Possible Hydrocarbon Plays in the South Adriatic Basin and Analogues with Ionian and Apulian Geological Provinces*

Marin Matešić¹, Lilit Cota¹, and Josip Bubnić¹

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¹INA Oil Company, Zagreb, Croatia (marin.matesic@ina.hr)

Abstract

Although 128 exploration wells exist on the Croatian side of the Adriatic Sea, the area has been unevenly explored. Most of the wells have been concentrated in the shallow water area of Northern Adriatic where biogenic gas has been produced from the shallow Pliocene clastic section. The underlying carbonates have several wells with Cretaceous heavy oil shows found at moderate target depths, whereas Vlasta-1 found Triassic oil but at substantial depths, in which case the costs of drilling is significant. In contrast, the southern part of the Croatian Adriatic has a lower density of exploration wells, especially in its deep-water portion. In the shallow water portion, most of the wells tested the carbonate shelf edge play, where only the Južni Jadran-3 well found noncommercial quantities of oil. The Adriatic Basin belongs to genetically related Ionian and Apulian geological domains in Italy and Albania where one order of magnitude higher number of exploration wells exists with a significant amount of discovered oil and gas fields. Thus, hydrocarbon plays in Apulian and Ionian basins have been better understood. Mature source rocks, reservoirs, seals and timing of hydrocarbon generation have been well studied. Evidence has been found in outcrop and well data. Therefore, lessons learned in proven hydrocarbon provinces should be applied as analogy in the Croatian Adriatic. This article aims to balance the view on analogues with Apulian and Ionian zones and estimate chances of finding hydrocarbons in deep water of the Adriatic Sea.

References Cited

Barbullushi, R., 2015, HC Plays in Albania: Prize Reserves Management Ltd internet publication.


Technical Documentation, INA-Naftaplin, Zagreb.


Possible hydrocarbon plays in the South Adriatic Basin and analogues with Ionian and Apulian geological provinces

Marin Matešić, Lilit Cota, Josip Bubnić

Barcelona, 4 October 2016.
Although 128 exploration wells exist on Croatian side of the Adriatic Sea, the area has been unevenly explored. Most of the wells have been concentrated in the shallow water area of Northern Adriatic where biogenic gas has been produced from the shallow Pliocene clastic section.

In Northern Adriatic numerous wells were drilled to deeper carbonate platform sediments including those of Jurassic, Cretaceous and Paleogene age;

The underlying carbonates have several wells with Cretaceous heavy oil shows found at moderate target depths, whereas Vlasta-1 found Triassic oil but at substantial depths, in which case cost of drilling is significant.
Seismic data

- North Adriatic has better 3D seismic coverage of biogenic gas play
- During the last seismic campaign 2013 Spectrum recorded regular grid over the entire Adriatic area.
- In South Adriatic INA recorder 1216 km2 and 800 km of 2D seismic.
In contrast, the southern part of the Croatian Adriatic has lower density of exploration wells, especially in its deep-water portion. In shallow water portion most of the wells tested carbonate shelf edge play, where only Južni Jadran-3 well found noncommercial quantities of oil.

<table>
<thead>
<tr>
<th>Country</th>
<th>Discoveries</th>
</tr>
</thead>
<tbody>
<tr>
<td>Montenegro</td>
<td>JJ-3</td>
</tr>
<tr>
<td>Italy</td>
<td>Rovesti, Aquila, Medusa, Giove, Falco</td>
</tr>
<tr>
<td>Albania</td>
<td>Patos-Marinza, Kucova, Visoka, Ballsh-Hekal, Shpirag, Cakran-Mollaj, Gorisht-Kocul, Amonica, Delvina, A4-1X</td>
</tr>
</tbody>
</table>
Until Paleocene, the South Adriatic Basin had a wide geographical extent from the North of Italy to the South of Greece.

During Oligocene the area differentiated when thrusted Albanides created a foredeep and thick Flysch deposits, later on covered by Molasse during Miocene-Pliocene.
Petroleum systems and play maturity

• The Adriatic basin belongs to genetically related Ionian and Apulian geological domains in Italy and Albania where one order of magnitude higher number of exploration wells exists with a significant amount of discovered oil and gas fields.

• Hydrocarbon plays in Apulian and Ionian basins have been better understood. Mature source rocks, reservoirs, seals and timing of hydrocarbon generation have been well studied. Evidence has been found in outcrop and well data.

• Therefore, lessons learned in proven hydrocarbon provinces should be applied as analogy in the Croatian Adriatic.

