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NATURAL AND TECHNOGENIC CATASTROPHIC BLOWOUTS AND GAS EXPLOSIONS IN THE ARCTIC AND OTHER REGIONS (ONSHORE AND OFFSHORE)

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Summary. The authors created the geoinformation system "The Arctic and World Ocean" (GIS "AWO") with a huge amount of constantly updated geospatial data, allowing a comprehensive analysis of various natural and man-made phenomenon directly or indirectly related to the degassing of the Earth. In the Arctic, a large amount of expeditionary work has been carried out with a wide range of geological and geophysical methods, which is analyzed in conjunction with remote sensing data from space and using unmanned aerial vehicles. This made it possible to obtain fundamentally new information about the gas-dynamic mechanisms of dangerous processes in the permafrost, including catastrophic gas blowouts and explosions with the formation of giant craters, and large mud volcanic structures. In total in the north of Western Siberia about 18.5 thousand potentially dangerous objects were identified, including 4.5 thousand intensive gas blowout zones on the bottoms of thermokarst lakes, as a result of which underwater craters-pockmarks are formed. This gave possibility to identify the most dangerous gas-explosive zones in the north of Western Siberia, mainly located in the eastern part of the Yamal peninsula. Taking into account previously discovered mud volcanoes on the land of Alaska, Greenland and Iceland, as well as on the bottom of the Beaufort, Kara and Norwegian seas, it can be argued that there is a Circum-Arctic mud volcanic province.

Introduction

In recent decades due to the global warming attention has significantly increased to the study of various processes of greenhouse gas emissions into the atmosphere and changes in their concentration in the atmosphere (Jackson et al., 2020; Report…, 2022; State…, 2023). The concentration of greenhouse gases grow rapidly, which causes the intensification of greenhouse effect, melting of glaciers and rising of the World Ocean level up to 4.6 mm per year in last decade (State…, 2023).

Among the causes of natural and anthropogenic emissions of greenhouse gases, where methane is one of the most dangerous, deep and near-surface processes, only a part of which appears on the Earth surface, including the bottom of the World Ocean, as widespread seeps of underground fluids, mostly mixtures of hydrocarbon gases, are of particular importance (Hovland et al., 1984; Judd, Hovland, 2007; Bogoyavlensky, 2012; Etiope, 2015; Guliyev et al., 2018; Bogoyavlensky et al., 2020b; Kerimov, Abdullayeva, 2022). Over the half-century history of studying submarine gas emission from the bottom of various parts of the World Ocean, hundreds of papers have been published (Hovland et al., 1984; Judd, Hovland, 2007; Sergienko et al., 2012; Etiope, 2015; Paul et al., 2015; Andreassen et al., 2017; Guliyev et al., 2018; Mironyuk et al., 2019; Bogoyavlensky et al., 2021d; Bogoyavlensky et al., 2022a; Kerimov, Abdullayeva, 2022;Bogoyavlensky et al., 2022c; Kishankov et al., 2022; Bogoyavlensky, Kishankov, 2023; Sokolov et al., 2023).

Massive gas blowouts causing the formation of large and giant craters (tens or even hundreds of meters in diameter) are widely spread both onshore and offshore (Hovland et al., 1984; Judd, Hovland, 2007; Andreassen et al, 2017; Bogoyavlensky, 2020; Bogoyavlensky et al., 2020b; Bogoyavlensky, 2021; Bogoyavlensky et al., 2021a; Bogoyavlensky et al., 2021b; Bogoyavlensky et al., 2022a).

Moreover some of the papers are dedicated to the study of active degassing from the bottoms of the Arctic thermokarst lakes with continuous or sporadic taliks (Kruglikov, Kuzin, 1973; Walter et al., 2006; Badu, 2018; Bogoyavlensky et al., 2018; Bogoyavlensky et al., 2020a; Bogoyavlensky, 2021; Bogoyavlensky et al., 2021c; Bogoyavlensky et al., 2021b). Many of these lakes have bubbles of frozen gas in their ice cover and numerous craters (pockmarks) on the bottom.

One of the most dangerous processes of the Earth degassing is the formation of mud volcanoes (MVs) (Kopf, 2002; Aliyev et al., 2015; Bogoyavlensky, Bogoyavlensky, 2022; Yusubov, Guliyev, 2022). The global research of Azerbaijani scientists (Aliyev et al., 2015) gives the information about 2505 MVs, the most of which (1401 or 55.9%) were discovered on the bottom of the World Ocean. The presence of MVs is one of the prospecting indicators for oil and gas, wherein they give significant information of sedimentary cover lithology. The gas erupted from MVs frequently explodes and self-ignites. The height of burning flares above MVs can reach hundreds of meters, the measured height is up to 500 m (Aliyev et al., 2015; Yusubov, Guliyev, 2022). In 1940 the height on the mud volcanic island Khare-Zirya (Bulla) was even 1200 m (Yusubov, Guliyev, 2022, p. 18).

In the Circum-Arctic region MVs were found onshore, in Alaska, Greenland and Iceland, and offshore, in the Beaufort, Kara, Norwegian and Barents seas (Haakon Mosby and Borealis) (Paull et al., 2015; Serov et al., 2015; Mironyuk et al., 2019; Bogoyavlensky, Bogoyavlensky, 2022).

Oil and Gas Research Institute of the Russian Academy of Sciences (OGRI RAS) studies the processes of the Earth degassing in their various geological forms and appearances for more than 30 years, the results were reported on many conferences, including (Earth degassing …, 2002). The studies of the authors are not limited geographically by the north latitudes of the Arctic regions with cryolithogenesis, but expand to other parts of the World related to different forms of natural and technogenic degassing, including mud volcanism, gas hydrate dissociation and behind-the-casing flows (Bogoyavlensky et al., 2018; Bogoyavlensky, 2020; Bogoyavlensky et al., 2020a; Bogoyavlensky et al., 2020b; Bogoyavlensky, 2021; Bogoyavlensky et al., 2021b; Bogoyavlensky et al., 2021c; Bogoyavlensky, Bogoyavlensky, 2022; Bogoyavlensky et al., 2022a; Bogoyavlensky et al., 2022b).

The main goal of this work is to comprehensively analyze the insufficiently studied dangerous endogenous processes of generation, accumulation and migration of gaseous hydrocarbons up to their discharges on the Earth surface and the bottom of the World Ocean in the form of permanent, pulsating and/or periodic powerful impulse (explosive) degassing of the subsoil, often leading to catastrophic changes in terrain, including the formation of giant craters and landslides.

Methods

Over the past decade, the authors have annually carried out expeditionary work in the Arctic to study a new dangerous phenomenon associated with the processes of powerful emissions, self-ignition and explosions of gas on land, as well as from the bottoms of thermokarst lakes, rivers and coastal zones of the Kara Sea (Bogoyavlensky et al., 2018; Bogoyavlensky, 2020; Bogoyavlensky et al., 2020a; Bogoyavlensky et al., 2020b; Bogoyavlensky, 2021; Bogoyavlensky et al., 2021b; Bogoyavlensky et al., 2021c; Bogoyavlensky et al., 2021d; Bogoyavlensky, Bogoyavlensky, 2022; Bogoyavlensky et al., 2022a). Also expeditions have been carried out in the Azov and Black seas, Tatarstan, Tula, Nizhniy Novgorod and Saratov regions. Field studies in the Arctic involves a wide set of geological and geophysical methods including seismic prospecting (2D-4D), ground penetrating radar studies, echo sounding, shallow drilling, gas, water and ground sampling for geochemical analysis.

In all of the studied regions the unmanned aerial vehicles (UAV) are used with great efficiency. They give possibility to receive fundamentally new data on unique objects. The photogrammetric processing of data from UAV Mavic Pro and Mavic Mini (DJI, China) in Agisoft Metashape («Geoscan», Russia) and ArcGIS (ESRI, USA) software allows building 3D-4D models of the investigated objects available for additional study in virtual reality (Bogoyavlensky, 2021; Bogoyavlensky et al., 2021b; Bogoyavlensky et al., 2021c). The scaled layouts of digital models using additive techno logy are also made on a 3D printer.

