Petroleum System of East Part of Ionian Zone in Albania

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Abstract

Based on gjeochemical studies, it has been concluded that the Ionian zone is a petroleum system, including its components and processes that make up a system. In the carbonate section, there are seven levels of source rocks, who are involved in the oil window. Phases of hydrocarbon migration occurred during the Serravalian and Pliocene-postpliocene time (Prifti & Muska, 2013). Consequently, oil and gas fields are discovered in reservoirs of limestone, while the sandstone reservoirs are superimposed on eroded limestone.

The eastern part of the Ionian zone, including Permeti syncline and Berati anticline belts, has not followed the same history of geological development. This sector has changed into a mainland after the end of flysch deposits of the upper oligocene (Pg_3^3). The source rocks in this area have not been subjected to a new stage of maturity as in the western part of the Ionian zone.

Oil seeps have actually been found in carbonate, flysch and molasses sections. Traps of oil have been discovered in molasses section, also were taken positive results during petroleum research in carbonates section.

Looking at the complex data we judge that eastern sector of the Ionian zone represents another petroleum system. The stage of maurity of source rocks and tectonical phases after upper oligocene time (Pg_3^3) have an important role.

Petroleum systems include components (according to research conducted in the field of oil systems) as source rocks, migration routes, reservoir rocks, seal formation and traps. These components must undergo processes of generation, migration, accumulation and preservation of petroleum (Magoon & Schmoker, 2000).

KEYWORDS: Petroleum system, oilfield, source rocks, anticline, migration, trap.

Geological setting

The **Albanides** represents the assemblage of the geological structures in the territory of **Albania**. The Albanides are divided into two units: the Internal Albanide (efuzivo-sedimentary series) and the external Albanides (Triassic-Pliocene sedimentary series). Oilfields and gasfields are located in the area of the Ionian zone and Adriatic depression.

Ionian zone is represented by several units called belts which are anticlines or synclines. So from the east to west, we can point out the Permeti syncline belt, Berati anticline belt, Memaliaj syncline belt, Kurveleshi anticline belt, Shushica syncline belt and Çika anticline belt. Ionian zone in the east is in contact with Kruja zone (Gavrorvo in Greece), while in the west with the Apulia platform (Website: www. Petrmanas.com).

Oilfields were discovered in Kurveleshi belt, Berati belt and molasses section of Miocene extending over the eroded limestone. Meanwhile the natural gas fields are located on the Adriatic depression. Geological and petroleum geochemical studies

have emerged in the conclusion that the Albanide meet two petroleum systems: petroleum system of the Ionian zone and Adriatic depression.
Petroleum exploration in the area of Shpiragu discovered oil at a depth of about 5000 meters (website: www. Petromanas.com), where the fluid type is not the same as in the west of the Ionian zone (in this depth it should have been condensate and wet gas).

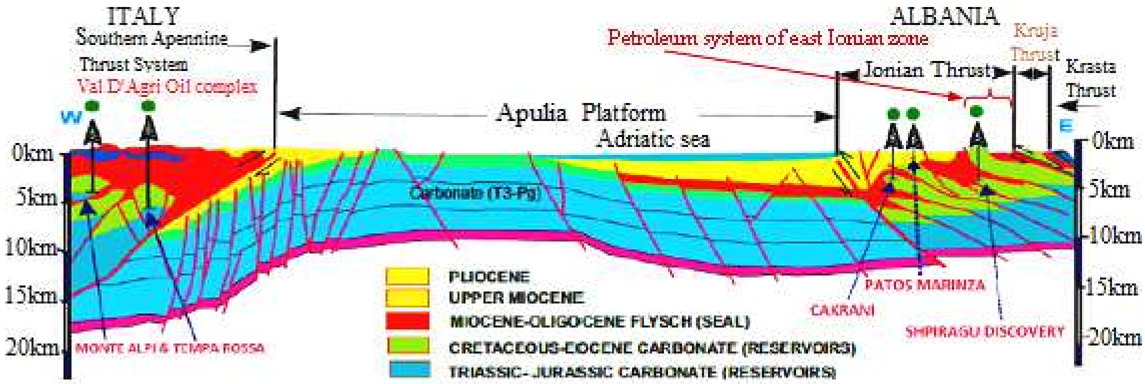

Figure1. Southern Apennine & Ionian/Kruja thrust systems (source: www. Petromanas.com; modified by Prifti)

This prompted us to repeat the interpretation of geological setting and some geochemical parameters.
The north part of Berati anticline belt is constructed by three units:

- The Diapir of Dumre,
- The Tectonic blocks of Berati anticline belt,
- The Syncline of Ballagati, whose southern extreme lies on the eroded limestone of Kucova anticline.

Diapir'sDumre is placed in the continuation of the northern anticline structures of Berati belt. Dumrea evaporate formation is of age earlier than the Upper Triassic, or the Permo-Triassic.
The explosion of Diapir has occurred on the western part of Maraku anticline (northern structure of Berati belt) where there was greater intensity, expressed as the most advanced westward diapir. The current form is performed after the Pliocene tectonic phase. This has been confirmed by seismic studies and the drilling of the well Dumre-7.
The Berati anticline belt, consisting of two tectonic blocks called "thrust sheet Berat" and "thrust sheet Sqepuri".
The change in orientation of the Berati anticline belt about West-East is a result of the impact of the Dumrea diaper (Bandilli *et al.*, 2002).
Eastern flank of the Ballagati syncline placed on the Oligocene flysch deposits and on the eroded limestone Kucova anticline.
Advancing the Dumrea diapir towards South-West (about 10-15 km) has shifted and covered the east side of syncline giving form we see today (Figure 3).
In western and southern periphery of diapir are located oil seeps, Kuçova oilfield and Rase-Pekisht oilfield.

Oil seeps and oilfields

The Berati anticline belt meets four types of oil seeps.

Bituminous sands of Messiniane deposits belong to Driza formation. They are located on the east side of the Ballagati syncline in Kuçove, in Murriz (between Kucova and Rase) and Karthnek (northern of Rase-Pekisht oilfield). Bituminous sandstone in flysch deposits of lower Oligocene in Zhapokik village occurs (south of the city of Berat). Traces of oil seep are met in the flysch deposits of the lower and middle oligocenein Osmanzeze village (field observations) and fresh oil at the place of the well Osmanzeza-4. Meanwhile the oil seep in limestone section of Cr-Pg is met in the Komar anticline (south of Zhapokika). The traces of oil seeps in Osmanzeze are recent, while the others are biodegraded.

Kuçova oilfield

It is the oldest oil field in Albania with considerable oil reserves, discovered and put into production in 1928.

Three formations participate in the geological construction of the Kucova region. Carbonate and flysch formation build the Kuçova anticline, which is the northward of the Berati anticline belt. Molasses formation overlaps transgresively over the eroded limestone of the Kuçova anticline, and represents the most extreme eastern of PeryadriaticDepression.

