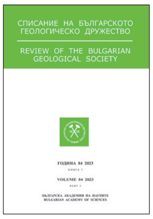
СПИСАНИЕ НА БЪЛГАРСКОТО ГЕОЛОГИЧЕСКО ДРУЖЕСТВО,
год. 84, кн. 3, 2023, с. 223–226

REVIEW OF THE BULGARIAN GEOLOGICAL SOCIETY,
vol. 84, part 3, 2023, p. 223–226



Национална конференция с международно участие „ГЕОНАУКИ 2023“
National Conference with International Participation “GEOSCIENCES 2023”

Heat flow over a gas hydrate deposit in the Danube paleodelta: cruise MN249, 10-20/09/2023

Atanas Vasilev, Petar Petsinski, Raina Hristova, Rosica Pehlivanova

Institute of Oceanology, Bulgarian Academy of Sciences, PO Box 152, Varna 9000; E-mail: gasberg@io-bas.bg

Топлинен поток над находище на газови хидрати в палеоделтата на Дунав: експедиция MN249, 10–20/09/2023

Атанас Василев, Петър Пецински, Райна Христова, Росица Пехливанова

Abstract. This work presents results from the first purposeful *in situ* temperature measurements in seafloor sediments above a scalable gas hydrate deposit in the deep-water Danube paleodelta. Temperatures and temperature gradients with accuracy 5 mK and sensitivity 1 mK are measured with 3 MTL loggers with clamps (Antares GmbH) welded to a gravity corer with length of 6 m, outer diameter of 130 mm and weight ~300 kg. During the cruise MN249 on board of the Romanian R/V Mare Nigrum 10-20/10/2023, the gravity corer was deployed on 23 stations with successful temperature measurements and >3 m sediments lifting on 11 stations. Temperature gradients above the gas hydrate deposit (BSR area) are in ~20–50 mK/m when the background is ~30 mK/m. Additional data needed to determine the effects from the 2 main factors formatting temperature gradients – gas hydrate masses and sedimentation rates.

Keywords: heat flow, gas hydrates, paleodelta, Danube, Black Sea.

Introduction

The aim of the presented temperature (T) measurements is to cross with a line of heat flow (HF) stations the deep-water South BSR area/gas hydrate deposit (GHD) in the Danube Fan. This work is a part of a study of the possibility marine GHD to create measurable heat anomalies in the near bottom sediments – a main hypothesis of the Bulgarian Science Fund project GEOHydrate.

The area of interest presented in Fig. 1, is studied during the implementation of a number of International projects (Popescu et al., 2006; Vassilev, 2006; Bialas et al., 2020; Riedel et al., 2021b).

Method and equipment

Heat flow measurements during the cruise DOORS2 Leg2 on board of the Romanian research vessel RV Mare Nigrum 11–20 Sep. 2023 are conducted with 3 autonomous temperature (T) loggers 1854C in clamps (Antares GmbH, Germany; www.antares-geo.com) welded in the down half of the barrel of a gravity corer (GC) with distances between them of 1 m (error 0.4%). In a cross section plane the distance between clamps/loggers is at angles of 120° to insure measurements in undisturbed from down loggers penetration sediments. The clamps are made of Stainless steel 316. Loggers’ numbers 864, 865 and 866 are in the Down, Middle and Upper clamps (D, M, U in the text and file names) and measure temperature at depths of ~4.50, ~3.50 and ~2.50 m from the upper barrel welding (base of the weights). Corresponding down clamps bases are at distances 451.2, 351.2 and 250.8 cm from the same upper barrel welding. Loggers tips are 28 mm in front of the clamps bases. Thermistors are 3 mm

