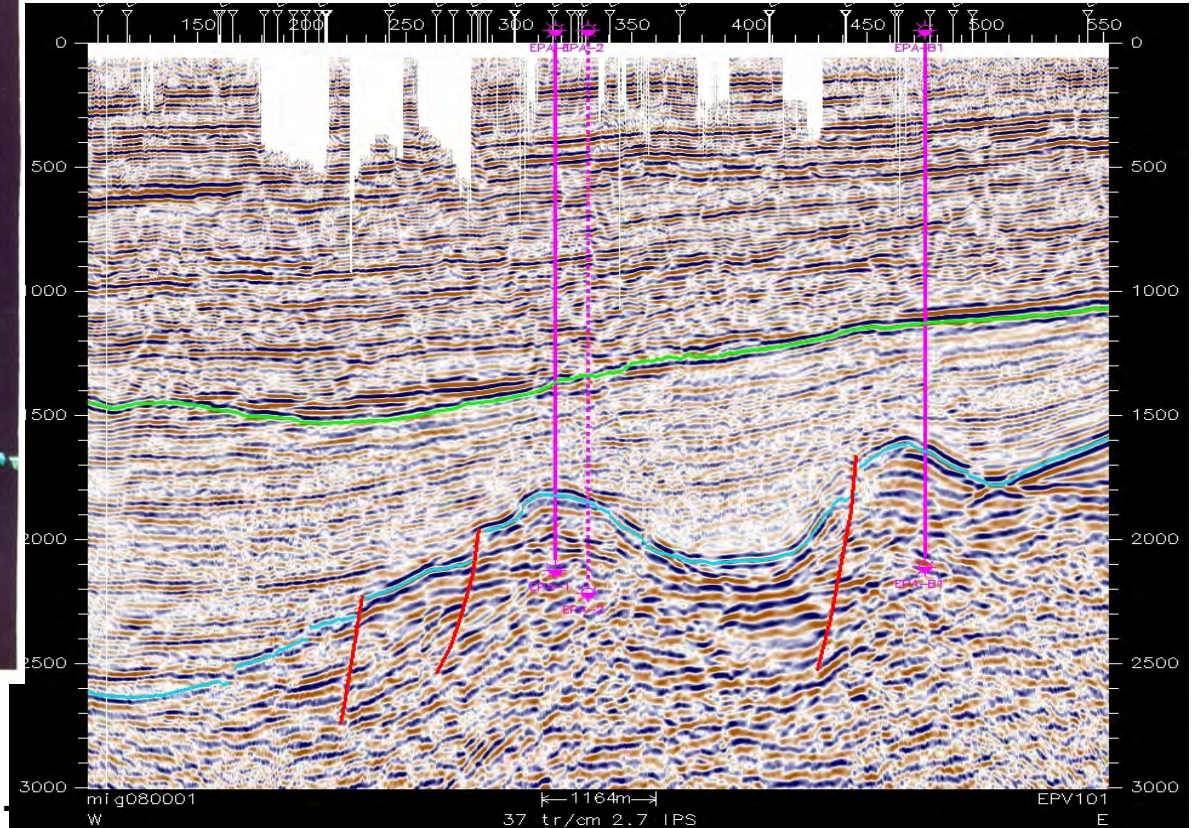
2.360 Km onshore seismic
4.700 km offshore seismic
12 onshore wells, 1980-92
2 offshore wells, 1986

- **Proven Petroleum System.**

- Discovery of Epanomi gas field.
- Big basin with thick sedimentation.
- Multiple targets (Miocene, Mesozoic).
- Dense coverage offshore and onshore with seismics from the 80's and 90's.
- Mapping of stratigraphic traps requires 3D seismic but the acquisition is rather difficult in Epanomi area due to the urban development.



Thessaloniki basin- Epanomi – Thermaikos gulf 2/2



The gas field of Epanomi was discovered in 1988/89. Recoverable reserves are estimated to 14Bscf.

N. Roussos F. Marnelis, Oil and Gas Journal, 1995

North Aegean – Thracian Sea

(not including the Prinos and S. Kavala concession)

Companies other than DEP:

Different companies acquired 5000 Km of seismics (1970-74)

1 well (1973)

NAPC acquired 6000 Km of 2D seismic (1970-84)

Two 3D campaigns (1993 & 1997)

16 exploration wells (1971-98)

Many production wells

DEP:

More than 4.000 km 2D seismic

- **Proven Petroleum System:**

Discovery of Prinos and S. Kavala fields

- Coverage with rather old seismic data of the Thracian Sea. Limited insufficient coverage of N. Aegean.
- Targets similar to the ones producing in Thracian sea or in Eastern Trace are expected but a denser seismic coverage is required.
- Water depth in N. Thracian sea is less than 100m but between Chalkidiki and N Sporades water depth exceeds 1000m.



Hellenic Trench - Mediterranean Ridge 1/2

Basins of Hellenic Trench

- Unknown but probable Petroleum system based on the known geology and relevant references.
- With the exception of Kyparissiakos area very limited seismic coverage.
- Great water depth and rough sea bottom topography.

Mediterranean Ridge

- Petroleum system not proven but the thick expected sedimentary section may have generate hydrocarbons. East and West flags are the most promising.
- Very limited seismic coverage. Most of the programs have been acquired by different Universities' or Institutes' projects. Existing data may indicate some structures but are inadequate to map any targets.

