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

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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.

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

INA

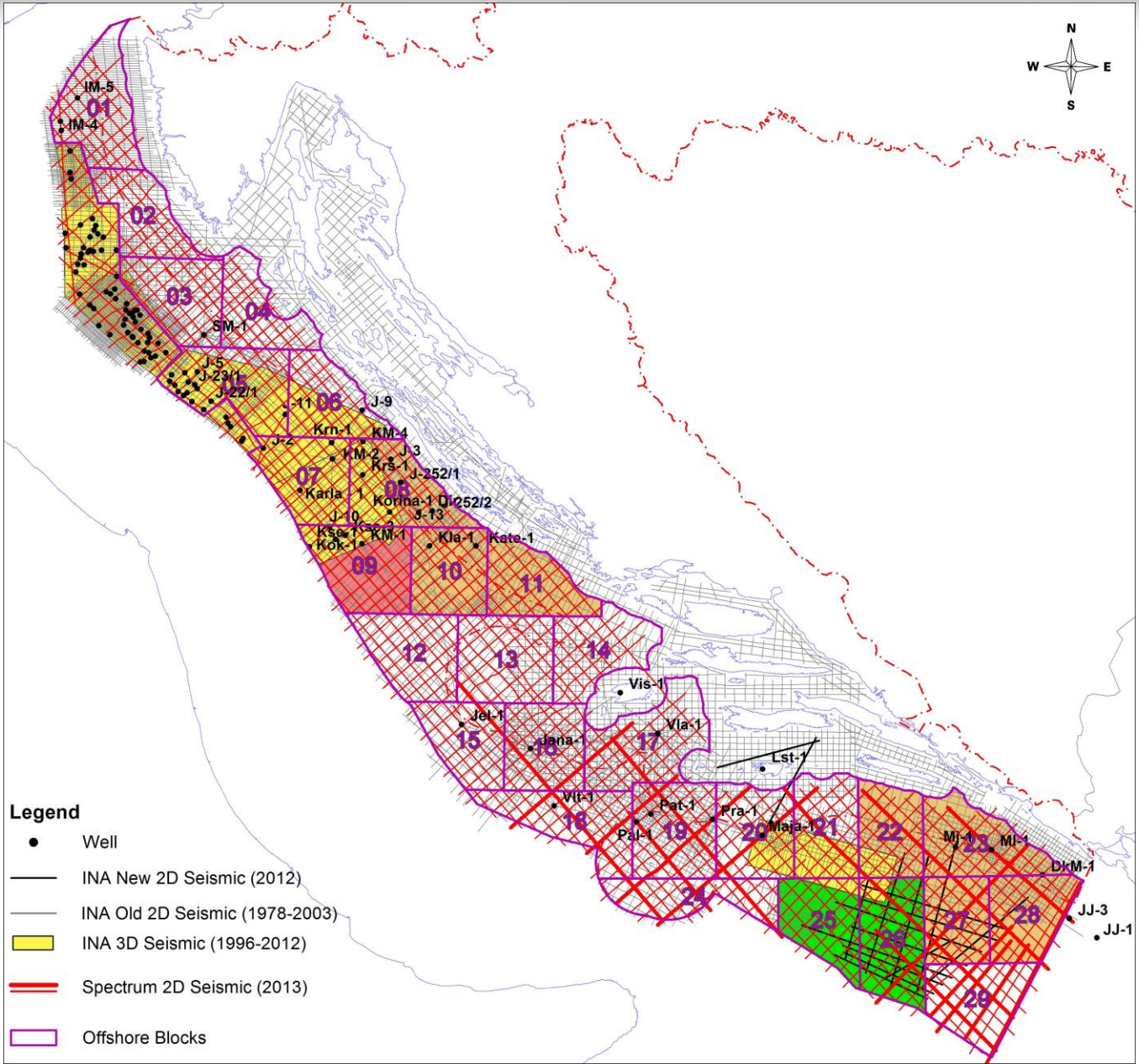
Marin Matešić, Lilit Cota, Josip Bubnić

Barcelona , 4 October 2016.

Introduction

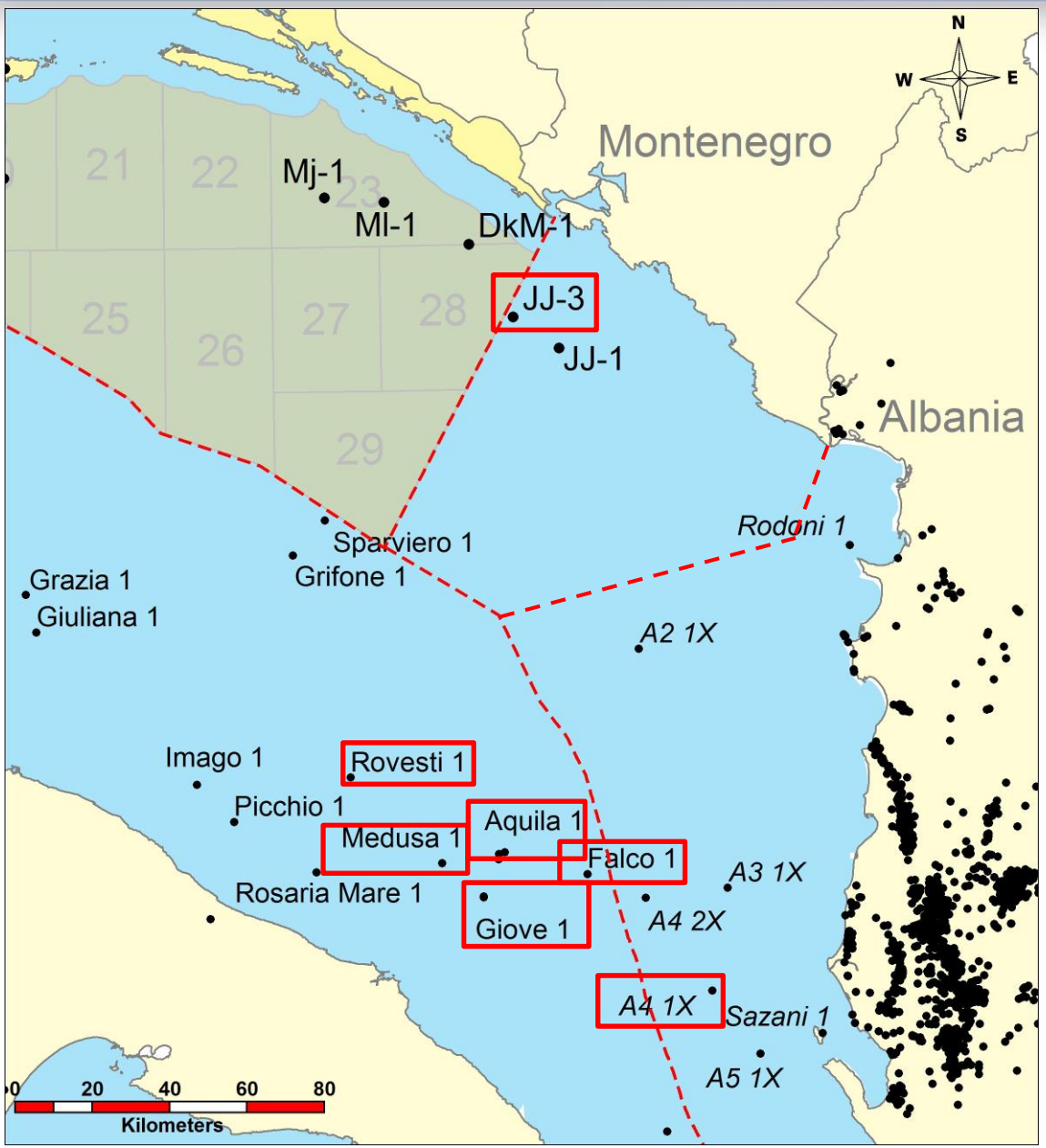
- Although 128 exploration wells exist on Croatian side of the Adriatic Sea, the area has been unevenly explored. Most of the wells have been concentrated in the shallow water area of Northern Adriatic where biogenic gas has been produced from the shallow Pliocene clastic section.
- In Northern Adriatic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

