On the issue of the Black Sea methane hydrate potential development

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First successful pilot test to produce methane from submarine gas hydrate field in the East Nankai trough offshore Japan has resumed practical interest to develop giant methane hydrate potential of the World Ocean and the Black Sea basin as well. The paper features geological aspects and technological problems of submarine gas hydrates exploitation and discuss methane-hydrate potential assessment and promising exploration prospects in the Ukrainian part of the basin. The recommendations to methane hydrates development in the Black Sea are given.

Key words: gas hydrate, methane production, World Ocean, Black Sea, recourses, subsea deposits

The methane hydrates of the World Ocean, due to their huge geological resources, may become one of the sources for provision of the constantly growing energy needs of the mankind in the near future. The theory of their formation and existence under certain thermodynamic conditions is rather well developed [1, 2]. Today, however, a number of geological, technological and environmental problems require the scientific study and practical solution, in order to allow the industrial and environmentally sound extraction of gas hydrates.

Apart from the concurrent operation of methane hydrate caps together with free gas on giant fields of Messoyaha and Prudhoe Bay, the practical start of extraction of the proper gas hydrates should be considered the hydrate deposit extraction using a thermal cyclic test method in Mallic well in the Mackenzie Delta in the Canadian part of the Buford Sea basin in 2002. Later on, in the Arctic slope of Alaska the research trials of Mount Elbert well in 2007 and 1-Ihnik Sikumi in 2012 was conducted, which tested the possibility of combined gas hydrate extraction via injection of carbon dioxide in the hydrate-bearing collector and methane replacement while reducing the pressure during pumping off of the formation water, then the gas hydrate was decomposed, and the released methane was fed into the well. The pressure and flow rate was measured at its estuary, the gas composition was analyzed, and the gas was burned in a flare. The methane hydrate facility is represented here by three horizons of fine-grained turbidite sands of Pleistocene Osaga formation with intergranular porosity 42-45% (the hydrate cements the rock and covers 80% of the pore space), so it is no surprise that the research well began excreting the sand intensively and form the tubes, due to which the extraction had to be stopped. The overall hydrate reservoir layers occupy up to 20% in the sand-clay section of the front part of the underwater cone of the said formation [4]. The hydrate deposits lie at the depths of 290 to 300 m from the ocean bed and are characterized by double seismic horizon BSR (bottom simulating refector).

Fig. 1. Location of research and production wells (red star); the methane hydrate deposits nearby the coast of Japan are shown in blue

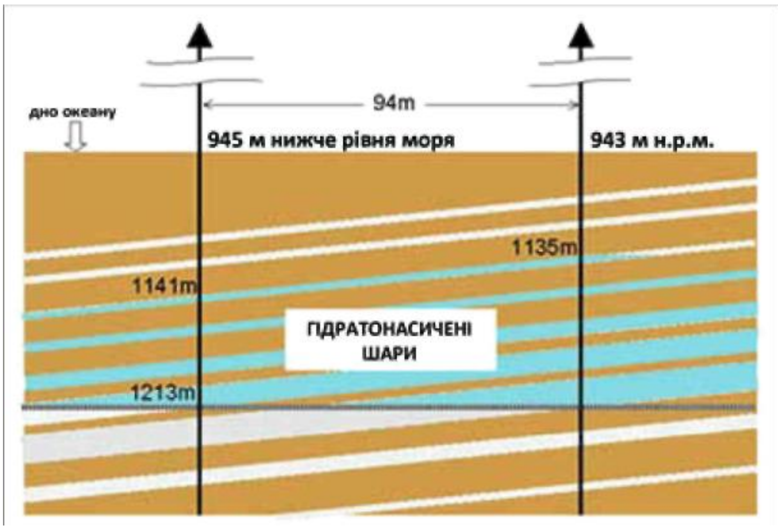

Fig. 2. The gas and hydrate bearing layers in Osaga Pleistocene formation disclosed be parametric wells [3]