Four formations are separated from the down to the upper layer, in the Kuçove oil field: Driza, Gorani, Polovina and Kucova belonging Messiniane age (Figure 2). Crude oil of Kuçova oil field are aromatic- asphalt type (Gjoka *et al*.,.2002). This quality distinguishes from others Albanide crude oils. Crude oil of Rase-Pekisht oilfield have a deviation from this trend to be linked to different conditions of migration. This is evident in the triangular diagram where the crude oil of Kuçova falls outside the normal oils (This is the only oil field in Albania where oil-bearing sandstone bodies are screen-lithological). Geologicall oil reserves are approximately 78,331,800 tons.

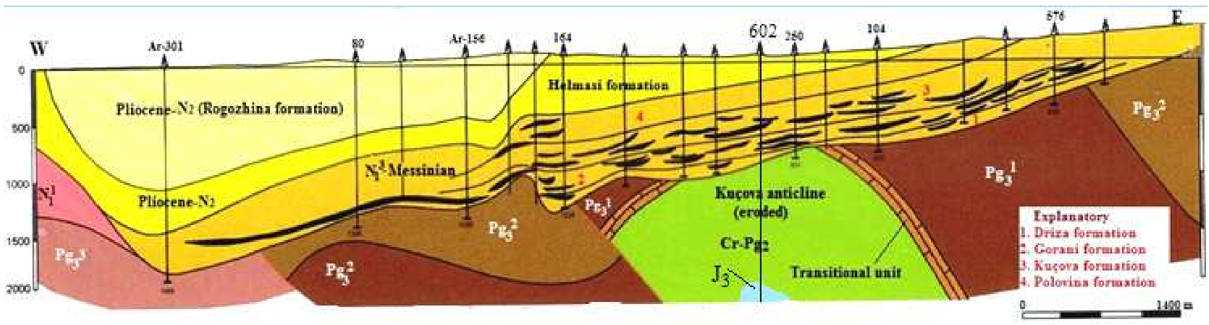

Figure 2. Section of Kuçva oilfied (source: Gjoka *et al*., 2002, modified by Prifti)

The Rase- Pekisht oilfield

The Rase- Pekisht oilfield lies in the north-west of Dumrea diapir. Its reservoir rocks are the sandstones of Messiniane. The proximity of the oil trap to transgresion base of Messiniane linked to westward pressure of Dumre's diapir. This pressure has returned to the vertical position of oil trap .

Crude oils of Rase-Pekisht oilfield are lighter compared with those of Kuçova. Scientific debate on the origin of oils in the Rase-Pekisht oilfield is in these directions:

- The oil has migrated from the eroded Kuçova anticline thought a nearly horizontal, secondary migration of sandstone reservoirs. Distances has to happen natural chromatographic effects and in Rase-Pekisht oilfield lighter oils occur.
- Pekishtit oil naphthenic are more than those of Kuçova. This indicates either natural chromatography (distance away from the source) or have different supply sources.

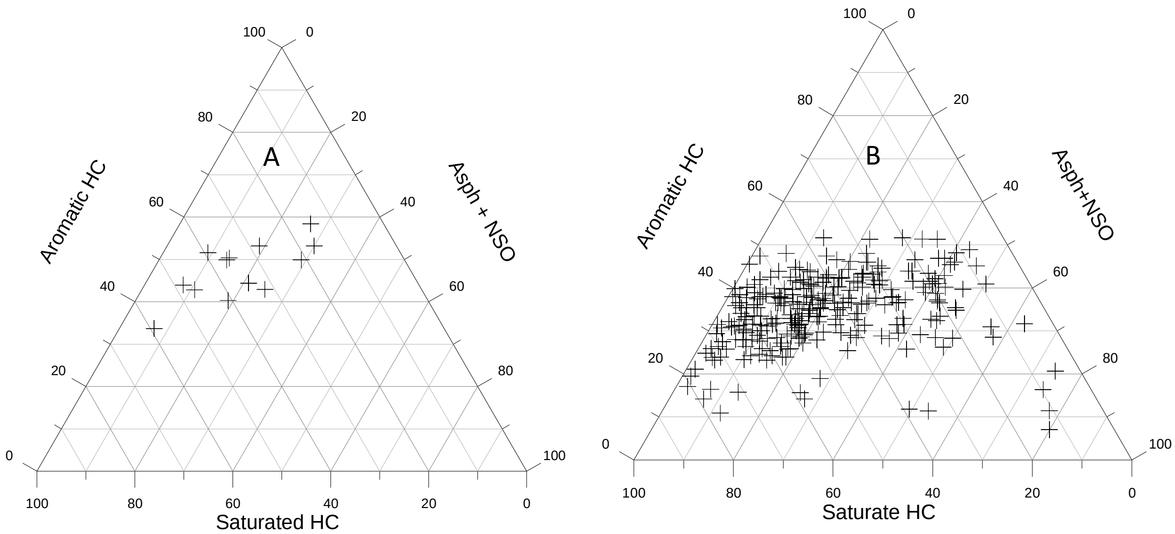

Figure 3.Triangular composition diagram of Berati anticline belt (A) and Albanian oils (B) (source: Prifti *et al*. 1999)

