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Hydrocarbons generating conditions on the Romanian Black Sea Shelf

Daniela - Doina Neagu

Universitatea Petrol-Gaze din Ploieşti, B-dul Bucureşti nr. 39, Ploieşti
e-mail: ndinu_daniela@yahoo.com

Abstract

Studies concerning source rocks, for The Histria Basin oil fields established that the main generaring formation consists of shally oligocene deposits formed in a narrow euxinic basin enriched with significant amounts of organic matter of continental origin. Shales have a mainly sapropellic character and recived an important apport of plants enabeling them to generate important amounts of petroleum. HC (hydrocarbons content of the rock) has an averge value of 428,1 ppm, corresponding to a moderate hydrocarbons generating potential. Production tests shown a small content of sulphur (lesser than 0.12%) and high values, about 90%, of aromatic hydrocarbons saturation. These are speciffic to clays generated hydrocarbons. Petroleum has been locally generated, migration paths and distances being short.

Keywords: *rock surce, reservoir, traps, field.*

Introduction

A first attempt to evaluate the Black Sea shelf's hydrocarbons potential has been accomplished in a study from 1966. Since then, beginning with 1969 a suite of seismic research works, more than 57000 km seismic lines covering more than 33 000 Km^2 was acomplished.

In the same time have been drilled more than 120 wells, among them about 60 geological research wells. Also olifield development wells provided a lot of geological data, improuving geological model of basin and oil accumulations.

Seismic lines interpretetion and drilling programs upgraded the tectonic models of the zone. Matching together the informations obtained from seismic sections, well logs, production tests and oilfields exploitation, me may estimate that the main objectiff, haveing simultaneously a significant volume of source rocks and favourable conditions of petroleum accumulations occurence is Histria Basin.

The Romanian offshore is one of most explored areas in the Black Sea. Extensive seismic acquisition and exploration drilling have led to the discovery of seven oil and gas fields located on a northwest-southeast trend on the northern margin of Histria Basin:

- East Lebada Albian oil field
- East Lebada Upper Cretaceous oil field
- East Lebada Eocene gas field

- West Lebada Albian oil field
- West Lebada Upper Cretaceous oil field
- West Lebada Eocene oil field
- Sinoe field

The purpose of the present paper is to describe the source and reservoir rocks and on the trap types in the Romanian offshore.

Hydrocarbons generation and accumulation; resources/reserves estimation

Source rocks

Studies on the source rock and the origin of oil discovered in the reservoirs of the Histria Basin were carried out by several national and foreign companies: C.C.P.E.G. Bucharest, Romanian Geological Institute - Bucharest, UNOCAL (1991), ARCO (1991), PETROFINA (1991), EXXON (1992) and MOBIL (1993).

The main conclusions of these studies are:

- *Main source rock:* Shales deposited during the Oligocene transgressive event are the "effective" source of all oil fields. The source shales are predominantly sapropelic in character, an important plant input is also present in the source kerogen which generated the oil.
- *Total organic carbon (TOC)* values, from the analyzed samples (mechanical cores) are greater than 0.5% with a maximum of 3.12% (Lebada East #89, interval 1855-1859m). The source potential derived from this parameter alone is good (Table 1).
- *Extractable organic matter (EOM)* is at least 500 ppm within a source rock. It varies between 312 ppm on Sinoe field and 3070 ppm on Cobalcescu field. By eliminating those samples contaminated with drilling fluid, the maximum value of EOM remains 2098 ppm on Ovidiu field. An increment of values with deposits' depth may be emphasis
- *The amount of hydrocarbons within the rocks (HC)* should be greater than 300 ppm for a source rock. In the present analyses, HC has an average value of 428.1 ppm, corresponding to a moderate oil generating potential.
- *The "productivity" of the extractable organic matter (EOM/TOC)* may be used as a generation/maturity index. The values recorded for the Oligocene shales range between 6 to 20%, corresponding to a marginally mature - mature stage of generation.
- *The hydrocarbon within the extractable organic matter (HC/EOM)* is usually more than 50% for a source rock. This parameter lies between 19.77% and 54.43% for the Oligocene shales.
- *The hydrocarbon "production" (HC/TOC)* is the best indicator for the quality of the organic material. For HC/TOC between 5-8%, the rock has a good oil potential and for a ratio greater than 8%, the rock has an excellent oil potential. Table 1 show that approximately 30% of the samples have a HC/TOC ratio higher than 5%.
- *Depositional setting:* The geological environment of source rock deposition is interpreted to be a salinity-stratified narrow trough, in which significant algal upwelling (diatoms) took place during climatic periods in which run-off was very pronounced. The oil samples are

