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BULGARIAN BLACK SEA OIL AND GAS - COMMON MYTHS AND UNCOMMON FACTS

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ABSTRACT
First quantitative model estimations of the oil and gas potential of the deep-water western part of the Black Sea basin, based on historico-genetic approach, show a level of hydrocarbon generation as high as in richest regions as the Caspian Sea and Niger Gulfs. But the data available are still insufficient for substantial evaluation - there are no drilling data. Therefore, to make better estimation is equivalent to apply better models, new and last reinterpreted data
The new theories, applied for temperature field reconstruction, are:

- 2D model for basin analysis with sedimentation and fluid flow history reconstruction;
- 2D inverse geothermal problem.

The new data is compilation from published and presented on scientific meetings information from the last ten years. Essentially new are suggestions for temperature field evolution, hydrocarbons migration and deep-sediments geochemistry in the light of last theoretical results and expedition measurements at areas with gas hydrates and mud volcanoes
The reinterpreted data is from in-situ geothermal measurements. These results are corrected accounting for gas hydrates existence
In conclusions, geological objects are classified on the base of their oil and gas potential.

INTRODUCTION

Black Sea – "the world's largest anoxic basin" and "the largest surface water reservoir of dissolved methane" – 96 Tg (Teragrammes; 1 Tg=10^{12} g) (Reeburgh et al., 1991). Moreover, this mass 2.4-6 times greater than the total annual geological methane contribution to the atmosphere (16-40 Tg - Judd et al., 2002).

State of O&G production in BG

Today on Bulgarian shelf are known 2 small fields with some economical value – oil field Tiulenovo (offshore part of found at 1951 coastal field) and Galata - gas field discovered in 1996 (Beckman, 2000).

History of offshore potential evaluation

The hydrocarbon potential is evaluated on the basis of traditional estimates (Bokov, 1979; Monahov et al., 1990) and the historic-genetic approach (HGA - Троцюк, 1982). Published are results from HGA models: for the Bulgarian shelf with 29 estimation points or sites (Геодекян и др., 1984); for the deep Black Sea basin (Гольмшток, Троцюк, Хахалев, 1989); for the Bulgarian continental slope - 9 sites (Троцюк и др., 1990); and more detail estimation for results of the whole Bulgarian offshore - 82 sites (Vassilev, 1995). These studies consider as most highly ranked the early Cretaceous, late Eocene - Oligocene- sediments or Paleocene-Eocene.

DEEP SEA HGA ESTIMATIONS COMPARISON

The historico-genetic approach (HGA) is used for estimation of the masses of generated oil and gas in the western Black Sea area between 27°30'-30°00'E and 42°00'-43°40'N. This area is shortly named Bulgarian in this work although the offshore economical zone of Bulgaria is approximately 33,200 km^2 or 88% from the studied area of 37,800 km^2

The input of the different complexes in the total amount of hydrocarbons (HC) generated by the Cenozoic sediments of the Bulgarian Black Sea sector is:

- Paleocene-Eocene - 76.3%
- Oligocene - 21.9%
- Miocene - 1.7%
- Pliocene - 0.1%

All evaluated sites took part in the process of generation during the last 20 to 65 million years (My) when 98% of proto gases were formed. Approximately 2/3 from the oil mass and 3/4 from the gases are produced in the Paleocene-Eocene sub complex. The quotas of the main morphological elements of the Black Sea basin in the generated gas masses are: shelf – 620 Petagrammes (Pg; 1 Pg = 10^{15} g); slope – 1,356 Pg; rise – 494 Pg; abyss – 1,872 Pg

A clear reflection of a simultaneous acting of all favorable for gas creation factors is the maximum at the sites from the Dolna-Kamchia trough. Their sections are characterized by the greatest thickness of the Eocene sub complex and a great amount of TOC.

The Oligocene sediments play an important role for HC generation in the North part of the slope. The quantity of HC-generation of the Oligocene at these sites is 70-100%. Therefore, the major generators of HC in the Cenozoic section of the examined areas are the Oligocene sediments and the upper sub complex of the Eocene.