Particular information is Earth remote sensing (RS) data from space, which in many cases provide an opportunity for a retrospective analysis of the features of potentially dangerous objects formation, as well as catastrophic events that have occurred since the first large-scale satellite imagery started in the early 1960s. The ArcticDEM digital elevation models are widely used allowing monitoring the changes of terrain, especially in places of catastrophic gas blowouts and explosions (Bogoyavlensky, 2021; Bogoyavlensky et al., 2021b; Bogoyavlensky et al., 2021c).

In the study of methane concentration in the atmosphere we use the TROPOMI spectrometer data from Sentinel-5P satellite of the European Space Agency Copernicus program, held for the “Global monitoring for Environment and Security of Earth and its atmosphere” (GMES) (Bogoyavlensky et al., 2020b; Bogoyavlensky et al., 2022b).

The Arctic and World Ocean (AWO) GIS was created based on ArcGIS software in 2008 (Bogoyavlensky et al., 2018; Bogoyavlensky, 2020; Bogoyavlensky et al., 2020a; Bogoyavlensky et al., 2020b; Bogoyavlensky, 2021; Bogoyavlensky et al., 2021b; Bogoyavlensky et al., 2021c; Bogoyavlensky, Bogoyavlensky, 2022; Bogoyavlensky et al., 2022a). The geospatial data including the authors' and other scientists' information is uploading in it to form continuously developing and systematized data arrays (Big Data), available for complex analysis. In particular, the "AWO" GIS contains data on natural hazards like earthquakes, stratovolcanoes, MVs, meteorite craters, craters of gas blowouts, oil and gas seeps, gas hydrates, pingos and perennial heaving mounds (PHMs), thermokarst lakes with gas blowouts craters (TLGBCs) on the bottoms, sea ice, catastrophes while drilling and transportation of oil and gas, and others (Fig. 1). An integrated approach to the study of various geospatial data makes it possible to reveal hidden trigger relationships that have direct or indirect impact on the degassing of the Earth and other processes.

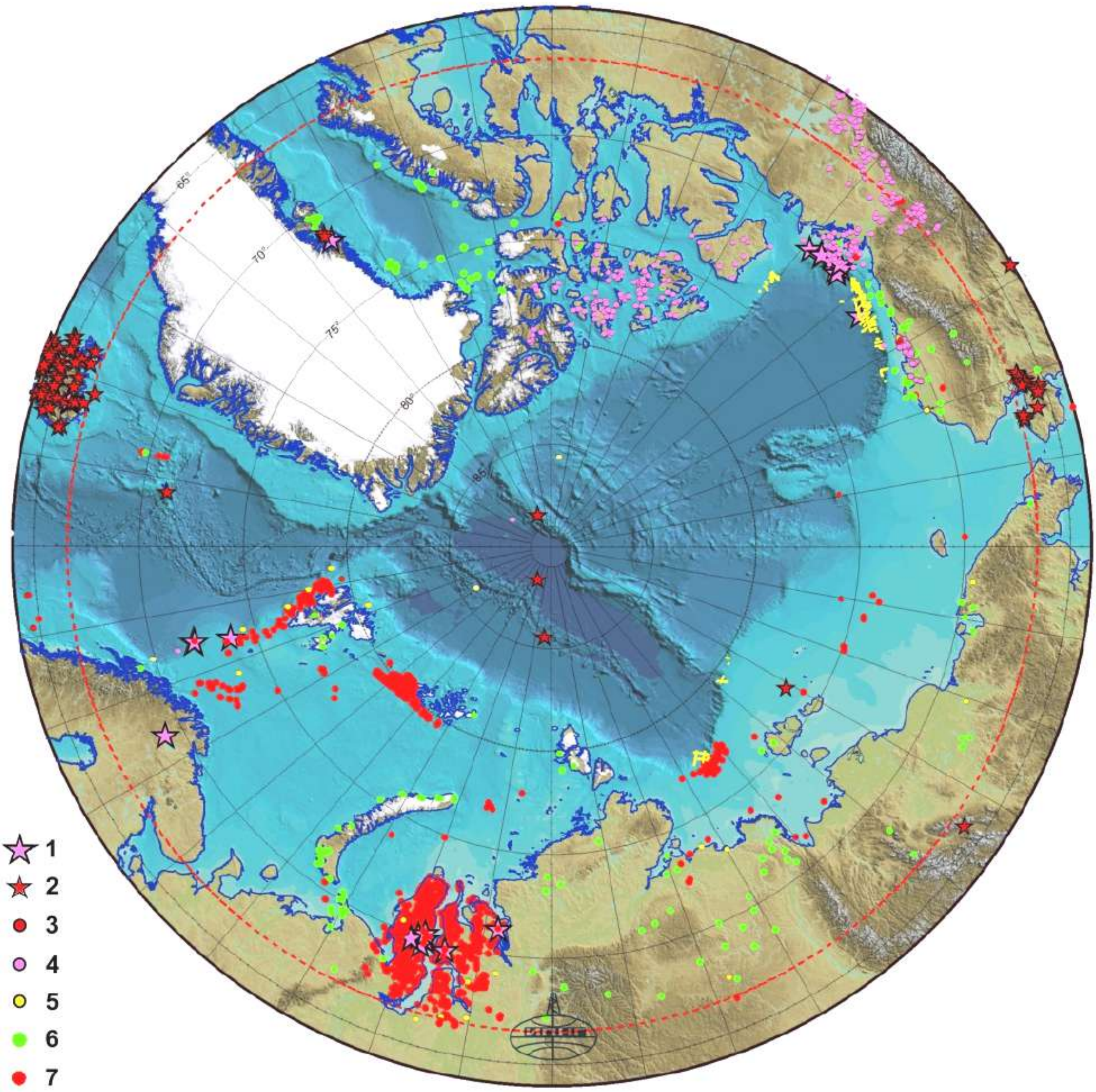

Fig. 1. The cartographic scheme of oil and gas shows onshore and offshore Arctic region (version-23, 2023). Legend: 1– MVs; 2 – stratovolcanoes; 3 – gas hydrates (proven); 4 – gas hydrates based on log data; 5 – gas hydrates based on BSR; 6 – gas seeps; 7 – oil seeps

Results and discussion

1. Explosive degassing in the Arctic

Since 2014 the authors study regions and objects of massive (explosive) gas blowouts with formation of craters. In "AWO" GIS there are about 20 of them analyzed in different degrees of detail (Fig. 2). Some of them (C1, C2, C9, C17 and others, as mentioned in "AWO" GIS) formed near the infrastructure of the Bovanenkovo oil and gas condensate field on the Yamal Peninsula. In all three eyewitness cases (C3, C11 and C12) there was self-ignition and explosion of gas (Bogoyavlensky et al., 2018; Bogoyavlensky, 2020; Bogoyavlensky et al., 2020a; Bogoyavlensky et al., 2020b; Bogoyavlensky, 2021; Bogoyavlensky et al., 2021b; Bogoyavlensky et al., 2021c; Bogoyavlensky, Bogoyavlensky, 2022; Bogoyavlensky et al., 2022b). In our opinion, confirmed by a number of facts, these self-ignition and explosion have happened due to electrostatic discharges (Bogoyavlensky, 2020; Bogoyavlensky, 2021). We think that these processes are the main triggers of gas self-ignition during the MVs eruptions in the Azov and Black seas region and in other places (Bogoyavlensky, Bogoyavlensky, 2022).

The results of the Bovanenkovo C17 object studies, on which in May-June 2020 a powerful gas blowout occurred with the formation of a giant crater are Of particular interest (see Fig. 2 - C). As a result of photogrammetric processing of pictures taken during the expedition from the DJI Mavic Pro UAV at two height levels (including the photos from inside the crater), a digital 3D model was built in Agisoft Metashape software. Based on this model, a high-precision 3D plastic model on a scale of 1:800 was created using additive technology on a 3D printer (Fig. 3). The use of new technologies of "Industry 4.0" made it possible for the first time to create a high-precision digital twin of the underground cavity and gas blowout crater of the unique Bovanenkovo C17 object, which allows surveying the underground space in virtual reality.

As a result of the gas blowout and explosion study authors have no doubts that explosions in the Arctic were preceded by the formation of giant gas-saturated cavities in the ground ice (real thermokarst), the upper parts of which, under the action of a gas-dynamic mechanism, formed PHMs on the Earth surface (Bogoyavlensky, 2020; Bogoyavlensky, 2021). At abnormal gas pressures in the cavities, which significantly exceed the lithostatic pressure and the elastic-strength characteristics of frozen rocks, explosive destruction of the tops of the PHMs occurs with the formation of giant craters. In particular, during the formation of the C1 crater the pressure of gas exceeds the lithostatic more than 9 times (assuming the density of frozen rocks in the upper part of the section as 1.7 g/cm^3) (Bogoyavlensky, Garagash, 2015; Bogoyavlensky, 2020; Bogoyavlensky, 2021).

