UDC 622.791.(315)

N. A. Drizhd, Dr. Sc. (Tech.), Prof.,
R. K. Kamarov, Cand. Sc. (Tech.), Prof.,
D. R. Akhmatnurov,
N. M. Zamaliyev,
I. M. Shmidt-Fedotova

Karaganda State Technical University, Karaganda, Republic of Kazakhstan, e-mail: ipk-kargtu@kstu.kz; d_akhmatnurov@mail.ru

COAL BED METHANE OF KARAGANDA BASIN IN THE GAS BALANCE OF THE REPUBLIC OF KAZAKHSTAN: STATUS AND PROSPECTS

М. О. Дріжд, д-р техн. наук, проф.,
Р. К. Камаров, канд. техн. наук, проф.,
Д. Р. Ахматнуров,
Н. М. Замалієв,
І. М. Шмідт-Федотова

Карагандинський державний технічний університет, м. Караганда, Республіка Казахстан, e-mail: d_akhmatnurov@mail.ru; ipk-kargtu@kstu.kz

МЕТАН ВУГІЛЬНИХ ПЛАСТІВ КАРАГАНДИНСЬКОГО БАСЕЙНУ В ГАЗОВОМУ БАЛАНСІ РЕСПУБЛІКИ КАЗАХСТАН: СТАН І ПЕРСПЕКТИВИ

Purpose. Preliminary evaluation of coalbed methane resources. Substantiation of the relevance of the development of the fuel and energy complex of the country based on the study and implementation of non-conventional sources of energy raw materials, among which, one of the most important is coalbed methane.

Methodology. The methodical basis was to collect, analyse and generalize the results of the world experience of commercial production of coal bed methane defining the methane reservoir characteristics of coal seams in comparison with traditional gas and geotechnical parameters of CBM fields prospects for commercial production of methane.

Findings. The analysis of the world and national literature on the experience of the development of coal bed methane is presented. The problems of methane extraction technologies, assessment of the resource base of coal deposits of the Republic of Kazakstan are reviewed. The expediency of industrial extraction of methane in the Karaganda basin is substantiated. A comparative analysis and comparison of geological parameters of coal deposits in the Republic of Kazakstan and foreign countries, where projects of coal-bed methane production are successfully implemented.

Originality. Scientific novelty consists in the following:

- the differences in terms of location and movement of natural gas in conventional porous and fractured reservoirs, and methane in coal seams, which predetermine differences in methods of exploring and technologies of the development of traditional gas and CBM fields are determined;

- characteristics and criteria of industrial importance of coalbed methane resources for commercial production are identified;

- the objective conditions of the prospects of technology development and production of methane from coal seams in the Karaganda basin are substantiated.

Practical value. To create the new gas industry in the Republic of Kazakhstan, based on the integrated development of gas-bearing coal deposits to solve a wide range of social, energy and environmental problems in Central Kazakhstan.

Keywords: *methane, coal seam degasification, production prospects, industrial use, methane safety, gas recovery*

Introduction. The main energy sources of today are the geological energy resources: oil, coal, gas, oil shale, peat, uranium, etc. They account for 93 % of the energy produced in the world. The remaining 7 % are reimbursed using renewable energy sources, i. e., water, sun, wind, biomass, geothermal and other [1]. However, no type of natural resources, no matter how great its reserves are, can be limitless.

The program of the President and the Government of Kazakhstan for restructuring the energy and thermal industries requires the use of huge amounts of investment, which should be directed at solving problems across the country.The solution of this problem is based primarily on the mobilization and the balanced use of natural resources of Kazakhstan. The total amount of investment required to implement from now until 2050, will amount to an annual average of 3.4 billion of US dollars. The main part of this volume – a little over 90 billion US dollars, or 3/4 of the total investment for the whole period up to 2050 – will be spent on the implementation of measures for energy efficiency and development of renewable energy and the creation of the gas infrastructure.

Analysis of the recent research and publications. Over the past two decades in many mining countries of the world a lot of attention is paid to the development of vast resources of methane in coal deposits, since modern coal deposits are essentially coal and gas as methane reserves are comparable to natural gas. Integrated development of gas-bearing coal deposits allows in the addition obtaining and using one of the large-scale energy sources coal bed methane. According to various sources, the world resources of coal bed methane are estimated at 260–470 trillion m^3 [1] (Fig. 1). Such a large difference in the resource estimates of methane is due to the lack of a single, reliable and complete inventory valuation method. Modern approaches allow estimating the stocks of certain resources only roughly. The reliability assessment of the prospects of a territory depends on the varying degree of geological knowledge, and different approaches to stock assessment.