In the Cenozoic sections of the Bulgarian continental slope high quantities of generated HC are established within the boundaries of the Dolna-Kamchia trough. Their values tend to increase with the water depths. The best conditions for HC migration and accumulation are supposed to exist in the northernmost flank of the slope.

Table 1. Site numbers, area (zone), latitudes and longitudes

Site #	Area	Lat, deg	Lon, deg	Site #	Area	Lat, deg	Lon, deg
4A	KF	28.70	42.87	7928	WB(r)	29.42	42.98
5A	KF	28.70	42.53	12	WB(r)	29.12	42.88
6A	KF	28.60	42.82	13	WB(r)	29.20	42.80
7A	KF	28.48	42.83	41	WB(r)	29.43	43.23
8A	KF	28.42	42.70	42	WB(r)	29.53	43.15
617	KF	28.93	42.79	44	WB(r)	29.68	43.02
53	KF	29.03	42.35	45	WB(r)	29.90	42.90
54	KF	28.85	42.48	67	WB(r)	29.08	42.10
55	KF	28.65	42.62	78	WB(r)	29.82	43.17
56	KF	28.58	42.68	79	WB(r)	29.98	43.05
68	KF	28.92	42.08	89	WB(r)	29.17	43.05
69	KF	28.80	42.02	90	WB(r)	29.33	42.95
70	KF	28.65	42.03	91	WB(r)	29.48	42.83
71	KF	28.78	42.78	101	WB(r)	29.07	42.58
111	KF	28.48	42.58	1G	WB(r)	29.67	43.28
113	KF	28.90	42.35	2G	WB(r)	29.68	43.18
114	KF	29.02	42.22	3G	WB(r)	29.45	43.05
7G	KF	29.02	42.83	4G	WB(r)	29.78	43.37
9G	KF	28.77	42.28	5G	WB(r)	29.83	43.23
5S	KF	28.27	43.91	6G	WB(r)	30.08	43.27
6S	KF	28.12	42.90	8G	WB(r)	29.28	42.83
7S	KF	28.17	42.84	14	WB(a)	29.37	42.68
8S	KF	28.29	42.72	15	WB(a)	29.48	42.58
3L	KF	27.85	43.02	16	WB(a)	29.63	42.47
1A	NS	29.63	43.42	18	WB(a)	29.85	42.33
2A	NS	28.86	43.04	19	WB(a)	29.95	42.27
3A	NS	28.70	42.97	22	WB(a)	29.63	42.10
5	NS	28.75	43.12	52	WB(a)	29.27	42.20
6	NS	28.80	43.08	92	WB(a)	29.78	42.62
10	NS	28.92	43.02	93	WB(a)	29.98	42.48
32	NS	29.23	43.35	102	WB(a)	29.25	42.42
34	NS	29.12	43.25	103	WB(a)	29.47	42.25
35	NS	29.18	43.15	104	WB(a)	29.62	42.20
36	NS	28.97	43.10	1S	MP	29.07	43.65
40	NS	29.33	43.28	2S	MP	28.58	43.33
61	NS	28.93	43.13	3S	MP	28.44	43.23
65	NS	28.93	42.97	4S	MP	28.18	43.05
74	NS	29.38	43.40	1L	MP	28.47	43.40
76	NS	29.50	43.40	2L	MP	27.80	43.20
7904	WB(r)	29.97	43.30	4L	BK	27.62	42.58

Shown tables discuss differences in data between authors.

The total organic carbon (TOC) is calculated from 11 polynomials of 3 degree, with respect to the age of rocks. For each site and age interval corrections for the sedimentation rate are made. In the Paleocene-Eocene sediments the average TOC varies in wide range from 0.01% to 0.74% (average - 0.34%). This changeability is determined by the increase of the sedimentation rate from very low value (1 m/My – site 2L near Varna) to moderate one (>300 m/My in site 101 at the abyssal plain). It is important to note the good correlation of the estimated TOC (0.7% at site 67) with the results of measurements in the closest Turkish offshore wells Igniada and Karadeniz. This fact, as well as the coincidence between the results of calculations and sample analysis in Samotino area shows the high precision of this prognosis.