Fig. 2. Giant cavities in ground ice after the blowouts and explosions of gas on the Yamal Peninsula. A - C1, B - C12, C - C17 (photos by V.I.Bogoyavlensky, 2014, 2015 and 2020)

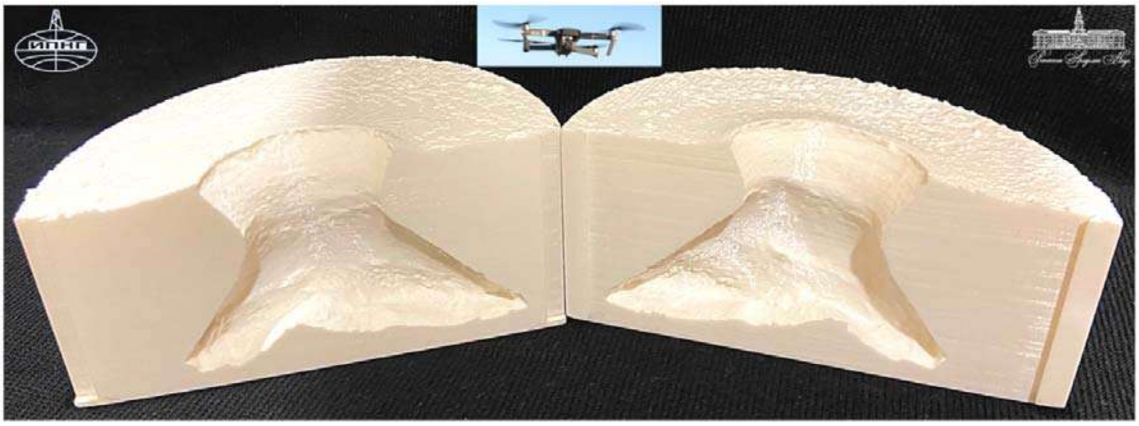

Fig. 3. Physical 3D-model of the underground cavity and gas blowout crater on the Bovanenkovo C17 object

With the use of RS data, including winter satellite images and ArcticDEM, more than 14000 PHMs were detected in the north of Western Siberia. In a comprehensive analysis of the detected objects of powerful gas blowouts, it was found that the greatest danger is presented by PHMs, located not in khasyreys, like classic frost mounds - bulgunnyakhs (closed systems), but by PHMs with an open inflow of underground gas-saturated fluids (gas in free and/or dissolved states), usually located on the hills and slopes of sea terraces, as well as in the channels and floodplains of rivers (Bogoyavlensky, 2020; Bogoyavlensky, 2021). Such PHMs are formed by the gas-dynamic mechanism.

2. Degassing from the bottoms of thermokarst lakes

More than half a century ago, in the north of Western Siberia, near the Urengoy oil and gas condensate field, thermokarst lakes with gas blowout craters (TLGBC) at the bottoms were discovered for the first time, while geochemical studies of methane in them showed its deep genesis (Kruglikov, Kuzin, 1973). The authors continued the search and study of TLGBCs in the last decade using RS data from space and during numerous helicopter flights over the Yamal Peninsula (Bogoyavlensky et al., 2020a; Bogoyavlensky et al., 2020b; Bogoyavlensky et al., 2021b; Bogoyavlensky et al., 2021c; Bogoyavlensky et al., 2022b).

Figure 4-A shows the WorldView-2 satellite image (July 20, 2022, ultra-high resolution 30-50 cm) of the previously unnamed TLGBC discovered in the central part of Yamal 60 m north of Lake Tobato and named by us Tobato-Severnoye (70.697° N, 71.0234° E). This lake has dimensions of 320x500 m, and the diameters of the largest craters at its bottom reach 19 m (not counting the sizes of the merged craters). Such objects have also been found on a number of neighboring lakes, including Tobato. It should be noted that the number of pockmark craters at the bottom of some of the lakes is many hundreds, and possibly even thousands. The visible by the resolution of WorldView-2 satellite image number of craters on the bottom of Tobato-Severnoye lake (Fig. 4-A) is about 350.

It should be noted that at the bottoms of the TLGBCs, small accumulative uplifts (parapets) are observed around the recently formed craters, which are made of bottom sediments ejected by gas (for example, see Fig. 4-A). Different-temporal satellite images show that over the course of several years, loose accumulative deposits of parapets are washed out and slide inward, while the diameters of the craters increase, and the depths decrease.

As a result of the studies in the north of Western Siberia (the Yamal, Gydansky and Tazovsky peninsulas), according to RS data from space, more than 4.4 thousands of degassing zones from TLGBCs, as well as rivers and coastal zones of the Kara Sea, were discovered and shown on Fig. 4-B. Based on a comprehensive analysis of the TROPOMI spectrometer data (Sentinel-5P satellite), an unambiguous regional relationship between the identified degassing zones and areas of increased methane concentration in the atmosphere was established (Bogoyavlensky et al., 2020b).

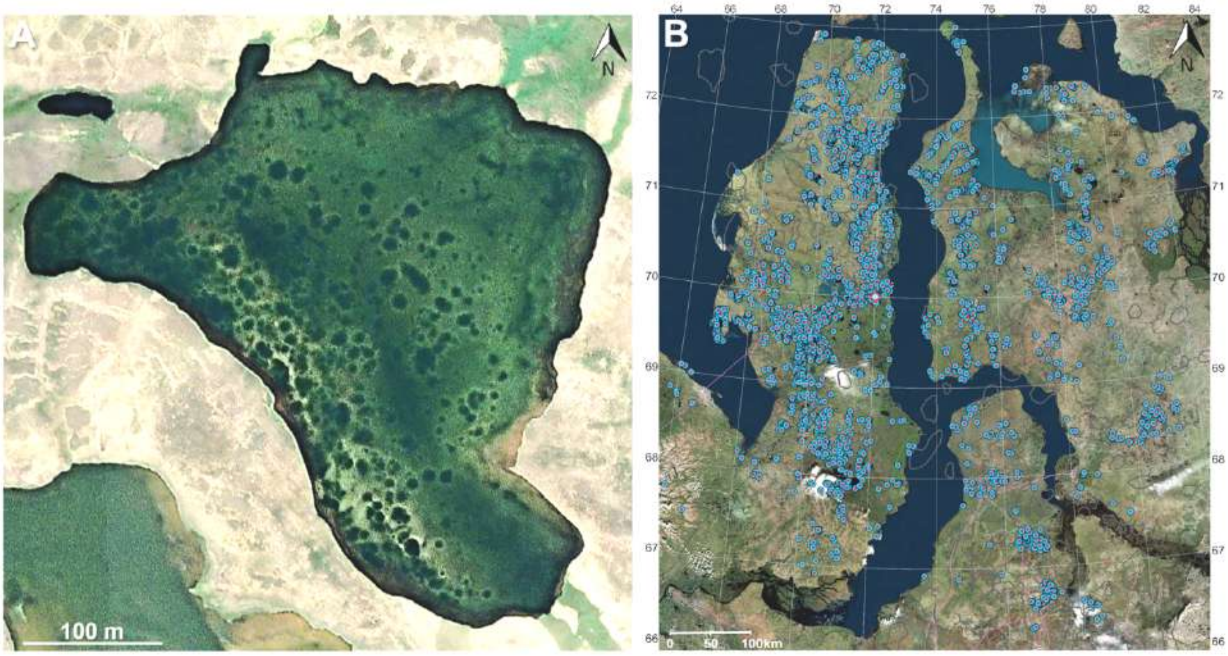

Fig. 4. WorldView-2 satellite image of the Tobato-Severnoye lake with gas blowout craters on the bottom (A) and cartographic scheme of TLGBC distribution in the north of Western Siberia (B)

3. Mud volcanism

On a number of discovered objects of intensive degassing on the Yamal Peninsula, the authors substantiate the mud volcanic mechanism of eruptions. According to GOST R 57123-2016 (GOST…, 2016), an MV is "a geological formation that constantly or periodically erupts mud and gases", usually confined to faults.

