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Gas hydrates in the West Arctic sector: Prospects and problems

V.S. Zakharenko

*Faculty of Natural Sciences of Murmansk State Humanitarian University,
Department of Geography and Ecology*

Abstract. History of gas hydrates study, possible models of their formation within the West Arctic continental margin have been considered in the paper. Prospects of gas hydrates development and problems of environmental risk have been discussed. The interpretation of gas saturated thickness unit within the Pomorsky trough according to seismic-acoustic data has been given.

Аннотация. Рассматривается история изучения газогидратов, модели их образования на Западно-Арктической континентальной окраине, обсуждаются перспективы развития газогидратов и проблемы, связанные с экологическим риском. Приводится пример интерпретации газонасыщенной толщи в Поморском прогибе по данным непрерывного сейсмоакустического профилирования.

Key words: Pomorsky trough, West Arctic continental margin, continuous seismic-acoustic profiling, continental slope, alluvial fans, gas hydrates

Ключевые слова: Поморский прогиб, Западно-Арктическая континентальная окраина, непрерывное сейсмоакустическое профилирование (НСАП), континентальный склон, конусы выноса, газогидраты

1. Introduction

Recently the continental margin basins generate more and more interest from the standpoint of hydrocarbon exploration. After the discovery in the mid-twentieth century of previously unknown properties of natural gases to form in the Earth's crust under certain thermodynamic conditions deposits in the solid state researches of gas hydrates in the oceans have been intensified.

Crystalline compounds are formed under certain conditions of temperature and pressure of the water and gas. In the 1940s, Soviet scientists hypothesized the existence of gas hydrates deposits in the permafrost zone (Strizhov, Mokhnatkin, Chersky). In the 1960s, they discovered a first deposit of gas hydrates in the north of the USSR, and at the same time the possibility of formation and existence of hydrates in nature found its laboratory confirmation.

Since then, gas hydrates are regarded as a potential source of fuel. Their wide distribution in the oceans and continents of permafrost, the instability with increasing temperature and decreasing pressure are found out.

To some extent, gas hydrates are ice-like mass of white colour, formed by water and gas. In addition to methane (ethane, propane) gas hydrates contain carbon dioxide and hydrogen sulfide. Features of formation of gas hydrates and their distribution patterns in nature are detailed in the works of *Vasiliev et al.* (1970), *Ginsburg and Soloviev* (1994), *Zhizhchenko* (1972), *Efremova* (1979), *Makogon* (2003), *Trofimuk et al.* (1979) and others.

The growth of research activity is explained by the following factors:

– the search for alternative sources of hydrocarbons in the countries that do not possess energy resources, as gas hydrates are non-conventional sources of hydrocarbon raw materials, research and industrial development of which may begin in nearest future;

– the need to assess the role of gas hydrates in the subsurface layers, particularly in relation to their possible influence on global climate change;

– manifestations of natural hydrates could serve as markers of a more deep-seated oil and gas fields;

– intensive development of hydrocarbon fields located in the complex natural environment (the deep shelf, the Arctic regions), where the problem is exacerbated by man-made gas hydrates;

– feasibility of reducing operating costs to prevent hydrate formation in the systems of commercial production of gas by switching to energy-saving and environmentally friendly technologies;

– the possibility of using gas hydrate technology in the development, storage and transportation of natural gas.

2. Studies in the Western Arctic sector

In the Western Arctic sector gas hydrates are found to the north-west of Svalbard (*Posewang, Mienert*, 1999). Their study was carried out with high-frequency seismic, with an analysis of travel-time curves and velocity.

However, the area of the West Spitsbergen continental margin and especially of the continental slope has been studied insufficiently. Systematic integrated geological and geophysical studies have been conducted here since 2003 by Marine Arctic Geological and Geophysical Expedition of Murmansk. As a result of these studies information about the foundation has been obtained, the structure of the sedimentary cover and features of sedimentation reflected in the avalanche sedimentation rate of the formation of alluvial fans on the continental slope and the foot have been studied (Zakharenko, 2007; 2012; Zakharenko *et al.*, 2007a,b; 2010).