Low level of TOC (especially the average value of 0.17% for sites 6A and 7A) is characteristic for the Oligocene sequences. This is the main difference from the previous results based on lithological types extrapolation – average 0.98% for the same sites. New TOC concentrations are with bigger variations caused by the sedimentation rates - from 1.

Table 2. Correlation of predicted in this paper different age sediment thickness and quoted or measured from Tugolesov et al. (1985), Monahov et al. (1990) and Trotsjuk et al. (1990)

			Qu				***Pl***		***Mi***		***Ol***		***Eo+Pa***	
			Predicted	Quoted	Measured	Measured	**Pred**	Quot	**Pred**	Quot	**Pred**	Quot	**Pred**	Quot
Site #	**ID**	**Name**	**V*t, km**	Trotsju	Tugolesov	Monahov	**V*t, km**		**V*t, km**		**V*t, km**		**V*t, km**	
1A	NS	1	**1.096**	1.400	1.800	2.329	**0.781**	1.050	**0.635**	0.800	**1.040**	0.350	**0.380**	1.550
2A	NS	2	**0.374**	0.500	0.727	0.800	**0.314**	0.600	**0.220**	0.700	**0.960**	0.300	**0.400**	0.600
3A	NS	3	**0.356**	0.400	0.633	0.667	**0.463**	0.600	**0.231**	0.500	**0.992**	0.600	**1.000**	1.400
4A	KF	4	**0.484**	0.400	0.704	0.758	**0.441**	0.500	**0.708**	0.400	**1.035**	0.700	**2.295**	2.800
5A	KF	5	**0.406**	0.650	0.700	0.708	**0.267**	0.200	**0.589**	0.600	**1.332**	1.900	**6.557**	4.700
6A	KF	6	**0.485**	0.750	0.655	1.000	**0.466**	0.500	**0.680**	0.500	**0.877**	0.550	**2.756**	3.350
7A	KF	7	**0.485**	0.900	0.554	1.000	**0.731**	0.500	**0.376**	0.300	**0.598**	0.400	**2.229**	1.800
8A	KF	8	**0.323**	0.600	0.547	0.980	**0.707**	0.450	**0.376**	0.200	**0.477**	0.300	**3.786**	3.600
		Sum, km	**4.010**	***5.600***	***6.320***	***8.241***	**4.170**	***4.400***	**3.816**	***4.000***	**7.312**	***5.100***	**19.403**	***19.800***
		Pr/Qu, %		**72**	**63**	**49**		**95**		**95**		**143**		**98**
1S	MP	1I	**0.387**		0.000	0.395	**0.419**		**0.268**		**0.260**			
2S	MP	Nanevo	**0.165**	0.000	0.000	0.000	**0.341**		**0.208**	0.155	**0.071**	0.073		0.120
3S	MP	Elizavetino	**0.186**	0.110	0.000	0.000			**0.183**	0.119	**0.279**	0.059		0.073
4S	MP	1III	**0.152**		0.000	0.000	**0.341**		**0.287**		**0.480**		**0.188**	
5S	KF	BG1	**0.242**		0.214	0.331	**0.620**		**0.242**		**0.526**		**1.906**	
6S	KF	Samotino E	**0.155**	0.030	0.030	0.000	**0.213**		**0.241**	0.220	**0.526**	0.508	**2.849**	2.650
7S	KF	Samotino S	**0.157**	0.045	0.148	0.222	**0.246**		**0.218**	0.210	**0.476**	0.473	**2.939**	2.880
8S	KF	BG2	**0.232**		0.385	0.510	**0.407**		**0.298**		**0.111**		**3.008**	
22	WB(a)	380	**0.574**	0.627	0.894	1.042	**0.509**	0.237	**1.305**	>.213	**3.280**		**4.500**	
		Sum, km	***2.250***		***1.671***	***2.500***	***3.098***		***3.250***		***6.010***		***15.390***	