low-sulphur (less than 0.12%), hydrocarbon-rich (approx. 90% saturated and aromatic hydrocarbons) crude oils. These are characteristic of oils generated from shales.

- Oil correlation: The oils were generated and expelled from the same source rocks. Whole-oil gas chromatograms illustrate the strong correlation and most of the source-related parameters agree within analytical errors (Figs. 1 and 2). The oils are commercially of high quality. They are low in sulphur and predominantly composed of saturated and aromatic hydrocarbons.

Table 1. Characteristic source rocks on wells from Histria Basin.

No	LOCATION	WELL	DEPTH (m)	TOC (%)	EOM (ppm)	HC (ppm)	HC/EOM (%)	EOM/TOC (%)	HC/TOC (%)
1	ALBATROS	40	3017.0-3019.0	0.42	530	323	60.94	12.62	7.69
2			3083.8-3084.0	0.87	1025	441	43.02	11.78	5.07
3	MINERVA	22	1852.5-1853.5	1.19	1281	333	25.99	10.76	2.80
4	LEBĂDA EST	8	1162.0-1164.0	1.53	885	329	37.17	5.78	2.15
5			1300.0-1303.0	1.78	936	296	31.62	5.26	1.66
6			1380.0-1381.0	1.65	568	130	22.89	3.34	0.78
7		82	1442.0-1445.0	1.50	1312	356	27.13	8.75	2.37
8		83	1675.0-1676.6	0.6	649	201	30.97	10.81	3.35
9		85	1753.0-1755.0	1.88	1210	372	30.74	6.43	1.97
10		89	1855.0-1859.0	3.12	984	504	51.22	3.15	1.61
11	LEBĂDA	25	1816.0-1821.0	1.0 04	497	230	46.28	4.78	2.21
12	VEST		1936.0-1941.0	1.3	427	251	58.78	3.28	1.93
13		817	1908.0-1912.0	1.37	1003	328	32.70	7.32	2.39
14		818	2144.0-2147.5	1.03	1196	558	46.65	11.61	5.41
15			2322.0-2328.5	0.68	1385	713	51.48	20.36	10.48
16			2328.5-2338.0	1.12	1289	626	48.56	11.50	5.58
17	SINOE	33	1939.3-1941.0	0.62	312	84	-	-	-
18	PORTIȚA	11	1384.1-1382.0	0.661	730	227	31.09	11.96	3.72
19	MIDIA	12	2574.0-2575.5	1.37	589	161	27.33	4.29	1.17
20			2817.5	0.58	580	204	35.17	10.00	3.51
21	OVIDIU	1	3941.0-3946.0	0.98	1224	242	19.77	12.49	2.46
22		k28L1	4406.0-4410.5	1.49	1380	740	53.62	9.26	4.97
23		k28L2	- // -	1.31	1374	648	54.43	10.00	4.94
24		k30L1	4562.0-4567.0	1.83	1818	918	50.49	10.00	5.02
25		k30L2	- // -	2.9	1756	880	50.10	7.34	3.68
26		k31X	4820.0-4824.5	2.34	1536	626	40.79	6.56	2.67
27		k31Y	- // -	1.12	2098	902	42.99	18.73	8.05
28			5001.0-5006.0	1.95	1664	822	49.39	8.53	4.21
29	COBALCESCU	75	3496.2-3496.4	1.92	2147	1917	89.29	11.18	9.98
30			3597.4-3597.5	0.91	488	236	48.36	5 36	2.59
31			3601.6-3601.8	1.49	3070	2308	75.18	20.60	15.48
32			3714.0-3714.5	0.93	326	176	53.98	3.50	1.89
33			3996.7-3997.0	1.91	1812	604	37.75	9.49	3.58

Estimation of the amount of hydrocarbons generated by the source rocks was made by the simulation of source rocks generative capacity.

