GEOCHEMICAL FEATURES OF UPPER TRIASSIC- LOWER JURASSIC SOURCE ROCKS IN THE DUKAT REGION (WESTERN SIDE OF THE IONIAN ZONE IN ALBANIA)

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Abstract. Studies have identified multiple levels of oil source rock, spanning a wide range of geological ages, from the dolomitic-carbonate section of the Upper Triassic to the carbonate section of the Cretaceous. Notably, source rocks found in the western part of the Ionian zone specifically in the Dukat region, belong to the Upper Triassic-Liassic geological section of the Çika anticline. During the study with the fluorescent microscopy method, they fluoresce in a reddish color. This feature has not been observed in other source rocks in the Ionian zone. Their geochemical study revealed a high content of organic carbon, mainly the first type of organic matter. The organic matter of the source rocks is destructured and appears in the form of "coals". Bituminite is the most abundant maceral in the shales. Some researchers have interpreted bituminite as vitrinite. The maturity of the organic matter has been assessed mainly by the reflectance of vitrinite and the source rocks have entered in the "oil window". The content of free hydrocarbons is associated with high organic carbon values. The generated oil has migrated from the source rock levels. This migration is also evident from the oil traces found in the northern part of the Dukat region, which are remarkably light. Based on isoprenoid hydrocarbon indicators, the source rocks were sedimented in a reducing marine environment with high salinity.

Keywords: dolomite, bituminite, hydrocarbons, isoprenoid, reducing, micrinite.

Rezumat. Caracteristici geochimice ale roclor sursă Triasic superior-Jurasic tnferior din Regiunea Dukat (partea de vest a Zonei Ionice din Albania). Studiile au identificat mai multe niveluri de rocã sursã de petrol, care acoperã o gamã largã de epoci geologice, de la secțiunea dolomitic-carbonatã a Triasicului superior până la secțiunea carbonatată a Cretacicului. În special, rocile sursã gãsite în partea de vest a zonei ionice, în special în regiunea Dukat, aparțin secțiunii geologice Triasic-Liasic superior a anticlinalului Çika. În timpul studiului cu metoda microscopiei fluorescente, acestea au o culoare roșiaticã. Această caracteristicã nu a fost observatã în alte roci sursã din zona ionicã. Studiul lor geochimic a relevat un conținut ridicat de carbon organic, în principal primul tip de materie organicã. Materia organicã a rocilor sursã este destructuratã și apare sub formã de cãrbuni. Bituminitul este cel mai abundent maceral din șisturi. Unii cercetãtori au interpretat bituminitul ca vitrinit. Maturitatea materiei organice a fost evaluatã în principal prin reflectanța vitrinitei, iar rocile sursã au pãtruns în fereastra de ulei. Conținutul de hidrocarburi libere este asociat cu valori ridicate ale carbonului organic. Uleiul generat a migrat de la nivelurile rocii sursã. Această migrație este evidentã și din urmele de petrol gãsite în partea de nord a regiunii Dukat, care sunt remarcabil de ușoare. Pe baza indicatorilor de hidrocarburi izoprenoide, rocile sursã au fost sedimentate într-un mediu marin reducãtor cu salinitate ridicatã.

Cuvinte cheie: dolomit, bituminit, hidrocarburi, izoprenoid, reducãtor, micrinite.

INTRODUCTION

In the Dukat region, three levels of source rocks are encountered in the carbonate-dolomite section with Upper Triassic and Lower-Upper Liassic ages. The organic carbon content reaches up to 51.7% and represents the richest levels in the Ionian zone (source rocks in other sectors, TOC reaches up to 36%). S1+S2 is high (exceeding 100), indicating that the organic matter is of very good to excellent quality, corresponding to the first or second type according to the hydrogen index.

Organic matter (or kerogen) of the first or excellent type is found in those of the Lower Liassic. East of the village of Palasa, there was a mine that operated for the exploitation of source rocks referred to as "coal" (now the mine is abandoned).

The organic matter is destructured and the bituminite content is high. The source rocks in the Dukat region fluoresce red during the petrographic study (in the polished surface of samples). The source rock levels have entered the "oil window". In the levels of the first type of source rocks, oil expulsion has occurred. The heavy hydrocarbon fractions have remained in the source rocks. Light oil has been encountered in the Vlora-11 well on the tectonic line of Çika (northern side), which indicates the possible presence of oil deposits.

Geological setting: The Dukat region is located in the western part of the Ionian zone, in contact with the Apulian zone (PRIFTI & UTA. 2012). This contact has caused a harsh relief in the Dukat region. This region belongs to the Çika anticline. The samples for the study were taken within the Upper Triassic-Lower Jurassic age carbonate section (Fig.1).

We treat the lithological description in detail for the geological section T_3-J_1^1.

The Upper Triassic deposits are distributed only in the western part of the Dukat region. They form the cores of the anticlinal of the Çika Mountain. Lithologically they are represented by massive crystalline diagenetic dolomites, in the lower part interbedded with breccia dolomites and dolomitic limestones. In the upper part, layered dolomites and dolomitic limestones predominate (HASANI 2008), which in some sectors are accompanied by thin interbedded 5-6-10-15 cm. bituminous shales (source rocks).

The incomplete thickness of these deposits, which is about 600 meters, appears on the surface.

