Shared optimistic-pessimistic model of the Black Sea gas hydrates

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Introduction

The gas hydrates (GHs) are most important geological objects at present. Only one percent of their methane could decides the global energy problem for centuries or makes the planet climate unbearable.

This work aims to create optimistic and pessimistic (O&P) models of the BS GHSZ:

— Make a better model of GHSZ;

— Create O&P input data sets and run the model twice;

— Assess GHs deposits, GHs structures, methane contents and multiple BSRs;

— Analyze the connection GHSZ — gas seepages (GSs).

Model

The presented GHSZ model is initiated in 1999 and developed consecutively for the projects CESUM-BS, GASHYDAT, CRIMEA, GEO-HYDRATE and ASSEMBLAGE.

The first program (Vassilev, Dimitrov, 2002) implements Gornitz and Fung's (1994) approach additionally accounting for the two main theories of GHs formation — in situ bacterial and pore fluid expulsion. The next version (Poort et al., 2005) adds i) catastrophic flood model (Ryan et al., 1997) — 7,150 ybp (years before present) the Mediterranean flooded the BS — then partially evaporated fresh water lake with a level of 150 m below the present; ii) modeled time period — the Valdai glaciations (duration of 60,000 a — Kutas et al. (1997).

The program results are 19 maps with a horizontal step of 2 km.

Database

It was significantly expanded during the last 5 years projects ASSEMBLAGE, BLASON, CRIMEA, GHOSTDABS and MARGASCH. The database includes:

— Heat flow measurements at 568 stations (Vassilev, Dimitrov, 2002);

— Grid of 2,320 points of bottom water temperature for the last 100 years — the IO-BAS archive;

— Main 17 basin's faults and Quaternary sediment thickness (Finetti et al., 1988);

— BSRs (Popescu et al, 2006 — 5 areas and 11 seismic segments;

— Gas seepages (275 — BlaSON and ASSEMBLAGE projects; 42 — IO-BAS; 1,774 — CRIMEA).

Effect of the fault system

The main faults divide geological volumes with considerably different evolution and parameters. Therefore the separate data gridding at two sides of every fault gives visualization closer to reality than the traditional contouring resulted in anomalies gradation — fig. 1.

The BS heat flow shows a "zebra" type distribution, started and ended (from E to W) with the highest values (50-60 mW/m^2) and with parallel NW-SE belts axes.

O&P assessments

The difference is that the optimistic approach does not use nitrogen data and the normalized gas content consists mainly methane.

Thickness of GHSZ (BSR depth). Figure 2 presents the O&P (A and B) depths of the bases of GHSZs. The value of the deepest GHSZ base is mapped because more than one GHSZ could exist in the cross-section. The general parameters of the GHSZ are given in table 1.

In the optimistic model (O-model — fig. 2A), the larger W BS part has a GHSZ which covers only the half of its area, while the smaller E part is 80-90%

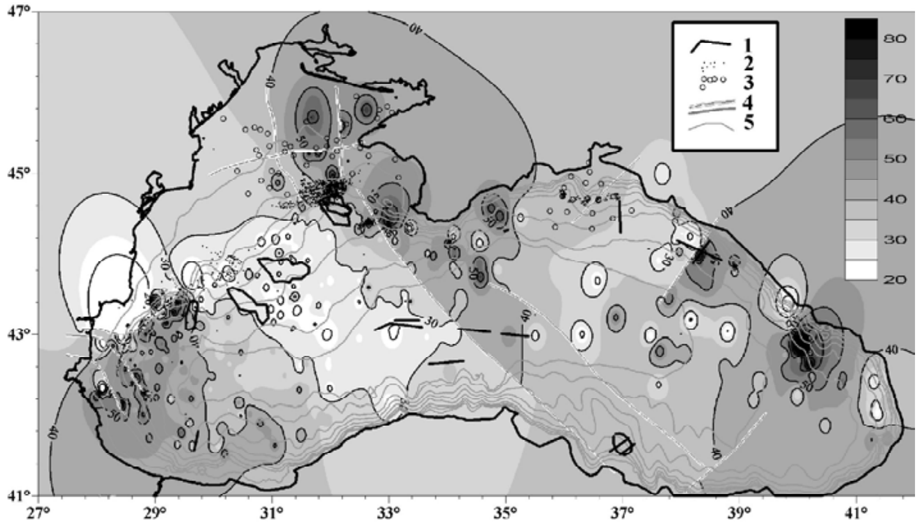

Fig. 1. The Black Sea heat flow (mW/m^2; thin black lines with values) and fault system map
Legend**:** **1.** BSR areas boundaries or seismic lines (thick black lines); **2.** Gas seepages (black points); **3.** Local structures — potential oil and gas fields (black clear circles); **4.** Faults (thick white lines with black axes in this figure and thick 50% black lines on next); **5.** Isobaths (thin 50% black lines). The depths presented by isobaths starting from the coast are 50, 100, 200, 500, 1000, 1500, 2000 and 2100 m.

covered by its GHSZ. The ratio of the E to the W GHSZs areas is approximately 2/3 but their thicknesses ratio is 3/2.

