

Editorial: Gas hydrates in Arctic and permafrost regions special issue

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The Arctic regions of the Earth, including the Arctic continental shelf, are among the most promising and actively developed areas. This is primarily due to the abundance of natural resources, including major oil and gas reserves as well as significant deposits of metallic mineral resources. New transportation corridors are of particular importance in the Arctic, most notably the Northern Sea Route connecting Southeast Asia with Western Europe, as well as port infrastructure facilities located along the coasts of the Arctic seas. However, the development of the Arctic regions is complicated by a number of factors, including the harsh climate, unique permafrost and geological conditions, challenging logistics, and other environmental and infrastructural constraints. The presence of permafrost represents a major geotechnical challenge for the construction and long-term operation of engineering structures and infrastructure facilities. A serious source of geological risk in the development of Arctic regions is represented by natural gas hydrate accumulations. In the Arctic, these geological formations are mainly associated with the formation and evolution of the cryolithozone, driven by global climatic changes on Earth. The widespread occurrence of permafrost in Arctic regions and its considerable thickness, reaching several hundred meters, create favourable thermobaric conditions for gas hydrate accumulation over a wide interval of the geological section, both onshore and within the Arctic shelf. As a result, many shallow gas reservoirs located beneath permafrost may be converted into the gas hydrate state, while permafrost sequences can act as an effective caprock, promoting the accumulation of natural gas in the form of gas hydrates supplied from the Earth's interior during degassing processes. Large gas hydrate accumulations occurring above conventional hydrocarbon reservoirs in the Arctic are considered promising targets for future development as currently exploited gas fields become progressively depleted.

Particular attention is currently being paid to permafrost degradation processes in the Arctic associated with global climate change. This issue is also highly relevant to the Arctic shelf, where relic subsea permafrost, formed during earlier periods of subaerial exposure, is widespread. Permafrost degradation leads to the destabilization of both intrapermafrost and subpermafrost gas hydrate accumulations. This, in turn, results in the intensification of gas-dynamic processes within rock sequences and promotes

active methane emissions both on the Arctic shelf and onshore. In recent years, numerous methane seep sites have been identified on the Arctic shelf. According to a number of researchers, these features are associated with the degradation of subsea permafrost and the dissociation of gas hydrates. Active gas seepage from permafrost is also observed in the Arctic tundra and is frequently recorded both under natural conditions and during the drilling of various types of wells. Cases of explosive gas emissions from the upper horizons of Arctic permafrost have also been documented, resulting in the formation of large gas-emission craters up to 40 m in diameter and 50 m deep. According to many researchers, their formation is likewise associated with gas hydrate dissociation processes.

This special issue of *Environmental Geotechnics* is devoted to research on gas hydrates in Arctic and permafrost regions. It is based on contributions presented at the First Russian Gas Hydrate Conference, which was held on 25–31 August 2024, at Lake Baikal (Listvyanka, Irkutsk Region, Russia). The issue includes original research articles addressing gas hydrate stability zones on the Arctic shelf and their relationship to the evolution of subsea permafrost, the assessment of hydrate formation conditions in low-temperature gas reservoirs, the potential application of various geophysical methods to the investigation of permafrost and gas hydrate accumulations in the Arctic, as well as the processes of gas hydrate formation and dissociation in freezing and frozen sediments.

The paper by Chazov *et al.* (2026) is devoted to the investigation of relic subsea permafrost and gas hydrates on the Laptev Sea shelf. Based on the analysis of seismic data, the authors identified geophysical indicators of relic subsea permafrost, demonstrated several patterns in its distribution, and established that it supports an extensive gas hydrate stability zone.

The need to combine geophysical methods with other investigative approaches is discussed in the paper by Misyurkeeva *et al.* (2026) which evaluates the potential of an integrated approach that combines shallow electromagnetic surveying, drilling, and well logging data for the investigation of gas hydrate deposits in Arctic permafrost. This approach makes it possible to reconstruct

detailed geological models incorporating physical properties of permafrost strata, identify decompression zones, tectonic faults, and potential gas hydrate-bearing intervals. Thus, in an area near Salekhard (Yamal), such investigations have enabled the construction of detailed geological and geophysical cross-sectional models extending from depths of several meters to 500–700 m. The anomalously high electrical resistivity of gas hydrates relative to the surrounding sediments provides a basis for the application of electromagnetic methods to the exploration of Arctic gas hydrate resources; however, their successful implementation requires further technological advances and an interdisciplinary approach.

Experimental modelling of gas hydrate formation and dissociation processes in cryolithozone sediments is the focus of two papers contributed by a group of authors led by E. Chuvilin *et al.* (2026a). In the first paper, “Kinetics of phase transitions in ice- and hydrate-bearing sediments under thermal impact”, experimental modelling is used to investigate the response of frozen hydrate-bearing sediments to thermal loading, simulating the conditions that intrapermafrost gas hydrate accumulations may encounter during natural and anthropogenic permafrost degradation. According to the experimental results, the response of permafrost containing stable pore-filling gas hydrates to increasing temperature begins with thawing, whereas gas hydrate dissociation requires higher temperatures. In contrast, the dissociation of metastable gas hydrates in warming permafrost begins prior to ice melting within the pore space, at temperatures several degrees below the thawing point, depending on the composition and properties of the permafrost. In the second paper by Chuvilin *et al.* (2026b), “Formation of pore CO₂ hydrates in permafrost: evidence from laboratory modelling”, laboratory experiments on the formation of carbon dioxide hydrates in freezing and frozen sand are presented, demonstrating that sediments within and beneath permafrost may serve as potentially suitable reservoirs for carbon dioxide sequestration in these horizons. Proceeding from the experimental results, porous and permeable permafrost can ensure reliable disposal of production-related carbon dioxide as hydrate. The formation of gas hydrate can strengthen the permafrost and thus compensate its thawing and thinning caused by interaction with injected carbon dioxide.

The application of numerical modelling to gas hydrate studies is addressed in the papers by Smirnov *et al.* and Butuzov and Vasilieva. In the paper by Smirnov *et al.* (2026), the key factors controlling gas hydrate formation on Arctic shelves are examined.

The authors present the results of numerical modelling of gas hydrate stability zones on the Arctic shelf over the past 26 000 years. Several principal types of gas hydrate stability zones are identified, including permafrost-associated, post-permafrost, subglacial, and postglacial zones, as well as conventional deep-seated gas hydrate stability zones controlled by hydrostatic pressure and geothermal heat flux. Examples of Arctic regions where these types of stability zones may occur are also presented. The authors emphasise the need to account for glacial influences and seismically active zones when investigating offshore methane hydrate deposits, as these factors affect geotechnical hazards, including submarine landslides and methane releases.

In the paper by Butuzov and Vasilieva (2026), non-isothermal gas flow in low-temperature reservoirs within the near-wellbore zone of a gas well is analysed through numerical modelling using a case study from an Arctic gas field. The Joule–Thomson effect in porous media and its influence on temperature reduction in gas reservoirs is evaluated. The proposed calculations make it possible to determine the conditions for hydrate-free well operation.

All papers presented in this special issue make a significant contribution to the study of gas hydrate occurrences in areas of permafrost distribution, demonstrating the diversity of approaches to investigating this complex natural phenomenon.

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