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Ecological and hydrogeological state of oil and gas bearing areas of the Barents and Kara seas shelf

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ABSTRACT

The article deals with the ecological and hydrogeological conditions of the hydrogeological structures in the Barents-Kara shelf. Based on the hydrogeological and geoecological state of the Barents-Kara shelf, geoecological hazards were considered and distributed within the oil and gas regions of the West Siberian and East Barents oil and gas provinces. Preliminary geoecological zoning was performed and eco-geological zones were identified on the territory of first-order hydrogeological structures corresponding to the borders of several oil and gas-bearing regions of the East Barents and West Siberian oil and gas-bearing provinces. Thus, the current geoecological state of the Barents-Kara shelf was assessed. When drawing up the map of geoecological hazards, the hazards of technogenic origin caused by human economic activity and natural origin were taken into account, in particular, the influence of the neotectonic mode on the territory of the Barents-Kara shelf.

Keywords: Geoecological hazards, Eco-geological zones, Geoecological zoning, Hydrogeological structures, Neotectonic mode, Barents-Kara shelf.

INTRODUCTION

During 1970-1990, the main volume of geological studies of the Soviet sector of the Arctic was carried out by various institutions of the Ministry of Natural Resources. As a result of these works, ideas about the structure of the geological section, geocryology, seismological situation, hydrophysical characteristics were obtained and a number of geological maps included in the mandatory set of state geological mapping were constructed. Among them, the following maps should be distinguished: bedrock, minerals, geophysical fields, Quaternary and modern sediments. Due to the continuous development of the richest hydrocarbon deposits in the territory of West-Siberian oil and gas province gained particular importance to the issues of hydrogeological studies of oil and gas structures, and the use of data on Geology island within the Western seas of the Russian Arctic (Gusev *et al.* 2020). The results of the analysis of geological and geophysical materials showed that the most promising areas of the Russian Arctic shelf are the Barents and Kara seas, in the waters of which there are mainly gas-bearing deposits and the share of free gas here accounts for the vast majority of the total recoverable reserves (Kontorovich & Kontorovich 2019; Kontorovich 2020). In addition to the oil and gas potential of the shelf of the West Arctic seas, intensive industrial development of the water area is also associated with the use of the Northern Sea Route. For a detailed systematization of materials and gas research, we should take into account a number of regional hydrogeological patterns used in the search for oil and gas offshore that were previously considered in the study of hydrochemical zoning of groundwater basins by a number of domestic and foreign authors (Chilingarian & Rieke 1969; Collins 1975; Bull *et al.* 2000; Raymond & Leffler 2017), since the main taxonomic elements of hydrogeological zoning of hydrogeological structures are represented by pools of underground waters continued in the sea, data on which

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were obtained mainly from the results of exploratory and exploratory drilling (Elhag & Bahrawi 2017). In the framework of solving the issues of hydrogeological zoning of oil and gas prospective areas of the Barents and Kara seas, it is necessary to mention the importance of geoecological aspects of the study object. To date, there are contradictions between the exploitation of deposits of the Barents-Kara shelf and the risk of environmental damage to the water area due to its oil and gas pollution, as well as the features of the geological structure of the studied area, which requires reliable methods for predicting negative geoecological consequences and minimizing their impact on the ecological state of the Barents and Kara shelf. In addition, the risks of deterioration of the hydrogeoecological situation associated with both man-made processes and global warming are often not taken into account.

In the system of economic development of marine and continental waters, an important role belongs to the geoecological component associated with both possible environmental disturbances and measures to minimize them, and with the creation of a forecast of possible negative impacts on certain structures (Efremkin 2011).

The results of scientific activities of organizations are also included in the materials used in the construction of geoecological maps of the Barents-Kara shelf. Therefore, this study examines and classifies the factors that determine the geoecological state of the natural environment of the Barents and Kara seas.