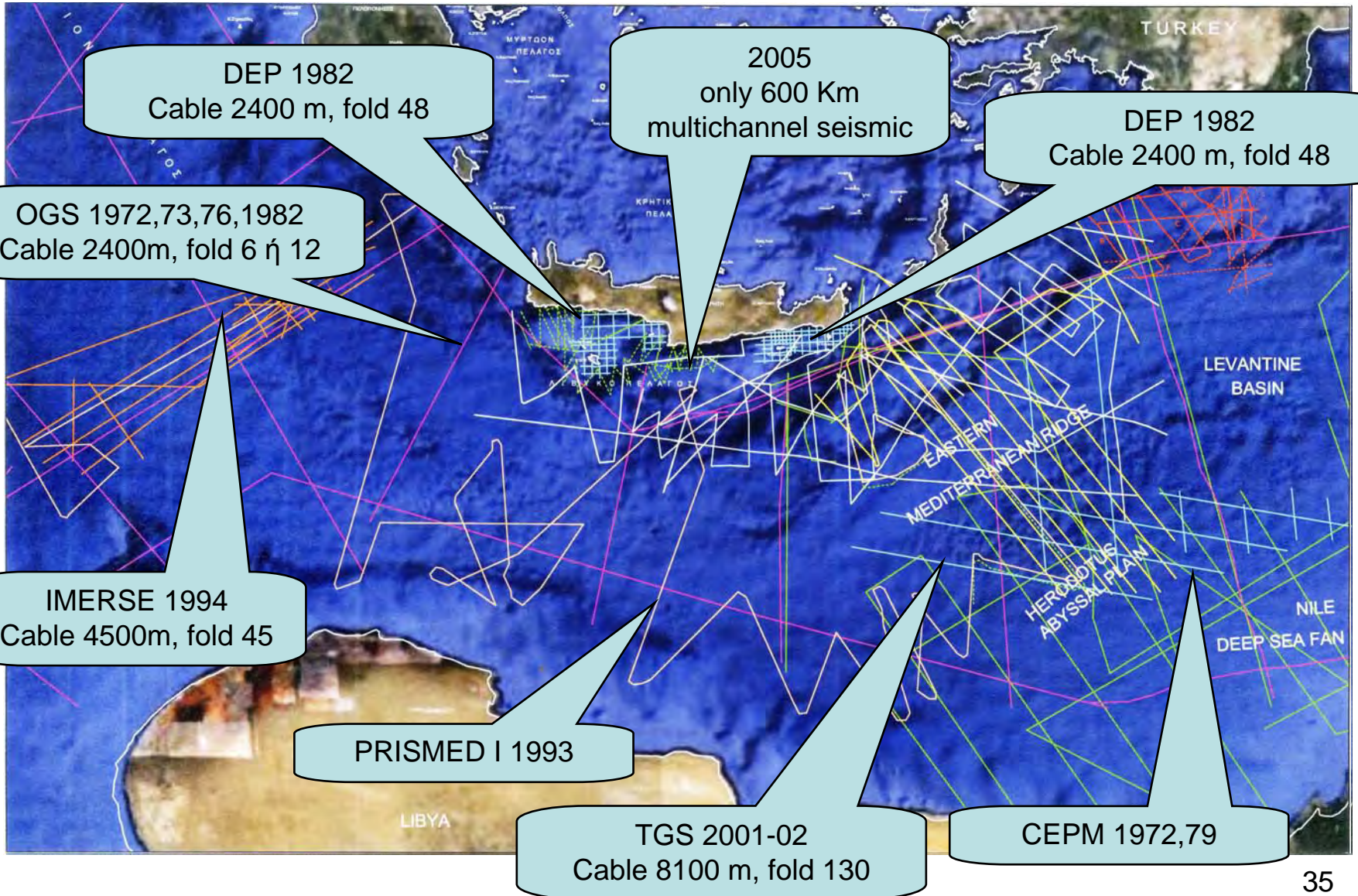


Abyssal plain

- The Herodotus plateau at the East is consider to be the most promising.
- The few existing data are inadequate to map any targets.

Hellenic Trench - Mediterranean Ridge 2/2

Seismic coverage



Conclusions

Conclusions

- Most promising areas are:
 - **Deep waters of North Ionian sea and basins in Central and South Ionian sea.**
 - **Deep targets in NW Greece, not drilled yet.**
 - **Thermaikos –Thessaloniki basin as well as basins in North Aegean.**
- Depending on the exploration results in NW Greece, Aitoloakarnania and NW Peloponessos areas could be upgraded.
- Grevena and Evros-Orestiada areas could be consider as a second priority.
- Hydrocarbon potential of Hellenic Trench and Mediterranean Ridge is not known yet. Despite the results of some scientific projects, it is impossible to identify and map targets with the existing seismic data.

The way ahead

- Re-evaluation of available data for all Greek basins.
- Synthesis of geological models based on modern geological approach.
- New Geophysical data implementing new techniques in acquisition processing and interpretation.
- Use of advanced technology in drilling, logging and testing.
- Basins that had been abandoned in the past can be revisited due to the changes in technology and hydrocarbon price.
- Many basins are underexplored and some areas are unexplored.

To find oil, you have to drill (Schlumberger 2011)

...across these and other areas, the industry is challenged by deeper water, more difficult logistics, increasingly complex geological settings, and higher degrees of temperature and pressure. **The result is greater difficulty in transforming resources into reserves and reserves into production.**

Given this context, an old industry adage holds truer than ever: **If you want to find oil, you have to drill.** But not only do you have to drill, you also have to increase the intensity at which you drill, in terms of technological sophistication, well and reservoir complexity, and operational efficiency and effectiveness.

Thank you