Periodical eruptions of underground fluids were detected and explored on TLGBC Otkrytiye (Fig. 5-A) with size of 440x750 m, situated in the central part of the Yamal Peninsula (70.006° N, 72.01° E). In 2019 there was a powerful gas blowout (pneumatic explosion) on a crater C (see Fig. 5-A), which broke the ice of 1.5 m thickness and spread the ice boulders on more than 50 m distance (Bogoyavlensky et al., 2020a). The analysis of satellite images from Sentinel-2 and Landsat-8 during the melting of ice (May-June) proved that the blowouts had occurred from the same crater C during winters of 2016-2019. But in 2020-2023 there were no witnesses of significant gas blowouts.

According to RS data and on the basis of expeditionary work at the TLGBC Otkrytiye, four neighboring large craters (diameter from 30 to 40 m) were found, located along the predicted deep submeridional fault (azimuth 345°), as well as several craters of smaller diameter up to 4-6 m (Fig.5-B). Conducting expeditionary studies using echo sounding and ground penetrating radar made it possible to detect landslide bodies on the walls of the craters and the bottom of the lake, formed by presumably loamy rock erupted from vents. In connection with the foregoing, four underwater objects with large craters on Lake Otkrytiye can be classified as MVs with a high probability according to GOST R 57123-2016 (GOST…, 2016).

RS data also showed several thermokarst lakes on Yamal, at the bottom of which, with clear water, cone-shaped volcano-like uplifts are observed (Bogoyavlensky, 2023). Fig. 6-A shows the WorldView-2 summer satellite image, from 13th of July, 2018 with ultra-high spatial resolution, of a large (1.6x2.1 km) thermokarst lake Labvarto, located in the central part of the Yamal Peninsula (69.985° N, 71.9356° E), situated in 3.7 km to the south-west from Lake Otkrytiye., Three zones of pockmark existence (P1, P2 and P3) and two objects (V1 and V2), which we identified as mud volcanic structures, were found at its bottom. This is confirmed by their specific conical shape and the presence of rounded/elliptical calderas with vents, which are especially visible on the V1 volcano, together with the sinter forms on its surface (see Fig. 6-B1).

Taking into account the fact that the thickness of lake ice can reach 1.5-2.0 m in these latitudes, we believe that the depth of the top of the V1 volcano is not less than these values. The top of the V1 object has dimensions of 75x80 m, and its visible base is 150x185 m. Due to new eruptions of mud breccia, the top of the volcano can rise above the water level, but its formation is limited by erosion and annual shearing by melting ice moving downwind.

According to RS data in 1985-2022 (Landsat and Sentinel) direct signs of winter gas eruptions from V1 and V2 tops were found in the form of annual early (May-June) thaws in ice above them, as well as trails of distribution of gas jets and/or reservoir fluids with dissolved gas in the water during the summer ice-free period (Fig. 6-B2).

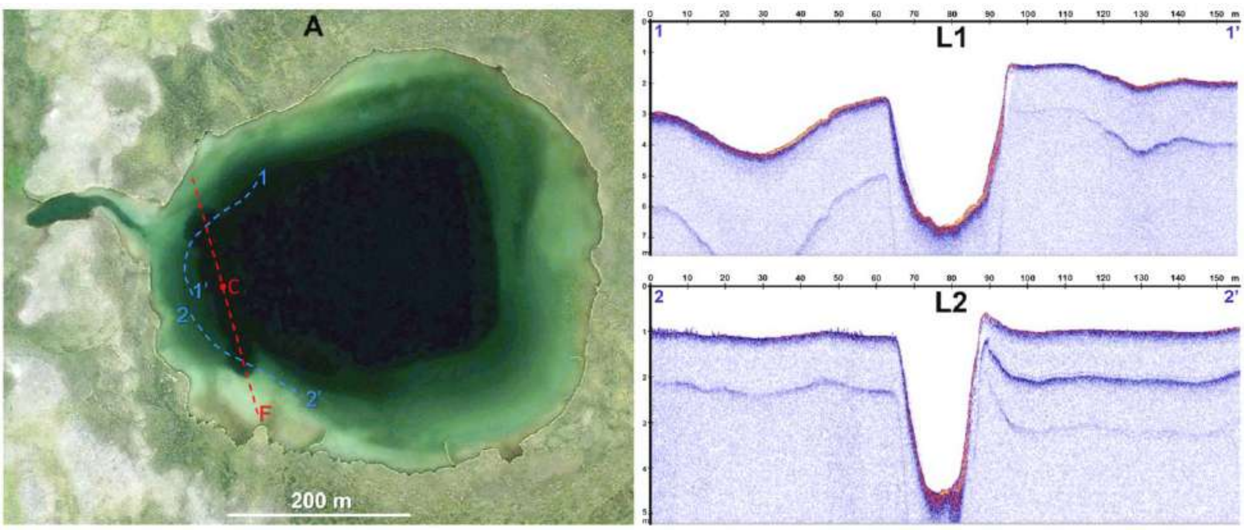

Fig. 5. WV-2 satellite image (13 of July, 2018) of Otkrytiye thermokast lake (A) and two echo sounding data records (L1 and L2) from profiles 1-1' and 2-2' through the underwater craters. Legend for Fig. 5-A: 1-1' and 2-2' – the L1 and L2 profiles location; F – predicted fault strike position; C – crater of gas blowout

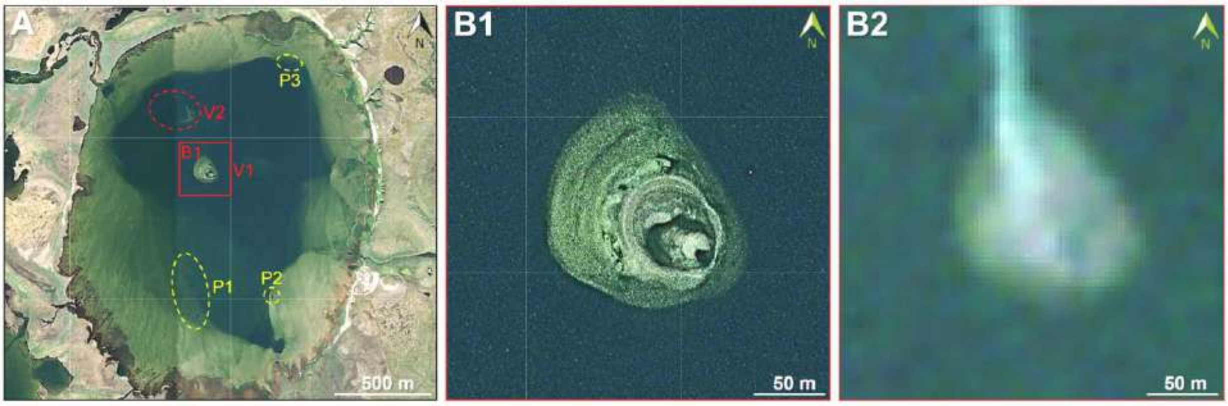

Fig. 6. Thermokarst lake on the Yamal Peninsula with degassing zones: P1, P2 and P3 – pockmarks; V1 and V2 – mud volcanoes

4. Technogenic eruptions of hydrocarbon mixtures

The authors analyzed the consequences of catastrophic blowouts (fountains) of mixtures of gas and oil with the formation of giant craters near the heads of emergency exploration wells drilled in the Arctic, in the southern regions of Russia and in the Caspian region, as well as in a number of oil and gas producing countries of the world (USA, Mexico, Canada, Indonesia, etc.) (Bogoyavlensky et al., 2017a; Bogoyavlensky, Bogoyavlensky, 2019). Thus, important information was obtained on the basis of RS data from space. Despite the liquidation of the fountains many decades ago, it has been proven that active emission of hydrocarbons continues at the present time at some of the studied objects.

As one of the examples, let us cite one of the biggest disasters in the Arctic happened on November, 1980 during the postcompletional flow test of the Kumzhinskaya-9 well located near the mouth of the Pechora River, on the left bank of the Maliy Gusinets channel in the north of the Kumzhinskoye gas condensate field, discovered in 1973 (Bogoyavlensky et al., 2017b). Due to the technogenic pool, formed in the upper part of the section with the area of around 30 km^2 (gas blowouts were detected in the 3 km radius), the gas escaped in the atmosphere in a number of points, including wells 9, 5, 10 and 134. It led to the formation of 3 giant craters from 70 to 130 m in diameter near the heads of destructed wells, flooded by river water, on the emergency site with the size of 260x600 m (Fig. 7A). The hard fight with catastrophic gushing continued for about 6.5 years (2362 days). The fire on the gushing fountain was put out only on the 18th of May in 1987. The lake, closed with the dams, was created on the emergency site in the channel of the Pechora River (Bogoyavlensky, 2020; Bogoyavlensky et al., 2017b).