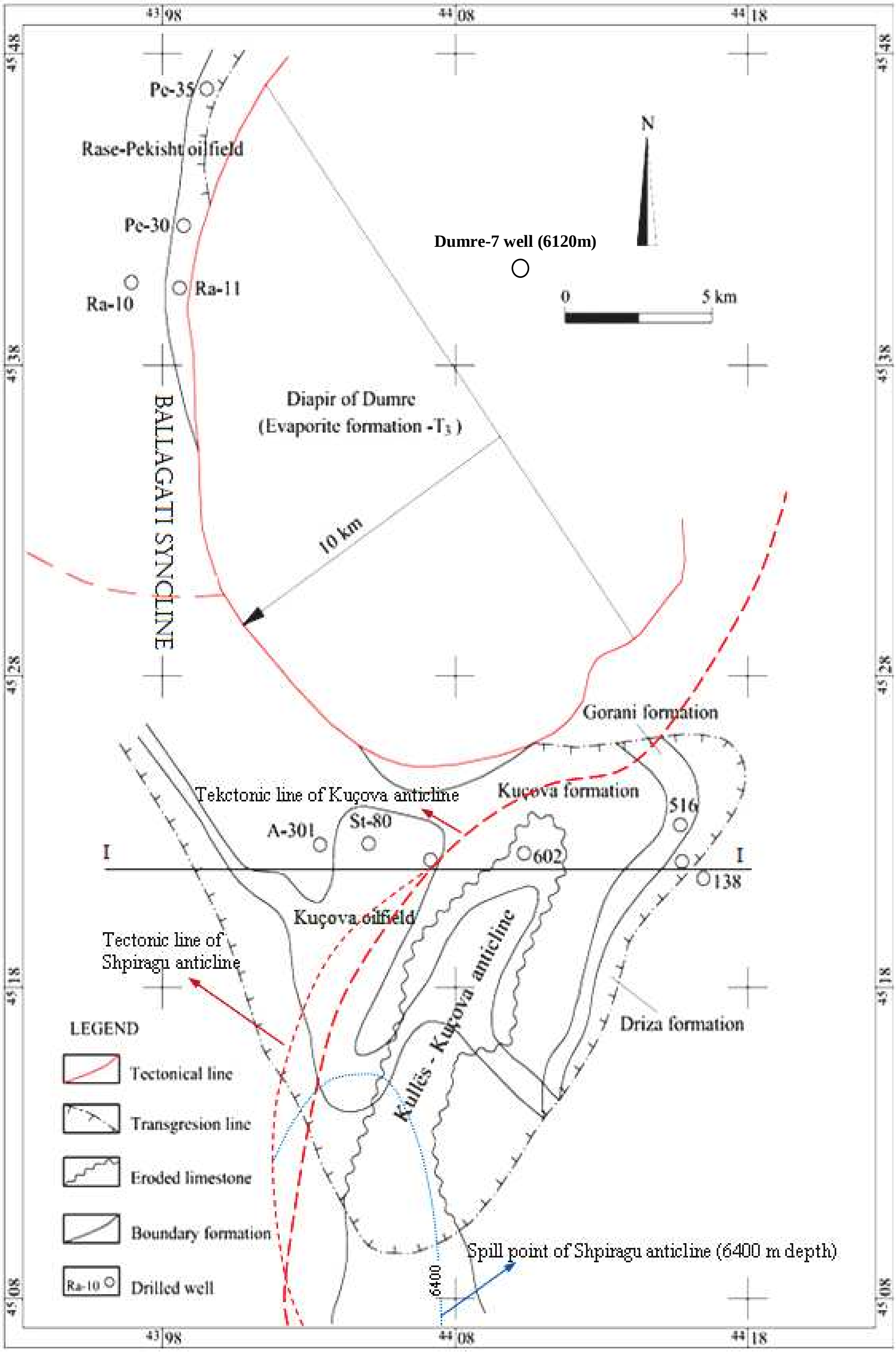

Figure 4. Relations of the oil fields (Kuçova and Rase-Pekisht) with the diapir'sDumrea (source: Gjoka *et al*. 2002; modified by Prifti)

Based on the composition and distillation Engler of crude oils (Prifti & Bitri 1999), Rase-Pekisht oilfield differ from those of Kuçova oilfield. Geological oil reserves are 1,970,400 tons .

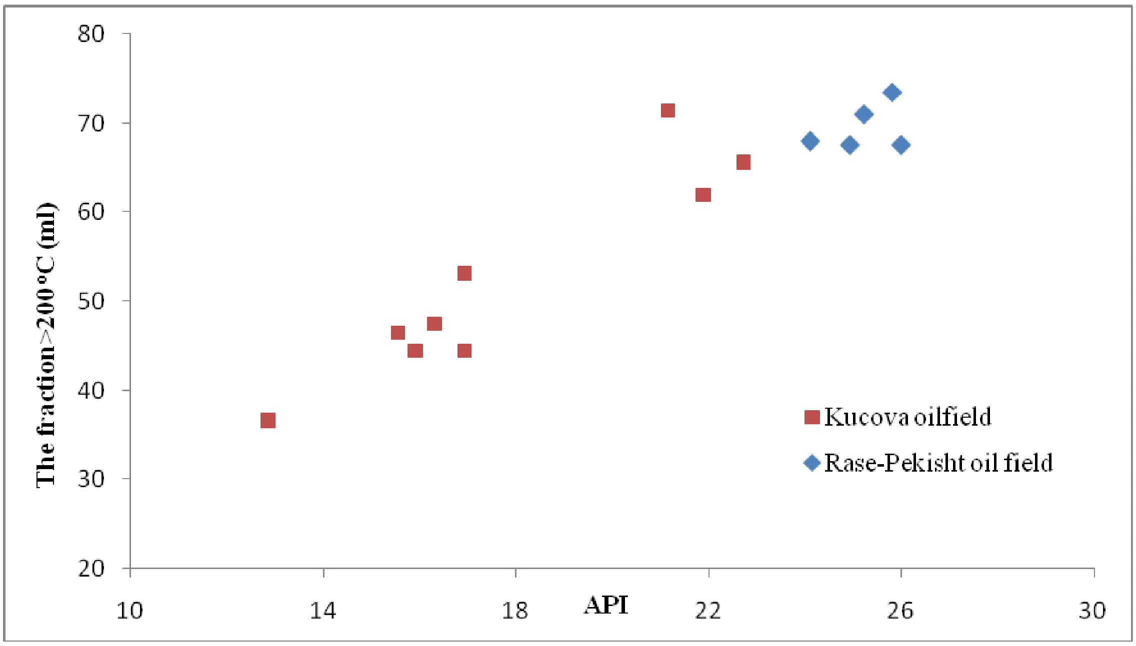

Figure5. Relations of Engler distillation vs API of crude oils in the region of Kucova (source: Prifti & Bitri 1999).

Shpiragu oil trap

de oils

Based on information of "Petromanas" company oil trap is found in the Shpiragu structure about 5000 m depth. After 17 month drilling period Shell and Petromanas Energy Inc (PMI) announced that their first drilled well Shpiragu 2 resulted with flow rates of 1,500 to 2,200 barrels per day of oil equivalent (800 to 1,300 barrels per day of 35 to 37 degree API oil and 2 to 5 mmcfd of gas) observed during the test period. PMI and Shell also believe they have identified an 800 meter oil column in fractured carbonate reservoirs at the Shpiragu structure, but were only able to test 400 metres due to drilling setbacks (www. Petromanas.com).

oils

Source rocks

Source rocks are met in the carbonate section of Ionian zone. There are no changes of source rocks within the sectors of the Ionian zone. Changes are evident in the burial history during and after the sedimentation of flysch formation. In the Kuçova anticline are met source rocks from middle Jurassic to lower Cretaceous.

Table 1. Rock-eval data of limestone section of Kuçova anticline (Kuçova-602 well).