https://doi.org/10.52215/rev.bgs.2023.84.3.223

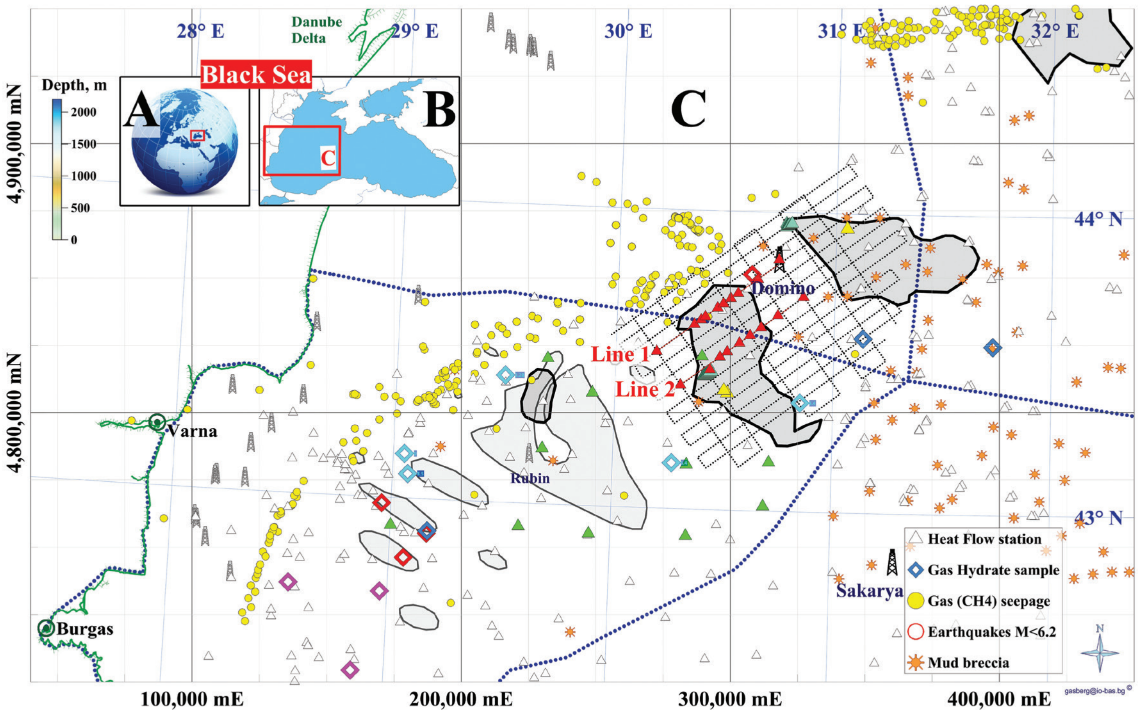


Fig. 1. Heat flow stations above gas hydrate deposit (BSR area) grouped in 2 lines with numbers increasing from left to right (Table 1). Sakarya, TR and Domino, RO are the biggest conventional gas fields in the Black Sea with ~450 and ~90 bcm gas reserves. The different colors of the map symbols for heat flow stations and gas hydrates in sediments samples show results from different cruises.

from the loggers tips or 25 mm out from the clamps bases. Therefore, T-measurements at each station are at distances from the maximum reached depth under the seafloor (sample length) of 39.8, 139.8 and 240.2 cm.

An Infrared camera for thermal analyses FLIR ONEpro was used to check 4 samples immediately after their lifting on board for negative T-anomalies produced from the gas hydrates (GHs) melting. T-anomalies and signs from GHs were not obtained.

Results

Three speeds determine the number of deployments: 1) GC speed to the seafloor of ~5 m/s; 2) lifting speed of ~0.5 m/s; 3) vessel speed between stations of ~15 km/h. The vessel is without thrusters and the drift from the wind, waves and currents create angle from the vertical of the GC rope of 15–30° for the most of deployment time.

There were 2 unsuccessful GC stations on 12 September. which cannot lift sediment samples on board. Both attempts were at the shelf boundary and the grabber shows massive broken shells deposits on the seafloor.

Ten from totally 23 GC deployments lift sediments on board. The short penetrations in the bottom of two of them make impossible the HF measurements with 3 loggers (HF1-2: 0.80 m; HF1-5: 1.62 m). The rest 8 deployments sample lengths are in 3.00–3.90 m (average 3.42 m). In two deployment, the GC was lifted above the water with crown up and weights down fixed to the rope from other part of rope (HF1-9 and HF3-2). The measured temperatures at station HF3-2 show that the problem with the rope and the sediments lost appears after a successful process of T-measurements in sediments and therefore even without lifted sediment sample on board it is a successful HF station.