Basing on seismic and geochemical studies, we highlighted a potentially promising area – along the shelf edge, within which much of the hydrocarbon gas is of epigenetic nature, suggesting the migration of hydrocarbons in these areas from the deeper horizons, and therefore, the presence of hydrocarbons. This work presents the results of studies of gas hydrates based on seismic activities of MAGE in the project "Integrated geological and geophysical studies in the Pomorsky trough of West-Spitsbergen continental margin", 2009 (Fig. 1).

The interpretation of the wave field by geophysical transects, as well as the construction of maps was carried out using a digital interactive system Kingdom Software 8.2 SMT.

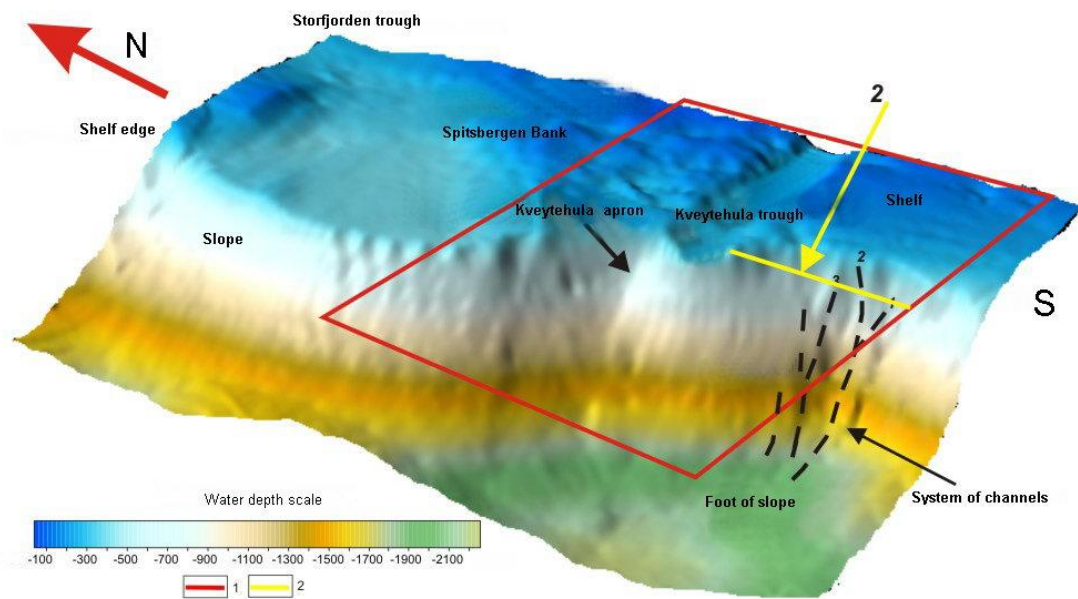


Fig. 1. Map of the studied area.

The presentation of the bottom topography 3D (Zakharenko, 2012):

1 – the research area, 2 – the system of erosion cuttings (channels) on the edge of the shelf and continental slope

3. Sedimentation model for the formation of gas hydrates

We are basing the sedimentation model of gas hydrates formation on the ideas about stream sedimentation, in particular, the turbidity currents that carry sediment material to the base of the continental slope or the bottom of the trenches. If the body of landslides and avalanches giving rise to such flows contain the free gas, then, as it moves down the slope, the gas bubbles can (under favorable conditions) form a cluster of buried hydrate.

It is known that the cause of landslides can be not only the decomposition of hydrates, but also their formation, which can cause redistribution of stresses in the arrays of deposits and cause them to move – geodynamic consequence. Continental margins are areas of discharge of fluids, like moving from the land and the squeeze from the sediment under the influence of tectonic stress. A prerequisite for the formation of the rising fluid is a high rate of sedimentation on continental margins.