Depth(m)	Age	So	S_1	S_2	Tmax	TOC	HI	PI $(S_1/(S_1+S_2)$
499-507	Pg2	0	0,45	1,23	417	0,33	372	0,267857
857-859	Pg1	0	0,49	8,94	425	1,22	732	0,051962
1295-1299	Cr2	0	0,21	1,9	424	0,27	703	0,099526
1396-1402	Cr2	0	0,34	4,93	430	0,67	635	0,064516

1461-1466	Cr2	0	0,29	4,84	429	1,06	456	0,05653
1504-1510	Cr2	0	0,1	0,936	423	0,17	547	0,096525
1600-1602	Cr1	0	0,21	3,4	432	0,47	723	0,058172
1652-1652	Cr1	0	0,1	2,34	430	0,37	632	0,040984
1702-1704	Cr1	0	0,28	2,33	433	0,36	647	0,10728
1749-1752	Cr1	0	0,14	2,97	433	0,99	300	0,045016
2772-2774	J2-3	0	0,12	1,7	433	0,24	708	0,065934

While in Shpiragu anticline are met all levels of the source rocks by wells (oral information). In previous studies were conducted geochemical characterization of them. We put forth a summary of the characteristics of source rocks.
Below is rapresent a summary of the conclusion for the indicator of organic matter in Kucova anticline. There have been taken in consideration three elements: quantity, quality and maturity:
Source rocks of the upper Triassic and lower Liassic are richer in organic matter. Source rocks of the upper Liassic (Toarchian) presented type II-III organic matter. In its composition has a significant contribution of organic matter of continental origin.
Well quality levels with type I-II organic matter are those of upper Triassic levels, lower Liassic and the lower Cretaceous.
Maturity of source rocks is assessed with pyrolytic indicators. High values of productivity index (PI = S1 / (S1 + S2) indicates that hydrocarbon migration occurred from older or deeper source rocks (Shiri *et al*. 2013). So petroleum is generated in deeper sectors, this is an important way of finding petroleum gjeochemistry in petroleum exploration.
Reflection of vitrinites is assessed in two ways:

1. According to the definitions of the vitrinite's reflectance (assessed from PRIFTI I. on concentrated organic matter). Time Temperature Index (TTI) is not calculated according to standard manner, but by the vitrinite's reflectance in conformity with the equation. (Prifti, 1995):

$$\mathbf{Ro=2.20647*(logTTI)^2-0.10528*log\ TTI+0.5011}$$

While paleotemperatue is calculated on the basis of reaction with the vitrinite's reflectance.
Their results are displayed in Table 2.

2. Calculation of Vitrinite's reflectance (R_0) from biomarkers (Denis & Miller, 1993) maturity parameter of oils (ethylcholestane aßß20S/aaa20R ratio) in conformity with relation:

$$\mathbf{R_0 =[(aßß20S/aaa20R)*0.5 + 0.35]}.$$

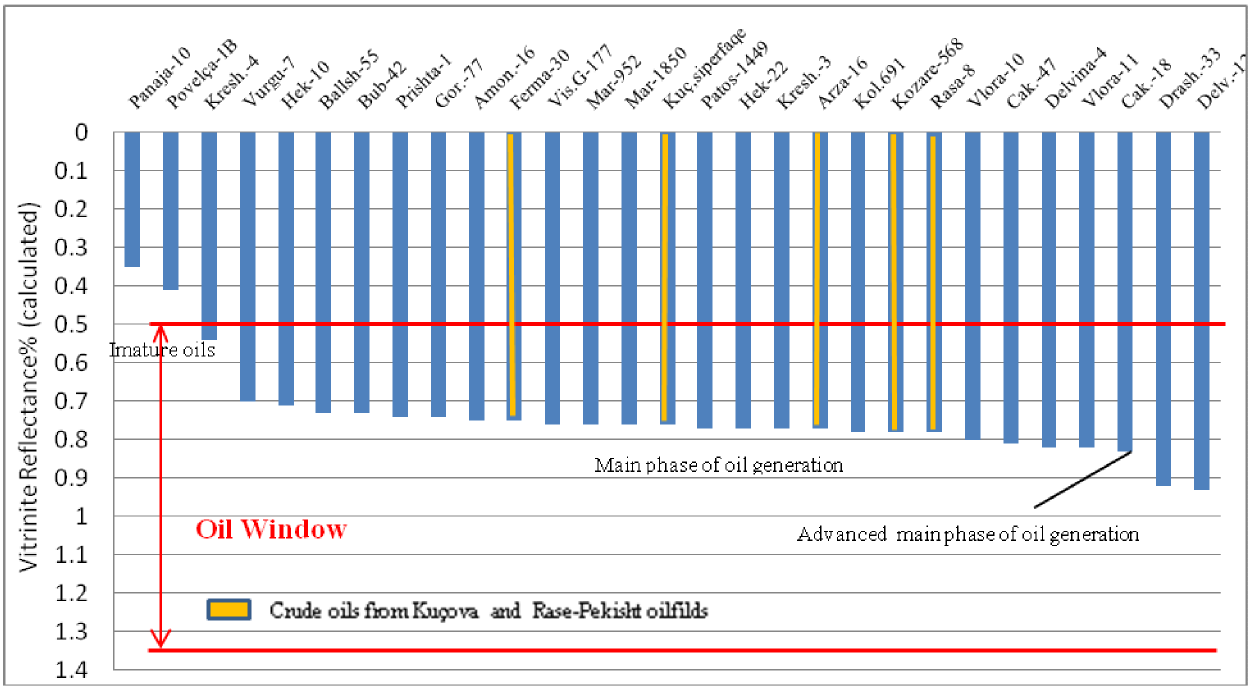

Figure 6. Maturation of Albanian oils based on calculated vitrinite 's reflectance (source: Denis & Miller, 1993; modified by Prifti)

Based on this indicator the organic matter has entered the oil window and is near theoil peak generation. Source rocks have not been condensatedat wett gas generation zone. Perhaps this is the main reason that crude oils of Kucova oilfield has lower gaseous factor (average 15 Nm^3/m^3) than of the Marinze oilfield. I think that such a phenomenon occurs in Shpiragu oil trap.