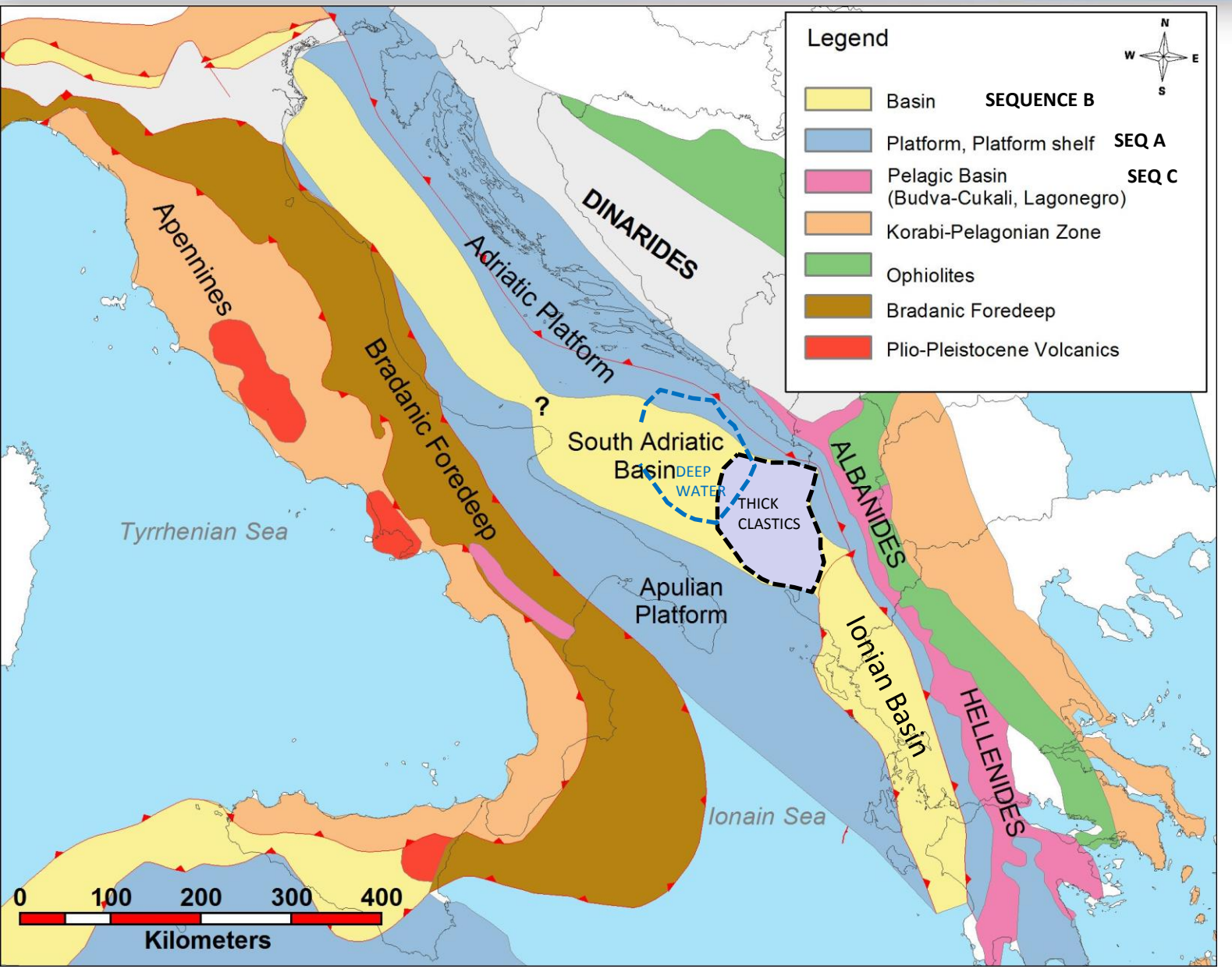
Southern Adriatic – well density



- 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.

Country	Discoveries
Montenegro	JJ-3
Italy	Rovesti, Aquila, Medusa, Giove, Falco
Albania	Patos-Marinza, Kucova, Visoka, Ballsh-Hekal, Shpirag, Cakran-Mollaj, Gorisht-Kocul, Amonica, Delvina, A4-1X

SAB-Ionian basin-Apulian platform, simplified



- 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.

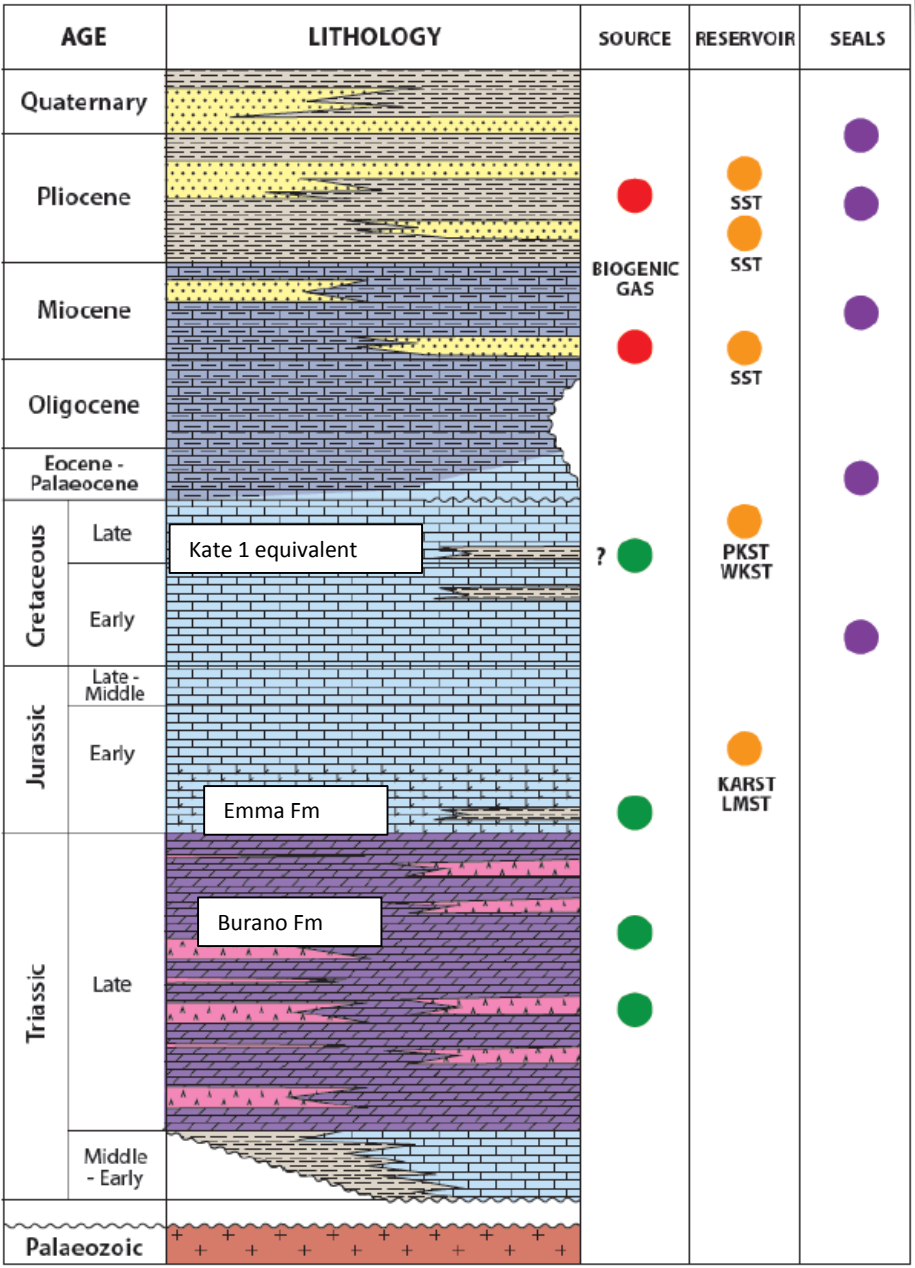
modified after Zappaterra, 1994 and Bega, 2015