Table 3. A comparison between the predicted in this paper values for Corg content and these from Trotsyuk et al. (1990)

			Qu		***Pl***		***Mi***		***Ol***		***Eo+Pa***	
			Pred	Quot	**Pred**	Quot	**Pred**	Quot	**Pred**	Quot	**Pred**	Quot
Site #	**ID**	**Name**	**Corg, %**		**Corg, %**		**Corg, %**		**Corg, %**		**Corg, %**	
1A	NS	1	**0.73**	0.4	**1.19**	0.8	**0.46**	0.7	**0.19**	0.8	**0.03**	0.4
2A	NS	2	**1.62**	1.2	**0.62**	1.6	**0.16**	0.5	**0.17**	0.8	**0.03**	0.2
3A	NS	3	**1.63**	1.2	**0.91**	1.6	**0.17**	0.5	**0.18**	1.0	**0.08**	0.3
4A	KF	4	**1.49**	1.2	**0.87**	1.6	**0.51**	0.5	**0.18**	1.1	**0.18**	0.4
5A	KF	5	**1.58**	1.5	**0.53**	1	**0.42**	0.6	**0.24**	1.4	**0.71**	0.5
6A	KF	6	**1.49**	1.2	**0.92**	1.6	**0.49**	0.5	**0.16**	1.0	**0.22**	0.5
7A	KF	7	**1.48**	1	**1.22**	1.6	**0.27**	0.2	**0.11**	1.0	**0.18**	0.4
8A	KF	8	**1.47**	1.2	**1.23**	1.6	**0.27**	0.9	**0.09**	0.8	**0.30**	0.5
Min			**0.73**	0.40	**0.53**	0.80	**0.16**	0.20	**0.09**	0.80	**0.03**	0.20
Max			**1.63**	1.50	**1.23**	1.60	**0.51**	0.90	**0.24**	1.40	**0.71**	0.50
Average			**1.44**	1.11	**0.94**	1.43	**0.34**	0.55	**0.16**	0.99	**0.22**	0.40
AvP/AvQ			**1.29**		**0.66**		**0.62**		**0.17**		**0.54**	

Table 4. A comparison between the predicted in this paper density and these from Trotsyuk et al. (1990) and measured in samples from 3 sea boreholes

			Qu		***Pl***		***Mi***		***Ol***		***Eo+Pa***	
			Pred	Quot	**Pred**	Quot	**Pred**	Quot	**Pred**	Quot	**Pred**	Quot
Site #	**ID**	**Name**	**Density, g/cm3**		**Density, g/cm3**		**Density, g/cm3**		**Density, g/cm3**		**Density, g/cm3**	
1A	NS	1	**1.91**	1.90	**2.17**	2.40	**2.31**	2.50	**2.43**	2.60	**2.50**	2.65
2A	NS	2	**1.77**	1.60	**1.90**	1.80	**1.99**	2.30	**2.15**	2.40	**2.29**	2.50
3A	NS	3	**1.77**	1.60	**1.92**	1.80	**2.03**	2.00	**2.19**	2.20	**2.36**	2.50
4A	KF	4	**1.79**	1.60	**1.96**	1.80	**2.12**	2.00	**2.30**	2.20	**2.50**	2.50
5A	KF	5	**1.78**	1.60	**1.90**	1.70	**2.04**	2.20	**2.26**	2.50	**2.61**	2.67
6A	KF	6	**1.79**	1.70	**1.96**	2.10	**2.13**	2.20	**2.29**	2.30	**2.51**	2.58
7A	KF	7	**1.79**	1.70	**2.00**	2.20	**2.15**	2.30	**2.26**	2.40	**2.46**	2.58
8A	KF	8	**1.76**	1.60	**1.95**	1.90	**2.11**	2.20	**2.21**	2.30	**2.50**	2.50
		Average	1.79	1.66	1.97	1.96	2.11	2.21	2.26	2.36	2.47	2.56
		Dp/Dq	**1.08**		**1.00**		**0.95**		**0.96**		**0.96**	
2S	MP	Nanevo	**1.73**		**1.83**	300/1.5	**1.93**		**1.97**	310/1.7		
6S	KF	R-1 Samotino Et	**1.72**		**1.80**		**1.89**		**2.01**	1.70	**2.37**	2.20
7S	KF	R-1 Samotino S	**1.72**		**1.81**		**1.89**		**2.01**	1.65	**2.37**	2.20