We must underline that reliable evaluation of petroliferous potential may be done only from Rock-Eval analysis interpretation (on estimated source rocks samples). Thus we may determine the initial generative capacity (IGC), residual generative capacity (RGC), total generative hydrocarbons capacity (TGHC), and also an estimation of migrated hydrocarbons (MHC).

For the present evaluation we considered, as main source rocks, for Black Sea Continental Platform, the Oligocene ones, subsidiary the Jurassic ones (shally formation) and accidentally and locally, thin Albian sections.

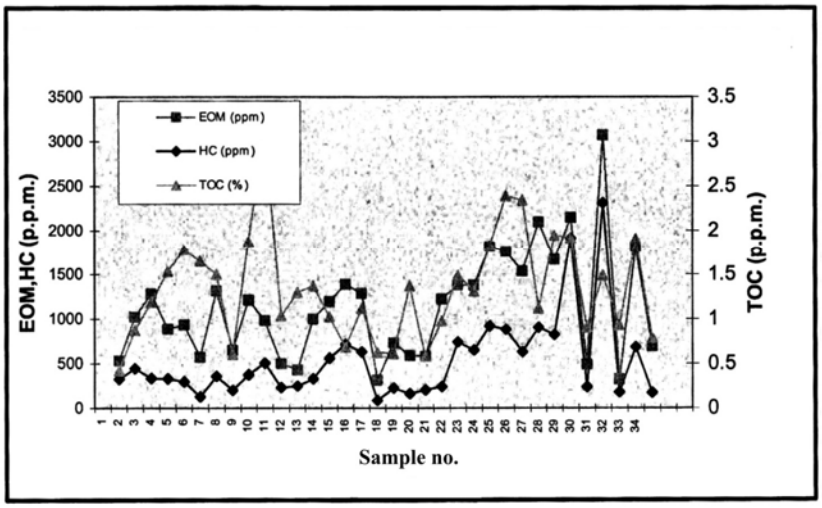

Fig. 1. Geochemical parameters (EOM, HC and TOC) of the Oligocene source rocks of the Histria Basin

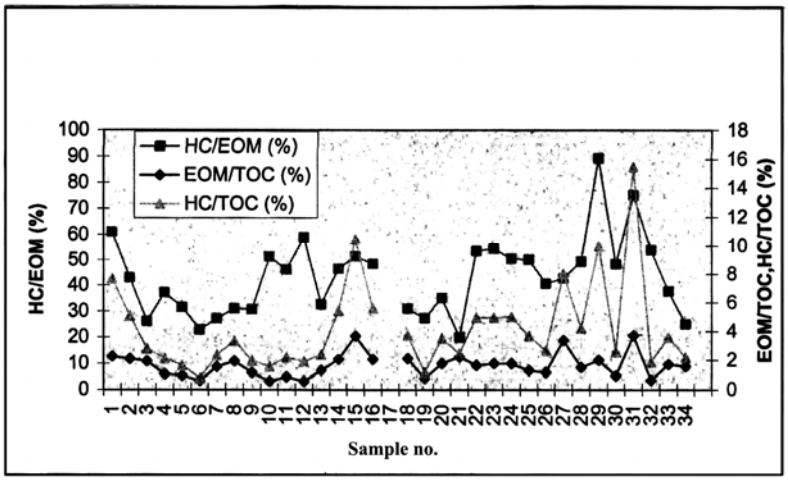

Fig. 2. Geochemical parameters (HC/EOM, EOM/TOC and HC/TOC) of the Oligocene source rocks of the Histria Basin

Estimations have been done for these three potential hydrocarbons generating formations.

a) *Oligocene,* may be considered, by politic (generating) facies length with a surface exceeding 6000 km^2 occurring (after seismic sections and litho facial maps aspects) about 40 to 50 km east of the present Black Sea shore line. This is related with the burial depths of sediments (minimum 2000 m) in order to reach a sufficient degree of thermal/organic metamorphism.