MATERIALS AND METHODS

Ecological status evaluation of the hydrogeological structures in the Barents and Kara seas, the analysis of influence of natural and anthropogenic factors on the groundwater and sediments, and the nature of the distribution of environmental hazards in the study area was made primarily on the basis of several studies by I. M. Efremkin together with the Limited Liability Company «Gazflot» related to geoecological substantiation of development of oil fields in the Russian sector of the Arctic (Efremkin 2011). At all stages of geoecological work in the system of rational development of offshore oil and gas fields, one of their most important types is geoecological monitoring, which is a complex of interrelated, time-synchronized and geographically combined works to monitor the state of the environment, including pollution factors and migration of pollutants, which is the basis for the preparation of an environmental impact assessment. Geoecological monitoring is based on a set of specific parameters of the measured characteristics: physical, chemical, biological, lithological and object. These parameters are included in the most generalized classification of monitoring proposed by a group of authors (Kędra & Grebmeier 2021). To conduct monitoring studies in the development of offshore oil and gas fields, the concept adopted by specialists of the Public Joint Stock company «Gazprom» (Sestras *et al.* 2021) is provided, the essence of which is to provide measures to control methane leaks and calculate the area of oil spills. When monitoring the ecological state of oil-producing territories, it is worth mentioning to use the space mapping methods for hard-to-reach and vulnerable terrestrial tundra and marine ecosystems (Maximova 2018). For better indicators of monitoring measurements, there should be a tendency to reduce sampling and observations performed on board the ship and in stationary laboratories, and to increase the number of measurements in the "in-situ" mode when the ship is moving, when anchoring and drifting, and when using automatic measuring tools. One of the new approaches to taking into account the hydrogeoecological situation in pre-project developments and forecast estimates is the use of advanced economic and mathematical models and methods of strategic planning. At the stage of pre-project assessment of the project prospects of Arctic shelf development considering factors enhance the identified geo-environmental hazards it is necessary to use advanced mathematical models and methods of strategic planning, one of which is, in particular, the tools of the theory of fractals (Vasiltsov & Vasiltsova 2018). The main properties of the fractal (self-similarity, recurrence, fractionality and the presence of correlation between all points of the fractal) allow us to systematize the changing values of the parameters of the Arctic shelf development project, including those related to ensuring geoecological safety, which allows us to minimize errors in forecasting.

Identification of zones of geoecological hazards in the Barents-Kara shelf

The main objectives of the study are to characterize, structure and distribute the main geoecological hazards within several oil and gas-bearing regions of the West Siberian and East Barents oil and gas provinces corresponding to hydrogeological structures of the first order (artesian basins). The study and analysis of geoecological hazards was also used in a number of schemes and structural-tectonic maps of previous studies (Barinova 1998; Galimov *et al.* 2006; Kruk *et al.* 2018). Finally, their spatial distribution in bottom waters and bottom sediments was determined (Fig. 1). Were considered three elements of the geo-environmental hazards:

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1-Increased seismic activity;
2-Cryogenic phenomena (including potentially cryogenic phenomena);
3- Increased corrosion capacity;

Increased seismic activity

Almost all of the western and southwestern coasts of the New Land archipelago and the Central part of the Kara Sea are characterized by increased seismic activity and the presence of tectonic faults. At the same time, the area of New Land is considered as an area with a neotectonic regime of active uplifts and is limited along the periphery by areas with tectonic movements of mainly weak and moderate dips. The central part of the Kara Sea can be described as a fragment of a single depression structure with areas of powerful sediments and elevations, perspective for hydrocarbon exploration, which was confirmed by the survey of oil and gas of the Russian Arctic (Kontorovich 2015: Hosseinpour *et al.* 2018). The regime and features of the oil and gas content of sedimentary basins within the Barents-Kara (Eurasian) block were significantly influenced by rifting (Peron-Pinvidic & Manatschal 2019), since in the northern part of Western Siberia in recent times there was an increase in the amplitudes of positive structures by several tens of meters and sharply increased near the folded structures of the Polar Urals and the Yenisei Ridge. In most of the territory of the West Siberian oil and gas province, all large zones of increased neotectonic tension correspond to the contours of oil and gas-bearing regions, which is probably true for the Barents-Kara Plate.