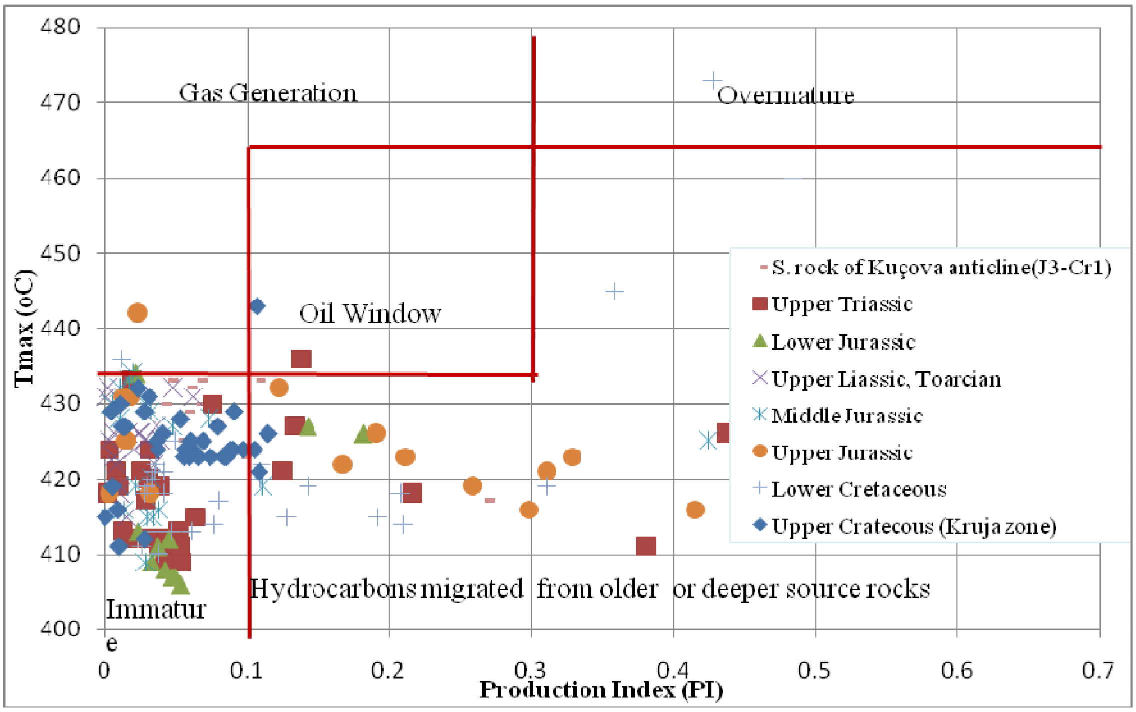

Figure 7. Maturation of source rocks based on rock-eval data (soure: Prifti , based on Shiri *et al*..2013)

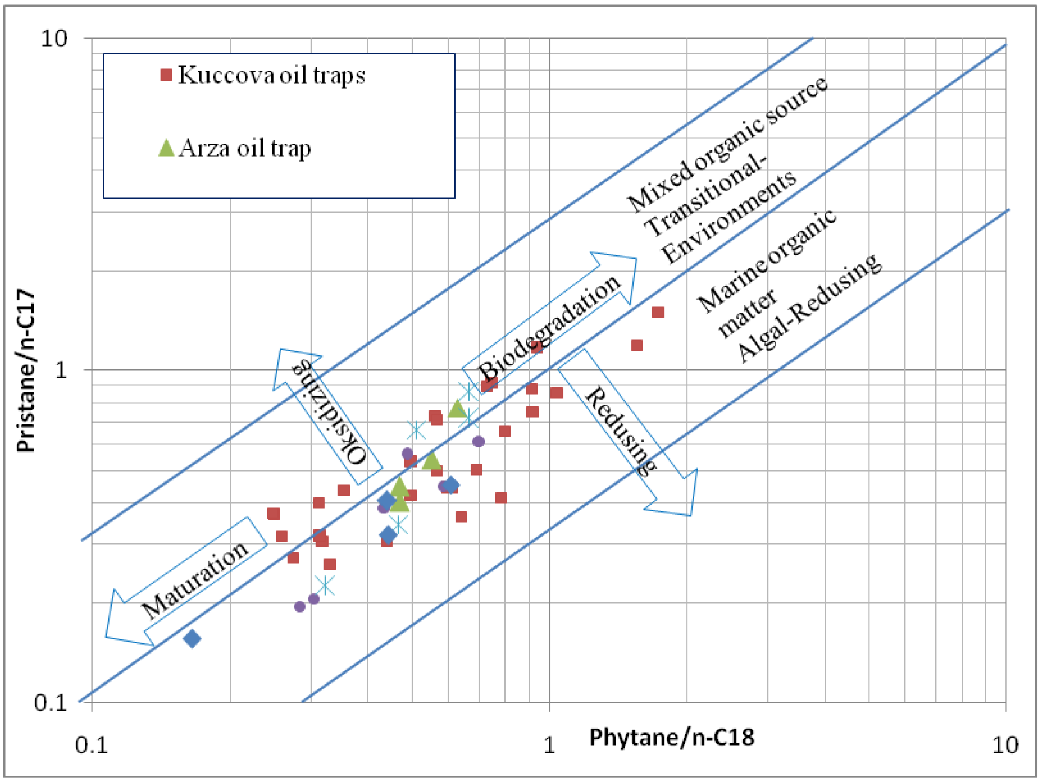

Figure 8. Environmental sedimentation of source rocks based on hydrocarbon isoprenoids (Source: Prifti & Muska ,2013; Aldahik, 2010)

Based on the biomarker maturity indicators of the crude oils, it is reached the conclusion that the oil of Kuçove and Rase–Pekisht oilfields are generated from mature source rocks in main phase of oil generation. Crude oils of
Berati region are generated from source rock formed in redusing and transitional marine environments (according isoprenoid hydrocarbons).

Table 2 Vitrinites reflectance of Kuçova-601well (limestone section) from concentrated organic matter.

Depth (absolute, m)	Ro(%).Reflectance of vitrinite	Ro% (calculated)	Paleotemperature ^{o}C (calculated by Ro)	TTI (calculated by Ro)
1915	0,538	0,519	66.2	4.4
1925	0,505	0,521	66.3	4.54
2110	0,539	0,543	68.7	5.92
2150	0,55	0,548	88.8	6.24
2315	0,556	0,559	71.5	7.63
2372	0,59	0,567	72.2	8.18