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

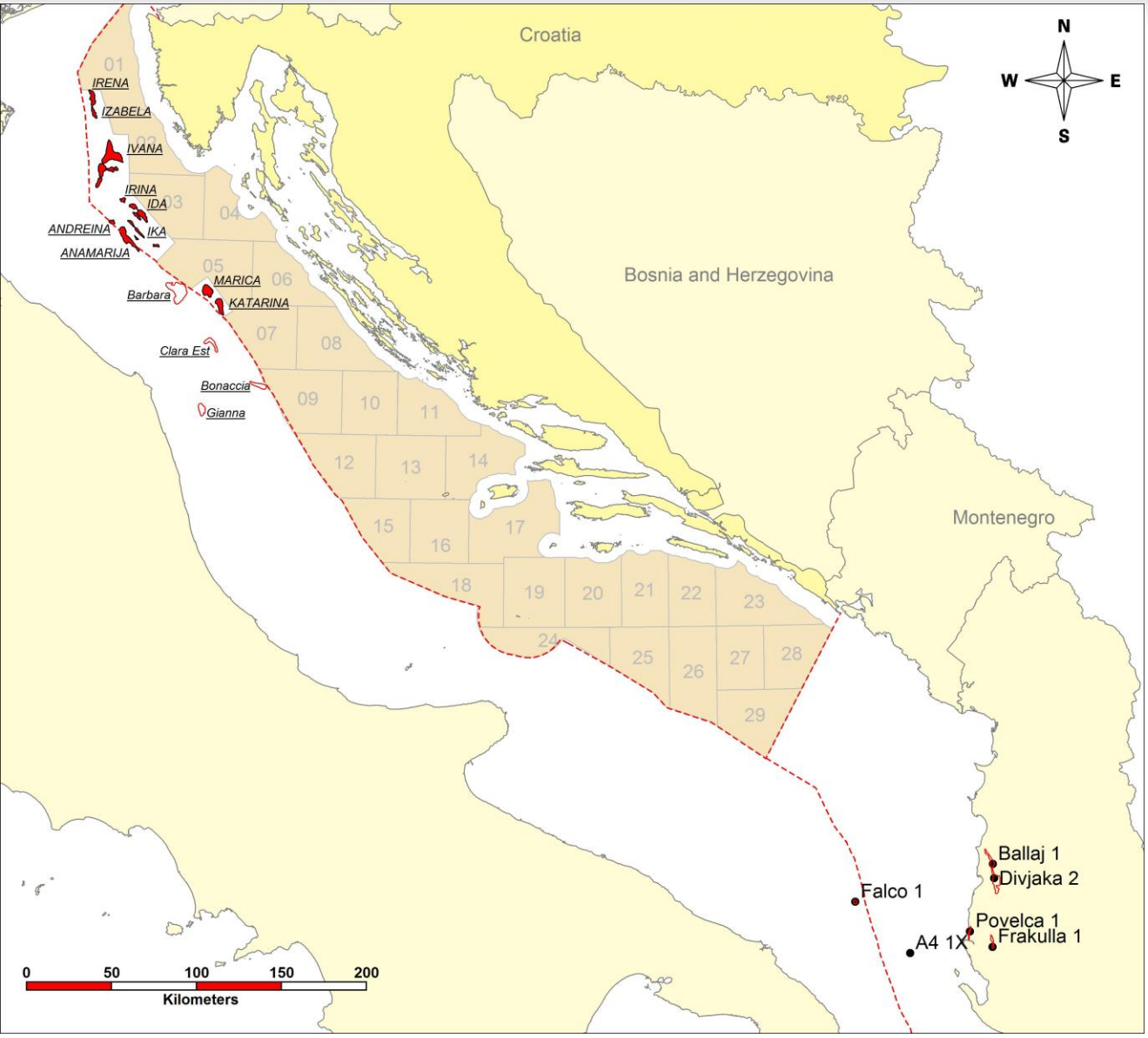
- Early Cretaceous Maiolica Fm. - pelagic carbonates
- Oligocene Scaglia Cinerea silty marl
- Miocene marls and shales
- Pliocene marls and shales

Generation & migration during Late Tertiary likely in different pulses

- Generation & migration pulses occurred in Mid-Late Miocene & Post-Pliocene.

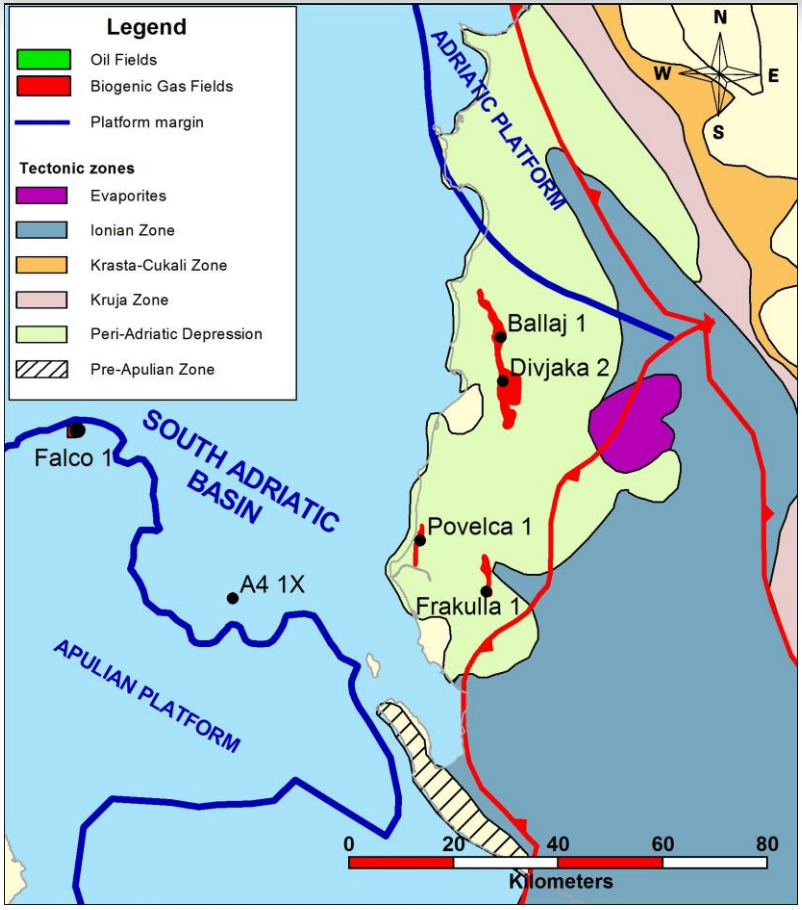
modified after Caldarelli and Robinson, 2013

Plio-Pleistocene biogenic gas system

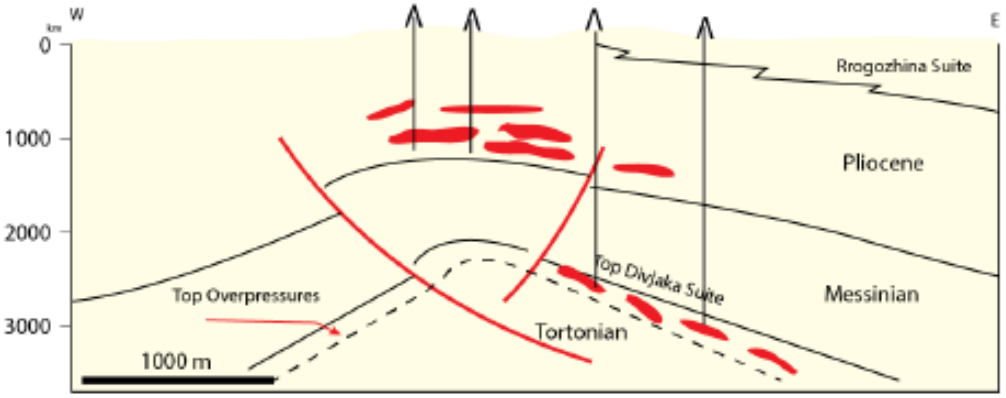


- The biogenic gas play was in the past decades the prime focus of exploration efforts in the North Adriatic area and is now in a mature stage
- Interpretation of New Seismic data indicated existence of bright spots but without typical North Adriatic gas saturation response
- Different sediment input 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