We may consider that the generative area is extending basin ward on a length about 120 km. This value is not conditioned by the facies length but of the initial migration average/maximal distance (path) for generated hydrocarbons.

From north to south me may consider a lengh of generative rocks, limited mainly from administrative conditions, about 250 km.

The estimated total generative surface is about 5000 km^2.

Migration paths arer dependent of the deposits'tectono-sedimentary arrangement. The main, regional, migration trend is considered to be from south-east to north-west, upward formations' dipping.

Basinward oligocene deposits thickness is growing and may exced 3000 m. Related with this thick sediemntary section we may consider that, based on wells logs electrofacies correlation, the ratio between total thickness and source rocks thickness is from 15% in the edge areas untill more than 20% in the most favourable zones.

The supposed averge value fro source rocks thickness is about 500 m.

Generated hydrocarbons amounts are shown in the table bellow.

Table 2. Generative Potential for Oligocene deposits.

Initial Generative Capacity (mil. t)	Total Migrated Hydrocarbons (mil.t)
190	570

b) *Albian,* have been considered as a potential generative, a source rock only for small areas and with insignificant organic content.

It covers an area about 2000 km^2 with a thickness around 40 m.

Because we have no direct determined informations concerning the oleogennetic parameters, we extrapolated the oligocene existing data to this interval.

Generated hydrocarbons amounts are shown in the table bellow (table 3).

Table 3. Generative Potential for Albian deposits

Initial Generative Capacity (mil. t)	Total Migrated Hydrocarbons (mil.t)
≥100	≥30

c) *Jurassic,* represented of the shally formation is characterised by a discontinuous repartition thus the potential generative areas are smaller than 2000 km^2, and their ponderate thickness is about 100 m.

Generated hydrocarbons amounts are shown in the table bellow (table 4).

Table 4. Generative Potential for Jurassic deposits

Initial Generative Capacity (mil. t)	Total Migrated Hydrocarbons (mil.t)
200	60

The total amount of generated hydrocarbons (considering all the formations analyzed above) is about 2200 million tones corresponding to a total amount of expelled hydrocarbons around 660 million tones.

Petroleum accumulations favorable zones estimation

The following conditions had to be met in order to identify the areas containing hydrocarbons accumulations:

- the existence of hydrocarbons source rocks;
- the existence of migration processes;

- the existence of reservoir rocks;
- the existence of protecting rocks;
- the existence of traps;
- the temporal shift of processes responsible for migration and creation of traps

The geological evolution of Black Sea Continental Platform is carachterized by the existence of some tectogenic phases which determined its uplifting or subsidence. The subsidence value was different for different zones and moments of basin evolution so that, even we can emphasis more relatively unitary sedimentary cycles, the sedimentary cover thickness corresponding to them is very different on basin surface warring from 0 to over 10000 m (in the central part of the sea basin).

In these conditions the favourable areas for hydrocarbons generating and accumulation are related with the existence of some important depressionary and uplifted zones induced by the tectonic evolution of the geological unit. So the possible generating hydrocarbons Oligocene deposits have been connected with older formations, Eocene and Cretaceous, thus the hydrocarbons migrated from the source rocks accumulated into the Eocene and cretaceous reservoirs.

Migration processes

Primary migration

Primary migration processes were conditioned initially by the migration time and the characteristic tectonic-sedimentary conditions of Black Sea Continental Platform.