The wave field detected acoustically transparent body, which in combination with other indirect signs (sudden interruption of the correlation of reflecting horizons, dome-shaped "bulge" of overlying horizons, the presence of the characteristic noise "migrating" on the layers up the hill) indicate gas saturation in the leistocene strata area (Fig. 1, 2).

On the plan this area is located in a decrease between two alluvial fans, and geological conditions are consistent with the above conditions of formation of gas hydrates. Comparison of the results of deep seismic data has shown a direct spatial connection with anticline uplift in the sedimentary cover, which was further confirmed by the results of gas hydro-chemical shooting and with zones of high concentrations of dissolved hydrocarbons.

Analysis of the power distribution of Quaternary sediments indicates the intense removal of terrigenous material on the chute Kveytehola with the formation of young alluvial fan (Zakharenko, 2012).

In the southern area of the structure lower Pleistocene seismostratigraphic subcomplex acquires a specific character. On the profiles along the strike of the continental margin at the top and bottom of seismic complex some anomalies of the wave field are indicated. They are interpreted as erosion channels (amplitude of the "incision" to 200 ms) and probably representing the channel flow, cut during the oscillation of ice sheets and legacy from the late Pliocene (Fig. 3). These anomalies of the wave fields are marked between the alluvial fan Storfjorden and fan Bjornoyai. Erosion on the sides of cuttings is allocated to cross-bedded seismic facials pattern of seismic records interpreted as alluvial ridges.

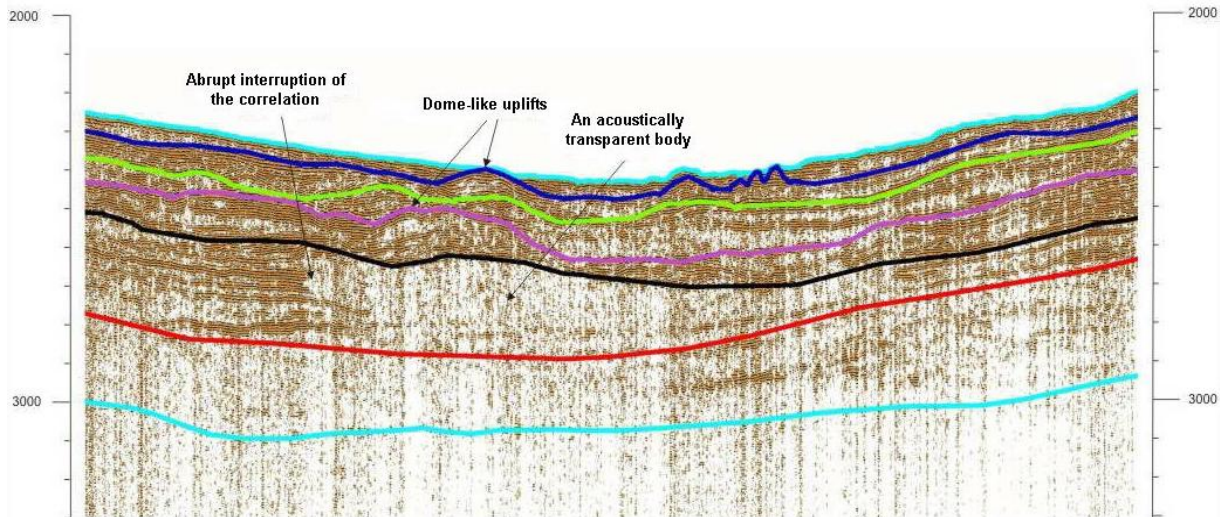


Fig. 2. The example of an acoustically transparent body associated with gas hydrates

At the bottom topography we see a highly dissected surface formed by drainage channels (Fig. 1). In the eastern part of the studied area regressive appearance of deposits shows the prevalence of shallow-water conditions, here sandy sediments of terrigenous origin of slope incision are possible. Further west, the shallow-water sediments are distributed in the zone of great depths where in general sediments of more clayey composition dominate. Most of these complexes have been eroded by shelf glaciations of the last 0.8 million years. Shortly after the start of the cycle of the ice shelf formation in the Barents Sea, a huge landslide formed on the slope and shelf edge (Richardson *et al.*, 1992).