The bottom of the southern part of the Kara Sea is characterized by the direct continuation of oil and gas-bearing land structures on the shelf. The Barents-Kara shelf hydrogeological region is a special oil-and-gas-bearing basin that is loosely connected to the continental rim. The greatest prospects can be associated with local uplifts that complicate the bottom of the Barents-North Kara mega-bend, which, with increased sedimentary cover thickness, experienced a significant increase in amplitudes at the neotectonic stage. This type of structure includes local structures that frame the Seclusion trough in Kara Sea (Vlasenko & Sudarikov 2020).

Cryogenic phenomena

Cryogenic dangerous phenomena is caused by the influence of a decreased water temperature of the seas in different periods and in certain geographical zones of the Earth (Savvin *et al*. 2021). Most of the Barents-Kara shelf was in the area of dangerous cryogenic phenomena. Perhaps one of the main reasons for this danger is the change in the geocryological regime due to the influence of warm Atlantic waters entering the Barents Sea basin from the west, and the removal of pollutants from the White Sea, which also affected the spatial distribution of the complex of trace elements in most of the Barents Sea (Fig. 1; Ivanov 2013). Cooling of the surface layer leads to an increased density and convective mixing, which spreads to the bottom, and ultimately leads to the flow of dense water along the slopes of the bottom relief (Laukert *et al.* 2020). The ice regime of the Barents Sea is characterized by a sharp seasonal variability in the degree of its ice cover, which was confirmed by significant fluctuations in its ice cover based on the results of long-term observations (Myslenkov *et al.* 2020). Large stretches of the coastal zone are exposed to sea ice, currents, tides, waves, thermal and other factors. The central and southern regions of the Barents Sea, located south of the edge of the drifting ice, are experiencing thermal convection.

In Kara Sea, in addition to the influence of the neotectonic mode, which caused a change in reservoir pressures in the deposits, the main role in changing the geocryological regime and the presence of areas of possible dangerous cryogenic phenomena was played by the production of hydrocarbons at the Rusanovskoye and Leningradskoye fields, accompanied by accidental releases of petroleum products, as well as the removal of contaminated water by the Ob River into the Kara Sea. Thus, according to studies of the removal of petroleum products into the Kara Sea, the waters are saturated with heavy metals and radioactive Cs-137 (Yakushev & Chuvilin 2000; Marguí *et al.* 2010).

Increased corrosion capacity

Increased corrosion capacity as an element of geoecological hazard has not been studied well enough in the Barents-Kara region. Corrosion ability in this case is considered as spontaneous destruction of metals in an aqueous medium as a result of electrochemical processes in an aqueous medium. When considering this type of hazard, attention should be paid to the properties of the environment: the presence of free ions in the water, temperature, etc.

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Almost the entire western part of the coast of New Land archipelago and the southern part of the Kara Sea include zones of increased corrosion capacity. In most of this area, alterations in the activity of heavy metal ions in bottom sediments have been studied. High values were observed in the western part of the Novaya Zemlya archipelago and in the central part of the Kara Sea (Efremkin 2011). One of the factors of increasing the corrosion capacity and changing the composition of bottom sediments is the flow of groundwater to the bottom surface from the lower aquifers of submarine structures (Churilova *et al.* 2018). Notably, on the map of geoecological hazards of the Barents and Kara seas (Fig. 1), zones of increased corrosion hazard are confined to areas of increased seismic activity, which allows us to conclude that the change in corrosion activity is also influenced by a change in the neotectonic mode.

In addition, characteristic spatial combinations of disjunctive elements that provide a certain level of corrosion acceleration were previously noted. Based on the analysis of structural and tectonic maps and diagrams, Efremkin identified areas of increased corrosion capacity (Efremkin 2011). In these areas, abnormal oxygen contents are observed, which are reduced in relation to the background, which indicates that the active oxygen consumption during corrosion is observed. One of the attempts to systematize hazards was to identify ecological-formation zones – spatio-temporal aggregates of natural and technogenic processes, united by fancies, geochemical, geocryological, engineering-geological and geodynamic features, as well as the same type of ecological state of the lithosphere functioning (Efremkin, 2011). A total of 8 zones were identified, but the peculiarities of oil and gas geological zoning and the influence of the neotectonic regime of this territory were not taken into account. The identification of shelf artesian basins as parts of the Barents-Kara shelf hydrogeological region (Novikov 2017) and current information about the East Barents oil and gas Province allowed us to supplement the results of geoecological zoning.