About 70 countries have the largest coal reserves, and more than 40 of them started work on the development of coalbed methane in one form or another. Approximately 20 countries implement active drilling programs today, or used to in the past. Gas factor in underground coal seams, has become one of determining factors to ensure the safety of mining operations, particularly while increasing the depth of mining operations.

In the fields of active mines, production of methane is considered, on the one hand, as a source of affordable and cheaper gas fuel, on the other, as a way to reduce the gas content and outburst coal seams in order to create safe working conditions. It should be noted that for the first time in the world experimental and development works on degassing coal seams in advance via drilled hydrofracturing their surface with vertical wells have been successfully performed in the Karaganda basin. Simultaneously, similar work was carried out in the Donetsk coal basin.

Since the 60s in collaboration with the Moscow Mining Institute specialists in "Karagandaugol" and Karaganda Research Coal Institute have conducted research and pilot projects aimed at hydrofracturing coal seams in the mines of the Karaganda basin. Intended purpose of work was to reduce the natural gas content and powerful outburst of coal seams k_{12} and d_6. In 1961 prof. Nozhkin N.V. conducted hydrofracturing of k_{12} formation (Upper Marianne) by high-pressure injection of water mixed with small fraction quartz sand to uncover and fix intrastratal cracks. In 1967 prof. Vasyuchkov Y.F. was the first to test industrially a technological plan of hydrofracturing k_{12} formation of Kostenko mine field by batch injection of hydrochloric acid solution. For more than 50 years during the execution of these works in the mines of the Karaganda basin, 155 vertical wells have been drilled by hydrofracturing beds, more than 80 million tons of coal geological reserves have been processed, 245 coalseam operations have been produced and 104.2 million m^3 of methane has been extracted with an average production rate of the well being 1840 m^3/day; reduction in gas content of mine workings by 30–70 % has been achieved as well.

Since 1979 practical implementation of these ideas and large-scale commercial production of methane has been conducted in the United States, where the branch of industry works on gas production from coal beds. From the very first coal bed methane extraction projects leading position in this sector has been held by the US. This industry is still the best-developed there. According to the National Geological Survey coal bed methane reserves in the United States (excluding Alaska) make 20 trillion m^3, 25 % of which is economically recoverable if using current technology.

About 200 US companies operate in this sector. The main production is carried out on undeveloped coal