On the WorldView-2 satellite image (taken from ESRI database) the pronounced thaws and holes in the ice are seen, polluted with liquid hydrocarbons even 36 years after the catastrophe (Fig. 7-B). Such ice cover breaches are visible every year from 2016 to 2023 on the different satellite images, including Sentinel-2 and Landsat-8. In 2023 the emission of HCs was seen on images from Sentinel-2 on May 3, 17, 20, 22, 23 and 25 (the traces of fluids were detected also on of March 18 and 24).

Conclusion

The authors performed a large amount of expeditionary work with a wide range of geological and geophysical methods in the Arctic, which, together with RS data from space, made it possible to obtain fundamentally new information about the gas-dynamic mechanisms of dangerous processes in the permafrost, including catastrophic gas blowouts and explosions with the formation of giant craters. There is no doubt that the studied craters were formed at the sites of existence of underground gas-saturated cavities (thermokarst) formed under the action of endogenous mechanisms, and the explosions occurred due to a gas-dynamic mechanism with superlithostatic gas pressure in the cavity.

There is a widely spread Earth degassing happening in the Western Siberia. About 4.5 thousand of intensive gas blowout zones were detected from the bottoms of thermokarst lakes. On the basis of statistical data on the distribution of perennial heaving mounds and thermokarst lakes with gas blowouts craters the most dangerous areas were identified in the north of the Western Siberia.

On Yamal at the bottoms of thermokarst lakes with through and/or non-through taliks, a number of mud volcanic degassing objects, including large mud volcanic structures were discovered for the first time. Taking into account a number of previously discovered MVs onshore Alaska, Greenland and Iceland, as well as on the bottom of the Beaufort, Kara and Norwegian seas, it can be argued that there is a Circum-Arctic mud volcanic province.

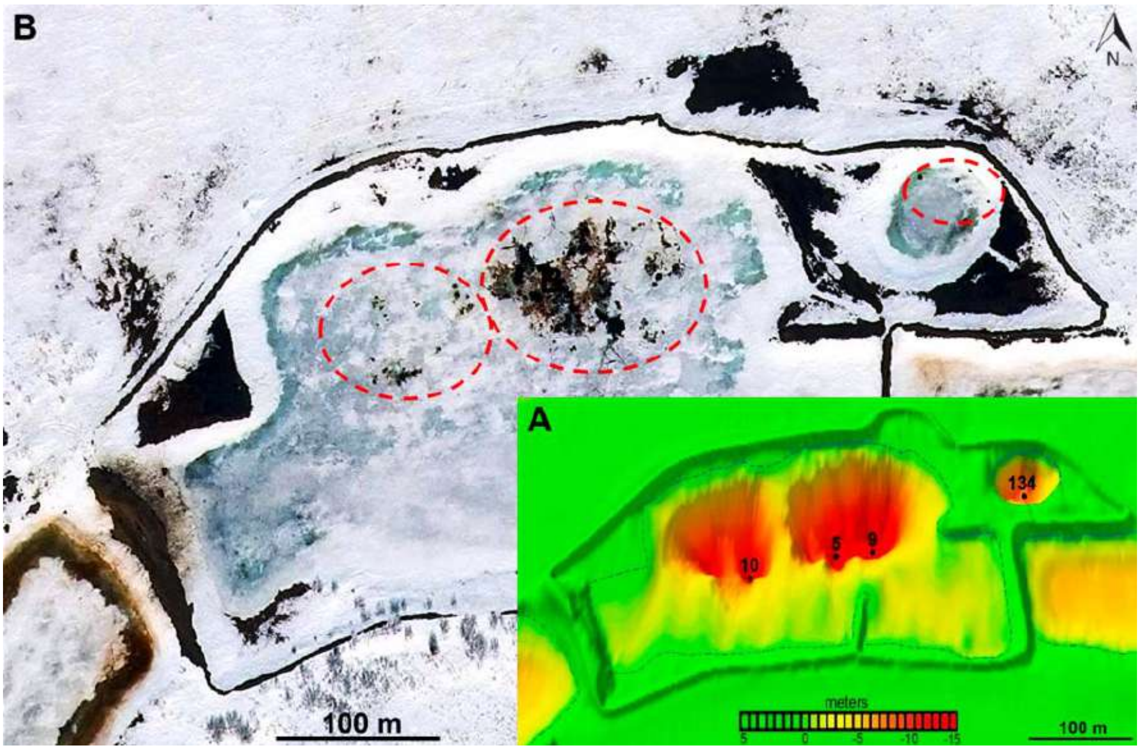

Fig. 7. Kumzhinskoye field disaster: 3D digital elevation model of technogenic lake bottom with craters and surrounding land (A) and WorldView-2 satellite image from the 2nd of May 2016 (B)

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REFERENCES

Aliyev Ad. A., Guliyev I.S., Dadashev F.G., Rakhmanov R.R. The mud volcano atlas of the World. Nafta-Press. Baku, 2015, 323 p. (in Russian).

Andreassen K., Hubbard A., Winsborrow M. et al. Massive blow-out craters formed by hydrate-controlled methane expulsion from the Arctic seafloor. Science, Vol. 356, 2017, pp. 948-953, DOI: 10.1126/science.aal4500.

Badu Yu.B. Cryogenic strata of gas-bearing structures in Yamal. On the influence of gas deposits on the formation and development of cryogenic strata. Nauchny mir. Moscow, 2018, 232 p. (in Russian).

Bogoyavlensky V.I. Fundamental aspects of the catastrophic gas blowout genesis and the formation of giant craters in the Arctic. Arctic: Ecology and Economy, Vol. 11, No. 1, 2021, pp. 51-66, DOI: 10.25283/2223-4594-2021-1-51-66 (in Russian).

Bogoyavlensky V.I. Natural and technogenic threats in fossil fuels production in the Earth cryolithosphere. Russian Mining Industry, No. 1(149), 2020, pp. 97-118, DOI 10.30686/1609-9192-2020-1-97-118 (in Russian).

Bogoyavlensky V.I. New data on mud volcanism in the Arctic on the Yamal Peninsula. Doklady Earth Sciences, Vol. 512, No. 1, 2023, pp. 92-99, DOI: 10.1134/S1028334X23601116 (in Russian).

Bogoyavlensky V.I. Prospects and problems of the Arctic shelf

ЛИТЕРАТУРА

Andreassen K., Hubbard A., Winsborrow M. et al. Massive blow-out craters formed by hydrate-controlled methane expulsion from the Arctic seafloor. Science, Vol. 356, 2017, pp. 948-953, DOI: 10.1126/science.aal4500.

Bogoyavlensky V., Bogoyavlensky I., Nikonov R., Kargina T., Chuvilin E., Bukhanov B., Umnikov A. New Catastrophic Gas Blowout and Giant Crater on the Yamal Peninsula in 2020: Results of the Expedition and Data Processing. Geosciences, Vol. 11, No. 71, 2021a, 20 p., DOI: 10.3390/geosciences11020071.

Bogoyavlensky V., Bogoyavlensky I., Nikonov R., Yakushev V., Sevastyanov V. Permanent gas emission from the Seyakha Crater of gas blowout, Yamal Peninsula, Russian Arctic. Energies, Vol. 14, No. 17, 5345, 2021b, DOI: 10.3390/en14175345.

Bogoyavlensky V.I., Kishankov A., Kazanin A., Kazanin G. Distribution of permafrost and gas hydrates in relation to intensive gas emission in the central part of the Laptev Sea (Russian Arctic). Marine and Petroleum Geology, Vol. 138, 2022, 105527, pp. 1-15, DOI: 10.1016/j.marpetgeo.2022.105527.

Etiope G. Natural Gas Seepage. The Earth's Hydrocarbon Degassing. Springer. Switzerland, 2015, 203 p. DOI: 10.1007/978-3-319-14601-0.