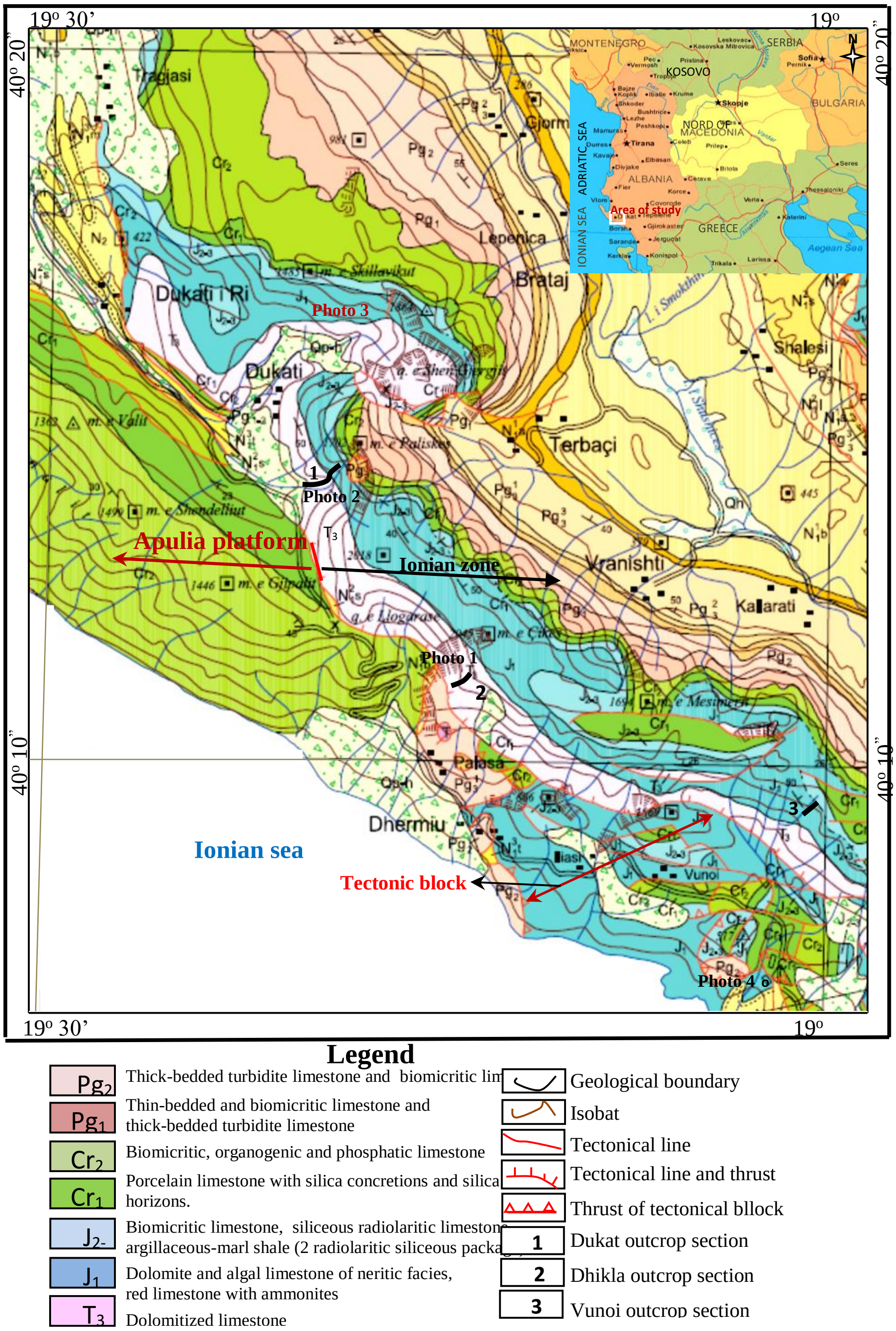

Figure 1. Geological map of Dukati region (VRANAJ. et al., 2002; HASANI, 2008; modified by Prifti).

The Lower Jurassic carbonate deposits are represented by the lithofacies of dolomites and algal limestones. These deposits are mainly represented by dolomites and algal dolomitic limestones of neritic facies without clear stratification.

The thickness of the Lower Jurassic section varies in the range of 850-1000 meters.

The deposits of **the upper part of the Upper Lias** (J_1^3 - Toarian) are represented by two lithological lithofacies: The lithofacies of the "**red limestones with ammonites**" (Amonitiko rosso), where reddish-brown shale limestones predominate. An abundant ammonite assemblage has been encountered in these deposits.

The lithofacies of the **"Posidonia shales"** are represented by carbonate clays, clayey limestones, clayey marls with Posidonia bronni and Belemnites and conglomeratic limestones. This lithofacies is variable in different sectors. The thickness of these lithofacies varies up to 60-70 meters ((HASANI, 2008).

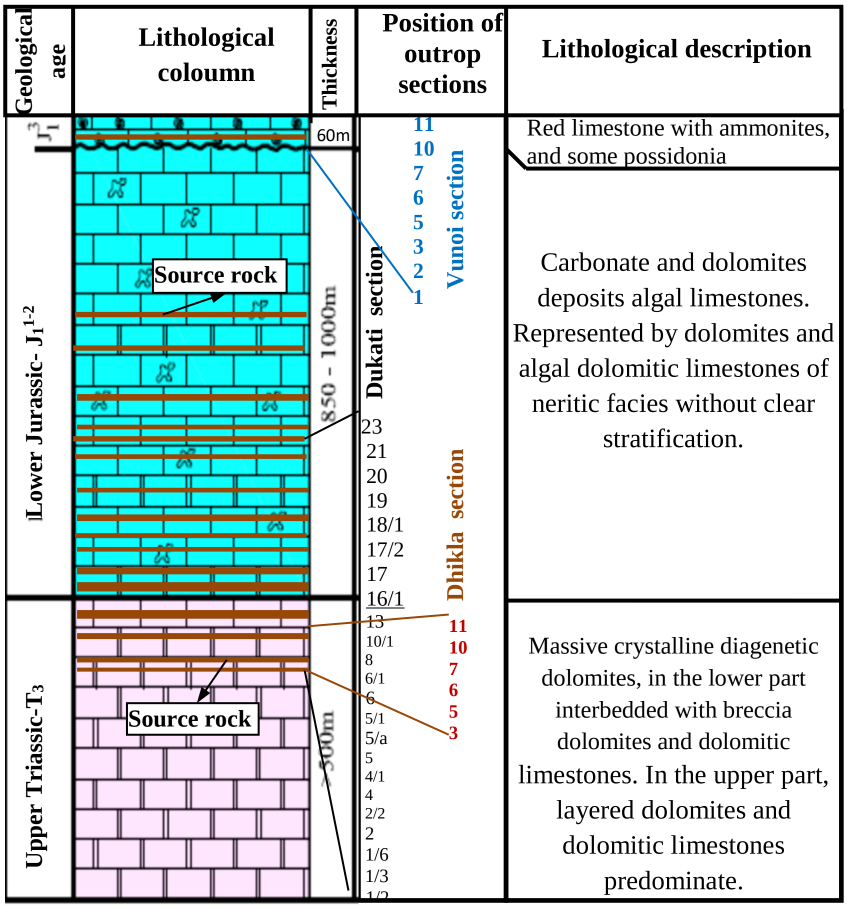

Figure 2. Lithological coloumn in Dukati region (HASANI .2008, modified by Prifti).

MATERIAL AND METHODS

The Dukat source rocks are the last to be studied in the Ionian area. During studies using the organic petrography method, a rare phenomenon was observed: the source rocks fluoresce in red (microscopic study in fluorescent light on polished surfaces). This was the initiative for conducting the study of the source rocks.

The outcrop samples were taken in the field in three different sectors, Dukat, Dhikla and Vunoi (Fig.1). In the Dukat geological section, 37 samples were taken (15 samples in the Upper Triassic section, 8 samples in the Lower Liassic section). In the Dhikla section, 6 samples were taken in the Upper Triassic section. In the Vunoi section, 8 samples (Fig.2) were taken in the Toarcian (J_1^3).

The first analysis used was the "Rock-eval Analysis" using the "Oil Show Analyser". Through this method, the following indicators were determined: the amount of organic carbon (TOC %), the amount of free oil in the rocks (S_1=mgHC/gr.rocks), the amount of oil that will be generated from the source rocks after catagenesis (S_2=mgHC/gr.rocks), the hydrogen index (Hydrogen Index=S_2/TOC*100). The Productivity Index PI=$S_1/(S_1+S_2)$ was also calculated.

The organic petrography method was successfully applied to 31 samples (by Irakli Prifti), utilising two study modes: (1) reflected light analysis and (2) fluorescent reflected light analysis on polished sample surfaces. Two types of polished surfaces were used: directly on the rock and on concentrated organic matter. The organic petrography method was used for maceral analysis and the evaluation of vitrinite reflectance (Ro).

13 samples were subjected to extraction with organic solvents (8 samples from the Upper Triassic section, 4 samples from the Lower Liassic section and one sample from the Toarcian section). The hydrocarbon composition of the extract was determined by the liquid phase chromatography method where: saturated hydrocarbons, aromatic hydrocarbons, NSO components and asphaltenes were determined.