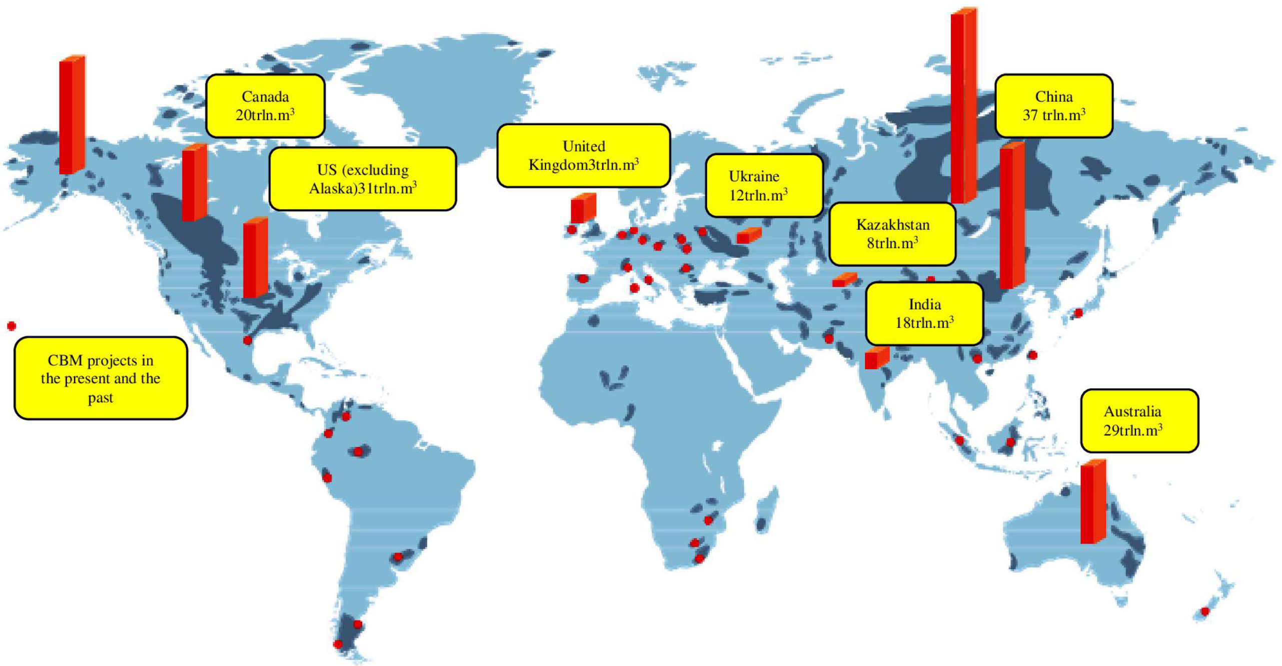

Fig. 1. Evaluation of geological resources of coal bed methane across countries

seams of the San Juan Basin on the border of New Mexico and Colorado, the Black Warrior Basin in Alabama and the Powder River Basin on the border of the states of Wyoming and Montana, where methane resources are estimated to be 2.4 trillion m^3 and 566 billion m^3 and 849 billion m^3, respectively. Extraction of methane in the San Juan Basin began in 1970, when 2 million m^3 was mined from three wells. In 1993, there were 2700 wells. The San Juan Basin, until recently, was the leading producing region in the US, giving more than 60 % of the coal-bed methane production. Only in the last few years a leading position in the production of methane was taken by the Powder River basin, where mining was started in 1986. Methane is extracted from a depth of 122–152 m from the Vayodek coal seam with capacity of 42 m.

For the past 10 years production of coal bed methane in the US reached 60 billion m^3/year, accounting for about 8.9 % of traditional gas production in the United States. In 2013, production fell slightly to 46 billion m^3, it can be attributed to a decrease in productivity of wells and some reorientation of the sector companies [1]. The successful experience of coalbed methane production in the United States has attracted the attention of specialists of a number of countries that have large reserves of hard coal and have already started or plan to start in the near future exploration and development of coalbed methane reserves.

In Australia, exploration of coal bed methane reserves in the Bowen coal basin began in 1976, but only in December 1996 in the framework of the project "Valley Dawson" in a coal mine "Moura" started its commercial production. The project is owned by Conoco Phillips. The largest share of coal gas production accounted for the Bowen and Syurat basins. In 2014 in Australia because of extensive coal reserves about 7 billion m^3 of methane were produced in this country, with its estimated forecast resource 29 trillion m^3.

In Canada, the experimental work on the extraction of methane was carried out in the Western Canadian sedimentary Basin, namely in the area of Palliser Alberta. Extraction of coal gas in Canada remains at an early stage of development, but the growth rates are obvious.The first well was drilled in 1997; however, in 2009 their number was 1848. Currently, there are over 14 thousand of existing wells. Annual volumes in the country of coal-bearing deposits of methane production grew from 0.5 billion m^3 in 2003 to 10 billion m^3 in 2014. The plans for 2019 are to increase production to 15 billion m^3. Canadian Gas Committee predicts that coal bed methane, whose resources amount to 20 trillion m^3 (whereas conventional gas resources in the country make 2 trillion m^3), in the future will become the main type of gas produced in a number of regions in Canada.

Great Britain, Germany, Poland, and China conduct methane projects. The last one strikes with the scale of its activities. They became interested in the extraction of methane from coal seams here in the early 1990s. Realizing the value of this resource, the Chinese government called the development of coalbed methane one of the 16 largest five-year plan projects. In various fields of the country built more than 13 thousand of vertical and horizontal wells with different designs and as of 2014, coal gas production was 17 billion m^3. Currently, production of methane is mainly concentrated in the province of Shanxi, the Tszinchin coal basin. According to the "Action Plan for the development of coal gas exploration", China intends to bring the production figures of up to 40 billion m^3 by 2020 while increasing proven reserves of methane to 1 trillion m^3 [2].

Since Ukraine is among the top ten states with the highest and still undeveloped resources of the methane, it would be wasteful not to use this resource as an additional guarantee of energy security of the country. Potential methane resources of coal deposits in Ukraine are estimated to be 12–26 trillion m^3 [2]. The Donetsk coal basin is the main fuel and energy base in Ukraine. In recent years, the Donbas has been considered not only as a coal region, but also as a major gas-bearing one. Prospects for the development of methane production are based on the considerable resources of hydrocarbon gases concentrated in geological and industrial areas of the Donbas. Predicted methane resources in rocks and coal seams of Donbas at depths ranging from 500 to 1800 m range from 4–6 to 22 trillion m^3, industrial ones – 11 trillion m^3, in the adsorbed state in coal seams over 0.3 m – 1.4–2.5 trillion m^3, including those in the fields of active mines – 855 billion m^3. The density of the estimated methane resources in coal seams on the areas of coal-bearing deposits is 90–107 million m^3/km^2 [3].