Hovland M., Judd A., King L. Characteristic features of pockmarks on the North Sea Floor and Scotian Shelf. Sedimenoil and gas fields development. Oil and drilling, No. 11, 2012, pp. 4-9 (in Russian).

Bogoyavlensky V.I., Bogoyavlensky I.V. Accidental and catastrophic gas blowouts during hydrocarbon resources development in the Arctic zones of the USA and Canada. Oil and drilling, No. 12, 2019, pp. 3-8 (in Russian).

Bogoyavlensky V.I., Bogoyavlensky I.V. Specificity of mud volcanic degassing of the Earth with catastrophic consequences. Labor safety in the industry, No. 12, 2022, pp. 20-28, DOI: 10.24000/0409-2961-2022-12-20-28 (in Russian).

Bogoyavlensky V.I., Garagash I.A. Justification of the formation process of gas blowout craters in the Arctic by mathematical modeling. Arctic: Ecology and Economy, No. 3, 2015, pp. 12-17 (in Russian).

Bogoyavlensky V.I., Kishankov A.V. Dangerous gas-saturated objects in the World Ocean: the Beaufort Sea, Alaska North Slope shelf. Arctic: Ecology and Economy, Vol. 13, No. 2, 2023, pp. 201-210, DOI: 10.25283/2223-4594-2023-2-201-210 (in Russian).

Bogoyavlensky V.I., Bogoyavlensky I.V., Kargina T.N. Catastrophic mud volcano eruption in Indonesia. Oil and drilling, No. 11, 2017a, pp. 2-11 (in Russian).

Bogoyavlensky V.I., Bogoyavlensky I.V., Kargina T.N. Catastrophic gas blowout in 2020 on the Yamal Peninsula in the Arctic. Results of comprehensive analysis of aerospace RS data. Arctic: Ecology and Economy, Vol. 11, No. 3, 2021c, pp. 362-374, DOI: 10.25283/2223-4594-2021-3-362-374 (in Russian).

Bogoyavlensky V., Bogoyavlensky I., Nikonov R., Kargina T., Chuvilin E., Bukhanov B., Umnikov A. New catastrophic gas blowout and giant crater on the Yamal Peninsula in 2020: Results of the expedition and data processing. Geosciences, Vol. 11, No. 71, 2021a, 20 p., DOI: 10.3390/geosciences11020071.

Bogoyavlensky V., Bogoyavlensky I., Nikonov R., Yakushev V., Sevastyanov V. Permanent Gas Emission from the Seyakha Crater of Gas Blowout, Yamal Peninsula, Russian Arctic. Energies, Vol. 14, No. 17, 5345, 2021b, DOI: 10.3390/en14175345.

Bogoyavlensky V.I., Erokhin G.N., Nikonov R.A., Bogoyavlensky I.V., Bryksin V.M. Study of catastrophic gas blowout zones in the Arctic based on passive microseismic monitoring (on the example of Lake Otkrytiye). Arctic: Ecology and Economy, No. 1, 2020a, pp. 53-64, DOI: 10.25283/2223-4594-2020-1-53-64 (in Russian).

Bogoyavlensky V.I., Kazanin A.G., Kishankov A.V., Kazanin G.A. Earth degassing in the Arctic: comprehensive analysis of factors of powerful gas emission in the Laptev Sea. Arctic: Ecology and Economy, Vol. 11, No. 2, 2021d, pp. 178-194, DOI: 10.25283/2223-4594-2021-2-178-194 (in Russian).

Bogoyavlensky V.I., Kishankov A., Kazanin A., Kazanin G. Distribution of permafrost and gas hydrates in relation to intensive gas emission in the central part of the Laptev Sea (Russian Arctic). Marine and Petroleum Geology, Vol. 138, 2022, 105527, pp. 1-15, DOI: 10.1016/j.marpetgeo.2022.105527.

Bogoyavlensky V.I., Kishankov A.V., Kazanin A.G., Kazanin G.A. Dangerous gas-saturated objects in the World Ocean: the East Siberian Sea. Arctic: Ecology and Economy, Vol. 12, No. 2, 2022a, pp. 157-171, DOI: 10.25283/2223-4594-2022-2-158-171 (in Russian)

Bogoyavlensky V.I., Perekalin S.O., Boichuk V.M., Bogoyavlensky I.V., Kargina T.N. Kumzhinskoye gas condensate field disaster: reasons, results and ways of eliminating the consequences. Arctic: Ecology and Economy, No. 1, 2017b, pp. 32-46, DOI: 10.25283/2223-4594-2017-1-32-46 (in Russian).

Bogoyavlensky V.I., Sizov O.S., Bogoyavlensky I.V., Nikonov R.A. Technologies for remote detection and monitoring of the Earth degassing in the Arctic: Yamal peninsula, Neito lake. Arctic: tology, Vol. 31, No. 4, 1984, pp. 471-480, DOI: 10.1111/j.1365-3091.1984.tb01813.

Jackson R. B., Saunois M., Bousquet P. et al. Increasing anthropogenic methane emissions arise equally from agricultural and fossil fuel sources. Environmental Research Letters, Vol. 15, No. 7, 2020, p. 071002, DOI: 10.1088/1748-9326/ab9ed2.

Judd A., Hovland M. Seabed fluid flow – impact on geology, biology and the marine environment. Cambridge University Press. Cambridge, 2007, 400 p., DOI: 10.1017/CBO9780511535918.

Kopf A.J. Significance of mud volcanism. Reviews of Geophysics, Vol. 40, No. 02, 2002, pp. 2-1–2-52, DOI: 10.1029/2000RG000093.

Paull C.K., Dallimore S.R., Caress D.W. et al. Active mud volcanoes on the continental slope of the Canadian Beaufort Sea. Geochemistry, Geophysics, Geosystems, Vol.. 16, No. 9, 2015, pp. 3160-3181, DOI:10.1002/2015GC005928.

Serov P., Portnov A., Mienert J. et al. Methane release from pingo-like features across the South Kara Sea shelf, an area of thawing offshore permafrost. Journal of Geophysical Research: Earth Surface, Vol. 120, No. 8, 2015, pp. 1515-1529, DOI: 10.1002/ 2015JF003467.

State of the Global Climate 2022. World Meteorological Organization. WMO-No.1316, 2023, 55 p.

Walter K.M., Zimov S., Chanton J.P., Verbyla D., Chapin III F.S. Methane bubbling from Siberian thaw lakes as a positive feedback to climate warming. Nature, Vol. 443, 2006, pp. 71-75, DOI: 10.1038/nature05040.

Алиев Ад.А., Гулиев И.С., Дадашев Ф.Г., Рахманов Р.Р. Атлас грязевых вулканов мира. Nafta-Press. Баку, 2015, 323 с.

Баду Ю.Б. Криогенная толща газоносных структур Ямала. О влиянии газовых залежей на формирование и развитие криогенной толщи. Научный мир. Москва, 2018, 232 с.

Богоявленский В.И. Новые данные о грязевом вулканизме в Арктике на полуострове Ямал. Доклады РАН, Науки о Земле, Вулканология, Т. 512, № 1, 2023, с. 92-99, DOI: 10.31857/S2686739723601084.

Богоявленский В.И. Перспективы и проблемы освоения месторождений нефти и газа шельфа Арктики. Бурение и нефть, № 11, 2012, с. 4-9.

Богоявленский В.И. Природные и техногенные угрозы при освоении месторождений горючих ископаемых в криолитосфере Земли. Горная промышленность, № 1(149), 2020, с. 97-118, DOI 10.30686/1609-9192-2020-1-97-118.

Богоявленский В.И. Фундаментальные аспекты генезиса катастрофических выбросов газа и образования гигантских кратеров в Арктике. Арктика: экология и экономика, Т. 11, № 1, 2021, с. 51-66, DOI: 10.25283/2223-4594-2021-1-51-66.

Богоявленский В.И., Богоявленский И.В. Аварийные и катастрофические выбросы газа при освоении ресурсов углеводородов в арктических зонах США и Канады. Бурение и нефть, № 12, 2019, с. 3-8.

Богоявленский В.И., Богоявленский И.В. Специфика грязевулканической дегазации Земли с катастрофическими последствиями. Безопасность труда в промышленности, № 12, 2022, с. 20-28, DOI: 10.24000/0409-2961-2022-12-20-28.

Богоявленский В.И., Гарагаш И.А. Математическое моделирование процесса образования кратеров газового выброса в Арктике. Арктика: экология, экономика, № 3, 2015, с. 12-17.