In Saturated hydrocarbons, the gas chromatography method was applied and isoprenoid hydrocarbons and their ratios were determined.

RESULTS AND DISCUSSION

As described above, after taking samples in the field, four study methods were applied: rock-eval (Table 1), organic petrography (Table 2), liquid chromatography (hydrocarbon composition of extracts, Table 3) and gas chromatography of saturated hydrocarbons (determination of isoprenoid hydrocarbons). The results are given in the following tables.

Table 1. Results of rock-eval data.

Nr.	Region Section	Sample Outcrops	Geological age	Rock-eval data					
				S_1 (mgr free HC/gr.rock)	S_2 (mgr.HC/gr.rock)	Tmax (ºC)	TOC (%)	HI	PI
1	Dukat	1/2	T_3	0.48	11.66	419	1.88	620	0.04
2		1/3	T_3	15.37	24.9	411	38.52	646	0.38
3		1/6	T_3	0.14	4.32	420	0.69	626	0.031
4		2	T_3	0.17	3.44	411	0.62	554	0.047
5		2/2	T_3	1.66	24.38	415	3.3	738	0.064
6		4	T_3	0.03	0.9	424	0.19	473	0.032
7		4/1	T_3	0.78	25.5	417	3.61	706	0.03
8		5	T_3	1.6	28.01	409	3.92	714	0.054
9		5/a	T_3	1.04	18.78	413	2.7	695	0.052
10		5/1	T_3	0.54	13.02	412	1.98	657	0.04
11		6	T_3	0.15	2.68	411	0.49	546	0.053
12		6/1	T_3	0.4	12.37	412	1.76	702	0.031
13		8	T_3	0.41	10.21	411	1.55	658	0.039
14		10/1	T_3	0.32	12.61	421	1.97	640	0.025
15		13	T_3	2.85	74.35	416	9.07	819	0.037
16		16/1	J_1^1	9.75	174.75	406	24.61	710	0.053
17		17	J_1^1	16.8	428	411	51.77	826	0.038
18		17/2	J_1^1	3.2	135.4	413	15.3	884	0.023
19		18/1	J_1^1	2.25	47.66	412	5.72	833	0.045
20		19	J_1^1	5.38	103.69	407	13.86	748	0.049
21		20	J_1^1	8.42	189.62	408	25.82	734	0.043
22		21	J_1^1	5.13	149.47	409	19.64	761	0.033
23		23	J_1^1	7.63	151.27	407	22.15	682	0.048
24	Vunoi	1	J_1^3	0.26	15.69	426	2.41	651	0.016
25		2	J_1^3	0.31	12.33	426	1.79	688	0.025
26		3	J_1^3	0.01	5.45	432	1.42	383	0.0018
27	Dhikla	3	T_3	0.02	1.19	412	0.52	228	0.017
28		5	T_3	0.04	4.91	421	1.23	399	0.008
29		6	T_3	0.26	20.76	413	3.87	536	0.012
30		7	T_3	0.01	4.12	418	0.99	416	0.0024
31		10	T_3	0.11	11.16	419	1.9	587	0.0098
32		11	T_3	0.01	3.79	424	0.8	473	0.0026

Table 2. Maceral analysis and reflectance of vitrinite of organic mater (on concentrated organic matter).

Region Section	Sample Outcrops	Geological age	Ro%	Organic petrography: maceral analysis (%)						
				Alginite	Liptod.*	Amorfinite	Bituminite	Vitrinite	Inertinite	Micrinite
Dukat	1/2	T_3	0.800	trace	trace	75.00	10.00	4.40	5.30	5.30
	1/3	T_3	-	trace	6.33	70.18	8.30	3.80	6.34	5.06
	1/6	T_3	-	trace	1.77	82.13	16.10	trace	trace	trace
	2	T_3	-	trace	3.75	73.00	15.00	2.00	2.50	3.75
	2/2	T_3	-	trace	2.94	67.35	15.00	2.94	2.94	8.82
	4	T_3	0.750	trace	trace	89.84	7.10	4.85	2.91	4.70
	4/1	T_3	0.817	trace	4.62	58.18	17.20	4.62	9.23	6.15
	5	T_3	-	trace	trace	84.50	9.94	2.86	2.86	4.22
	5/a	T_3	0.770	trace	1.92	84.89	5.61	0.96	4.82	3.88
	5/1	T_3	0.810	trace	1.45	79.00	12.30	2.90	8.67	4.32
	6	T_3	0.817	trace	trace	77.00	6.00	7.00	5.00	5.00
	6/1	T_3	0.814	trace	trace	79.43	8.20	5.47	2.34	4.56
	8	T_3	-	trace	5.26	82.00	22.21	3.51	3.51	3.51
	10/1	T_3	-	trace	trace	80.87	15.40	1.86	1.89	trace
	13	T_3	0.700	1.85	trace	64.7	18.04	4.66	6.48	4.30
	16/1	J_1^1	0.690	trace	5.41	60.38	19.40	5.35	4.05	5.41
	17	J_1^1	-	trace	trace	trace	100.00	trace	trace	trace
	17/2	J_1^1	0.740	trace	trace	65.00	22.00	6.00	3.00	4.00
	18/1	J_1^1	-	trace	trace	71.00	21.00	2.00	4.00	2.00
	19	J_1^1	-	trace	trace	86.11	3.00	1.98	1.98	6.93

	20	J_1^1	0.720	trace	4.71	65.40	18.05	9.41	3.63	3.53
	21	J_1^1	-	trace	2.39	84.00	4.40	1.30	2.63	5.26
	23	J_1^1	0.730	trace	trace	66.24	20.60	5.72	3.40	4.04
Vunoi	1	J_1^3	0.582	trace	trace	89.22	6.67	4.21	trace	trace
	2	J_1^3	0.650	trace	3.61	74.70	7.23	8.43	6.02	trace
	3	J_1^3	0.680	trace	trace	11.70	2.13	32.98	53.19	trace
	5	J_1^3	0.780	trace	4.05	59.46	12.16	13.11	7.70	3.51
	6	J_1^3	0.740	trace	trace	27.27	57.58	2.55	9.58	3.03
	7	J_1^3	0.730	trace	2.91	44.66	40.57	6.80	0.97	3.60
	10	J_1^3	0.744	trace	1.08	68.04	22.51	1.23	4.15	3.00
	11	J_1^3	0.752	trace	trace	79.04	9.19	6.79	1.79	3.20

* liptodetrinites

Organic matter content. The dolomitic and dolomitic limestone section of the Upper Triassic has an average of 3.88% total organic carbon (Dukat, Dhikla), with a range of 0.12% to 38.52%. Seven samples contain TOC<1%, and 13 samples contain TOC<10%. The Dukat 1/3 sample contains 38.52% TOC (Table 1). In the field, it gives the impression of "coal" layers with a thickness of 15 cm.

Table 3. Hydrocarbon composition and isoprenoid idex of ecstracts.