Table 5. A comparison between the predicted in this paper values for thermal conductivity and these from Trotsyuk et al. (1990)

			Qu		***Pl***		***Mi***		***Ol***		***Eo+Pa***	
Site #	**ID**	**Original Name**	**Predicted L, W/m.deg**	Quoted	**Predicted L, W/m.deg**	Quoted	**Predicted L, W/m.deg**	Quoted	**Predicted L, W/m.deg**	Quoted	**Predicted L, W/m.deg**	Quoted
1A	NS	1	**1.27**	1.20	**1.50**	1.60	**1.61**	1.60	**1.71**	1.70	**1.77**	1.75
2A	NS	2	**1.16**	0.90	**1.27**	1.20	**1.34**	1.40	**1.48**	1.60	**1.59**	1.60
3A	NS	3	**1.16**	0.90	**1.29**	1.20	**1.38**	1.30	**1.51**	1.40	**1.66**	1.63
4A	KF	4	**1.18**	0.90	**1.32**	1.20	**1.46**	1.30	**1.61**	1.40	**1.77**	1.66
5A	KF	5	**1.16**	0.90	**1.27**	1.00	**1.39**	1.40	**1.57**	1.60	**1.86**	1.76
6A	KF	6	**1.18**	1.00	**1.32**	1.30	**1.46**	1.40	**1.59**	1.50	**1.78**	1.68
7A	KF	7	**1.18**	1.00	**1.36**	1.40	**1.48**	1.50	**1.57**	1.60	**1.73**	1.65
8A	KF	8	**1.15**	0.90	**1.31**	1.20	**1.44**	1.40	**1.53**	1.60	**1.77**	1.66
		Average	1.18	0.96	1.33	1.26	1.44	1.41	1.57	1.55	1.74	1.67
		Dp/Dq	**1.23**		**1.05**		**1.02**		**1.01**		**1.04**	

Table 6. A comparison between the predicted in this paper temperatures and these from Trotsyuk et al. (1990) and Erickson & Von Herzen (1978)

			Qu		***Pl***		***Mi***		***Ol***		***Eo+Pa***		
			Predicted	Quoted	**Predicted**	Quoted	**Predicted**	Quoted	**Predicted**	Quoted	**Predicted**	Quoted	
Site #	**ID**	**Name**	**T, °C**		**T, °C**		**T, °C**		**T, °C**		**T, °C**		
1A	NS	1	**39**	49	**57**	75	**81**	111	**119**	126	**132**	190	
2A	NS	2	**26**	39	**41**	69	**51**	105	**90**	119	**105**	146	
3A	NS	3	**26**	32	**47**	59	**57**	86	**96**	117	**132**	178	
4A	KF	4	**31**	32	**53**	57	**85**	79	**128**	115	**213**	236	
5A	KF	5	**24**	40	**35**	54	**57**	115	**99**	175	**277**	364	
6A	KF	6	**27**	42	**46**	63	**71**	88	**101**	114	**184**	259	
7A	KF	7	**27**	53	**56**	73	**70**	86	**90**	102	**159**	209	
8A	KF	8	**24**	42	**55**	64	**70**	73	**88**	86	**212**	224	
		Average	28	41	49	64	68	93	101	119	177	226	***Average***
		Dp/Dq-1, %	**-0.32**		**-0.24**		**-0.27**		**-0.15**		**-0.22**		**-0.24**
			T, °C										
22	WB(a)	380	**30**	29	**51**	46	**99**	93	**202**	172	**336**	330	***Average***
		Tpr/Tqu-1, %	***0.05***		***0.10***		***0.07***		***0.17***		***0.02***		***0.08***
			H(pr), km										
			0.574		**1.083**	0.912	**2.398**		**4.678**	0.020	**9.178**		**4.500**
			Qu		***Pl***		***Mi***		***Ol***		***Eo+Pa***		