As of January 1, 2010, the State balance of mineral reserves of Ukraine considered 314 billion m^3 of methane C1 + C2 as accompanying mineral host rocks at 188 coal deposits, in particular, in the Donetsk coal basin – 303 billion m^3. However, only 8 % of the extracted methane is actually used in the country, that is 120 million m^3 per year, or half a percent of the state's gas needs.

The methane content in various types of coal increases with its depth, varying from 10.5 m^3/t in coal of D, G grades to 30–40 m^3/t in lean coal and anthracite. All coal seams of the Donbas (except anthracite) are gas bearing at a depth of 150–500 m (below the weathered zone of the gas). Production potential by 2030 is expected to be up to 3 billion m^3 per year (according to the Ministry of Natural Resources assessment, it is up to 5 billion m^3, according to the Ministry of energy and coal industry and State energy efficiency agency – up to 7 billion m^3) [3, 4].

Ukrainian scientists and manufacturers have gained considerable experience in the exploration and evaluation of methane resources. The results of scientific research and practical use of the various developed degassing methods allow counting on the prospects of a successful use of the potential production of the industry and utilization of coalbed methane, but to achieve these volumes, it is necessary to invest heavily into exploration, infrastructure and resource extraction.

Among CIS countries, Russia is the most active in working on commercial methane production organization, which has been carried out since 1995. Industrial extraction of methane held in the Kuzbass is caused by the feasibility of commercial production of coal gas in Russia due to the favorable geological conditions and bearing coal basins. In 2003, "Gazprom" PJSC began an assessment of prospects for methane production in the Kuzbass, the first experimental wells were drilled. Works are carried out in two areas, Taldinskaya and Narryksko-Ostashkinskaya. In 2010, the first enterprise for methane extraction from coal beds was put in Taldinskaya area, with confirmed reserves of 74.2 billion m^3. Six production wells are at the stage of experimental-industrial operation, with about 20 million m^3 of gas recovered so far. Construction of 10 wells is planned to be be completed by the end of 2016. Prospecting and evaluation works have started in the next potentially productive area – Narryksko-Ostashkinskaya area with approximate resource of 800 billion m^3, where 23.9 million m^3 was produced from exploration wells in 2010. Total methane reserves in the Kuzbass constitute 13 trillion m^3. By 2020, the total number of wells in the project should reach 1200 units, and gas production is to grow up to 3.5–4 billion m^3 [5].

The total world production of coal bed methane in 2014 amounted to about 125 billion m^3. However, these amounts are actually extremely significant because they were extracted from the source which had been hardly used until 1980. According to the International Energy Agency expected global production of coalbed methane by 2035 could reach more than 200 billion m^3/year [2].

Recognition of this unconventional resource as an alternative source of natural gas is confirmed by the level of investment in such projects around the world, and most importantly, by resources scale, most of which are concentrated in the CIS countries and where perspectives CBM fields are promising to create a new industry, where apart from coal, gas production is held (Fig. 2). But this will require modern approaches to the study of coal mines.

Unsolved aspects of the problems. The problem of degasification of mine fields has always been and is among the priorities that require rapid solutions. Despite the considerable work carried out in the Karaganda coal basin regarding degassing, the gas content cannot be reduced significantly, which is important for the safety of mining operations and a sharp increase in technical and economic indicators of work of the coal industry. Sudden outbursts of methane, which are accompanied

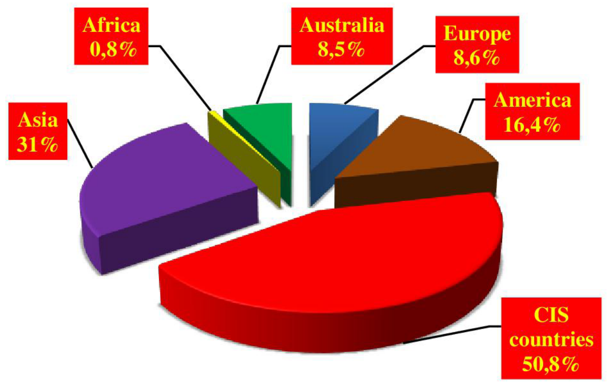

Fig. 2. Distribution of coalbed methane resources, %

by large human losses, material and financial losses, by 90–93 % are the cause of the total number of accidents that have occurred in the coal mines of the CIS countries over the past 5 years. High gas-bearing capacity of coal seams is one of the main causes of methane explosions in mines, leading to human tragedies. Only in the Karaganda basin mines alone, such accidents have claimed 138 lives in recent years [1].