Section	Outcrops	Age	Saturated HC (%)	Arom. HC (%)	NSO komp.(%)	Asphats (%)	Saturated / Arom.HC	Pr/ (n-C17)	Ph/ (n-18)	Pr/Ph
Dukat	1	T_3	3.86	17.19	29.87	48.85	0.224549	1	0.571	0.5
"	1/2	T_3	2.35	21.18	25.5	50.96	0.110954	0.32	0.411	0.348
"	1/3	T_3	9.55	12.8	19.85	57.79	0.746094	0.38	0.423	0.9
"	2	T_3	5.01	22.4	34.85	37.74	0.223661	0.571	0.526	0.386
"	2/2	T_3	2.85	11.92	17.88	67.35	0.239094	0.216	0.356	0.587
"	13	T_3	4.49	21.43	25.55	48.47	0.209519	0.425	0.65	0.523
"	17	T_3	6.45	7.12	27.81	58.62	0.905899	-	-	-
"	17/2a	T_3	4.82	17.66	39.07	38.45	0.272933	-	-	-
"	17/2b	T_3	5.21	17.18	35.11	42.07	0.30326	-	-	-
"	21	T_3	4.05	8.57	28.18	58.64	0.472579	-	-	-
Dhikla	6	T_3	10.04	11.18	33.63	45.11	0.898032	-	-	-
Dhikla	10	T_3	6.48	30.81	27.11	35.59	0.210321	4.2	2.611	0.894
Vunoi	1	J_1^3	35.66	38.42	10.45	15.49	0.928162	0.98	0.569	2.633
Vlor-11	Grude oil	-	45	41.9	8.7	4.4	1.073986	0.82	0.3	0.4

The source rocks encountered in the **Lower Liassic** geological section (J_1^1) are richer in organic matter, with an average of 8.225 TOC (%) and a range of 5.725 to 51.77%. The lowest organic carbon content is found in sample no. 18/1=5.72%. While in 6 samples (17, 17/2, 19, 20, 21, 23), the organic carbon value fluctuates in the range of 13.89% to 25.82%. The highest organic carbon value belongs to sample no. 16/1, with 51.77%. As can be seen, the shales (source rocks) encountered in the Lower Lias section have the highest organic carbon content. This tendency is also observed in the other indicators (Fig. 3).

Type of organic matter. The type of organic matter or its quality is determined by the residual genetic potential S_2. This indicator represents the amount of hydrocarbons that the source rock generates after passing the catagenesis stage and is expressed in mgr. hydrocarbon per gr. rock (S_2= mgr.HC/gr.rock). Based on the values of S_2, the hydrogen index is calculated (HI= (S_2/TOC)*100).

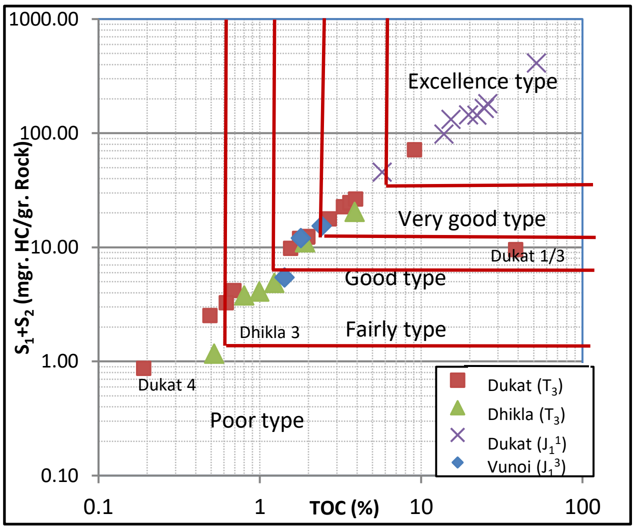

Figure 3. Type of organic matter based on TOC and S_1+S_2.

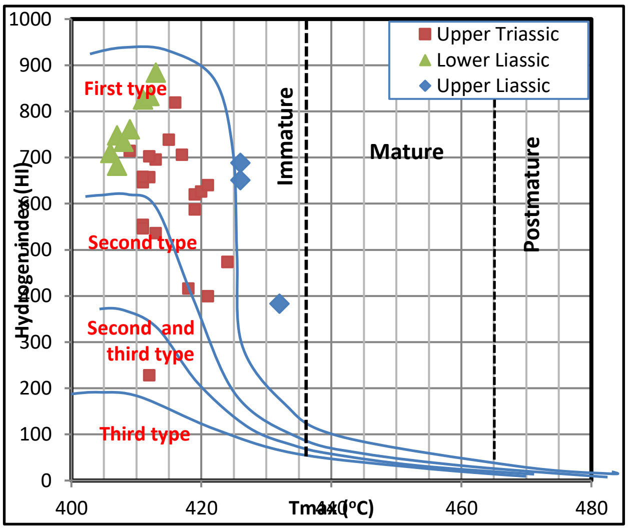

Figure 4. Type of organic matter based on Tmax and HI.

Source rocks, in addition to the process of hydrocarbon generation, expel the generated hydrocarbons. Thus, to assess the quality of organic matter, we will also use the sum $S_1 + S_2$ by correlating it with total organic carbon. From their correlation, 5 types of organic matter have been distinguished (Fig. 3):

1. Excellence type -Source socks of Lower Liassic and sample Dukat 1/3 of Upper Triassic;
2. Very good type- Source socks of Dukati section (Dukat: 2/2, 4/1, 5, 5/a) and Dhikla 6 of Upper Triassic ;
3. Good type- Source socks of Dukati section (Dukat: 1/2, 5/1, 6/1, 10/1) and Dhikla 10 of Upper Triassic. Source socks of Vunoi section (Vunoi:2, 3) of Toarian;
4. Fairly type- Source socks of Dukati section (Dukat: 1/6, 2, 6) and Dhikla (Dhikla:3, 7, 11) of Upper Triassic;
5. Poor type - represented only by the Dukat-4 sample.

The type of organic matter is also determined by the hydrogen index (HI). Based on the hydrogen index, the organic matter is mainly (RZGER et al, 2020) of the first type (HI>600). This type includes all the Lower Liassic source rocks and 13 Upper Triassic samples (Fig.4). The organic matter with high hydrogen index values in some studies is interpreted as having formed in lacustrine environments. In the Dukat region, the matter was formed in a reducing platform environment.

The second type of organic matter (HI ranges from 500 to 600) is found in four samples such as Dukat-2, Dukat-6, Dhikla-6, and Dhikla-10, capable of generating oil and gas hydrocarbons. We have also identified a transitional type of organic matter, the second-third type (HI ranges from 200 to 500). This type includes the samples Dukat-4, Dhikla-3, Dhikla-5, and Dhikla-7 of the Upper Triassic age and Vunoi-3 of the Toarcian age (Figs.4, 5).

The quality of organic matter has also been assessed by the method of **organic petrography**. This method was applied in two ways; in the study of polished surfaces of source rocks and concentrated organic matter (after destruction of mineral matter, separation with heavy liquid and solidification with resin) (Table 2). The latter was applied to concentrate vitrinite grains, as it is rarely found in source rocks.

The study of organic petrography was applied to the Dukat and Vunoi sections. The first study is carried out on the polished surfaces of the source rocks to study the relationship of organic matter with the rock structure. From the observations in the MPV3 microphotometer, a rare phenomenon was observed; the organic matter fluoresced in red colour (Photo 7, 8, 9, 10). This phenomenon has not been encountered in other regions of the Ionian zone (we have not even encountered it in the literature). We have compared it with a photo of the source rocks from the eastern regions of Dukat. In photo 11, alginites, and liptodetrinites, which fluoresce in a yellow-orange color (in fluorescent light reflected from the polished surface) are clearly visible.