			Predicted	Quoted	**Pred**	Quot	**Pred**	Quot	**Pred**	Quot	**Pred**	Quot									
			T, °C																		
22	WB(a)	380	**11.6**	10.5	**12.9**	12.8	**14.3**	16.8	**15.4**	14.8	**17.1**	16.6	**20.0**	19.4	**22.8**	22.4	**26.3**	25.1	**9.05**	8.59	***Average***
		Tpr/Tqu-1, %	***0.10***		***0.01***		***-0.15***		***0.04***		***0.03***		***0.03***		***0.02***		***0.05***		***0.05***		***0.02***
			H(meas), m																		
				67.5		104.5		142.5		171.0		218.5		294.5		370.5		465.5		0.0	

DATA

New (last 10 y)

Last 10 years are without brand new specialized measurements data. Absent deep structure results from OBS, this could clear the geological history, or satellite's images in different ranges for direct gas or oil slicks detection. But new data appears in closest north and east areas – heat flow, geological sampling, gas contents, etc. These data is from expeditions looking for gas hydrates, mud volcanoes, gas vents and other phenomena, connected with global climate change.

Reinterpreted – GH existence corrections

Most interesting are possible corrections in heat flow data, because measurements, used methods and probes are from time when wide spread of gas hydrates was unthinkable. But all primary measurements records are destroyed (private information) and now possible are only theoretical approximations.

Such revisions are needed in all research areas, accounting last 10 years information explosion and huge new DB appearing.

NEW MODELS

2D basin

Sophisticated basin analysis programs with load temperature, TOC, sedimentation and mass transport determination procedures, with implementation of HGA and Lopatin's method, using small space and time step could create series of realistic scenarios and potential estimation.

2D inverse T

Inverse problem theory in marine geothermy will become a power tool firstly for gas hydrate research and then for the purposes of oil & gas industry.

CONCLUSIONS

New models must apply all known reliable or reprocessed data or useful methods. For example:

▪ The vitrinite reflectivity in the Paleozoic and Mesozoic sediments on shelf (Николов, 1993) and territory of Bulgaria (Велев и др., 1997; Велев, 2002; Велев, Ранкова, 2002), which are of critical importance also for the prospectivity of the pre-Paleogene regional formations (remain out of the vision for most of the petroleum geologists). These results suggest that probably on wide Bulgarian shelf areas, the enriched with organic matter pre-Paleogene formations from the south part of Moesian platform and Balkanides, had realized early the bigger part of their potential and then stay as a chemically passive witness of the basin sinking.

▪ To create detail reconstruction with Lopatin's method of maturity process using recommendation of Waples (1980).

▪ There are known unsuccessful attempts are for lower concentration oil phase's emigration modeling (Welte, Yalcin, 1988) and therefore we consider as potential oil source only the rocks with organic matter content over 1% (clays, argillites and clayey alevrolites, and rarely - marls).

Still looking their answers next conclusions:

1. Formations older than Paleogene are not important in hydrocarbons generation.
2. Main source are the rocks of "Maikop formation" (Mainly Oligocene).
3. They are relatively enriched with organic matter.
4. Higher than 1% contents of TOC demonstrate mainly pelites' rocks of series.
5. From geothermal research Oligocene sediments are on different points of lithogenetic transformation.
6. In most general plan the movement of generated in series hydrocarbons is directed from locations of depocentres of Oligocene and Quaternary sedimentation.
7. Known 3 regional estimation of generated HC in the deep water Bulgarian part of the Black Sea give max and average values:

- Троцюк, 1990 – $11.9.10^6$ t/km^2 & $2.5.10^6$ t/km^2;
- Vassilev, 1995 –$16.0.10^6$ t/km^2 & $3.5.10^6$ t/km^2;
- Velev et al. 2003 - $1.3.10^6$ t/km^2

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