RESULTS

Conditional ecological and geological zoning of the Barents and Kara Sea

As international experience shows geo-ecological zoning of water areas, maps of environmental ranking of the areas, showing the areas of greatest probability of occurrence of adverse situations, based on the analysis of the distribution of the regions in which the centers of highest concentrations of pollutants are within the ecosystems with the least resistance to external influences. To assess the overall risk of adverse situations within water areas, the analysis of geoprocessing of rasters of the Spatial Analyst information module containing environmental information is used, as well as the analysis of maps with information about the geographical conditions of the studied region. At the same time, the presence of various natural factors, such as the dismemberment of the bottom relief, the level of anthropogenic impact on the water area is estimated (Davies 1979; Ефремкин *et al*. 2008; Omerzel & Antončič 2008; Maughan 2013; Czaja *et al.* 2013).

This study does not use raster geoprocessing tools, but identifies areas of water areas with an identical physical and geographical type of water area based on the analysis of the areas of the selected physical and geographical, thematic and ecological areas. As a result, a map of the geoecological zoning of the water area with ecological and geological zones is created for a general assessment of the risk of adverse situations. According to the results of the characterization of geoecological hazards and the study of materials of oil and gas geological zoning, four eco-geological zones were identified: the Central Barents, the North Barents, the South Kara, the Yamalo-Gydan (Fig. 1). Developed ecological-geochemical scheme, made on the principles of identification of ecological trouble on the local level, allows to analyze in detail the manifestations of the most important properties of marine ecosystems, the sources of such problems, focal effects, as well as set environmental priorities and constraints economic use of the territory. The boundaries of ecological and geological zones are mainly associated with the boundaries of promising oil and gas artesian basins or groups of basins located in the Barents and Kara seas, so the names of zones are chosen in accordance with the names of hydrogeological structures. The most complex ecological and geological situations are characterized by the Central Barents and South Kara zones, where dangerous cryogenic processes are developed along with increased seismicity, active accumulation of heavy metals and high suspension content in seawater.

Areas of maximum content of heavy metals (copper, cadmium, lead, etc.) in sediments and bottom waters and areas of high suspension content in seawater were previously identified by I. M. Efremkin on the basis of data from areal field studies performed during geoecological works, as well as prospecting exploration and mining operations performed with the Limited Liability Company «Gazflot» (Vorobiev, et al. 2017).

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The increase in the content of heavy metals in sediments and bottom waters could be influenced by the results of changes in the biochemical composition of organic matter due to a reduced area of ice cover, in connection with the hydrological features of various areas of the Barents Sea (Nemirovskaya 2020). The content of heavy metals in groundwater and bottom sediments of the submarine hydrogeological structure within the South Kara zone may be due to the movement of these particles by water flows and their entry into the lower layers and aquifers, thereby forming flows of contaminated groundwater, which was also observed in previously published works on this issue (Iqbal *et al.* 2021).