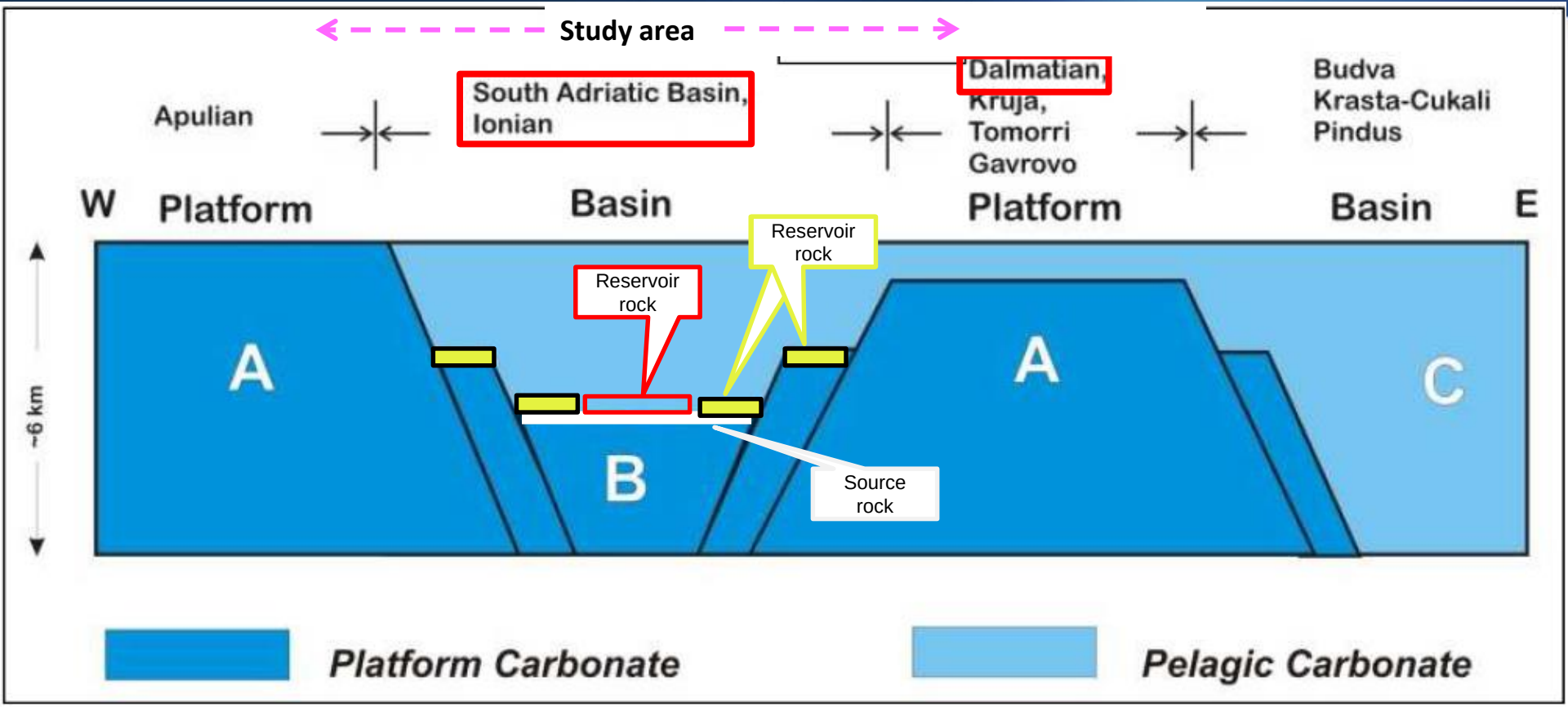
Field Name	Discovered	Reservoir depth (m)	Age of reservoir	Recoverable Reserves Gas (Bscf)
Divjaka	1963	2400-3000	Tortonian-Messinian,Pliocene	80
Ballaj-Krjevidh	1983	300-1700	pliocene	
Frakulla	1965	300-2500	Tortonian-Messinian	10
Povelca	1987	1800-3500	Tortonian-Messinian	10
A4-1X	1993	2565-2574	Post Evaporitic Messinian	69
Falco-1	1981	2400-2520	Messinian	200



- 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.

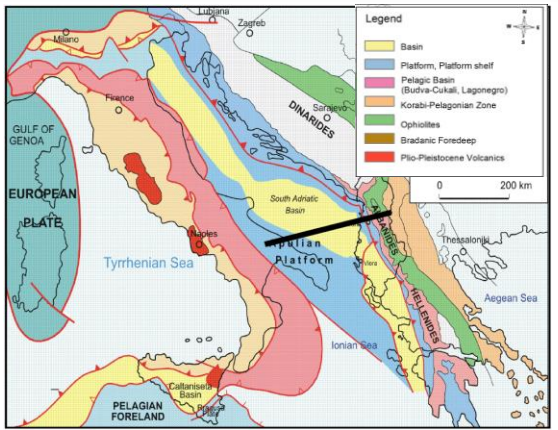
Barballushi 2015

Mesozoic platform vs basinal architecture

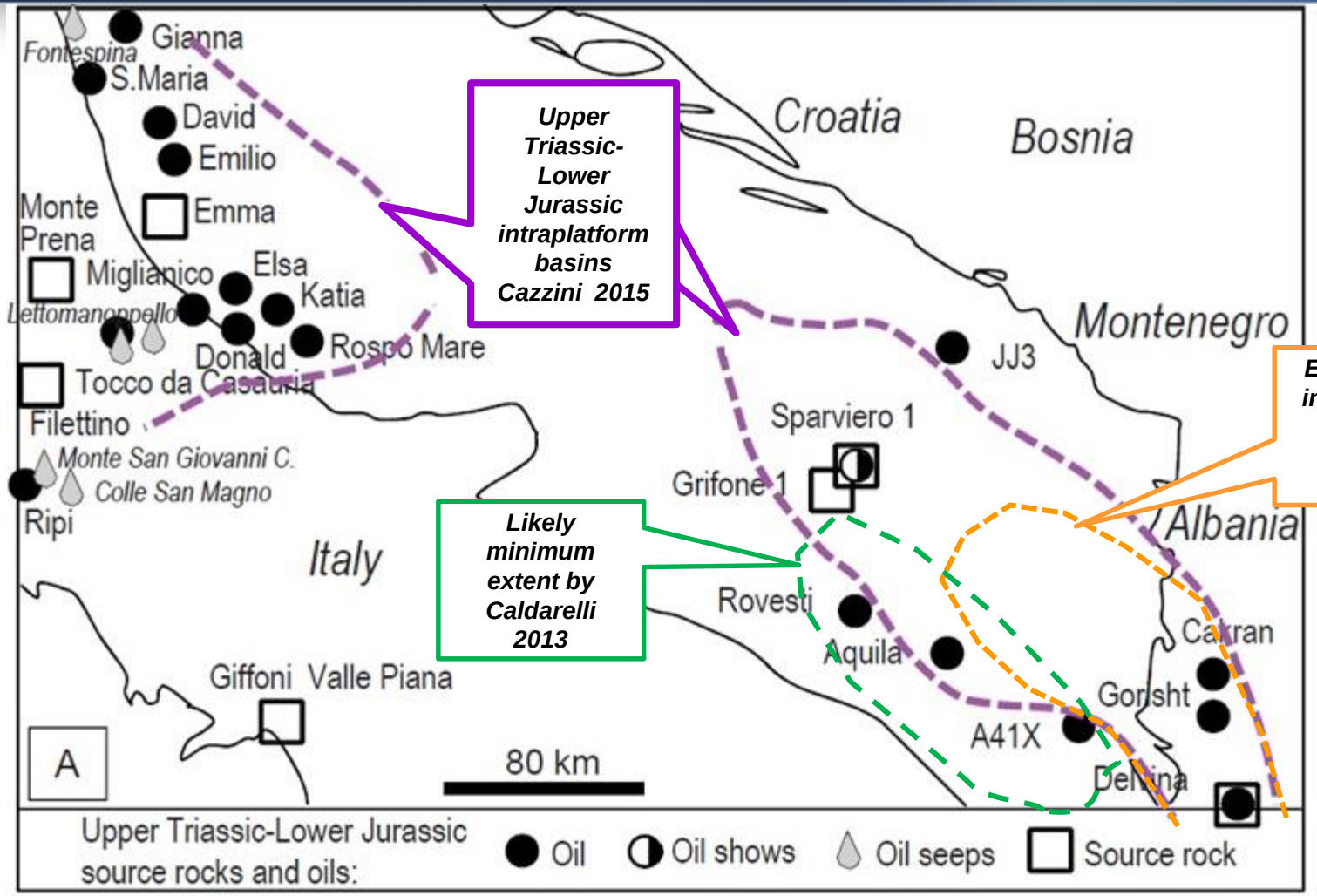


modified after Zappatera, 1994

- SR associated with South Adriatic- Ionian basn 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