• There are two petroleum systems in the Adriatic:
  – Plio-Pleistocene biogenic gas system
  – Mesozoic petroleum system.
### Simplified Stratigraphy and Petroleum System of the Adriatic Basin

#### Multiple Source Rock Sequences
- Late Triassic Burano Fm. proven carbonate source rock. Type II kerogen, HI 600 (Onshore Italy), TOC possibly up to 10-12%
- Early Liassic source, Calcari di Emma eq. Fm.
- Possible Cretaceous source
- Late Tertiary biogenic gas

#### Multiple Reservoirs
- Liassic Dolomites?
- Early Cretaceous – fractured Maiolica Fm. – pelagic carbonates
- Late Cretaceous ‘Monte Acuto and Monte S.Angelo Fm.’ resedimented platform carbonates
- Oligocene ‘Porto Badisco/Castro’ limestone
- Mio-Pliocene calcarenites

#### Multiple Seals
- Early Cretaceous Maiolica Fm. - pelagic carbonates
- Oligocene Scaglia Cinerea silty marl
- Miocene marls and shales
- Pliocene marls and shales

#### Generation & Migration during Late Tertiary Likely in Different Pulses
- Generation & migration pulses occurred in Mid-Late Miocene & Post-Pliocene.

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*modified after Caldarelli and Robinson, 2013*
The biogenic gas play was in the past decades the prime focus of exploration efforts in the North Adriatic area and is now in a mature stage.

- Interpretation of new seismic data indicated existence of bright spots but without typical North Adriatic gas saturation response.
- Different sediment input from Dinaric carbonate platform causes lack of quartz sand dominated reservoir.
- Falco 1 discovery and non-commercial discoveries in Albanian Peri Adriatic depression.
Biogenic gas, Albanian Foredeep

- The Albanian Foredeep is genetically related to the west-verging Albanide fold-and-thrust belt.
- A number of exploration wells were drilled here during the 1980s to target the Pliocene and upper Miocene (Messinian) successions, but only limited and noncommercial volumes of biogenic gas were discovered.

<table>
<thead>
<tr>
<th>Field Name</th>
<th>Discovered</th>
<th>Reservoir depth (m)</th>
<th>Age of reservoir</th>
<th>Recoverable Reserves Gas (Bscf)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Divjaka</td>
<td>1963</td>
<td>2400-3000</td>
<td>Tortonian-Messinian, Pliocene</td>
<td>80</td>
</tr>
<tr>
<td>Ballaj-Krjevidh</td>
<td>1983</td>
<td>300-1700</td>
<td>Pliocene</td>
<td></td>
</tr>
<tr>
<td>Frakulla</td>
<td>1965</td>
<td>300-2500</td>
<td>Tortonian-Messinian</td>
<td>10</td>
</tr>
<tr>
<td>Povelca</td>
<td>1987</td>
<td>1800-3500</td>
<td>Tortonian-Messinian</td>
<td>10</td>
</tr>
<tr>
<td>A4-1X</td>
<td>1993</td>
<td>2565-2574</td>
<td>Post Evaporitic Messinian</td>
<td>69</td>
</tr>
<tr>
<td>Falco-1</td>
<td>1981</td>
<td>2400-2520</td>
<td>Messinian</td>
<td>200</td>
</tr>
</tbody>
</table>
Mesozoic platform vs basinal architecture

- SR associated with South Adriatic-Ionian basin to platform “B” facies
- In terms of a reservoir, good primary properties are expected in platform edges and slope bases. Pelagic carbonates should be fractured in order to increase porosity-permeability properties.
- Oligocene clastic cover (Flysch) is expected as primary seal in the South Adriatic Ionian basin area

modified after Zappatera, 1994
Several authors agree on existence of the intraplate basin. Similar geochemical signature of oils has been found in the region. The extension is not well understood and changes each time a well intersects a source rock.

Thick cover of Flysch and Molasse in periadriatic depression coupled with great water depths is a main reason for lack of drilling in the area.
Triassic mini basin and Source Rock to Oil correlation

EVIDENCE OF TRIASSIC BASIN
(Vlasta-1, 1α and Vlatka-1 source rock defined)

Positive correlation
- Kerogen: d^{13}C -27 to -28‰
- Bitumen: d^{13}C -30 to -31‰
- Oil: d^{13}C -31 to -32‰

HC shows Bitumen

Oil d^{13}C -27 to -28‰ correlate with Burano formation oils

PREDICTED INTRAPLATFORM BASIN
(No source rock analytical data; Caldarelli et al. (2013))
- Basin model at proximal slope and JJ-3 non commercial discovery (tested 24°API oil) confirms existence of a working petroleum system and mature Triassic rock which could theoretically generate even lighter HC as in case of Aquila.
An alternative migration model has been proposed few decades ago (e.g. Roure, 2004) which is still used by many exploration companies.