As we mentioned before the main source rock consists of pelitic formations of Oligocene. In these conditions we may observe that hydrocarbons accumulation take place in older formations than the source rocks. That is possible only if the source rocks have the same or even deeper isobahic position as reservoirs. This was possible due to the existence of a paleorelief characterized by different levels of erosion that implied “pale geographical outcropping” of different terms of stratigraphical column which have been discordant covered by the Oligocene deposits. Thye tectonic scenario had an important influence, initially to the preoligocene paleorelief and latter in basin subsidence and hydrocarbons expeling

According with the structural arrangement primary migration took place from south-east to north-west, on distances at least equal with the ones observed in Moesian Platform. We may consider that the distance is about 100 km or eve more so the hydrocarbons generated in the central part of Black Sea Basin had the possibility to fill the shelf\slope reservoirs.

Migration processes took place relatively recent, according to the sediments entrance in the “oil window” or even later.

Secondary Migration

One of the most important features of the formations existing on the Black Sea Shelf is heterogeneity. Basely every reservoir has significant variations of porosity and permeability values. In this case the migration processes through the reservoirs had a random character, dictated by reservoirs properties variations.

Reservoir rocks

The main reservoir rocks in the Black Sea shelf (Histria Basin) are of Albian, Upper Cretaceous, and Eocene age. The Albian reservoir rocks are mainly detritc, turbiditic fan deposits with stratigraphic and structural-stratigraphic traps. The Upper Cretaceous reservoir rocks are mainly

carbonates deposited in an outer shelf environment, the trapping mechanism being controlled by the local development of fracture zones. The Eocene reservoir rocks are clastic and carbonate rocks with stratigraphic and structural-stratigraphic traps.

Albian reservoir

The Albian clastic sequence is the most important reservoir discovered until now to the Black Sea Shelf level.

The source area was the newly uplifted North Dobrogea and the major northwest-southeast, transport direction was controlled by the ancient structural axis. Apparently the Portita-Lebada Uplift acted like a barrier toward the north, guiding all the sediment influx to the south-east. In conclusion, the thickest and the coarsest Albian sequence occurs in the northwest part of the Histria Basin in the Portita area.

The lower part of the Albian formation comprises cycles of carbonate-rich, sandy limestones and carbonate-poor, calcareous cemented sandstones with a fine to medium grain size.

The upper part is usually composed of repetitive turbiditic sequences, normally grading from coarse quartzite and lithic sandstones or micro conglomerates to medium-grained quartzite sandstones and to medium and fine grained carbonated sandstones.

Another characteristic feature of the Albian reservoir is the interbedding of poorly-cemented porous zones with well-cemented compact zones. This is a consequence of detritic material transporting and sedimentation processes upgraded subsequently by the compacting and digenetic processes.

The average porosity to the collector rage is from 13% to 22% with maximum values in Sinoe field. Higher porosities in this area are explained by the shallower burial depth and by proximal locations in the fan. The average porosity decreases slightly toward the East Lebada field.

Average permeability of the pay zones are in the range of 6 to 200 md, with maximum values in the upper part of the Albian.

Upper Cretaceous Reservoir

The Upper Cretaceous reservoir comprises rocks of Turonian to Coniacian age. The dominant lithology consists of calcareous shelf deposits represented by micritic limestones, sandy limestones and chalky limestones, interbedded with thin layers of carbonaceous sandstones, micro conglomerates, marls and shales.

The thickness of the pay zone is range from 30 to 187 meters. The porosity is of fractured and intergranular type. The average porosity is 17% and the average permeability is 0.48 md. The very low permeability values contrasting with the good porosity suggest a very poor connection between the dominant vertical fractures. Cores analysis indicates a poorly-developed, micro-fracture system which connects zones of good porosity comprising intensely-fractured micritic limestones or carbonaceous sandstones levels developed in sandy limestones.

Eocene Reservoirs

Eocene reservoirs studied on Lebada West oil field and Lebada East gas field structures are carbonated type and consist micritic limestone, claily limestone and sandy limestone. The carbonate content ranges from 50 to 85%. Porosity types include fractured, inter-granular and inter-crystalline. The average porosity is 21% and the average permeability is 2 md.

The pay zone thickness varies from 65 to 150 meters.

Towards west occur quartz sandstones with 15% porosity and 177 md permeability.