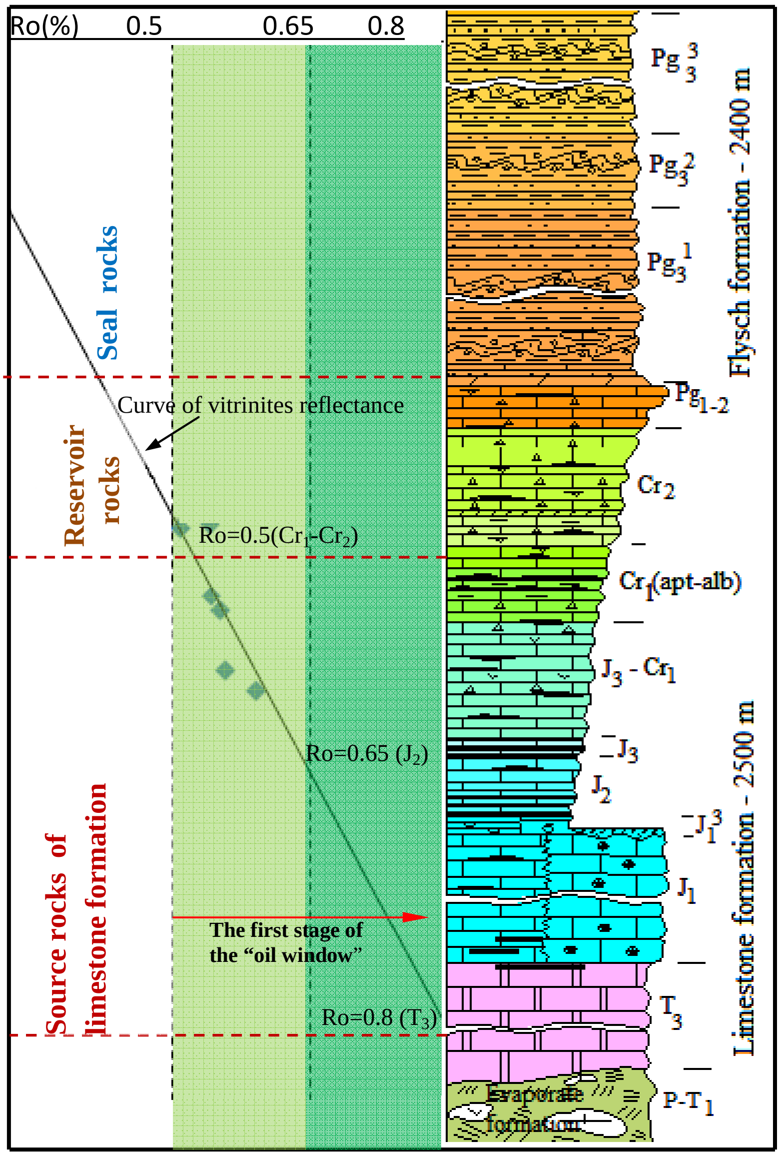

Figure 9. Model of oil generation based on vitrinite reflectance of Kuçova anticline (source: prepared by Prifti)

By the modeling performed in previous studies it is concluded that starting from the source rocks of the lower Cretaceous and older, have entered the "oil window".

Upper Triassic-lover Liassic (T_3-J_1^1) levels are in advanced stage of hydrocarbon generation but not at the level of condensate generation.

After the upper oligocene (Pg_3^3) had not other stage of maturity of source rocks since the region is back on the mainland (as has happened in the western part of the Ioian zone). Other stage of maturity may occur as a result of the diapirism phenomenon of evaporate formation (Downs, 2009). The diapirism phenomenon (evaporate formation has high thermal conductivity) increases the geothermal gradient until the diapir body is downthe carbonate formation. This phenomenon has started since the Toarcian time.

In these sectors can be generated even condensate (condensates of Blini wells in carbonate section, east of the Kucova anticline). Exposure of diapir body in surface

affects the temperature of the region by making it colder. This seems to reduce the geothermal gradient wells drilled near diapir of Dumre.
The paleotemperature gradient (according reflektances of vitrinites) varies in the range 15-17 ^{o}C/1000m, while studies in Greek territory confirm a 23^{o}/1000m gradient (Rigakis *et al.*, 2013). This is a result of the contact between the tectonics plate in Greece (African and Eurasian plates).

Primary migration
Primary migration (from source rocks to rezervoir rocks) is widely treated in many studies . The phenomenon of primary migration of hydrocarbons is accomplished by meeting the following conditions :

- Quality of source rocks,
- The maturity of source rocks,
- Creating conditions of reservoir rocks,
- Geostatic pressure reduction of source rocks

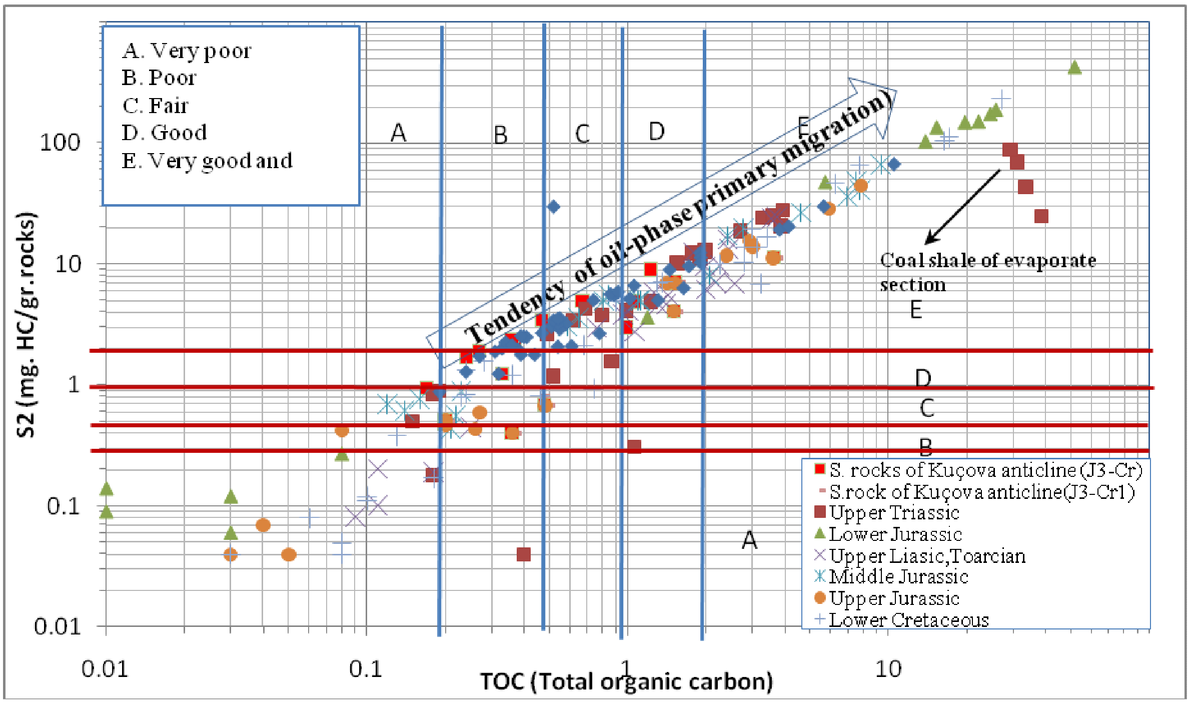

Figure 10. Quality of source rocks based on rock-eval data (source: prepared by Prifti)

The quality and bending nature of source rocks favor primary migration in even in the state of oil phase (England *et a*l.,1987). Also, source rocks are in the main stage of hydrocarbon generation and are ready to migrate. Reservoir rocks are the top of the carbonate section. Traditionally in conducted studies, it is concluded that after Seravalian time, the features of reservoir rocks are created. Potential reservoir rocks must be created after upper oligocene.
Return to the mainland after upper oligocene, the region has caused a significant decrease in geostatic pressure ofsource rock. This process causes a mass migration of hydrocarbons from source rocks to the reservoir. The largest contribution are give by the matured source rocks, so they of Triassic - Jurassic. This is called early generation of hydrocarbons in Ionian zone.