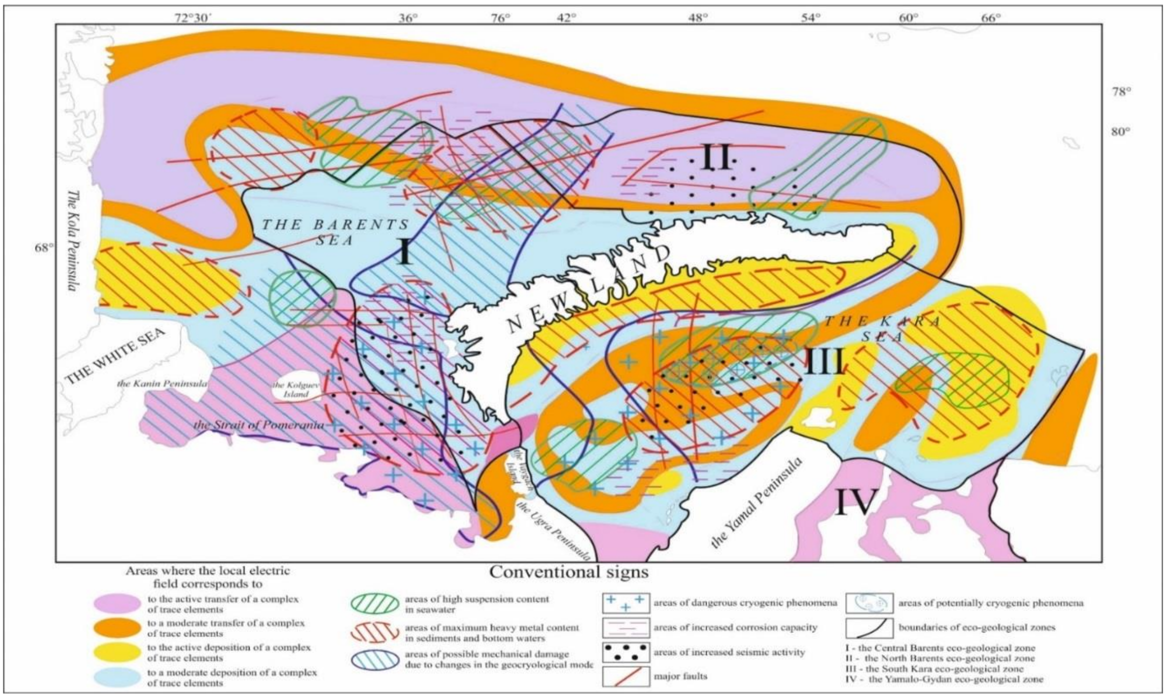

Fig. 1. Ecological-hydrogeochemical scheme of the Barents and Kara seas.

CONCLUSION

In the development of Arctic mineral resources, monitoring of the environmental situation in the mining areas will become increasingly important. Taking into account the unique natural conditions, it is necessary to apply innovative technologies for operational monitoring of large areas and long stretches of land, water and ice surface in hard-to-reach areas. In addition to the described methods of geoecological monitoring, which used measurements performed on board a ship or at anchorages, as well as the use of mathematical modeling tools, new methods of geoecological monitoring are currently proposed, which allow improving the methodology of geoecological mapping of promising geological structures of the Russian Arctic and taking into account the degree of hazards during the operation of deposits. The solution of the problem of operational monitoring is possible on the basis of the use of modern measurement systems installed on unmanned aerial vehicles, which makes it possible to combine remote and contact methods of monitoring studies. Modern avionics and aviation equipment of unmanned aerial vehicles allows you to fly in all climatic zones. At the same time, the range of their safe use in most cases is wider than that of manned civil aircraft. In this regard, attempts by developers and users to equip unmanned aircraft with technical means that allow them to solve not only observation tasks, but also perform very specific measurements are logical (Kremcheev *et al.* 2019). Based on the results of recent research in the St. Petersburg Mining University has been developed and implemented a monitoring system based on unmanned aerial vehicles for industrial environmental control and automatic transmission of streaming information to a ground control station equipped with special software. The developed monitoring system using a small-sized unmanned aircraft of helicopter or airplane type is used for remote aerial monitoring (including thermal imaging), video and aerial photography of terrain and objects from a height of 50 to 1000 m. Monitoring allows detecting oil spills and methane leaks, measuring radiation pollution of the atmosphere, quantifying the concentration of oxygen, carbon monoxide, carbon dioxide, nitrogen oxide, nitrogen dioxide, sulfur dioxide, hydrogen sulfide, as well as measuring temperature and pressure (rarefaction) in the sampling zone (Recchiuto & Sgorbissa 2018). For

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the first time, using the example of the basic model of an unmanned aircraft, a variant of solving the problem of creating a monitoring measuring complex included in the state register of measuring instruments is presented.