The model explains how fields (Aquila) and prospects in South Adriatic could be filled with Hydrocarbons coming from Albanian foredeep.
Hydrocarbon kitchen in Albanian Foredeep, lateral migration model, map view

- Notice the long migration paths
Fractured reservoirs, deep water carbonates, Ionian zone

- In the South Adriatic, in a setting away from the carbonate platform we are going to encounter pelagic carbonates covered with Flysch which primarily have poor porosities.
- Analogues from Albania (Ionian zone) provide encouragement in terms of fractures enhancing porosity and permeability.
- 3D seismic and image logs needed in order to assess the fracture system.
- Horizontal wells have been producing oil in Albania

### Field Name Table

<table>
<thead>
<tr>
<th>Field Name</th>
<th>Reservoir Depth (m)</th>
<th>Porosity (%)</th>
<th>Permeability (mD)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Visoke</td>
<td>800-1000</td>
<td>4-5 + frac</td>
<td>44-224</td>
</tr>
<tr>
<td>Gorisht-Kocul</td>
<td>1000-2500</td>
<td>4-5 + frac</td>
<td>44-224</td>
</tr>
<tr>
<td>Ballsh-Hekal</td>
<td>1000-3000</td>
<td>4-5 + frac</td>
<td>44-224</td>
</tr>
<tr>
<td>Cakran-Mollaj</td>
<td>3000-4500</td>
<td>4-5 + frac</td>
<td>44-224</td>
</tr>
<tr>
<td>Finiq-Krane</td>
<td>800-2000</td>
<td>3-4 + frac</td>
<td></td>
</tr>
<tr>
<td>Delvine</td>
<td>2800-3400</td>
<td>3-4 + frac</td>
<td></td>
</tr>
</tbody>
</table>

*Barballushi 2015*
The structural style and hydrocarbon play components of the Ionian Zone in Greece and Albania continue into Dinaric thrust belt of Montenegro and Croatia including carbonate platform margin play of South Adriatic.
Although there are articulated stratigraphic plays in the Adriatic (carbonate slope sediments for example) structural plays will be the first choice in a present or future exploration efforts.

### Composite Zig-Zag 2D line in Southern Adriatic of various vintages connecting Italy and Croatia. Gap between lines approx. 4.5 km

<table>
<thead>
<tr>
<th>PLAY</th>
<th>ITALY (ANALOGUES)</th>
<th>CROATIA/MONTENEGRO</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>FIELD/DISCOVERY/AGE</td>
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</tr>
<tr>
<td>Triassic carbonate platform</td>
<td>Villafortuna-Trecate Middle Triassic</td>
<td>Vlasta-1 U. Triassic</td>
</tr>
<tr>
<td>Carbonate platform edge</td>
<td>Medusa, Giov  Oligocene-Miocene</td>
<td>Južni Jadran-1 Cretaceous</td>
</tr>
<tr>
<td>Proximal slope talus</td>
<td>Aquila, Rovesti Cretaceous</td>
<td>Untested potential</td>
</tr>
<tr>
<td>Deep Basin structures</td>
<td>Sparviero-1bis, Grifone-1 Cretaceous</td>
<td>Untested potential</td>
</tr>
</tbody>
</table>

- Giove
- Aquila
- Rovesti
- Grifone-1
- Deep Basin Structures
- Proximal slope JJ-3
- Platform edge
Plays and analogues from Apulian side, in detail

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</table>

Modified after Tomljenović 2014
Conclusions

• Based on the genetic relationship with Apulian and Ionian provinces the South Adriatic is an attractive exploration province.

• Biogenic gas petroleum system has revealed its potential proven by Falco and Albanian gas discoveries. A success will hugely depend on the presence of Direct Hydrocarbon Indicators and 3D seismic.

• Although Ionian onshore plays are more similar with the Dinaric plays, fracture enhanced reservoir properties of pelagic carbonates could be used as analogue in the Southern Adriatic Deep Basin Structures.

• Mesozoic petroleum system has a relatively strong evidence of having the same origin of source rock in the South Adriatic-Ionian Basin, which is proven by tectonostratigraphic knowledge and oil-source correlation.

• Various authors agreed on the existence of an intraplateform basin, in the platform to margin setting, but the exact extension needs to be confirmed by further drilling.
Conclusions

• The lack of relation between the South Adriatic-Ionian Basin is due to absence of wells in the area Albanian foredeep area. The reason is a substantial Oligocene-Quaternary sedimentary package (up to 4000 m) and significant water depth.

• Two theories about migration paths exist:
  – Vertical, sourced from active source rock pod located beneath prospects
  – Lateral, originating from the Peri Adriatic Depression.

• Structural plays which are proven in the Italian side will be the first choice in a present or future exploration efforts in the South Adriatic. They are: Platform edge, Proximal slope talus, Deep basin structures.

• The Triassic carbonate high risk-high reward target has a main challenge in a significant well depths, circa 6000 m and challenges of drilling in a karstic medium.
References

6. Technical documentation, INA-Naftaplin, Zagreb