The Black Sea is characterized by the highest methane degassing vs. the other seas [1] and is one of the world's most promising basins for methane hydrates extraction. As you know, this is where the first methane hydrates were documented on the seabed. The experts of all Black Sea countries, i.e. Ukraine, Bulgaria, Turkey, Romania, Russia and Georgia, as well as international research groups [5, 6] study the hydrate capacity of the Black Sea. Recently a technology of the so-called "autoclave drilling" and sampling to a depth of 100 m from the seabed to explore the hydrate bearing layer was performed here [7]. However, the unresolved technological issues and a factor of the extremely environmentally sensitive semi-closed system of the Black Sea postpone the start of the practical work on development of its methane hydrate potential.

The recent decades the study of gas hydrates of the World Ocean showed that the gas hydrate layer at the depths of the sea, where there are favorable conditions for its existence, is not powerful and sometimes even not continuous, so the resource base of gas hydrates is adjusted continuously according to the new data. It is certain that the local zones of methane hydrates cover the edge fractured zones of offshore sedimentary basins, intercepting the powerful upward flow of the deep thermogenic methane and form a multilayered cap for sub-hydrate gas reserves in terrigenous reservoirs. The latter is somewhere broken with recent tectonic movements and mud volcanic processes.

In the most submerged part, where the tectonic faults are few, the gas hydrates contain mainly themicrobial methane of biogenic origin.

Due to the hydrate saturated soil sampling during research visits, seismic, seismic acoustic and geochemical surveys in the Black Sea several strong fields (deposits) of underwater methane hydrates representing the practical interest were mapped [1, 5, 8, 9]. The assessment of their geological resources in the Ukrainian sector of the Black Sea differs significantly, from 15 to 60 trillion m^3 in terms of methane, reflecting various methodological approaches of various researchers to the calculation of stocks of these yet poorly investigated raw materials, so this problem needs the further in-depth research.

The depths of the Black Sea show the following gas zoning: beyond the edge of the continental slope there is a circum-Black Sea area of off-hydrate through gas transit and a gas cluster invasion/migration zone in the bottom sediments (so-called chimneys) nourishing the submarine gas geysers (gas seeps) and is traced to the depth of approximately 750 m [10]; further in depth there is an area of the island hydrate saturation followed by the area of complete hydrate bearing (with powerful multilayered deposits in terrigenous reservoirs at fault paths of the upward gas migration and BSR proliferation) in the area of submarine slope and continental foot of the Black Sea. Finally, the deep central part is occupied by an almost unexplored area of low-capacity coating hydrate saturation in clay-mud basin sediments where the schlieren and embedded manifestations of methane hydrate do not form a continuous layer, so the BSR is not observed.

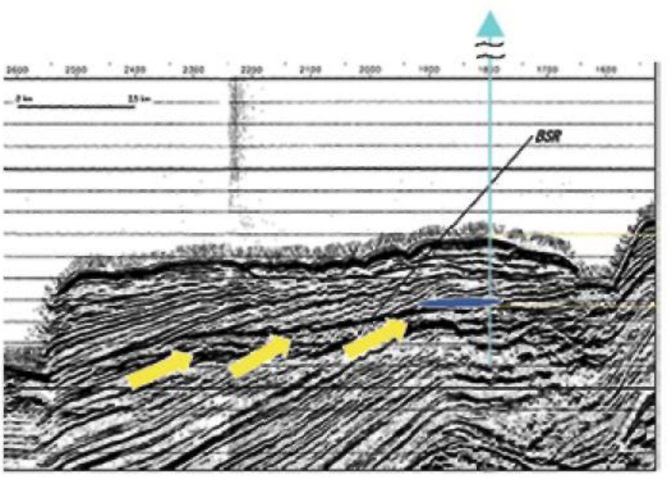

Fig. 3. The location of JOGMEG production well on the slope of the ocean cove. The arrows trace the double BSR [3]