Traps

Until now from the 30 explored structures are production Sinoe field, Lebada West oil field, Lebada East oil field and Pescarus field, with oil and/or gas reservoirs placed in Albian, Upper Cretaceous and Eocene.

Albian Traps

The Albian is the most important reservoir in the Romanian Black Sea offshore. It defines the main three oil fields: East Lebada oil field, West Lebada oil field and Sinoe field located on a northwest-southeast trend parallel to the regional structural trend.

These occur as linear type accumulating zone, according to general structural tendency north-west to south-east. In south-east extending, less important occur Pescarus field.

Trap forming mechanism is completed, intermediary traps occur, and is related with structural closure towards west and south, fault seal on northern flank and facial variations, compacting towards east.

Upper Cretaceous Trap

The Upper Cretaceous trap of the East Lebada field is developed as an east-west draping structure consisting of a zone of increase in fractured porosity. The seal consists of compacted Campanian limestones. Now oil-water and gas-oil contacts have been found.

Eocene Traps

In the north part of Lebada West structure occur, to the upper part of Eocene deposits two units with medium or good reservoir rock properties.

Reservoirs sealing is provided by shally superpositioned deposits. These units have the same value for GOC and different values of OWC.

The shallowest trap from Lebada East structure is the Eocene one. Although is represented by a dapping fold the Eocene trap is formed by a gradual reducing of reservoir rock's porosity both on horizontal and vertical plane.

Conclusion

- Hydrocarbons accumulations positioning is dictated by the structural-sedimentary model of the studied area;
- The most favourable zones, for some potential productive structures, are those placed on the north- north-west flancks of the depressionary areas neighbored by the tectonic uplifted zones;
- Local variations of rocks' porosity and permeability are responsible of the heterogeneous character of the reservoirs and the random distribution of the traps along the structural alignments;
- Stratigraphical factor has also an important role in traps forming and consists of unconformities, erosion, pinch out;
- Average accumulations resource's for one productive structure value is about 20 million tones for one productive structure;
- The extent of potential productive areas towards basin is restricted by the water depth and the possible compaction of reservoirs;

According with these conditions we estimate the existence of some new potential productive areas where we may find new productive structures in the north-east extent of the actual accumulation zone, respectively in east Cobalcescu area.

Also we may estimate as a perspective zone southward, the extent of Neptun alignment.

In the north part, neighboring the Serpilor Island occur also favorable conditions for the existence of some productive structures.

The total hydrocarbons resource calculated on the basis of generating surfaces, and the probability of hydrocarbons accumulation in productive structures is supposed to be about 220 million tones for Eocene and cretaceous reservoirs.

Considering the specific conditions of off sfore oilfields the recovery factor is much smaller than the onshore oilfields exploitation so that the total hydrocarbons reserve for the studied area is about 25-30 milion tones.

Reservoirs depth may variable between 3000 to 5000 m, and water depth, actually technological restriction to 100 m reduces even more the perspectives of reservoirs exploration/exploitation, mainly to the south part of the studied zone.

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Condiţii de generare a hidrocarburilor în zona şelfului românesc al Mării Negre

Rezumat

O primă evaluare a potenţialului de hidrocarburi pe şelful Mării Negre s-a realizat printr-un studiu elaborat în 1966, urmat de o suită de înregistrări complexe, seismice, geomagnetice, gravimetrice executate începând cu 1969. Studiile făcute pe rocile sursă pentru a stabili originile petrolului descoperit în zăcămintele din Bazinul Histria au arătat ca principala rocă sursă a tuturor zăcămintelor de hidrocarburi o constituie argilele depozitelor oligocene. Argilele, cu un caracter predominant sapropelic au primit şi un aport important de plante ce a permis generarea unor importante cantităţi de petrol. HC (cantitatea de hidrocarburi din rocă) are o valoare medie de 428,1 ppm, corespunzătoare un potenţial moderat de generare a hidrocarburilor. Probele de producţie au arătat un conţinut mic de sulf (mai puţin de 0,12%) şi valori ridicate, de aproximativ 90% saturare în hidrocarburi aromatice. caracteristice ţiţeiului generat de argile.