Богоявленский В.И., Кишанков А.В. Опасные газонасыщенные объекты на акваториях Мирового океана: море Бофорта, шельф Северного склона Аляски. Арктика: экология и экономика, Т. 13, № 2, 2023, с. 201-210, DOI: 10.25283/2223-4594-2023-2-201-210.

Богоявленский В.И., Богоявленский И.В., Каргина Т.Н. Катастрофический выброс газа в 2020 г. на полуострове

Ecology and Economy, No. 2(30), 2018, pp. 83-93, DOI: 10.25283/2223-4594-2018-2-83-93 (in Russian).

Bogoyavlensky V.I., Sizov O.S., Nikonov R.A., Bogoyavlensky I.V. Monitoring of the methane concentration changes in the Arctic atmosphere in 2019-2021 according to the TROPOMI spectrometer data. Arctic: Ecology and Economy, Vol. 12, No. 3, 2022b, pp. 304-319, DOI: 10.25283/2223-4594-2022-3-304-319 (in Russian).

Bogoyavlensky V.I., Sizov O.S., Nikonov R.A., Bogoyavlensky I.V., Kargina T.N. Earth degassing in the Arctic: the genesis of natural and anthropogenic methane emissions. Arctic: Ecology and Economics, No. 3 (39), 2020b, pp. 6-22, DOI: 10.25283/2223-4594-2020-3-6-22 (in Russian).

Earth degassing: geodynamics, fluids, oil and gas. Proceedings of international conference in memory of P.N.Kropotkin. GEOS. Moscow, 2002, 472 p. (in Russian).

Etiope G. Natural gas seepage. The Earth's hydrocarbon degassing. Springer. Switzerland, 2015, 203 p., DOI: 10.1007/978-3-319-14601-0.

GOST R 57123-2016 (ISO 19901-2:2004). Petroleum and natural gas industries – specific requirements for offshore structures. Part 2: Seismic design procedures and criteria. Standartinform. Moscow, 2016, 32 p. (in Russian).

Guliyev I.S., Mustayev R.N., Kerimov V.Yu., Yudin M.N. Earth degassing: scale and consequences. Mining Journal, No. 11, 2018, pp. 38-42 DOI: 10.17580/gzh.2018.11.06 (in Russian).

Hovland M., Judd A., King L. Characteristic features of pockmarks on the North Sea Floor and Scotian Shelf. Sedimentology, Vol. 31, No. 4, 1984, pp. 471-480, DOI: 10.1111/j.1365-3091.1984.tb01813.

Jackson R. B., Saunois M., Bousquet P. et al. Increasing anthropogenic methane emissions arise equally from agricultural and fossil fuel sources. Environmental Research Letters, Vol. 15, No. 7, 2020, p. 071002, DOI: 10.1088/1748-9326/ab9ed2.

Judd A., Hovland M. Seabed fluid flow – impact on geology, biology and the marine environment. Cambridge University Press. Cambridge, 2007, 400 p., DOI: 10.1017/CBO9780511535918.

Kerimov V.Yu., Abdullayeva V.K. Geography and scale of greenhouse gas degassing in Azerbaijan. ANAS Transactions, Earth Sciences, No. 1, 2022, pp. 51-67, DOI: 10.33677/ggianas20220100072 (in Russian).

Kopf A.J. Significance of mud volcanism. Reviews of Geophysics, Vol. 40, No. 02, 2002, pp. 2-1–2-52, DOI: 10.1029/2000RG000093

Kruglikov N.M., Kuzin I.L. Emissions of deep gas on the Urengoy field. Structural geomorphology and neotectonics of Western Siberia in connection with oil and gas bearing. Proceedings of ZapSibNIGNI, No. 37, 1973, pp. 96-106 (in Russian).

Mironyuk S.G., Ivanova A.A., Khlebnikova O.A. Landforms generated under fluid influence (fluidogenic) as an indicator of shelf interior oil-and-gas content. Proceedings of international conference "MARESEDU-2018" Vol. II (IV). JSC «PolyPRESS». Tver, 2019, pp. 120-125 (in Russian).

Paull C.K., Dallimore S.R., Caress D.W. et al. Active mud volcanoes on the continental slope of the Canadian Beaufort Sea. Geochemistry, Geophysics, Geosystems, Vol. 16, No. 9, 2015, pp. 3160-3181, DOI: 10.1002/2015GC005928.

Report on climate features in the Russian Federation for 2021. Rosgidromet. Moscow, 2022, 110 p. (in Russian).

Sergienko V.I., Lobkovsky L.I., Semiletov I.P. et al. The degradation of submarine permafrost and the destruction of hydrates on the shelf of East Arctic seas as a potential cause of the methane catastrophe: Some results of integrated studies in 2011. Doklady Earth Science, Vol. 446, No. 3, 2012, pp. 1132-1137, DOI: 10.1134/S1028334X12080144 (in Russian).

Serov P., Portnov A., Mienert J. et al. Methane release from pingo-like features across the South Kara Sea shelf, an area of thawing offshore permafrost. Journal of Geophysical Re-

Ямал в Арктике. Результаты комплексного анализа данных аэрокосмического зондирования. Арктика: экология и экономика, Т. 11, № 3, 2021c, с. 362-374, DOI: 10.25283/2223-4594-2021-3-362-374.

Богоявленский В.И., Богоявленский И.В., Каргина Т.Н. Грязевулканическая катастрофа в Индонезии. Бурение и нефть № 11, 2017a, с. 2-11.

Богоявленский В.И., Ерохин Г.Н., Никонов Р.А., Богоявленский И.В., Брыксин В.М. Изучение зон катастрофических выбросов газа в Арктике на основе пассивного микросейсмического мониторинга (на примере озера Открытие). Арктика: экология и экономика. № 1(37), 2020a, с. 93-104, DOI: 10.25283/2223-4594-2020-1-93-104.

Богоявленский В.И., Казанин А.Г., Кишанков А.В., Казанин Г.А. Дегазация Земли в Арктике: комплексный анализ факторов мощной эмиссии газа в море Лаптевых. Арктика: экология и экономика, Т. 11, № 2, 2021d, с.178-194, DOI: 10.25283/2223-4594-2021-2-178-194.

Богоявленский В.И., Кишанков А.В., Казанин А.Г., Казанин Г.А. Опасные газонасыщенные объекты на акваториях Мирового океана: Восточно-Сибирское море. Арктика: экология и экономика, Т. 12, № 2, 2022a, с. 158-171, DOI: 10.25283/2223-4594-2022-2-158-171.

Богоявленский В.И., Перекалин С.О., Бойчук В.М., Богоявленский В.И., Каргина Т.Н. Катастрофа на Кумжинском газоконденсатном месторождении: причины, результаты, пути устранения последствий. Арктика: экология и экономика, № 1, 2017b, с. 32-46, DOI: 10.25283/2223-4594-2017-1-32-46.

Богоявленский В.И., Сизов О.С., Богоявленский И.В., Никонов Р.А. Технологии дистанционного выявления и мониторинга дегазации Земли в Арктике: полуостров Ямал, озеро Нейто. Арктика: экология и экономика, № 2(30), 2018, с. 83-93, DOI: 10.25283/2223-4594-2018-2-83-93.

Богоявленский В.И., Сизов О.С., Никонов Р.А., Богоявленский И.В. Мониторинг изменений концентрации метана в атмосфере Арктики в 2019-2021 гг. по данным спектрометра TROPOMI. Арктика: экология и экономика, Т. 12, No. 3, 2022b, с. 304-319, DOI: 10.25283/2223-4594-2022-3-304-319.

Богоявленский В.И., Сизов О.С., Никонов Р.А., Богоявленский И.В., Каргина Т.Н. Дегазация Земли в Арктике: генезис природной и антропогенной эмиссии метана. Арктика: экология и экономика, № 3(39), 2020b, с. 6-22, DOI: 10.25283/2223-4594-2020-3-6-22.

ГОСТ Р 57123-2016 (ИСО 19901-2:2004). Нефтяная и газовая промышленность. Сооружения нефтегазопромысловые морские. Проектирование с учетом сейсмических условий. Стандартинформ. Москва, 2016, 32 с.

Гулиев И.С., Мустаев Р.Н., Керимов В.Ю., Юдин М.Н. Дегазация Земли: масштабы и последствия. Горный журнал, № 11, 2018, с. 38-42, DOI: 10.17580/gzh.2018.11.06.