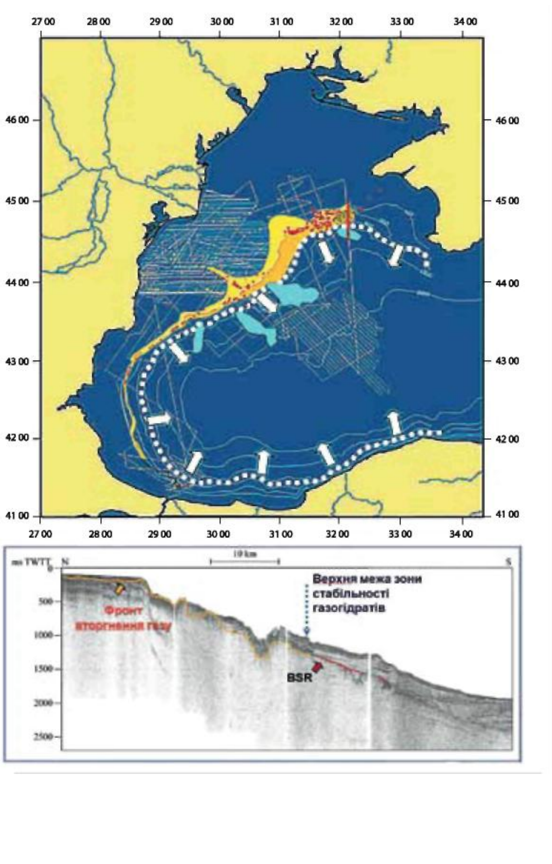

Fig. 4. Zone of underwater gas manifestations (red dots), the upper edge of gas hydrates distribution according to the simulation data (dotted line and arrow, white), gas hydrate deposits (green) in the Western Black Sea Basin [9]

Concerning the BSR seismic boundary, which is an indicator of selection of the gas hydrate thicknesses, it is worth noting the following. In 1970 the existence of an appropriate seismic reflective boundary in several environments rich in gas hydrates was revealed. Its position coincided with the thermodynamically determined depth of the gas hydrate stability zone (GHSZ) foot. These new results are widely used in the seismic data for massive gas hydrate deposits. The aforesaid reflecting boundary can be easily recognized because it is parallel to the sea bed and has a reverse polarity. BSR usually crosses the stratigraphic horizons on seismic profiles since its position is determined rather by difference of acoustic impedances between sediments saturated with gas hydrates (above the BSR, in the GHSZ area) and gas-saturated sediments beneath.

Yet BSR is not always evident or observed in seismic profiles located in the rich gas hydrate environments. For example, the gas hydrates have been found in some cases without a BSR. This suggests that other parameters such as the distribution of gas hydrates in the GHSZ stability zone, the total number and structure of gas hydrates, gas distribution below GHSZ etc. affect the BSR development. In some places with the well-marked BSR on seismic sections the small number hydrate samples was collected from the core [11]. Thus, BSR as an indirect proof of the gas hydrate availability can be used only as one of the criteria for selection of gas hydrate thickness in combination with the other direct and circumstantial evidence.

There are many examples of BSR allocation within the zone of continuous hydrate capacity of the Black Sea. Subject to its presence in the western part of the Black Sea, the Romanian researchers [9] clearly distinguish 4 projected hydrate bearing areas (Fig. 4).

Using these data, we explored the relevant anomalies on the materials of the regional 2D seismic investigation obtained by MSGT. As a result of processing of the data across multiple seismic profiles the BSR was traced (Fig. 5), and it was attempted to identify the projected methane hydrate deposit (Fig. 6).