Foto 1. Upper part of Triassic-Lower Jurassic source rocks of Ionian zone (source: Prifti)

Secondary migration `

Secondary migration of hydrocarbons is treated extensively in the literature. Here we will presents some aspects related to the region.

Secondary migration occurs directly after the primary migration, as the reservoir rocks are formed. Hydrocarbon migration conditions are related to the factors:

- The different stages of hydrocarbon generation.
- Migration routes, directions and distance migration.
- Oil-phase migration.
- Time of trap formation.

Generation of hydrocarbons is occurred in different tectonic phases related to the burial history of the source rocks and diapirism phenomenon of evaporate formation during the Miocene.

Hydrocarbon migration occurs after tectonic phases. Kucova's region is affected by this phenomenon and is accompanied by the migration of hydrocarbons in the Miocene section from carbonate section (through eroded surface of the carbonate section of Kuçova anticline), oil traps are formed in Kuçova oilfield, Rase-Pekisht oilfield and bituminus sandstones where oil has migrated on porous and permeable sands and sandstones. Eastern territories of Kucova's oilfield are also affected by the new phase of oil migration, but always before changing the tectonic plan of Berati anticline belt (Gjoka *et al*., 2002). While western territories of Kuçova oilfield and Rasen-Pekisht oilfield are not affected by the new phases of migration, after being broken off contact with the eroded limestone of Kuçova anticline.

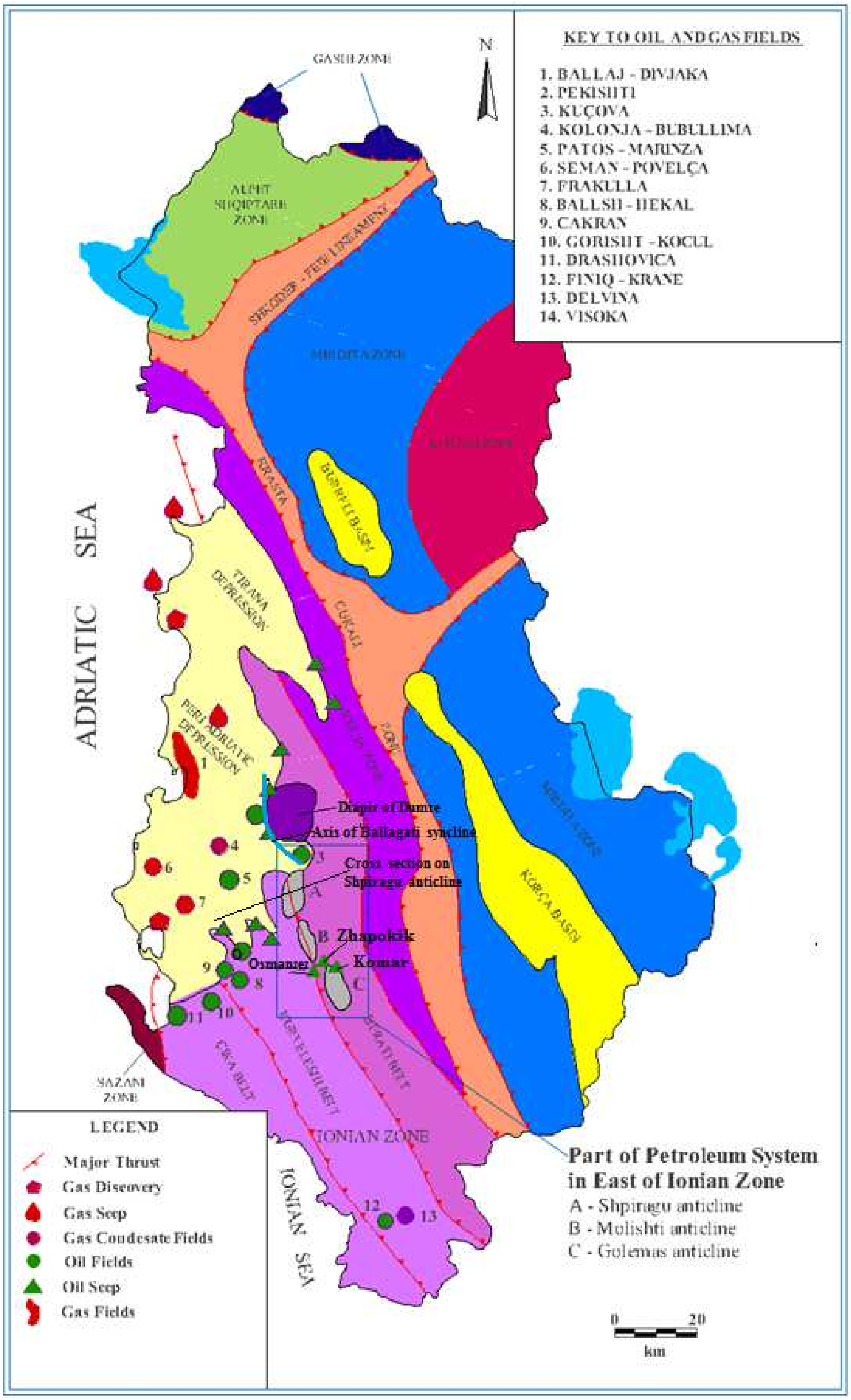

Figure 11. Scheme of Albanian hydrocarbon fields and part of petroleum system in east of Ionian zone (source: modified by PRIFTI I., and www.petromanas.com)