From the 9 successful HF stations, one is at a water depth 689 m out of the target BSR area, 6 are from the planned Line 1 of 10 HF stations, 1 is from the planned Line 2 of 9 HF stations and 1 from the 9 deployments for GH study. Additional data for line 1 are from the mentioned above stations HF1-2 and HF1-5.

Therefore, the successful HF deployments are 9 from 23 (39%), 2 other deployments give additional information and 8 of them are in the BSR area (7 from Line 1 and 1 from Line 2) and 3 outside the BSR area. Table 1 presents the heat flow and sediment sampling metadata and preliminary result from T-measurements in sediments in the column “Core/T, m/°C”.

Table 1. List of heat flow (HF) stations/gravity corer (GC) samples

Station	Latitude, N	Longitude E	Water depth, m	Core, m	z_U, m	T_U, °C	z_M, m	T_M, °C	z_D, m	T_D, °C	G_{MU}, mK/m	G_{DM}, mK/m	G_{DU}, mK/m
HF0	43°40.389'	30°21.084'	689	3.90	1.40	9.001	2.50	9.027	3.50	9.052	26	25	25.5
HF1-1	43°31.474'	30°11.210'	1044	3.57	1.17	9.085	2.17	9.118	3.17	9.147	33	29	31
HF1-2	43°37.186'	30°21.330'	800	*0.80*	*w*	*8.956*	*w*	*8.964*	*0.40*	*8.967*	*8*	*3*	*5.5*
HF1-3	43°38.165'	30°23.036'	774	3.08	0.68	9.001	1.68	9.026	2.68	9.053	25	27	26
HF1-4	43°38.743'	30°24.337'	855	3.71	1.31	9.055	2.31	9.087	3.31	9.116	32	29	30.5
HF1-5	43°40.645'	30°27.667'	986	*1.62*	*w*	*8.956*	*0.22*	*8.964*	*1.22*	*9.116*	*8*	*152*	*80*
HF1-6	43°41.409'	30°29.255'	928	3.00	0.60	9.025	1.60	9.055	2.60	9.080	30	25	27.5
HF1-7	43°42.503'	30°31.175'	1002	3.36	0.96	9.097	1.96	9.132	2.96	9.161	35	29	32
HF1-8	43°43.711'	30°33.148'	859	3.38	0.98	9.009	1.98	9.029	2.98	9.052	20	23	21.5
HF2-6	43°35.145'	30°31.196'	1153	3.38	0.98	9.091	1.98	9.126	2.98	9.150	35	24	29.5
HF3-2	43°25.453'	29°34.304'	1116	0	x_U	8.992	x_M	9.037	x_D	9.089	45	52	48.5

Note: stations with unsuccessful deployments are not shown in the table. *Legend*: Logger place on the GC barrel: U, up; M, middle; D, down; z, depth in sediments; T, temperature; G, temperature gradient; w, logger measurement in the near bottom water.

Measurements of nine sediment samples in the Technical University Gabrovo with TEMPOS thermal analyzer (METER Group, Inc.) show thermal conductivity and resistivity coefficients in the ranges 0.6017–0.8787 W/m.K and 1.14–1.66 °C.m/W (T ~18 °C, S_{yx} = 0.0004–0.0007).

Discussion

Probably the unsuccessful GC deployments resulted of the bad hydrodynamic stability of the gravity corer at the high speed during the "free falls" – a complex outcome of:

- the bad weather (NE wind, waves, currents);
- vessel drift because (thrusters absent);
- outside asymmetrically welded on the GC barrel 3 clamps with T-loggers;
- construction of the GC (not fully open top on the GC barrel; GC wings absent);
- construction of the GC "crown" (the sample "catcher"/"the orange" is not outside the internal crown diameter; the crown is not fixed to the GC barrel and its vertical axis could change in 5°; the internal "crown" and the internal plastic slaves diameters are equal);
- during a GC "free fall" the rope every few seconds escapes the winch with a hit from the separation with the closest parts of the rope on the winch.

Unsuccessful search for GHs is connected additionally with the lack of possibility on board *RV Mare Nigrum* to register gas seeps in the water volume and spots on the bottom with contrast acoustical back scatter. The problem of the most of the archive data is the low accuracy of the seeps and stations coordinates.