In the P-model (fig. 2B) the main differences are: i) the average and maximum thicknesses are much smaller (tbl. 1: 40 and 160 m against 270 and 780 m); ii) appearance at shallower water depths (in average 500 m against 750 m for the O-model); iii) only half of the E and 1/3 of the W GHSZs are thicker than 50 m; iv) structure I GHs appears in the uppermost part of the cross-section and the upper half of the continental slope.

Number of GHSZs/BSRs. Double, triple and quadruple (and probably quintuple) BSRs are found in the W BS continental slope (Popescu et al., 2006) at water depths of 2-2.3 s TWT.

The maximum obtained number of GHSZs in the cross-sections of the O&P models is respectively 7 and 4 (fig. 3).

The pure GH layer and methane quantity assessment. The maps on fig. 4 visualize the calculated thicknesses of the pure GH layer (if all dispersed GHs are collected together) for O&P models (A and B). The maximum thickness "optimistically predicted" is 165 m. The general description is the same as for GHSZ thickness (fig. 2) but with significantly low magnitudes. The reason is that the average O&P fillings with GHs are 8.5 and 0.9%. The BS methane deposits volume from the P-model is 1.2% from the optimistic.

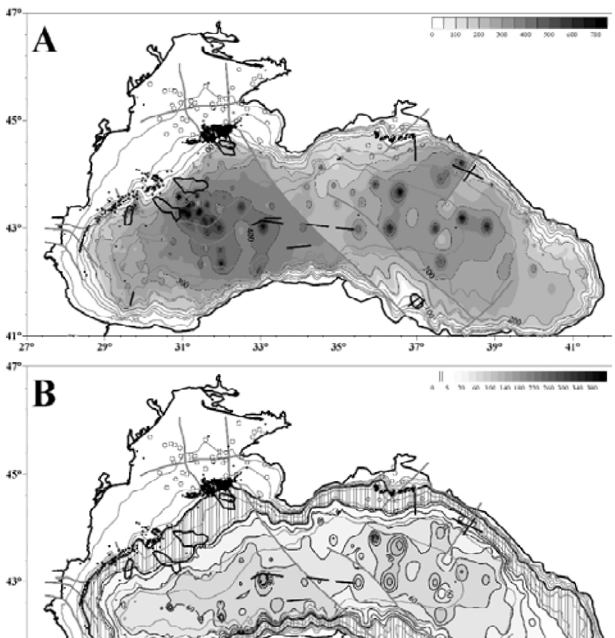

Fig. 2. **A, B** The Black Sea GHSZ thickness (m)
Legend**:** See fig. 1. **A** Optimistic model **B** Pessimistic model (Area with vertical lines is with thickness in the range 0-5 m)

Discussion

The first assessment of the BS GH methane of 6.5.10^3 km^3 (Krason, Ciesnik 1988) is an optimistic processing of pessimistic data — the base of GHSZ is at 322 m, assuming 100% methane.

*Table 1. General parameters of the GHSZs (**z; T; r; n; k** – depth bsf; temperature; density; porosity and conductivity of the base of the GHSZ)*

	***z*, m**	***T*, °C**	**r, t/m^3**	**n**	***k*, W/(m K)**
			Optimistic		
Min	0	7.22	1.69	0.42	1.09
Average	272	19.11	1.80	0.53	1.19
Max	1070	21.50	1.98	0.60	1.34
			Pessimistic		
Min	0	7.09	1.69	0.56	1.09
Average	32	9.61	1.71	0.59	1.11
Max	163	11.72	1.76	0.60	1.15

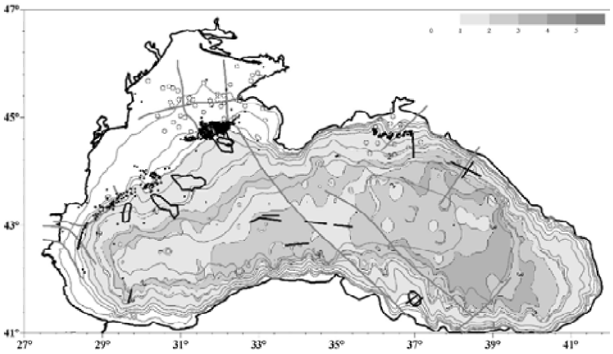

Fig. 3. The Black Sea number of BSRs in the cross-sections (Pessimistic model). The predicted maximum is 4. Optimistic model is not shown, because less than 5% of the zone area shows multiple BSRs. See description in the text.