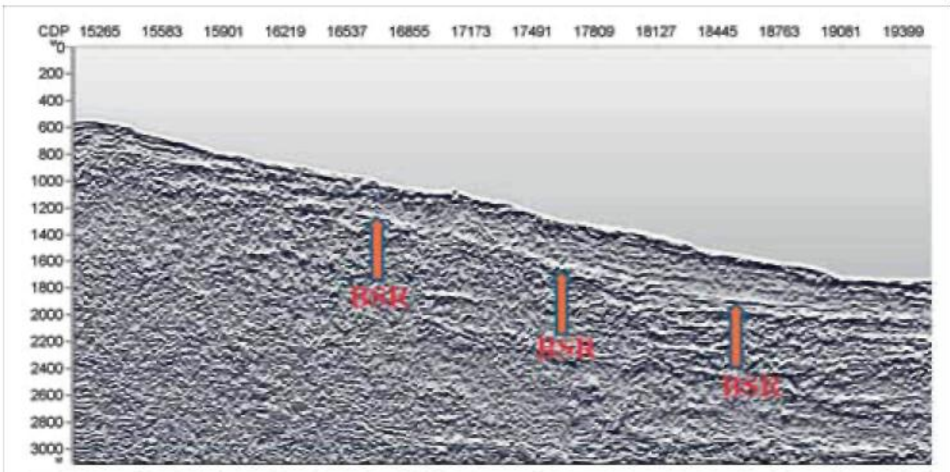

Fig. 5. BSR tracing on BS-05-26 seismic profile (deep cut)

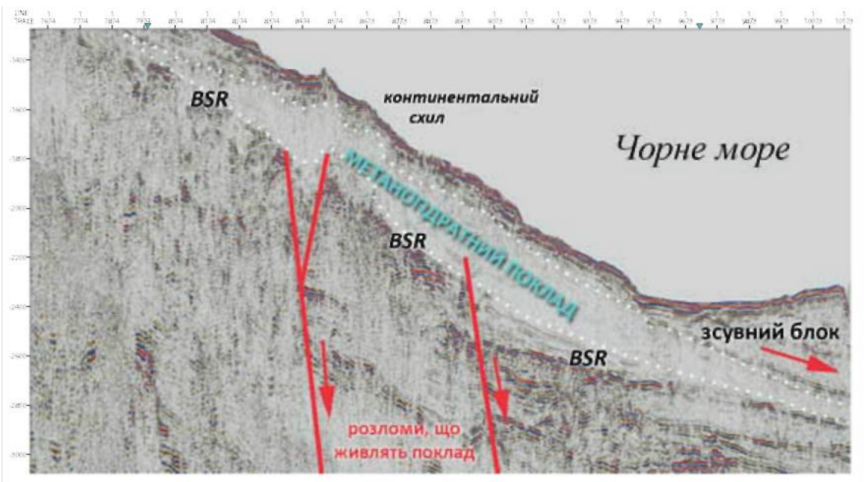

Fig. 6. Example of methane hydrate deposit allocation on the continental slope of the northwestern part of the Black Sea (seismic profile BS-05-26, time section)

Solving the problem of mapping the potentially gas hydrate-bearing facilities on the basis of 2D seismic materials require the use of the specialized dynamic data processing in order to learn more about the features of the geological environment. Solving the appropriate task required the implementation of all processing procedures in the mode of saving of the "true amplitudes" of seismic waves for the entire time period of registration. The "true amplitudes" are the amplitudes which suffered the minimal distortion of the dynamic characteristics of the seismic record while processing. The resulting seismic section a priori should reflect an adequate distribution of reflection coefficients both in literal and in the direction of increasing the time of registration.

To systematize the application of a sequence of procedures and determination of the values of their parameters the seismic data processing graph consisting of 6 blocks was developed.

Block 1. Formation of the geometry of observations subject to inclusion of information in the headers of the input seismograms and obtaining of a priori temporal section of the common midpoint.

Block 2. Weakening of various types of interferences, noise and short-wave reverberations on the input seismograms sorted by general arousal items.

Block 3. Reduction of the impact of low-rate interference waves.

Block 4. The correction of a seismic signal according to the slope of the reflecting boundary and entering of the adjustment for the wave arrival time, adjustment of summation velocity, formation of the final time cut, increase of the resolution and signal/noise ratio at the time of the final cut.

Block 5. Obtaining of the migrated image in the time scale.

Block 6. Obtaining of the migrated image in the depth scale.