While in the source rocks rocks in the Dukat region, alginites are not present, since the primary forms of organic matter of marine origin are destroyed. This phenomenon is expressed in the following photos 7, 8, 9, 10. The main component is bituminite, in some samples it is dominant. There are also horizons of rock that fluoresce in a reddish color (Photos 9, 10). This comes as a result of the impregnation of the rocks with destructed organic matter and is called "groundmass bitumen", which contributes to the content of amorphinites (PAUL et al, 2018).

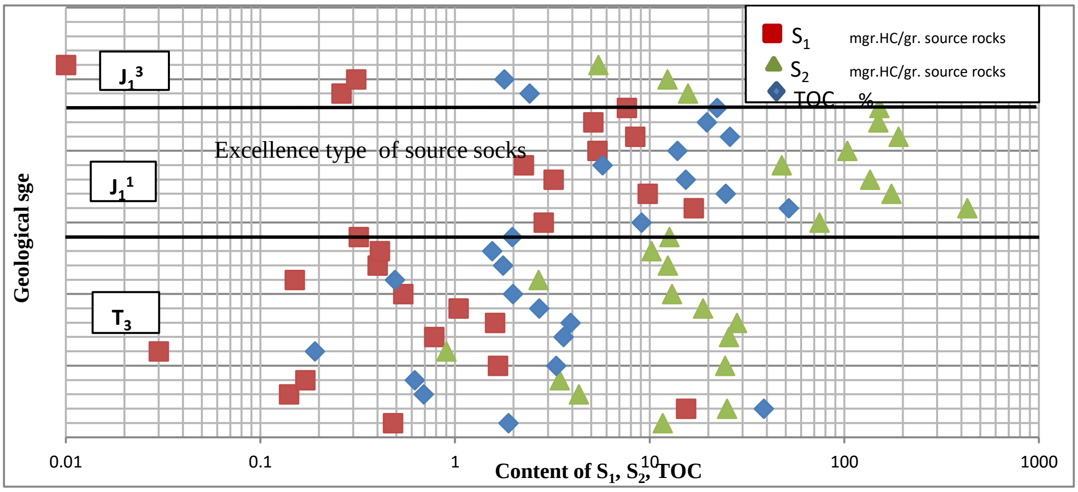

Figure 5. Rock-eval data of source rocks on geological section.

Maceral analysis was performed on polished surfaces of concentrated organic matter using fluorescent reflected light and natural reflected light methods. Macerals are components of organic matter (the equivalents of minerals), but in this case in coals and organic matter.

In the maceral analysis, three groups are distinguished: Liptinites, Vitrinites and Inertinites (Photo 5, 6), where Liptinites are dominant. The Liptinite group includes Alginites, Liptodetrinites, Amorphinites, and Bituminites (Table 2). Alginites are rarely found, the organic matter is destructed, so biological forms are not preserved. Liptodetrinites are residues of the destructuring process, their content varies from traces to 6.33%.

Amorphinites are the main components in shales (source rocks). This maceral comes from "groundmass bitumen", in this case, the mineral phase has been destroyed. Upper Triassic samples contain 58.18 5 to 89.8%.

Bituminite is pure maceral (100% organic matter), occurs in layered form (Photo 6, 9, 10), and reaches a thickness of up to 15 cm.

The liptinite group fluoresces in a reddish color. The red fluorescence must be related to the chemical properties of the environment (Algal-Reducing), to the properties of the fossilized plankton and the level of maturity (interpretation of the authors). The level of maturity of the organic matter is also expressed by the high content of micrinites.

Vitrinites are rare in the studied samples. In the Upper Triassic geological section in Dukat, they represent from traces to 7.0% (Photo 5), while in the Lower Lias geological section, they represent from traces to 9.41%. The highest content of vitrinites is found in the Vunoi geological section (Upper Liassic). This group represents 1.23% to 32.98% of the organic matter.

Macerals of the inertinite group are rarely encountered and we have divided them into two groups: inertinite which includes macerals of fusinite, sclerotinite etc. and micrinite (Photos 5, 12). Micrinite was separated because its origin is related to the oil generation process. Organic matter (bituminite, amorphinite), during oil generation, the residual product is micrinite. Thus the content of micrinite is also related to the level of maturity of the organic matter.

Organic matter in the studied samples is mainly of the first and second types (mainly liptinite), capable of generating liquid and gaseous hydrocarbons (PRIFTI et al, 1996).

The maturity of organic matter is determined by the rock-eval method and vitrinite reflectance. Other geochemical methods may also be helpful.

The indicators of rock-eval analysis that assess the maturity of organic matter are Tmax and the productivity index ($PI=S_1/(S_1+S_2)$). The values of these indicators do not provide a clear assessment of the level of maturity of organic matter. Tmax takes values lower than 424°C. Realistically, they should be higher than 430°C-435°C. While, the productivity index should be included in the range of 0.1 to 0.3 (Fig. 6). Although the Dukat 1/3 sample has a productivity index of 0.38 (PI=0.38), even this value should be taken with caution or hydrocarbon migration from the source rock may have not occurred.

While the indicators obtained by the organic petrography method assess the level of maturity of the organic matter (PRIFTI et al, 1996). Thus, for the Upper Triassic source rocks, the vitrinite reflectance (Ro) fluctuates in the range of 0.7% to 0.817%. In the Lower Liassic source rocks, the vitrinite reflectance fluctuates in the range of 0.65% to 0.740%. In the Upper Liassic source rocks, the vitrinite reflectance fluctuates in the range of 0.582% to 0.780%.

The maceral analysis revealed the presence of micrinite maceral, which was formed during the hydrocarbon generation process. Based on the vitrinite reflectance and micrinite content, the source rocks have entered the oil window (Fig.7). This conclusion is also supported by the isoprenoid hydrocarbon content and the distribution of normal paraffins, which will be discussed below.

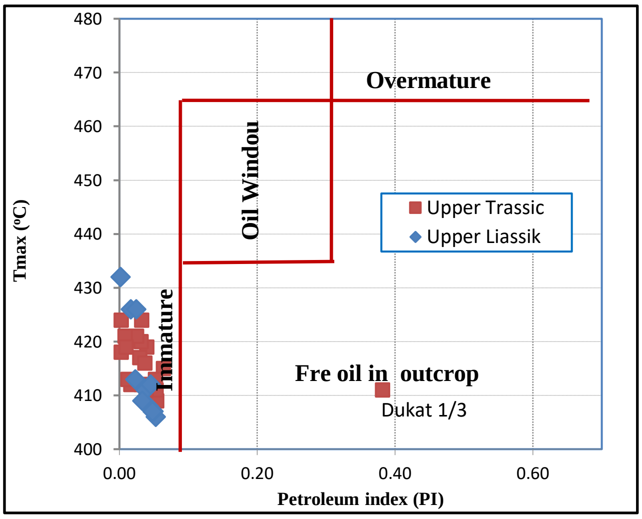

Figure 6. Maturity of organic matter by PI index and Tmax.