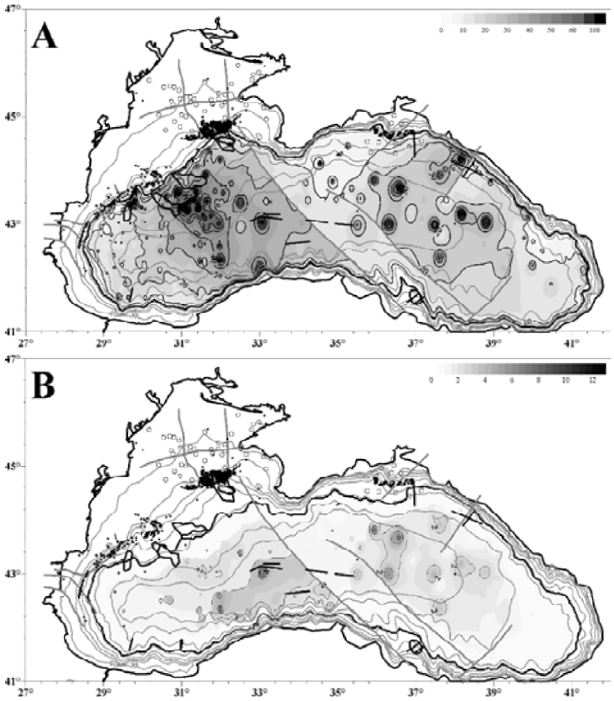

Fig. 4. **A, B** The Black Sea pure GHs thickness (m). "Red" areas: thickness > 50 m.
Legend: See fig. 1 **A** Optimistic model (biogenic HC gases generation) **B** Pessimistic model (thermogenic). The GHSZ boundary is presented with thick black line.

The raw O-estimated of Korsakov et al. (1989) GH methane volume is (20-25).10^3 km^3.

The detail O-model of Vassilev (2002) - (10-50).10^3 km^3 methane, compared with Krason and Ciesnik (1988) gives larger GHSZ area only with 2%, but volume — with 20%. A recalculation of two estimations for the same percentage of prospect area, determines Vassilev as bigger pessimists than Krason and Ciesnik.

The modeling of the regional response of the MHSZ (O-model) to the BS flooding 7,100 years ago suggests a drastic reduction of the reservoir volume (15-62%) (Poort et al., 2005) after the LGM, but at present GHs dissociation is started only at minimum water depths where intensive GSs are observed.

The maps (fig. 2-4) show a zone of GSs in the NW BS, started from the GHSZ and with width proportional to the corresponding shelf width. The "temperature engine" of the BS currents is the widest NW shelf where the seasons and climate change form the main water volume with contrast temperatures. This is the area where we expect the full and low tides of GHSZ. The most scalable methane seepages and wide areas with BSRs (Lüdmann et al., 2004) are found there.

Conclusions

GENERAL: The slope and abyssal show O&P "polarity" and respectively correspond to O&P models but there is no reasons for these two GHSZs to exist simultaneously in a cross section. The BS GHs deposits volume is estimated to 6,470 and 114 km^3, and methane of 44,000 and 500 km^3 SPT.
EXCEPTIONS: The expeditions from the last 25 years show pessimistic results searching for GHs on

the bigger part of the optimistic area (~95%). Quite the opposite, in the pessimistic abyssal area are found enough optimistic objects (MVs, fault zones) shown complex GHs structures and strong methane emissions.

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Споделен оптимистично-песимистичен модел на газовите хидрати в Черно море

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Абстракт. Моделирана е зоната на стабилност на газовите хидрати (ЗСГХ) в Черно море (ЧМ). Предимствата на модела включват: хоризонтална и вертикална стъпки от 2 km и 0,1 m; разделяне на басейна на геоложки провинции от основни разломи; 3D входни параметри — соленост на порови води и сложни газови смеси, както и едностъпални модели на изменението на климата и морското ниво. Главни задачи са изучаване на ЗСГХ и по-специално на кратните BSRs; оценка на потенциалните запаси от метан, като енергиен източник и кратка дискусия върху спецификата на връзката ГХ и газови сипове в ЧМ.