Triassic-Lower Jurassic source rock map



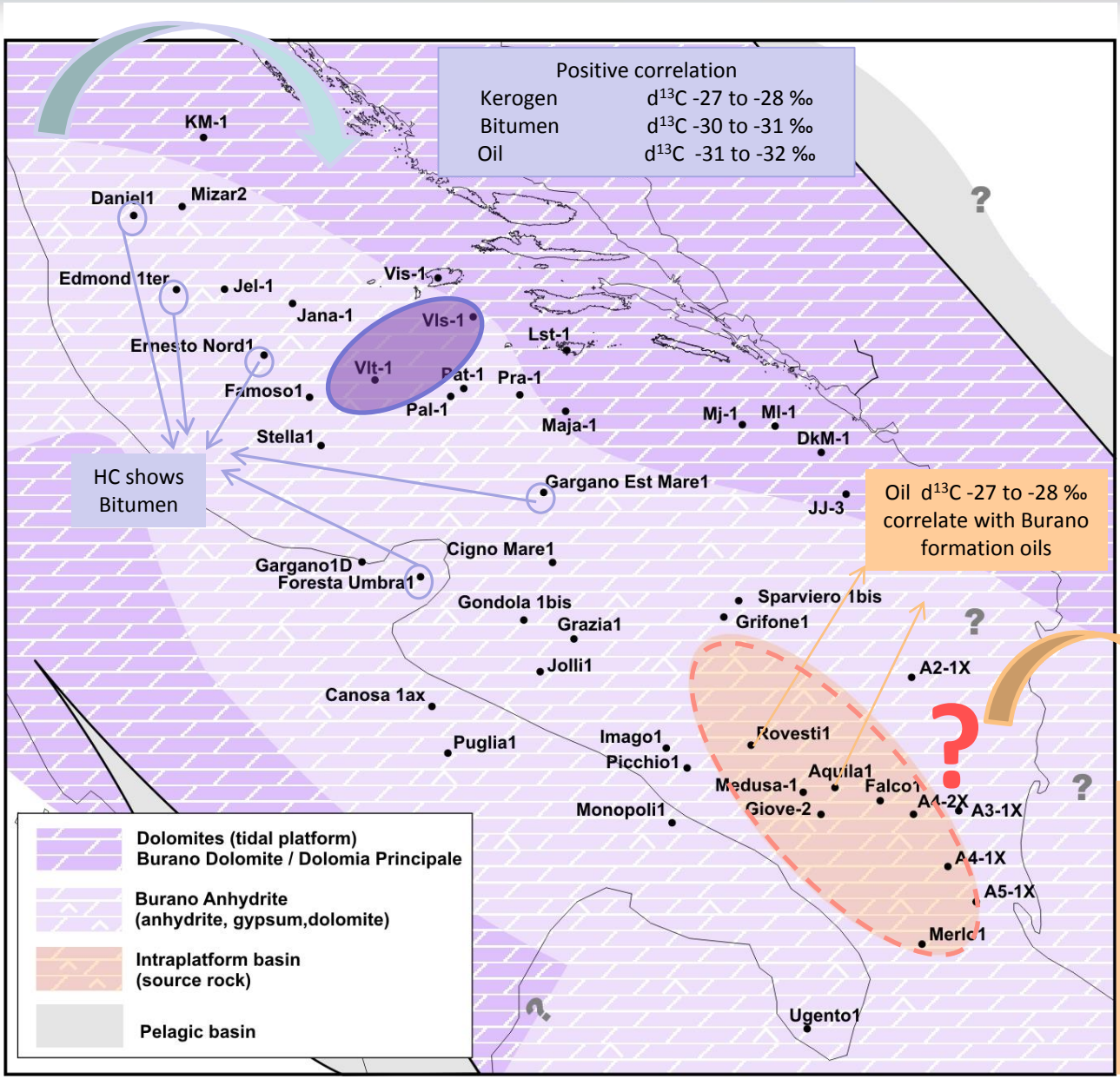
Modified after Cazzini et al. 2015

- Several authors agree on existence of the intraplatform 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)