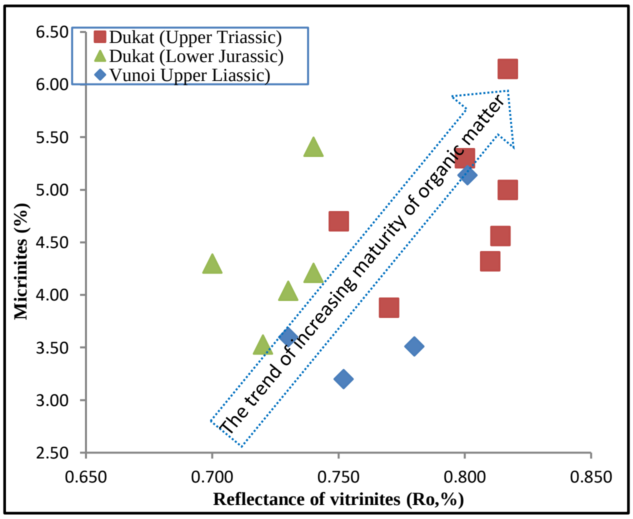

Figure 7. Maturity of OM by Reflectance of vitrinites and % of micrinites.

Based on hydrocarbon composition of the extracts, saturated and aromatic hydrocarbons in the extracts have a lower content (12.62% - 37.29%). The opposite is the case of the crude oil of the Vlora-11 well. While asphaltenes and NSO compounds have much higher content. This phenomenon appears in samples of geological sections in the Upper Triassic and Lower Liassic. The only exception is the sample Vunoi-1 (in the Toarcian-J_1^3 section), which contains 74.08% of saturated and aromatic hydrocarbons. The organic matter is mainly of the first type and capable of generating liquid hydrocarbons. Its origin is related to marine organisms, which generate oil with a higher content of saturated and aromatic hydrocarbons (MUSKA 2002). The extract of the Vonoi-2 sample is similar to some crude oils in oil fields (and crude oil from the Vlora-11 well). This discrepancy must be influenced by the primary migration process. This phenomenon could not have occurred in the Vunoi-1 sample since the sedimentation environment was "Transitional-Environments" which affected the low amount of organic carbon and the generated oil was not sufficient to be expelled. This is also expressed in the relationships of saturated hydrocarbons + aromatic hydrocarbons with NSO component + asphaltenes (Fig. 8).

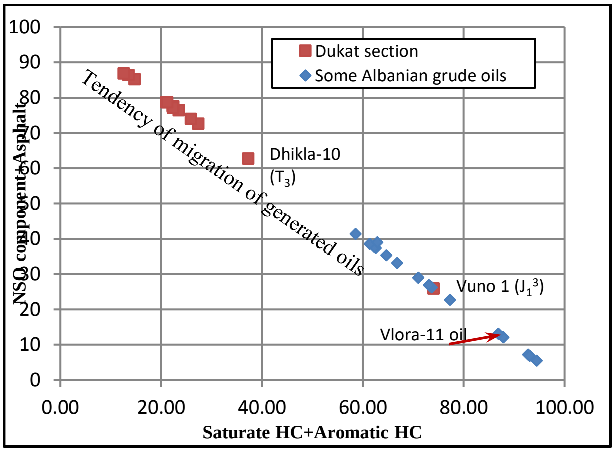

Figure 8. Corelation of saturate HC+aromatic HC vs NSO component+Asphalt.

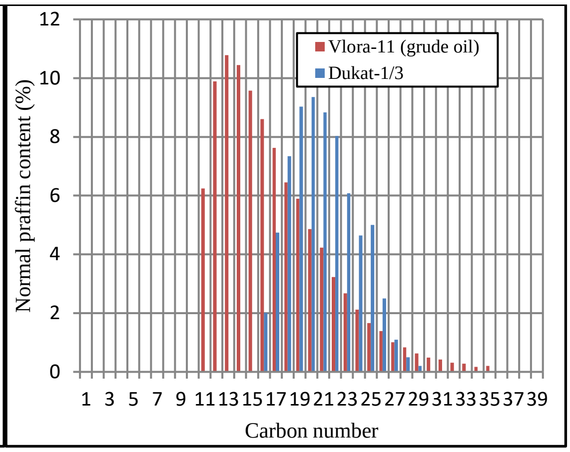

Figure 9. Distribution of normal paraffins on grude oil of Vlora-11 and exktract of Dukat-1/3.

Normal paraffin and isoprenoid hydrocarbons. Saturated hydrocarbons were subjected to gas chromatographic analysis, where normal paraffin and isoprenoid hydrocarbons were separated. Based on the content of normal paraffin, we constructed gas chromatograms (since we do not have the originals) for the Dukat-1/3 sample (Fig.9). We also constructed the chromatogram of the crude oil taken from the Vlora-11 well (about 4500 meters deep) on, the northern side of the Dukat region.

The chromatogram peak in the Dukati sample fluctuates in the range from carbon no. 18 to carbon no. 22 and the chromatogram continues up to carbon no. 27. While in the Vlora-11 well crude oil, the chromatogram peak fluctuates in the range nC_{11}-nC_{15} and the chromatogram continues up to nC_{35} (PRIFTI & MUSKA 2013). This discrepancy should be related to the contribution of several levels of source rocks in the generation of crude oil in the Vlora-11 well.

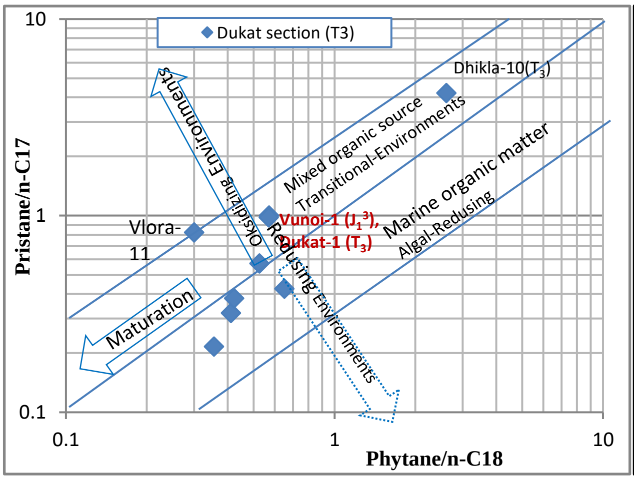

Figure 10. Interpretation of isoprenoid indexes in extracts and some Albanian grude oils.

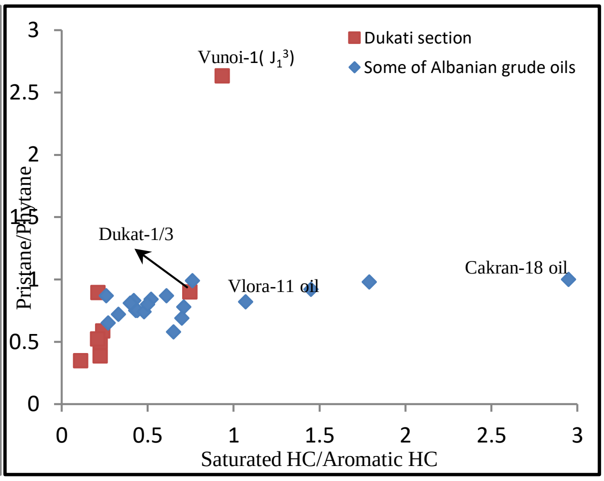

Figure 11. Corelation of Pr/Ph vs saturate HC/aromatic HC.