SUMMARIES

Exploring the main groups of environmental hazards in the Barents and Kara seas, managed primarily to establish that their nature is caused by both human activities and geological processes, especially the influence of neotectonic mode in the Barents-Kara seas (Eurasian) block, which has not previously been considered in research on geo-environmental substantiation of oil and gas areas of the Barents and Kara seas and are not included in the geo-environmental zoning of the area. This regime could have a direct impact on all these types of hazards, since most of them are confined either to the zones of large faults, or to the slopes of shelf troughs and depressions, that is, along the coast of the New Land archipelago. High-amplitude displacements of the Earth's crust within the selected ecological and geological zones led to an increase in the amplitudes of geostructures in the areas of the "continent – ocean" transition zone, changed reservoir pressures and the composition of hydrocarbons in deposits, which could also affect the formation and spatial distribution of geoecological hazard areas. Rational use of the oil and gas potential of the Arctic seas is based on the analysis of existing scientific ideas about the geological structure, engineering-geological and geocryological characteristics, hydrogeological, hydrophysical, oceanographic and lithodynamic processes. Only with a complex of modern knowledge on all these characteristics can we create a unified concept of mineragenic development of the Arctic Ocean shelf and, first of all, its western seas (Barents and Kara).

REFERENCES

Bull, ID, Nott, CJ, van Bergen, PF, Poulton, PR & Evershed, RP 2000, Organic geochemical studies of soils from the Rothamsted classical experiments—VI. The occurrence and source of organic acids in an experimental grassland soil. *Soil Biology and Biochemistry*, 32: 1367-1376.

Chilingarian, GV & Rieke, III, HH 1969, Some chemical alterations of subsurface waters during diagenesis. *Chemical Geology*, 4: 235-252.

Churilova, T, Strelnyk, V & Hres, N 2018, Environmental Audit of Subsurface Use. *Environmental Policy and Law*, 48: 144-152.

Collins, A 1975, *Geochemistry of oilfield waters*. Elsevier, 495 p.

Czaja, S, Beach, S, Charness, N & Schulz, R 2013, Older adults and the adoption of healthcare technology: Opportunities and challenges. *Technologies for active aging*, pp. 27-46.

Davies, AG 1979, Pollution studies with marine plankton: Part II. Heavy metals. *Advances in marine biology*, 15: 381-508.

Elhag, M & Bahrawi, JA 2017, Soil salinity mapping and hydrological drought indices assessment in arid environments based on remote sensing techniques. *Geoscientific Instrumentation, Methods and Data Systems*, 6: 149-158.

Galimov, EM, Kodina, LA, Stepanets, OV & Korobeinik, GS 2006, Biogeochemistry of the Russian Arctic. Kara Sea: Research results under the SIRRO project, 1995–2003. *Geochemistry International*, 44: 1053-1104.

Gusev, EA, Krylov, AA, Urvantsev, DM, Goremykin, YV & Krinitsky, PI 2020, Geological structure of the northern part of the Kara Shelf near the Severnaya Zemlya archipelago according to recent studies, 245 p.

Hosseinpour, J, Bravo, L & Samimi-Abianeh, O 2018, Computational study of unsteady cavitating flows and erosion in a fuel nozzle. In: ASME 2018 Internal Combustion Engine Division Fall Technical Conference. American Society of Mechanical Engineers Digital Collection.

Iqbal, J, Howari, FM, Mohamed, AMO & Paleologos, EK 2021, Assessment of radiation pollution from nuclear power plants. In: Pollution Assessment for Sustainable Practices in Applied Sciences and Engineering (pp. 1027-1053), Butterworth-Heinemann.

Ivanov, G 2013, Geoecology of the Western Arctic Shelf of Russia: Lithological and Ecogeochemical Aspects. Springer, 10 p.

Kędra, M & Grebmeier, JM 2021, Ecology of Arctic Shelf and Deep Ocean Benthos. *Arctic Ecology*, pp. 325-355.

Kontorovich, A 2015, Oil and gas of the Russian Arctic: History of development in the 20th century, resources and strategy for the 21st century. *Science First Hand*, 41: 42-61.

Caspian J. Environ. Sci. Vol. 19 No. 3 pp. 589~595 Received: Feb. 23. 2021 Accepted: May 19. 2021
DOI: 10.22124/CJES.2021.4954 Article type: Research

Kontorovich, VA 2020, A model of the geological structure and the oil and gas prospects of Neocomian (Berriasian–Lower Aptian) sediments of the West Siberia Arctic Regions and the Kara Sea Shelf. *Russian Geology and Geophysics*, 61: 1429-1447.