As a result of such processing in combination with the use of modern methods of parameter transformations on the experimental test site, we managed to:

detect the wave field anomalies, which spatially correspond to the projected gas hydrate-bearing facility;

identify the peculiarities of the gas hydrate-bearing boundaries determination;

establish the seismic parameters of the gas hydrate-bearing facility allocation.

During the processing, the focus was on maintenance of dynamic properties of the seismic record and obtaining of the wave field with high resolution, especially in the upper (pallet) range of the section part with favorable conditions for the methane hydrate formation. The time and depth seismic sections obtained in this way provide additional information about the structure of the upper (pallet) section part, help determining the morphology of predictive gas hydrate-bearing facilities and estimating their resources during the first approximation.

Based on the above, in view of some progress in predicting the gas hydrate deposits within the Black Sea and given the success of the experimental extraction of methane from ocean gas hydrates of the Eastern-Nankay ocean cove, we can speak about the reasons for the planning of relevant works in terms of the Ukrainian sector of the Black Sea waters.

The further practical steps in the development of methane hydrate resources in the Ukrainian sector of the Black Sea require the geological and economic evaluation of the implementation of resource potential based on the knowledge of their properties, spatial localization and geological resources in the underwater depths, practicing the environmentally friendly manufacturing processes of industrial production and the adjustment of the relevant legislation on subsoil management. These steps should create the required economic attractiveness for investors interested in frequent resources utilized in methane hydrate deposits, in order to accelerate their market development with the appropriate government regulation of this process.

We believe that Ukraine should rethink the fact that the development of gas hydrate resources is one of the promising areas in the state policy of resource provision and priority directions of development of domestic oil and gas industry. Accordingly, in the first place, it is necessary to amend the legislation governing the subsoil management and oil and gas extraction in Ukraine, including the Code of Ukraine on Subsoil, Tax Code, the Law of Ukraine on Oil and Gas, the Law of Ukraine on Alternative Energy, the Law of Ukraine on Licensing Certain Types of Activities and other laws and regulations in order to settle the legal framework of gas extraction from gas hydrates in Ukraine.

Second, it is required to develop and adopt the national target program for development of methane hydrate resources of the Ukrainian sector of the Black Sea up to 2030. The relevant concept and the program should be developed for the state budget funds.

Such target programs [12] exist in five countries, i.e. the U.S., India, Japan, Korea and China. In the four former countries these are the third programs in sequence and in China it is the first. Japan, which has moved ahead of the others in extraction of gas hydrates in marine conditions has invested more than USD 800 million its hydrate program, China – USD 200 mio, Korea – USD 132.5 mio, India – USD 85 mio, and U.S. - 58 mio. The experience and results of work of the relevant countries should serve as certain guidance for our country in planning of the works related to development of gas hydrates in the Ukrainian sector of the Black Sea.

In the course of development and implementation of the state target program it is appropriate to conduct the fundamental and applied research, which should include the works for:

determination of the conditions of formation, the characteristics of spatial localization and isotopic fractionation of methane hydrate deposits;

geological and economic evaluation of development of the methane hydrate resource potential;

determination of the optimal set of geological prospecting (seismic, seismo-acoustic, electromagnetic, geochemical, drilling, geophysical borehole investigations, geological and industrial, etc.) for prospecting and exploration of deposits and evaluation of methane hydrate reserves in the Black Sea;

determination of technologies for optimal drilling test operations to disclose and extract the methane hydrates in the Black Sea.

At the early stages of the gas hydrate resources development special attention should be paid to the search for deposits of the sub-hydrated gas in terrigenous reservoirs of the bottom arch structures and non-structural traps and study of their gas hydrate cap during exploration, and the work program to be performed under special permits for subsoil management and agreements on distribution of products for all contractors of geological exploration works in deep water of the Black Sea should provide for the obligation to examine the potential hydrate-bearing layer.

Another important task which must be addressed in Ukraine in connection with this problem is the purchase of the modern drilling platform with the ability to drill at a depth of more than 700 m and a better launching of construction of the platform for deep-water drilling at the shipbuilding enterprises of Ukraine, as a global demand for such platforms and vessels is growing.

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