The isoprenoid hydrocarbon indices can be interpreted as indicative of the sedimentation environment of the source rocks (Boecker et al. 2016). The values of phytane/normal C_{18} and pristane/normal C_{17} indices are influenced by marine algal organic matter sedimented in a reducing environment. The exception is the Toarcian sample Vunoi-1 (J_1^3), the organic matter of the second-third type was sedimented in a mixed organic source transitional environment and contains organic matter of continental origin (Fig. 10).

What stands out are the isoprenoid hydrocarbons of the crude oil in the Vlora-11 well. The source rocks that produced this crude oil must have been sedimented in a mature, redox-transient environment, similar to the source rocks encountered in the Dukat-1 and Vunoi-1 samples.

The Pristane/Phytane ratio is one of the main indicators of isoprenoid hydrocarbons and assesses the sedimentation environment and the origin of organic matter. We have compared the values of this indicator with those of several oils from oil fields. We have also correlated them with the Saturated Hydrocarbons/Aromatic Hydrocarbons ratio.

Based on the correlations of the above indicators, it is noted that the Dukat shales (source rocks) have a similar configuration to those of some oils in Albania. The Pristane/Phytane ratios have values less than 1 (one), which indicates that the Dukat shales (source rocks) and those that have generated the oils of the sources, sedimented in mainly reducing environments (Fig. 11).

The only exception is the Toarcian sample Vunoi-1 (J_1^3) with a Pristane/Phytane greater than one, which indicates a contribution of organic matter of continental origin. The sedimentation environment must be of the Transitional-Environments with mixed organic source type. This same type of environment is for the Toarcian levels in the Ionian zone.

CONCLUSIONS

The source rock levels lie in the Upper Triassic, Lower Liassic and Upper Liassic carbonate-dolomite sections. They are exposed at the surface above the tectonic plane of the Çika anticline.

The source rocks in the Ionian zone are remarkably rich in organic matter, with TOC values reaching up to 51.7%. The type of organic matter is predominantly of the first and second types, as indicated by the hydrogen index. Furthermore, S_1+S_2 values suggest that the organic matter quality is mainly very good to excellent. It is clear that the source rocks of the Lower Liassic exhibit excellent organic matter quality, whereas the levels encountered in the Vunoi section (J_1^3) are of the second-third type.

The main kerogen macerals are amorphinite and bituminite, which indicate destructured organic matter.

The petrographic study in reflected light (polished surfaces of the samples) revealed a rare feature, they fluoresce in red colour. This feature has not been observed in source rocks in other regions of Europe.

The maturity of the source rocks has been assessed by the reflectance of vitrinite and the presence of micrinites. Based on their values, the source rocks have entered the oil window.

In the levels of the first type of source rocks, oil expulsion has occurred. The heavy hydrocarbon fractions have remained in the source rocks. The exception is sample Vunoi-1(J_1^3), where a high content of saturated and aromatic hydrocarbons is noted.

Light crude oil was encountered in the Vlora-11 well on the tectonic line of the Çika anticline, suggesting the possibility of the presence of oil deposits.

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PLATE I

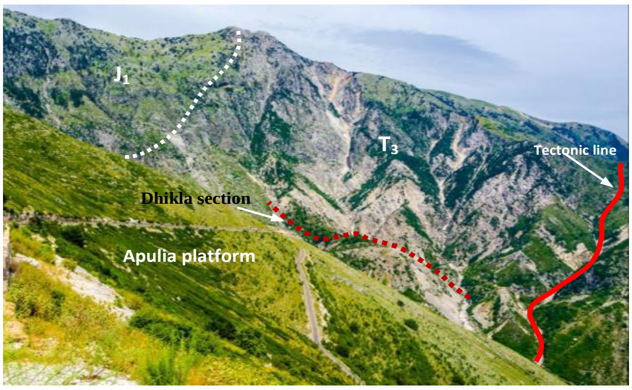

Photo 1. The Dhikla section in the dolomite-carbonate section of the Upper Triassic age.

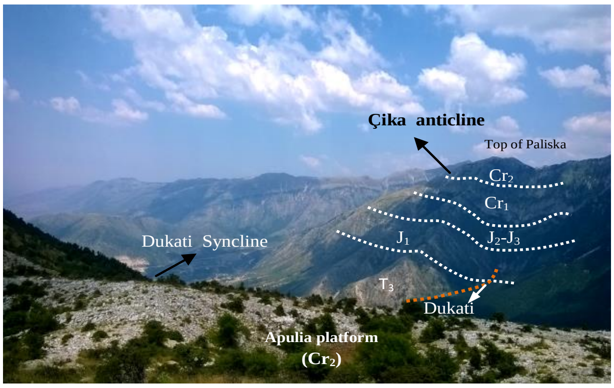

Photo 2. The Dukati section in the Upper Triassic-Lower Jurassic dolomite-carbonate section.

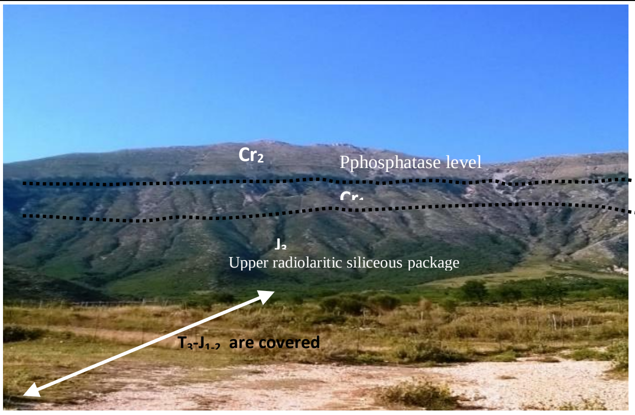

Photo 3. Geological panorama south of the Dukat range (above the village of Dukat).

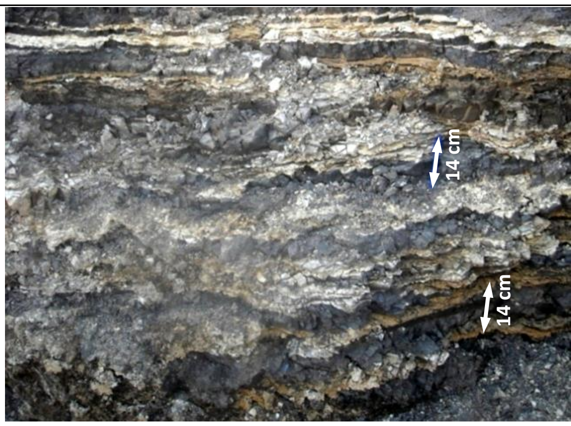

Photo 4. Lower Jurassic source rocks (excellent source rocks).