Kontorovich, VA & Kontorovich, AE 2019, November. Geological structure and petroleum potential of the Kara Sea shelf. In: *Doklady Earth Sciences, Pleiades Publishing* 489: 1289-1293.

Kremcheev, EA, Danilov, AS & Smirnov, YD 2019, Metrological support of monitoring systems based on unmanned aerial vehicles. Moscow, 235 p.

Kruk, M, Semenov, A, Cherepovitsyn, A & Nikulina, AY 2018, Environmental and economic damage from the development of oil and gas fields in the Arctic shelf of the Russian Federation. *European Research Studies Journal*, 21: 423-433

Laukert, G, Makhotin, M, Petrova, MV, Frank, M, Hathorne, EC, Bauch, D, Böning, P & Kassens, H 2019, Water mass transformation in the Barents Sea inferred from radiogenic neodymium isotopes, rare earth elements and stable oxygen isotopes. *Chemical Geology*, 511: 416-430.

Marguí, E, Van Grieken, R, Fontas, C, Hidalgo, M & Queralt, I 2010, Preconcentration methods for the analysis of liquid samples by X-ray fluorescence techniques. *Applied Spectroscopy Reviews*, 45: 179-205.

Maughan, RJ 2013, Quality assurance issues in the use of dietary supplements, with special reference to protein supplements. *The Journal of Nutrition*, 143: 1843S-1847S.

Maximova, D 2018, Sustainable development of the Russian Arctic zone: challenges & opportunities. Arctic Yearbook, 373 p.

Myslenkov, S, Medvedeva, A, Arkhipkin, V, Markina, M, Surkova, G, Krylov, A, Dobrolyubov, S, Zilitinkevich, S & Koltermann, P 2018, Long-term statistics of storms in the Baltic, Barents and White Seas and their future climate projections. *Geography, Environment, Sustainability*, 11: 93-112.

Nemirovskaya, IA 2020, Hydrocarbons in the Water and Bottom Sediments of the Barents Sea during Ice Cover Variability. *Geochemistry International,* 58: 822-834.

Novikov, DA 2017, Hydrogeochemistry of the Arctic areas of Siberian petroleum basins. *Petroleum Exploration and Development*, 44: 780-788.

Omerzel, DG & Antončič, B 2008, Critical entrepreneur knowledge dimensions for the SME performance. *Industrial Management & Data Systems*. 110: 175-192, DOI: 10.1108/02635571011020296

Peron-Pinvidic, G & Manatschal, G 2019, Rifted margins: State of the art and future challenges. *Frontiers in Earth Science*, 7: 218.

Raymond, MS & Leffler, WL 2017, Oil & gas production in nontechnical language. PennWell Corporation.

Recchiuto, CT & Sgorbissa, A 2018, Post-disaster assessment with unmanned aerial vehicles: A survey on practical implementations and research approaches. *Journal of Field Robotics*, 35: 459-490.

Sestras, P, Bilașco, Ș, Roșca, S, Dudic, B, Hysa, A & Spalević, V 2021, Geodetic and UAV Monitoring in the Sustainable Management of Shallow Landslides and Erosion of a Susceptible Urban Environment. *Remote Sensing*, 13: 385.

Savvin, DV, Fedorova, LL & Solovyov, EE 2021, March. GPR Technologies for Predicting the Development of Dangerous Cryogenic Processes in Subsurface Soils. In IOP Conference Series: Earth and Environmental Science (Vol. 666, No. 5, p. 052024), IOP Publishing.

Vasiltsov, VS & Vasiltsova, VM 2018, Strategic planning of Arctic shelf development using fractal theory tools. Moscow, 234 p.

Vorobiev, AE, Chekushina, T & Vorobiev, K 2017, Russian national technological initiative in the sphere of mineral resource usage. *Rudarsko-geološko-naftni zbornik*, 32: 1-8.

Yakushev, VS & Chuvilin, EM 2000, Natural gas and gas hydrate accumulations within permafrost in Russia. *Cold Regions Science and Technology,* 31: 189-197.

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