Дегазация Земли: геодинамика, геофлюиды, нефть и газ. Материалы Международной конференции памяти академика П.Н. Кропоткина, 20-24 мая 2002 года, г. Москва. ГЕОС. Москва, 2002, 472 с.

Доклад об особенностях климата на территории Российской Федерации за 2021 год. Росгидромет. Москва, 2022, 110 с.

Керимов В.Ю., Абдуллаева В.К. География и масштабы дегазации парниковых газов в Азербайджане. ANAS Transactions, Earth Sciences, № 1, 2022, с. 51-67, DOI: 10.33677/ggianas20220100072.

Кругликов Н.М., Кузин И.Л. Выходы глубинного газа на Уренгойском месторождении. Труды ЗапСибНИГНИ, № 37, 1973, с. 96-106.

Миронюк С.Г., Иванова А.А., Хлебникова О.А. Флюидогенные формы рельефа как индикаторы нефтегазоносности недр шельфа. Труды VII Международной научно-

search: Earth Surface, Vol. 120, No. 8, 2015, pp. 1515-1529, DOI: 10.1002/ 2015JF003467.
Sokolov S.Yu., Moroz E.A., Zarayskaya Yu.A., Abramova A.S., Ananiev R.A., Sukhikh E.A. Mapping of dangerous geological objects and processes at the Northern and Central parts of the Barents Sea shelf according to the hydroacoustic data from RV "Akademik Nikolai Strakhov". Arctic: Ecology and Economy, Vol. 13, No. 2, 2023, pp. 164-179, DOI: 10.25283/2223-4594-2023-2-164-179 (in Russian).
State of the Global Climate 2022. World Meteorological Organization. WMO-No.1316, 2023, 55 p.
Walter K.M., Zimov S., Chanton J.P., Verbyla D., Chapin III F.S. Methane bubbling from Siberian thaw lakes as a positive feedback to climate warming. Nature, Vol. 443, 2006, pp. 71-75, DOI: 10.1038/nature05040.
Yusubov N.P., Guliyev I.S. Mud volcanism and hydrocarbon systems of South-Caspian Depression (according to the newest geophysical and geochemical data). Elm. Baku, 2022, 168 p. (in Russian).
практической конференции «Морские исследования и образование (MARESEDU-2018)», Том II (IV). ООО «ПолиПРЕСС». Тверь, 2019, с. 120-125.
Сергиенко В.И., Лобковский Л.И., Семилетов И.П. и др. Деградация подводной мерзлоты и разрушение гидратов шельфа морей Восточной Арктики как возможная причина «метановой катастрофы»: некоторые результаты комплексных исследований 2011 года. Докл. Акад. Наук, Т. 446, № 3, 2012, с. 330-335.
Соколов С.Ю., Мороз Е.А., Зарайская Ю.А. и др. Картирование опасных геологических объектов и процессов северной и центральной частей шельфа Баренцева моря по данным гидроакустического комплекса НИС «Академик Николай Страхов». Арктика: экология и экономика, Т. 13, № 2, 2023, с. 164-179, DOI: 10.25283/2223-4594-2023-2-164-179.
Юсубов Н.П., Гулиев И.С. Грязевой вулканизм и углеводородные системы Южно-Каспийской впадины (по новейшим данным геофизических и геохимических исследований). Элм. Баку, 2022, 168 с.

ПРИРОДНЫЕ И ТЕХНОГЕННЫЕ КАТАСТРОФИЧЕСКИЕ ВЫБРОСЫ И ВЗРЫВЫ ГАЗА В АРКТИКЕ И ДРУГИХ РЕГИОНАХ МИРА (СУША И АКВАТОРИЯ)

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Резюме. Авторы статьи создали геоинформационную систему «Арктика и Мировой океан» с огромным объемом постоянно дополняемых геопространственных данных, позволяющих проводить комплексный анализ различных природных и техногенных явлений, прямо или косвенно связанных с дегазацией Земли. В Арктике выполнен большой объем экспедиционных работ с широким комплексом геолого-геофизических методов, которые проанализированы в комплексе с данными дистанционного зондирования Земли (ДЗЗ) из космоса и с применением беспилотных летательных аппаратов. Это позволило получить принципиально новую информацию о газодинамических механизмах опасных процессов в криолитозоне, включая катастрофические выбросы и взрывы газа с образованием гигантских кратеров и крупных грязевулканических построек. Всего на севере Западной Сибири выявлено около 18.5 тысяч потенциально опасных объектов, включая 4.5 тысяч зон интенсивных выбросов газа со дна термокрастовых озер, в результате которых образуются подводные кратеры-покмарки. Это позволило выделить наиболее газовзрывоопасные зоны на севере Западной Сибири, преимущественно расположенные в восточной части полуострова Ямал. С учетом ранее открытых грязевых вулканов на суше Аляски, Гренландии и Исландии, а также на дне морей Бофорта, Карском и Норвежском, можно утверждать о существовании Циркумарктической грязевулканической провинции. В Арктике, Каспийском и других регионах с помощью ДЗЗ исследованы причины и последствия техногенной дегазации недр на ряде аварийных скважин.
Ключевые слова: *дегазация Земли, выбросы и взрывы газа, грязевые вулканы, сипы газа, дистанционное зондирование Земли, беспилотные летательные аппараты*

ARKTİKADA VƏ DÜNYANIN DİGƏR REGİONLARINDA (QURU VƏ AKVATORİYALARDA) TƏBİİ VƏ TEXNOGEN FƏLAKƏTLİ TULLANTILAR VƏ QAZ PARTLAYIŞLARI

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Xülasə. Yerin deqazasiya proseslərinin öyrənilməsi Rusiya Elmlər Akademiyasının Neft və Qaz problemləri İnstitutu tədqiqatlarının əsas istiqamətlərindən biridir. Müəlliflər, geoməkani məlumatlarla daim zənginləşdirən nəhəng həcmə malik "Arktika və Dünya okeanı" (QİS "AMO") geoinformasiya sistemi yaratmışlar ki, o Yerin deqazasiyası ilə birbaşa və ya dolayı əlaqədə olan müxtəlif təbii və texnogen hadisələrin kompleks təhlilinə imkan verir. Arktikada geoloji-geofiziki metodların geniş kompleksi ilə böyük həcmli ekspedisiya işləri yerinə yetirilmiş, onlar pilotsuz uçuş aparatları tətbiq etməklə, kosmosdan Yerin distansion zondlaşdırma məlumatları (YDZ) kompleksilə birlikdə təhlil olunmuşlar. Bu, nəhəng kraterlərin və iri palçıq vulkanı qurumlarının əmələ gəlməklə fəlakətli tullantılar və qaz partlayışları daxil olmaqla, kriolitozonada təhlükəli proseslərin qaz-dinamik mexanizmləri haqqında prinsipial olaraq yeni informasiya almağa imkan verdi. Təkcə Qərbi Sibirin şimalında onların sayəsində sualtı krater-pokmarkaların yarandığı termokarstlı göllərin dibindən 4.5 qazların intensiv atılma zonaları daxil olmaqla,18.5 min potensial təhlükəli obyektlər aşkar edilmişdir. Bu Qərbi Sibirin şimalında, əksəriyyəti Yamal yarımadasının şərq hissəsində yerləşmiş ən təhlükəli qaz partlayışı zonalarını ayırmağa imkan verdi. Alyaska, Qrenlandiya və İslandiya zonalarında, həmçinin Bofort, Karsk və Norveç dənizlərinin dibində əvvəllər aşkar edilmiş palçıq vulkanlarını nəzərə alaraq, Sirkumartik palçıq vulkanı əyalətinin mövcudluğunu irəli sürmək olar. Yerin distansion zondlaşdırılmasını (YDZ) tətbiq etməklə Arktika, Xəzər və dünyanın digər regionlarında bir sıra qəzalı neft-qaz axtarış və kəşfiyyat quyularında yer təkinin texnogen deqazasiyasının səbəbləri və fəlakətli nəticələri tədqiq olunmuşdur.
Açar sözlər: *Yerin deqazasiyası, qazın atılma və partlayışları, palçıq vulkanları, qaz uğultusu, Yerin distansion zondlaşdırılması (YDZ), pilotsuz uçuş aparatları (PUA)*