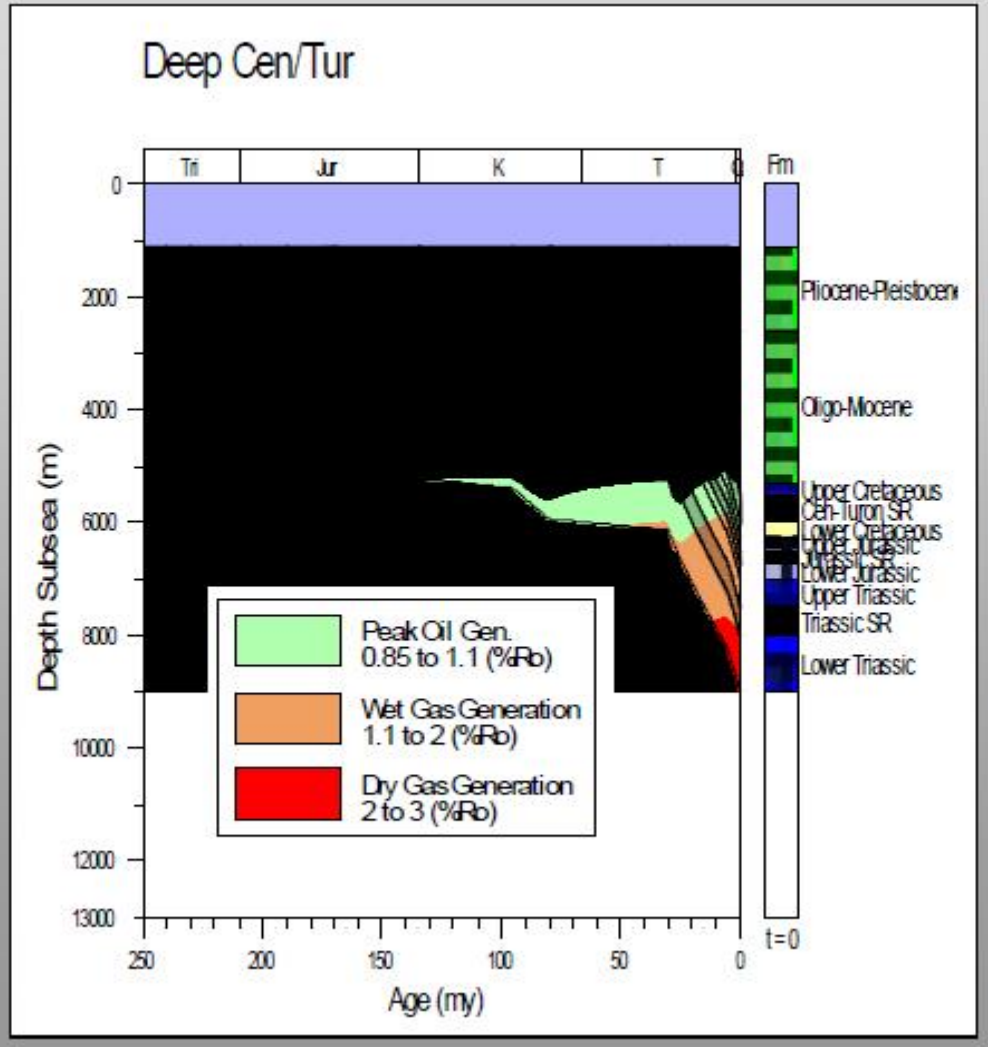


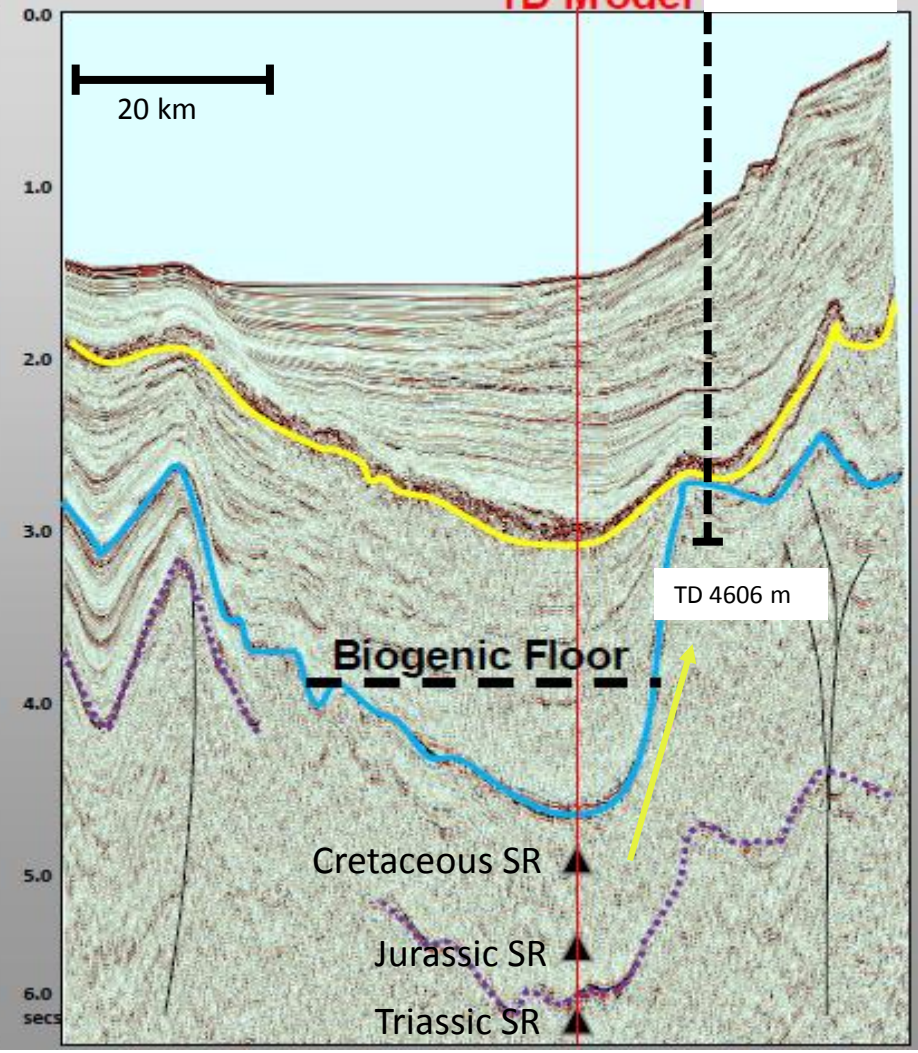
PREDICTED INTRAPLATFORM BASIN

(No source rock analytical data; Caldarelli et al. (2013)

Maturity of Source rock, vertical migration model

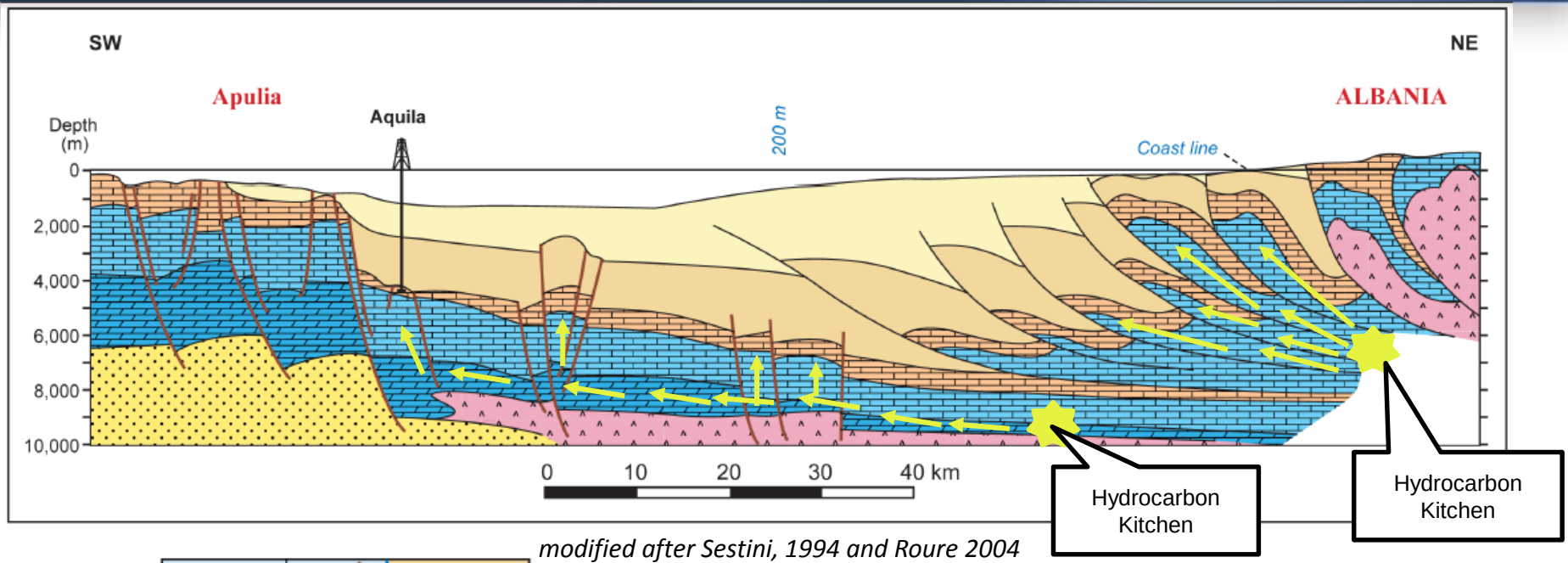
Modified after Joseph Pape, 2014 in "1st Offshore license round opening'' Croatian Hydrocarbon Agency Presentation



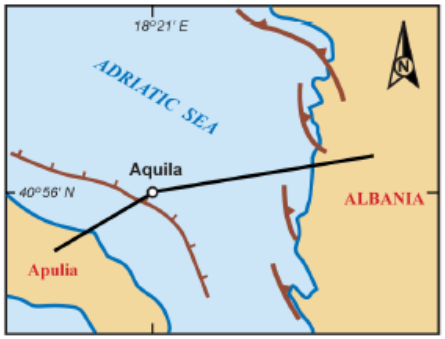


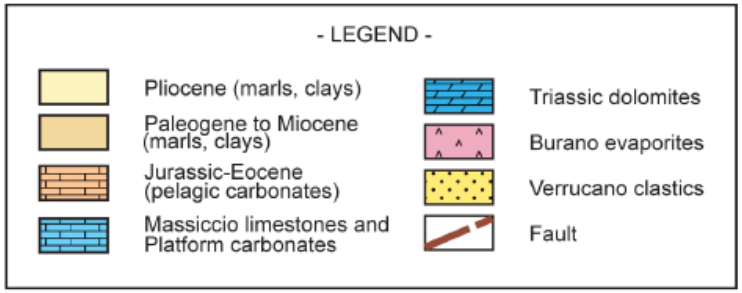
- Basin model at proximal slope and JJ-3 non commercial discovery (tested 24°API oil) confirms existence of a working petroleum system and mature Triassic rock which could theoretically generate even lighter HC as in case of Aquila.