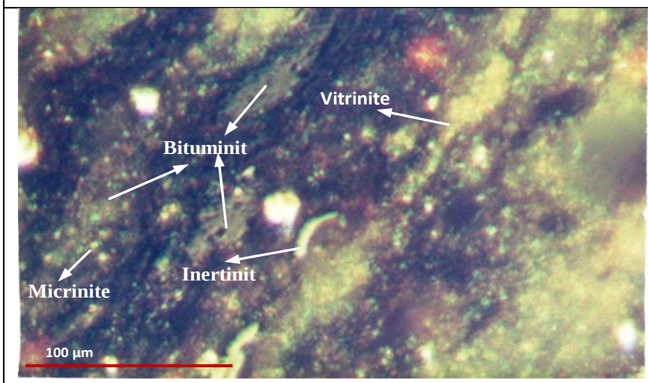

Photo 5. Microphoto in reflected light on the polished surface (immersion oil) of the Dukat 13 sample (T_3).

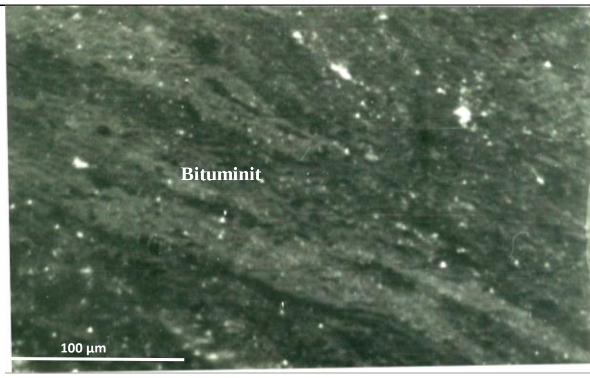

Photo 6. Microphoto in reflected light on the polished surface (immersion oil) of the Dukat 17 sample (J_1^1).

PLATE II

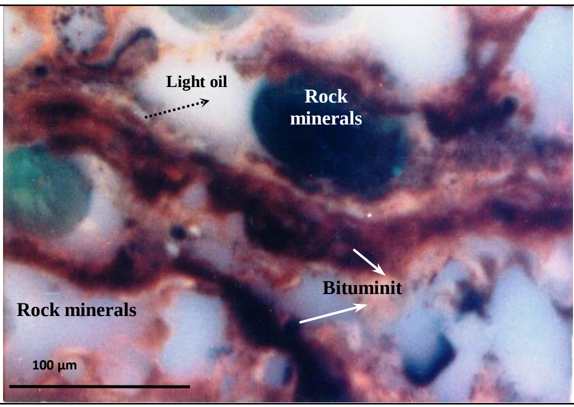

Photo 7. Microphoto in reflected fluorescent light on the polished surface (immersion oil) of the Dukat 1/3 sample (T_3).

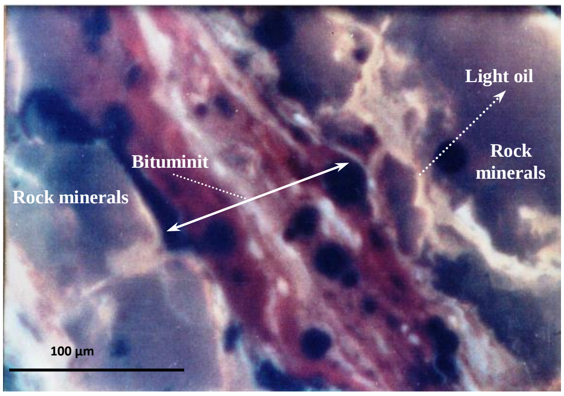

Photo 8. Microphoto in reflected fluorescent light on the polished surface(immersion oil) of the Dukat 13 sample (T_3).

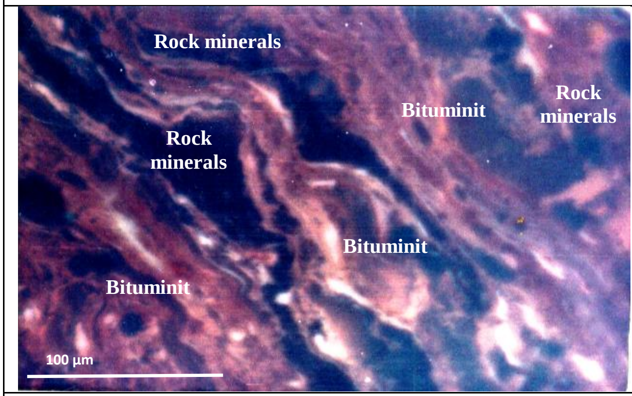

Photo 9. Microphoto in reflected fluorescent light on the polished surface (immersion oil) of the Dukat 17 sample (J_1^3).

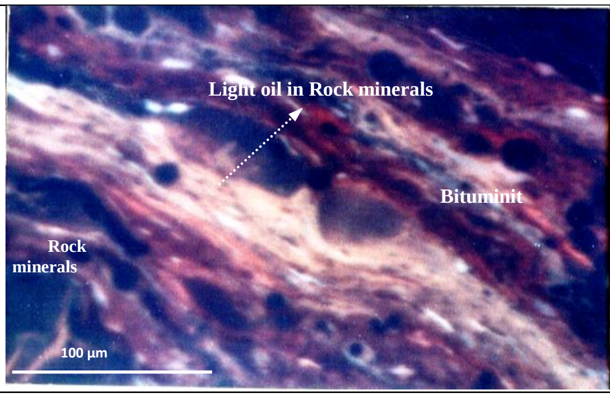

Photo 10 . Microphoto in reflected fluorescent light on the polished surface of the Dukat 20 sample (J_1^1).

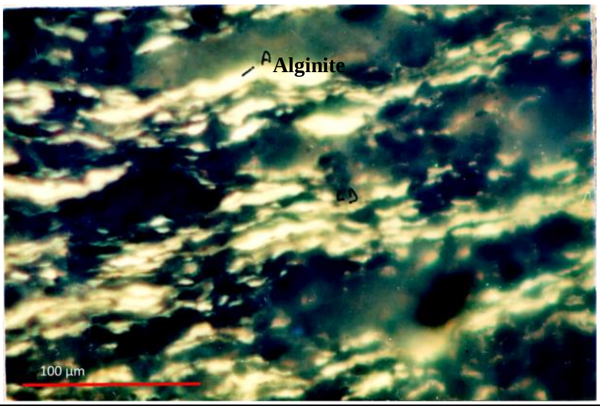

Photo 11. Microphoto in reflected fluorescent light on the polished surface (immersion oil) of the source rock in east sector of Çika anticline (J_1).

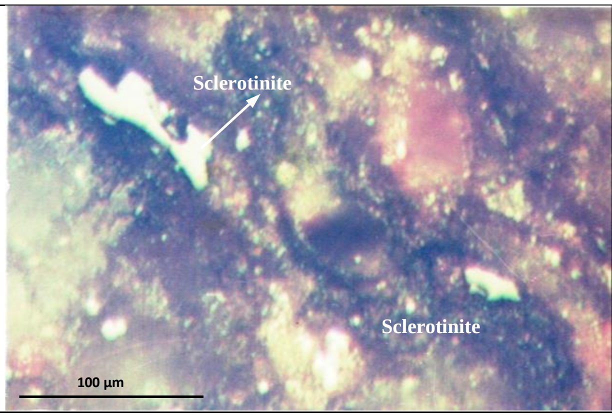

Photo 12 . Microphoto in reflected light on the polished surface (immersion oil) of the Dukat 6 sample (T_3).