Exploration history and Hydrocarbon Potential of Greece

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Exploration and Production of Hydrocarbons
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-Aitoloakarnania
- 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.
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

**Ionnina**: 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 Peloponessos**: 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.

**Aitoloakarnania**: 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):
Energean 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

<table>
<thead>
<tr>
<th>Lithology</th>
<th>Geologic Time</th>
<th>Formation</th>
<th>Source Rocks</th>
<th>Reservoir</th>
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### EASTERN GREECE

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<td></td>
<td>Intrusive basement</td>
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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

Dragopsa

Posidonia beds
**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.
Sub-evaporite plays
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
• 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 below the evapotite) have not been explored in full. Therefore the hydrocarbon potential below the Triassic evaporites 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
Offshore seismics in Western Greece

<table>
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<th>SHOT YEAR</th>
<th>Km</th>
<th>Source</th>
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<td>568</td>
<td>AIRGUN</td>
<td>48</td>
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<tr>
<td>1985</td>
<td>4050</td>
<td>AIRGUN</td>
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<tr>
<td>1977-1979</td>
<td>4330</td>
<td>VAPOURCHOC</td>
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<tr>
<td>1970</td>
<td>3181</td>
<td>MAXIPULSE</td>
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<tr>
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<td>4254</td>
<td>MAXIPULSE</td>
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<td>AIRGUN</td>
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<td>VARIUS</td>
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<td>1985-1986</td>
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<td>AIRGUN</td>
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<td>AIGUN</td>
<td>24</td>
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<td>1984</td>
<td>365</td>
<td>AIRGUN</td>
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<td>2000</td>
<td>1136</td>
<td>AIRGUN</td>
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</tbody>
</table>

YPKEA 2011
The Katakolo field was discovered in 1981/82.

Recoverable reserves are estimated to 3 MMbbls

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

- DEP 1982
  Cable 2400 m, fold 48

- OGS 1972, 73, 76, 1982
  Cable 2400 m, fold 6 \( \eta \) 12

- IMERSE 1994
  Cable 4500 m, fold 45

- PRISMED I 1993

- TGS 2001-02
  Cable 8100 m, fold 130

- 2005
  only 600 Km
  multichannel seismic

- DEP 1982
  Cable 2400 m, fold 48

- CEPM 1972, 79

- TGS 2001-02
  Cable 8100 m, fold 130

- CEPM 1972, 79
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