Ionian zone, a lateral migration model



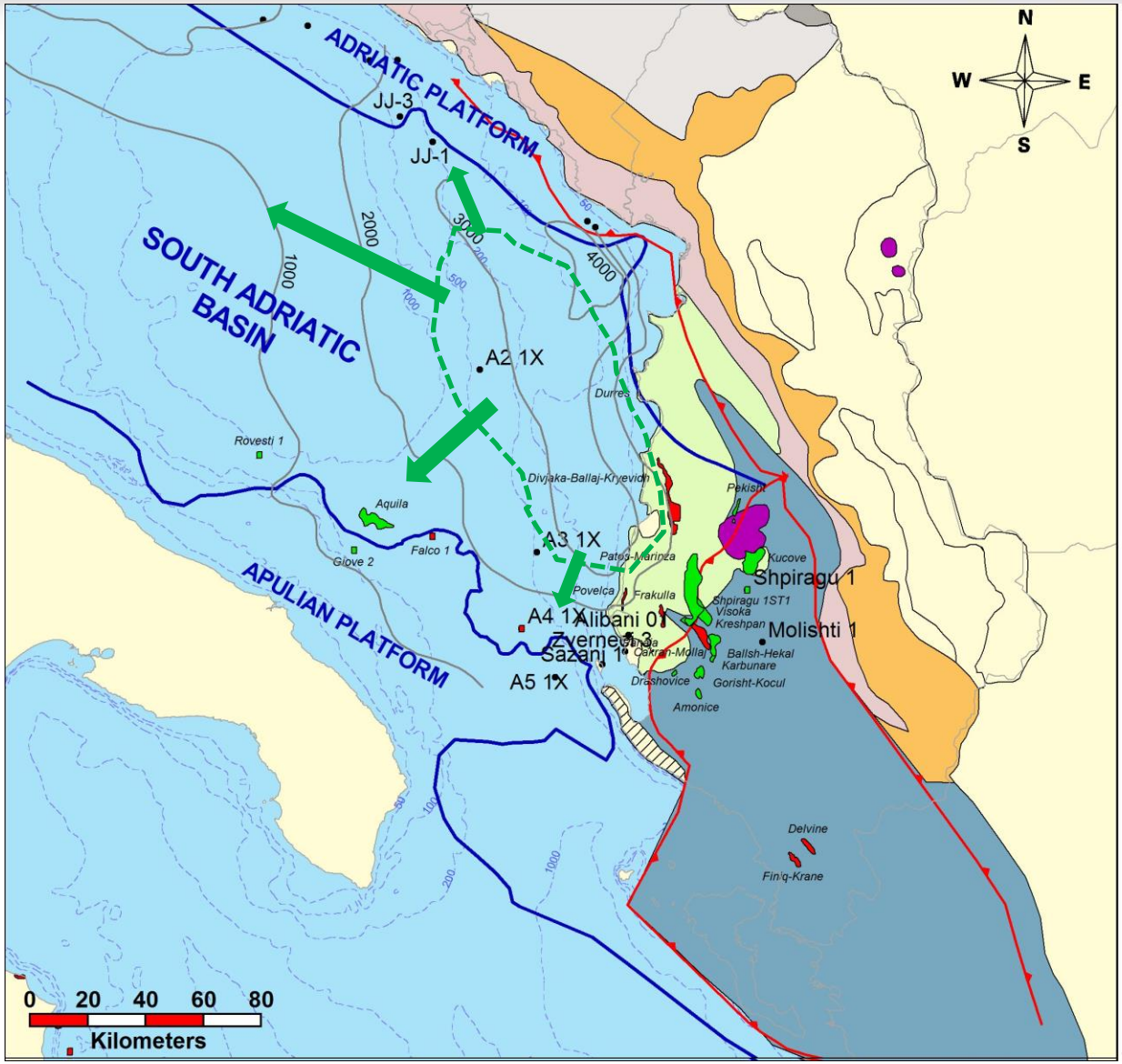
modified after Sestini, 1994 and Roure 2004





- 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



Legend

- Bathymetry
- Oil Fields
- Gas Fields
- Platform margin
- Oligocene-Quarternary Clastics

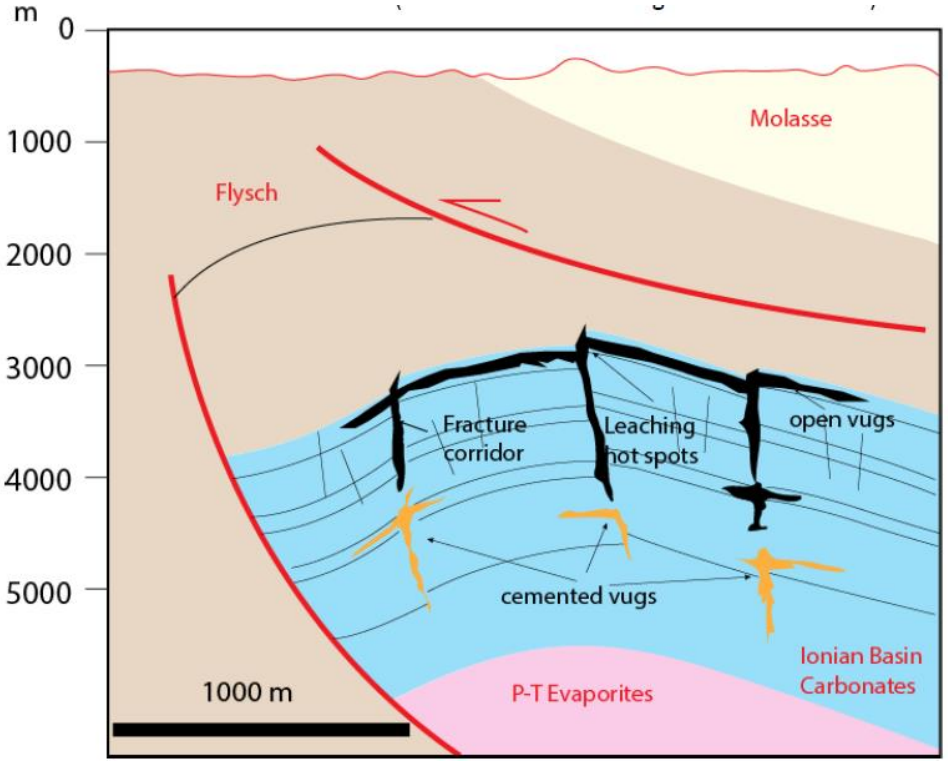
Tectonic zones

- Evaporites
- Ionian Zone
- Krasta-Cukali Zone
- Kruja Zone
- Peri-Adriatic Depression
- Pre-Apulian Zone

- Notice the long migration paths

Fractured reservoirs, deep water carbonates, Ionian zone

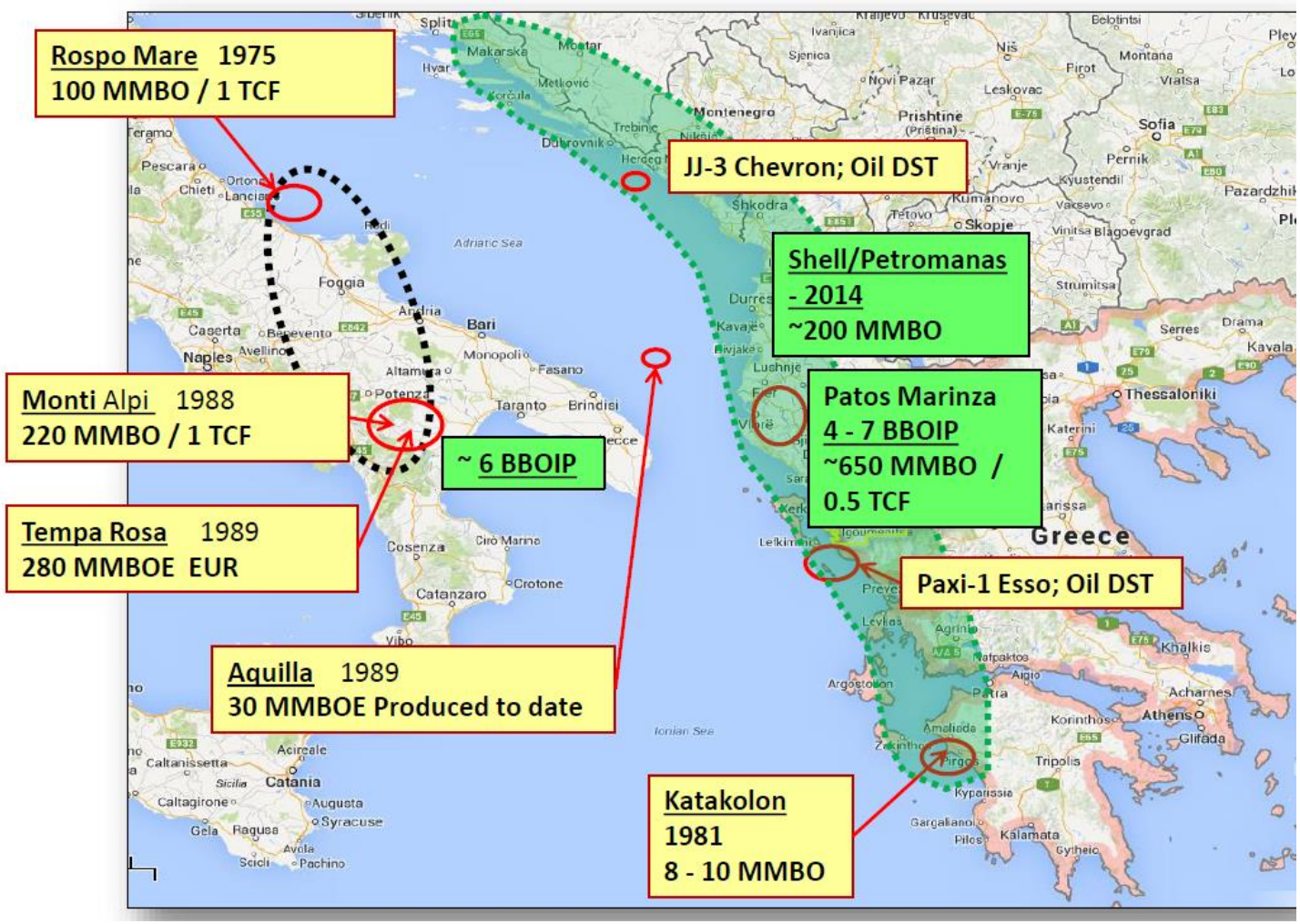
- In the South Adriatic, in a setting away from the carbonate platform we are going to encounter pelagic carbonates covered with Flysch which primarily have poor porosities.
- Analogues from Albania (Ionian zone) provide encouragement in terms of fractures enhancing porosity and permeability.
- 3D seismic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