The new temperature and heat flow data is the first crossing a GHD and therefore available for 2D geothermal interpretation. A preliminary analysis of the small negative and significant positive anomalies above the GHD in the BEEZ based on Vasilev (2015) shows that the process of the total GH mass growth is predominant over most of the GHD area and that exist areas with a high GH saturation and even with porosity clogging.

Conclusions

Temperature gradients above the gas hydrate deposit (BSR area) are in ~20–50 mK/m when the background is ~25 mK/m.

The measurements are proved of the complex temperature and heat flow fields above gas hydrate deposits and the existence of measurable positive and negative anomalies (Vasilev, 2015). These anomalies will be interpreted with inverse problem methods of geothermy to reconstruct the gas hydrate deposit formation process. GEOHydrate project results are scientific base a future Bulgarian Gas Hydrate Program.

The measured temperature values are in good agreement with measurements in the area (Riedel, Bialas, Haeckel, 2020; Riedel et al., 2021a) but our thermal conductivity results show that the assumed value from Riedel, Bialas, Haeckel (2020) of 1.05 W/m.K is increased with ~30%.

Additional data needed to determine the effect only from formation of gas hydrate masses: sea level and climate changes, sedimentation rates, cross-section distribution of lithology, salinity and gas contents. Crucial for the GH development in the BEEZ is the receiving of drilling data to check the results from geophysical interpretations and to provide accurate data for detail production models.

Acknowledgements: This work was supported by: Bulgarian Science Fund project KP-06-OPR04/7 GEOHydrate "Geothermal evolution of marine gas hydrate deposits – Danube paleodelta, Black Sea" (2018-2023);European Commission project 101000518 DOORS: Developing Optimal and Open Research Support for the Black Sea (2021–2025).

References

Bialas, J., T. Bohlen, A. Dannowski, G. Eisenberg-Klein, L. Gassner, R. Gehrmann, K. Heeschen, S. Hölz, M. Jegen, I. Klaucke, M. Krieger, J. Mann, C. Müller, J. Prüßmann, J. Schicks, E. Schünemann, K. Schwalenberg, M. Sommer, P. L. Smilde, E. Spangenberg, H. Trappe, T. Zander. 2020. Joint interpretation of geophysical field experiments in the Danube deep-sea fan, Black Sea. – *Mar. Pet. Geol.*, *121*, 104551; https://doi.org/10.1016/j.marpetgeo.2020.104551.

Popescu, I., M. de Batist, G. Lericolais, H. Nouzé, J. Poort, N. Panin, W. Versteeg, H. Gillet. 2006. Multiple bottom-simulating reflections in the Black Sea: Potential proxies of past climate conditions. – *Mar. Geol.*, *227*, 163–176; https://doi.org/10.1016/j.margeo.2005.12.006.

Riedel, M., J. Bialas, M. Haeckel, 2020. Heat flow data during Maria S. Merian cruise MSM34/2. PANGAEA; https://doi.org/10.1594/PANGAEA.912221.

Riedel, M., J. Bialas, H. Villinger, T. Pape, M. Haeckel, G. Bohrmann. 2021a. Heat flow measurements at the Danube Deep-Sea Fan, Western Black Sea. – *Geosciences*, *11*, 240; https://doi.org/10.3390/geosciences11060240.

Riedel, M., T. Freudenthal, J. Bialas, C. Papenberg, M. Haeckel, M. Bergenthal, T. Pape, G. Bohrmann. 2021b. In-situ borehole temperature measurements confirm dynamics of the gas hydrate stability zone at the upper Danube deep sea fan, Black Sea. – *Earth Planet. Sci. Lett.*, *563*, 116869; https://doi.org/10.1016/j.epsl.2021.116869.

Vassilev, A. 2006. Optimistic and pessimistic model assessments of the Black Sea gas hydrates. – *C. R. Acad. Bulg. Sci.*, *59*, 543–550.

Vasilev, A. 2015. Geothermal evolution of gas hydrate deposits: BEEZ in the Black Sea. – *C. R. Acad. Bulg. Sci.*, *68*, 9, 1135–1144.