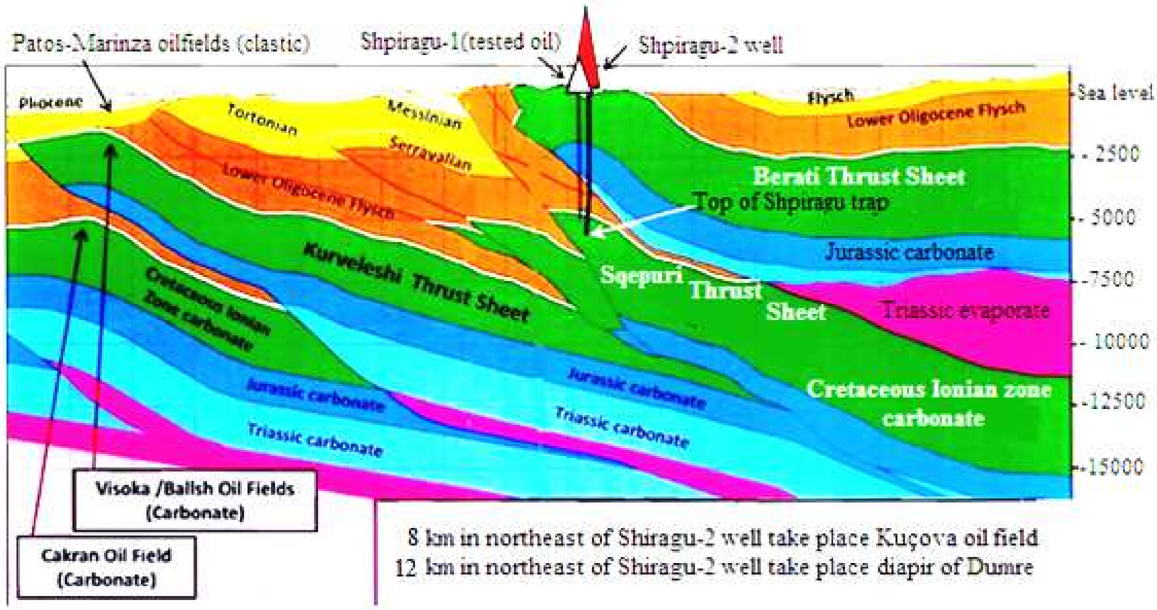

Figure 12. Cross section on Shpiragu antincline (source: www.petromanas.com)

The tectonic faults are the main migration routes of hydrocarbons (bituminous sands are formed in Zhapokike, belonging to the lower oligocene). Porous and permeable carbonate rocks, fractures and faults, are potential reservoir rocks, especially in bioclastic packages of carbonate section. These levels are the best reservoirs.

Vertical migration routes are more preferred because the difference of geostatic pressure is higher. Migration distances depend on the size of the east part of Ionian basin in which the oil accumulates.

Secondary migration of hydrocarbons is carried out according to the Gussow's principles where lighter oil (35 to37 API) replace heavier oil toward on shallow traps. So lighter oil of Shpiragu trap replacing heavier ones to Molisht trap.

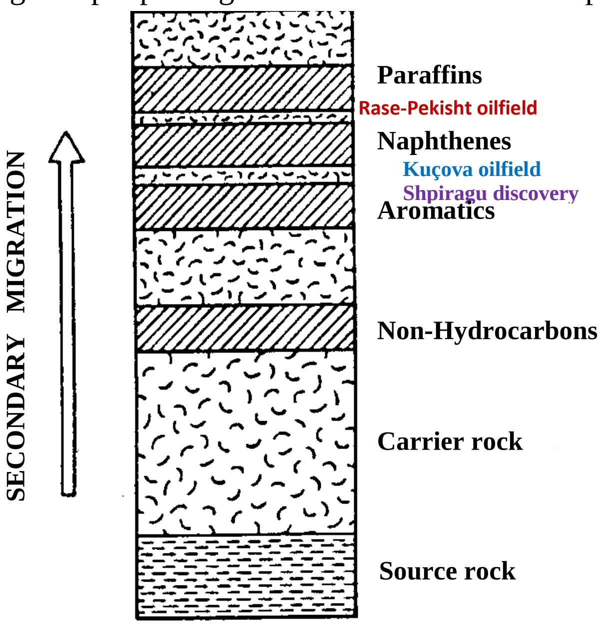

Figure 13. Separation of petroleum components during secondary migration as a result of chromatographic effects (source: Rondeel, 2001; modified by Prifti)

Liquid hydrocarbons during migration are closely linked to the level of maturity of source rocks. Migration of oil with dissolved gas is a characteristic of the formation of oil traps. Related to the quantity of dissolved gas; oil migrated in liquid phase with low amounts of dissolved gas, this fact has conditioned the formation of Kuçova, Rase-Pekisht oil fields.
Crude oils of Berat anticline belt are more aromatic than other oils, the only exceptions are crude oils of Rase- Pekisht oilfield.
Aromatic nature of crude oils is conditioned by two factors:

- On the origin of the organic matter of soure rocks. Organic matter of terrestrial origin increases content of aromatic hydrocarbons in crude oils.
- Short Distance of source rocks to reservoir (Rondeel, 2001).

These are the main reasons affecting the hydrocabon composition of crude oils. While crude oil of Rase-Pekisht oilfield is mainly methano-naphthenic after migration path in sandstone reservoirs is long and is committed natural chromatography.
Time of formation of traps in the eastern part of Ionian zone is the earliest, this is shown above in the figure 13.
Anticline forms of carbonate section available in the field should be similar to those in depth. Postmiocene tectonic phases have changed tectonic plan, setting up structures towards the south. This causes a reduction of spill point and reform of oil traps stimulating tertiary oil migracion.

Tertiary migration
Oil seepsmeet in Miocene sandtones (Kuçove, Pekisht), in the sandstones of the lower Oligocene (Zhapokike) and others in carbonate section. While oil seep in Osmanzeze vilage (fresh oil) are the result of the third phase of oil migration. The oil has migrated from the oil traps through tectonic faults and is exposed at the surface and in Osmanzeza-4 well.

Conclusions
Ionian zone is a sedimentary basin, which lies in the west of Albania and Greece. In the east part it contacts with the tectonic Kruja zone (Gavrovo zone in Geece), in the west with the Apulia platform. The anticline belt of Berati represents the extreme eastern Ionian zone.
Formations that build the region are: evaporate formation (P-T), carbonate formation (T_3-Pg_2) and flysch formation (Pg_3).
The Ballagati Syncline represents the eastern unit of PeriAdriatic Depression, where his southern centricline lies on the eroded limestone of the Kuçova anticline.
Source rocks of carbonate formation (T_3-Cr_1) are met by wells drilled in the region. They have entered the oil window and have the ability to generate liquid hydrocarbon from the Upper Oligocene time. New stage maturity of source rocks has been activated during the diapirism phenomena.
Primary migration started after Upper Oligocene. Quality and stratification of source rocks favor primary migration of the oil phase.
Oil traps in Miocene section on the syncline of Ballagat were formed during and after the Miocene epoch.
Oil traps in carbonate section are formed before the Miocene time. Changes in the tectonic plane during and after the Plioene time, have reformatted oil traps in carbonate reservoirs.
The aromatic nature of crude oils should be linked to organic matter of the source rocks and to the short distance of migration from source rocks to the reservoirs.The

lown gaseous factor in Kuçova oilfield is related to the maturity of the source rocks, who have generated light oil but not condensate and hydrocarbon wet gas. Source rocks extending under the Ballagati syncline have generated hydrocarbon wet gas, but belongs to another petroleum system.

The eastern part of the Ionian zone represents another petroleum system.

Finally we recommend investigating and evaluating, to determine the geochemical indexes of source rocks in order to prepare the hydrocarbon generation model. These levels are met by the wells drilled on the Shpiragu anticline. This is necessary because we have little geochemical data for the Shpiragu region.

Acknowledges

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