Barballushi 2015

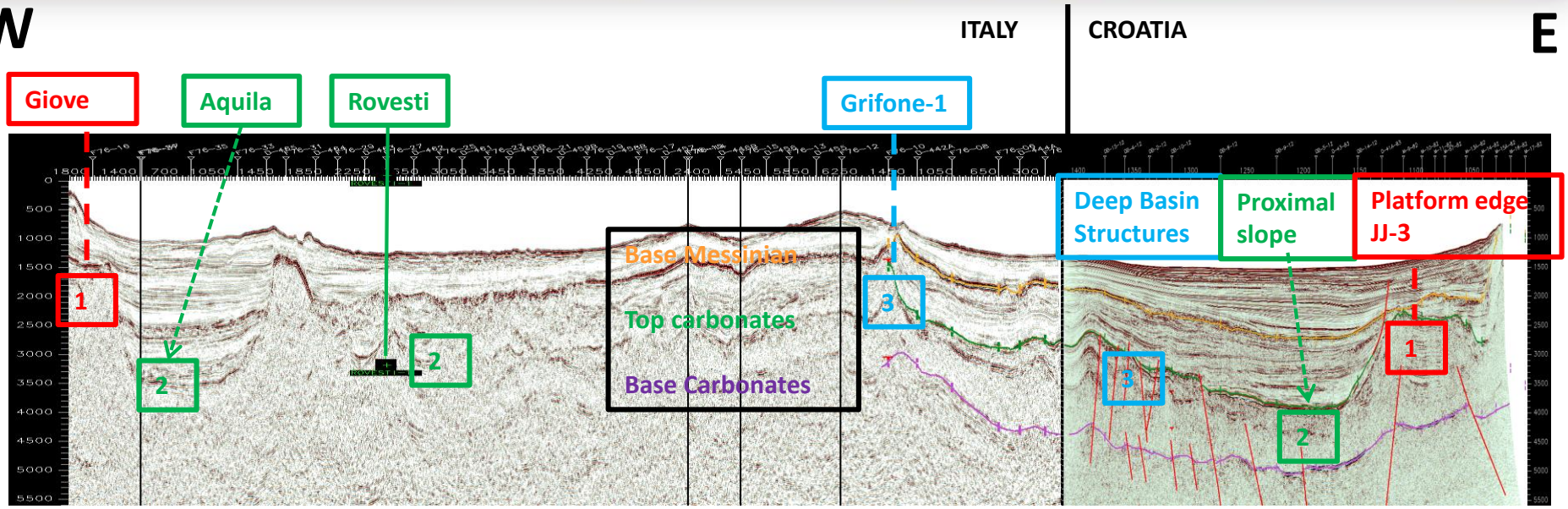
Field Name	Reservoir Depth (m)	Porosity (%)	Permeability (mD)
Visoke	800-1000		
Gorisht-Kocul	1000-2500	4-5 + frac	44-224
Ballsh-Hekal	1000-3000	4-5 + frac	44-224
Cakran-Mollaj	3000-4500	4-5 + frac	44-224
Finiq- Krane	800-2000	3-4 + frac	
Delvine	2800-3400	3-4 + frac	

Ionian zone analogues and discoveries



- The structural style and hydrocarbon play components of the Ionian Zone in Greece and Albania continue into Dinaric thrust belt of Montenegreo and Croatia including carbonate platform margin play of South Adriatic

Central & South Adriatic Apulian structural plays and analogues

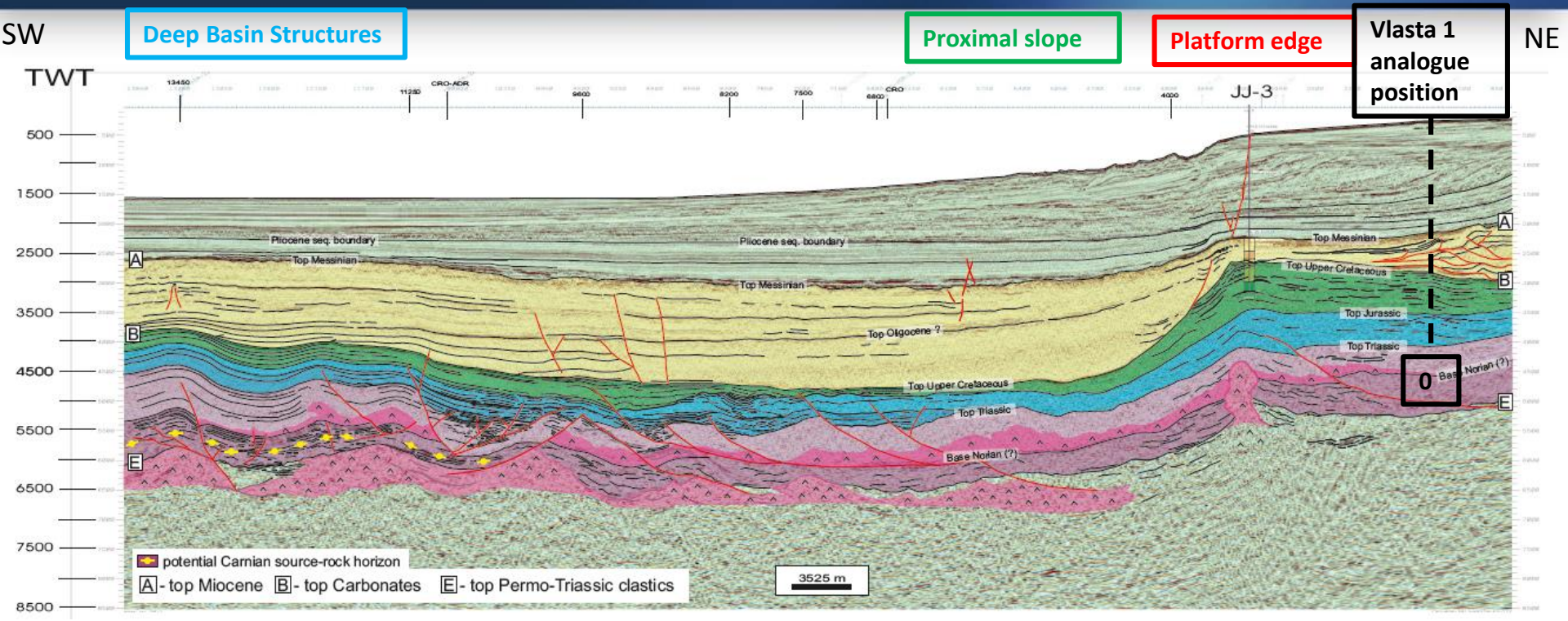


Composite Zig-Zag 2D line in Southern Adriatic of various vintages connecting Italy and Croatia. Gap between lines approx. 4,5 km

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

- 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.

Plays and analogues from Apulian side, in detail



Modified after Tomljenović 2014

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Proximal slope talus	Aquila, Rovesti	Cretaceous
Deep Basin structures	Sparviero-1bis, Grifone-1	Cretaceous

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 intraplatform 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.

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