The landslide is characterized by the presence of both alternating blocks and more chaotic parts formed probably due to the collapse of the materials and debris and material transport by turbidity currents. To a great extent this process is reflected in the sediments of the Late Miocene and Pleistocene sediments observed in the slope of the cones. It is assumed that the cause of the landslide could be the factors such as high rate of sedimentation and the presence of gas in the sediments. An additional factor causing the formation of a landslide could be seismic effects.

Thus, analyzing the patterns of distribution and the formation of submarine gas hydrates on continental margins, we can identify common features:

- Continental margins are areas of discharge fluid as moving from the land side, and squeeze of the sediment under the influence of tectonic stress.
- A prerequisite for the formation of the upward-fluid is a high rate of sedimentation on continental margins (avalanche sedimentation).
- Pleistocene period was characterized by development of turbidity currents formed in the degradation of the glacier, and possible presence of local desalinated water. Desalination of pore water is not evidence of indispensable presence of gas hydrates in the areas of abnormal salinity; however, it can be regarded as an auspicious sign for the hydrate.
- Features of the wave field discovered in some areas according to the seismic work of MAGE mark gas saturation zone of Pleistocene precipitation.

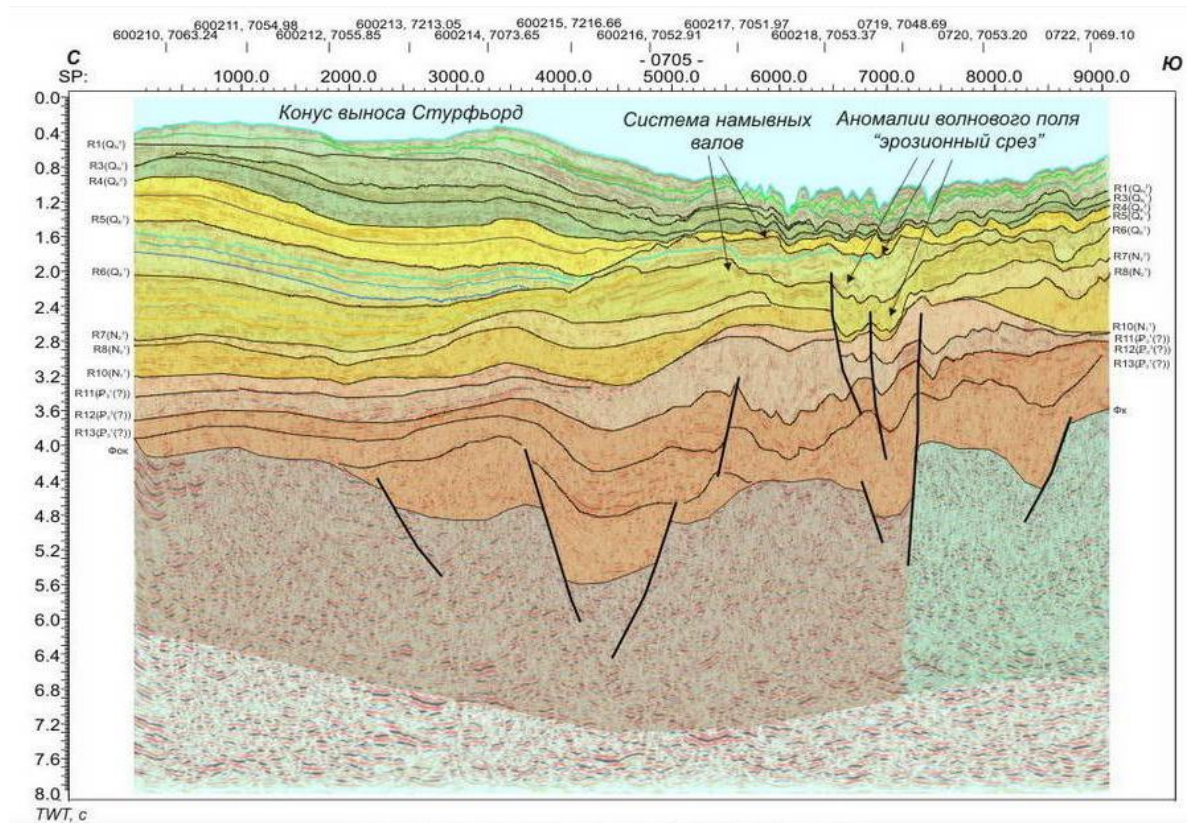


Fig. 3. Section of profile 0705 (MAGE)

4. Conclusion

In general, natural gas hydrates represent a very complex multifactor problem. Let us consider the main factors.

Gas hydrates – fuel of the future. The potential energy concentrated in natural hydrates can provide clean energy for the world for more than 200 years. They are more evenly distributed on the planet than oil and gas sources. Their development does not require super-deep wells, complex and expensive system of transportation of products. Development of gas hydrate deposits can be successfully made using existing technologies for prospecting and exploration, drilling and production of hydrocarbon fuels. The economic indices of development of gas hydrates deposits can be even more effective than in the case of oil and natural gas.

The technological aspect. The development of solid gas hydrate deposits has its own peculiarities which require serious consideration. The problem is that its production is technologically difficult, dangerous and therefore very expensive.

In the UK, a pilot plant is set up to produce hydrates with the productivity of 1 ton per day. This device is intended for testing technology for gas hydrates in the offshore platforms and their subsequent transport. In Japan there are plants for the production of "pills" from the ice-hydrate, which can be stored and transported at low temperatures (the results of these studies were actively advertised in the hydrate conference in Yokohama in 2002 and in Tokyo in June 2003 at the World Conference of gas).

