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REVIEW

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A NEW LOOK AT CRYOLITHOGENESIS OF MARINE SEDIMENTS OF THE GAS-BEARING STRUCTURES ON THE YAMAL PENINSULA (a review of the monograph by Yu.B. Badu "Cryogenic Strata of the Gas-bearing Structures of the Yamal Peninsula")

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Yu.B. Badu' cryolithological paradigm is discussed, based on the results of the many years' research of conditions of forming the cryogenic strata of the gas-bearing structures on the Yamal Peninsula. The geological structure, composition and state of the Middle Neopleistocene–Holocene strata testify to their occurrence against the background of the transgressions–regressions processes in the Arctic basin and their development under conditions of sedimentation, cooling and freezing under the impact of the heat flux and gas emission from the gas deposit.

Gas-bearing structure, Yamal, cryogenic strata, offshore and onshore cryolithologic provinces, submarine syncryolithogenesis

In 2018, the Moscow-based publishing house "Nauchny Mir" ("World of Science") published an interesting book written by Yury Badu "Cryogenic Strata of the Gas-bearing Structures of the Yamal Peninsula. On the Impact of Gas Deposits on Formation and Development of Cryogenic Strata" (232 pages). The author of the book, Yury Borisovich Badu, is a well-known permafrost scientist, the leading researcher of the geography faculty of MSU (the department of cryolithology and glaciology), a candidate of geographical sciences, an associate professor. The book is based on the results of the engineering, geocryological and cryolithological studies conducted by Yury Borisovich in the north of Western Siberia, including those performed in the gas condensate fields.

The long-term studies of the conditions of formation of the cryogenic strata of the gas-bearing structures in the north of Western Siberia allowed the monograph author to state original concepts of cryolithogenesis in the cryogenic strata of the gas-bearing structures of Yamal and of the adjacent offshore provinces. The author's idea is that cryolithogenesis in the area of modern and ancient accumulation of deposits is manifested by continuous gas saturation of marine sediments, the cryolithological structure of which is gradually formed in the process of accumulation of deposits in the respective facial environment.

The monograph consists of five chapters, each chapter containing conclusions. The content of the book is profound, logical, and consistent, and in fact, each chapter is a complete statement in itself. The detailed introduction substantiates the relevance and the novelty of the monograph's subject; the impressive scope of the investigations conducted is characterized; the objective of the study and its tasks allowing its achievement are determined; the main provisions of the author's concept of the modern condition of the cryogenic strata are delineated and the practical importance of the results obtained is proven.

In the first chapter, the author discusses the gas-bearing structures of Yamal and of the adjacent offshore provinces in view of systemic analysis. General classification of the gas-bearing structures of the region is provided, including the offshore and onshore cryolithological provinces. It is demonstrated that, for the structure of the geological section, the composition and state of the deposits, "the cryogenic strata in a gas-bearing structure" form a special cryolithological system, which developed in the Neo-Pleistocene–Holocene under conditions of sedimentation, cooling and freezing under the impact of a heat flux and gas emission from a gas deposit.

In the second chapter, general information about the geological structure of the Yamal Peninsula and of the adjacent offshore area, including the tectonic structure, stratigraphy within the cryogenic strata (from Cretaceous to Late Neo-Pleistocene) and correlation of the sections of Cenozoic deposits. The author made regional profiles of the strata of Pleistocene deposits crossing different gas-bearing structures of the Yamal Peninsula and of the Taz Peninsula.

Analyzing the data found by the preceding scientists and his own material, Yury Borisovich Badu developed a stratigraphic section of the little-known northern part of the Yamal Peninsula, using his own novel stratigraphic system of Cenozoic deposits; he divided the Kharasavey section and related the Bovanenkovo, the South Tambey and other stratons to it.

In the third and fourth chapters, analyzing a large amount of factual data, the author defines the parameters of the deposits constituting the cryogenic strata in different gas-bearing structures (the ground temperature, thickness of the cryogenic strata, the ice content and the cryogenic structure of the frozen deposits, the mineralization of the pore solution in the deposits of the cryogenic strata). The author shows that these parameters are determined by the conditions of sediment accumulation and freezing under the influence of heat flux and gas emission from the gas deposit. The text is amply illustrated with the temperature curves, maps of the cryogenic strata thickness, cryogenic strata sections, etc. The chapter contains a classification of the types of syncryolithogenesis, in which the author, developing the ideas of A.I. Popov, provides a new concept of formation of permafrost in subaquatic environments against the background of gas saturation of the deposits in the process of sediment accumulation and after its completion.

In the fifth chapter, the author analyzes gas showing in the strata of marine sediments of northern Yamal and states the basic concept of submarine cryolithogenesis of the marine sediments of the gas-bearing structures of Yamal. The novelty of the concept of formation of the cryogenic strata in marine environments is related to the fact that marine sediments freeze near the bottom surface practically synchronously with penetration of gases migrating from below and with the cooling and freezing action of the throttling effect of their expansion. Cryogenic strata develop differently in the marine environment depending on the sea depths. In the opinion of Yu.B. Badu, at the depths exceeding 40–50 m, bottom sediments freeze under conditions of *submarine syncryolithogenesis* due to heat loss from the bottom owing to the negative-temperature water. At the depths less than 40–50 m, *plicative syncryolithogenesis* at displacement of layered deposits sliding on submarine slope) and *diffusion syncryolithogenesis* (in adiabatic expansion of the penetrating gases) take place. After drying of the bottom in the subaerial condition, cryogenic strata thicker than 100 m become exposed to the thermal impact of the gas deposit.

Each chapter of the book is accompanied by original author's illustrations of good quality, clarifying the text.

This relatively small monograph comprises such a large amount of new materials that a brief review of it cannot reflect all the merits of the book: each reader will find interesting information for self-education, thinking, and discussion. The book is meant for geocryologists and cryolithologists (specialists, students, and post-graduates); however, it will be interesting for specialists in the oil and gas geology and for geologists in general.