The political aspect. Development of gas hydrate deposits in fact marks a new stage of redistribution of the world energy market. U.S.A. and Japan are planning to enter the commercial production of GH in 2010-2015. At the Russian Conference on Gas Hydrates (Novosibirsk, 2003) the need to create in the nearest future the Russian national program of research of gas hydrates was stressed (Kuznetsov et al., 2003). In Gubkin Russian State University of Oil and Gas the international conference "Prospects of development of gas hydrate resource fields" was held in November 2009. The reports focused on the latest scientific results in the study of physical and thermodynamic properties of gas hydrates, geophysical methods to detect them, the possibilities of their industrial use.

Gas hydrates as a factor of environmental risk. Natural gas hydrates in some cases must be regarded as an undesirable circumstance. They can lead to technological complications in drilling and operating wells for oil and gas in the construction of floating platforms, etc. In addition, with relatively small changes in temperature

and pressure conditions, gas hydrates decompose to water and gas, which is accompanied by uncontrolled release of gas into the atmosphere. Such explosions are actually observed in the tundra and sometimes in the sea. For the Western sector of the Arctic environmental risk factor is dominant. This is due to: – First, the problem of climate change, which may lead to changes in temperature and pressure conditions in surface waters. There is the hypothesis shared by many researchers that global warming will cause the destruction of the centers of formation of cold deep ocean water, which will slow or even stop currents such as Labrador current – carrying cold water from high latitudes to low. This, in turn, will lead to a weakening or complete halt of such flows as Gulf Stream – carrying warm water from low to high latitudes. – Secondly, the problem of seismic activity in the young faults and the resumption of tectonic activity in the areas of old faults, which may cause local explosions of GH (West Spitsbergen continental margin, Strait Storfiord). – Third, study of the stability of the seabed at the prospect of building a pipeline under the Barents Sea. Nowadays various lines of GS research are developing quite separately and often in isolation. Therefore, of great importance is the creation of flexible data base systems of gas hydrates. Research in this area should be co-ordinated on a global scale.

We hope that our research is a contribution to the coordination of these problems.

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