Kazakhstan, having ratified the Kyoto Protocol, defined commitments to reduce greenhouse gas emissions, which is one of the main methane emissions whose flow ventilation in coal mining from the mines and quarries of Kazakhstan makes up to 1 billion m^3 per year. In addition, the deployment and utilization of production of methane from coal deposits in Kazakhstan program will reduce the amount of coal burned in thermal power plants, and, consequently, reduce emissions of harmful components generated in coal combustion as well as the amount of accumulated solids.

In addition, imbalance of fuel infrastructure continues, when almost all sources of hydrocarbons are located mainly in western Kazakhstan (98 %), and the majority of the industrial enterprises are in Central and Eastern Europe. In this regard, the energy self-sufficiency of regions through the use of local energy resources, including unconventional ones, takes on particular significance.

Objectives of the article. Today, Kazakhstan's economy is dependent on exports of energy resources, and, therefore, to a large extent is exposed to harsh external commodity prices fluctuations.

Due to possible reduction of oil reserves and a negative attitude to nuclear exergy, over the last years in many countries increased interest in the exploration and development of unconventional sources of hydrocarbons is observed. This global trend is also the current direction of development of the fuel and energy complex of Kazakhstan among which, one of the most important is coalbed methane. It is the most affordable, cheap, clean and efficient, energy and chemical raw material from well-known ones in the world of non-traditional sources of flammable gases. The value of methane as an alternative fuel is significantly higher than conventional natural gas due to the fact that gas produced from coal contains 98 % of pure methane and is not contaminated with sulfur and heavy hydrocarbons. It requires hardly any pre-treatment and can be used directly in the production site.

The objective prerequisites for the organization and development of commercial production of coal bed methane in Kazakhstan are huge gas resources in coal deposits, the high concentration of methane in the amounts and on the squares spread of coal-bearing strata, as well as a well-developed infrastructure and large-scale consumers of gas in the vicinity of the mining sites.

Searching for the eco-friendly energy resources, improving the environmental situation in Kazakhstan, increasing energy security, and the need to take measures to ensure the safety of coal production develop a statement of research objectives, the development and use of modern and efficient technologies for industrial coalbed methane production.

The presentation of the main research. Methane coal deposits are specific: methane reservoirs in the physical and physicochemical properties are different from conventional reservoirs of natural petroleum gas (Table 1) [6]. The main difference of compared collectors is in fundamentally different ways of finding them, and the kinds of gases in the "natural gas-porous body" system.

Modern conceptions of methane and coal communication are based on theoretical positions and experimental physical chemistry, synthetic and natural sorbents. The major amount of coal seams gas is in physically and chemically bound state: mainly in the form of a solid solution (absorption), in a condensed form on the pore surface (adsorption) and condensed in the pores supramolecular. The phenomenon of the sorption of methane in coal is caused by the presence therein of micropores. The micropores, with a very small amount of them (comparable with the volume of the methane molecule) is an area of influence of the sorption forces. These micropores and gas in the intermolecular space of coal substance (solid solution of coal and gas) determine the basic amounts of of methane in coal seams. Connecting micropores and cracks are effective pore space of coal, in which complex physical and chemical processes occur.

In contrast to the oil and gas reservoirs, the majority of coal seams have lower values of natural porosity and filtration and diffusion permeability. The decisive role in the formation of the porous structure of coals is played by the original coal-forming material conditions for the accumulation of crop residues, gels dehydration conditions, as well as secondary processes related to metamorphism of coal and folds forming processes. Typical coal bulk porosity is more than 1 % and is mediated by cleavage of the space, wherein coal permeability is associated with cleavage space which is from 0.001 to 100 mD.

In accordance with modern concepts, a coal seam has a low permeability fractured block, that is, having a basic primary porosity, matrix (mineral skeletal) and a much smaller secondary porosity of the matrix (skeletal) of coal – crack, an environment with a huge anisotropy properties (Fig. 3). Coal aracturing has cleavage character when there occurs separation, dismemberment of coal, that is rock partibility by densely developed system of small cracks in the plates, fibers, lenses, bars, etc.

The character of fracture depends on the endogenous and exogenous factors. Such cracks are formed during coalification; moreover, due to the removal of water the volume of the matrix decreases and orthogo-

Table 1

Comparative characteristics of coalbed methane collectors and conventional gas collectors

Characteristics	Traditional gas	Coal bed methane
Arogenesis	Gas is formed in the rock, and then migrates within the reservoir	The gas is formed and trapped in coal
Structure	Mostly open macropores. Randomly dispersed cracks	The system of macro-, meso- and micropores. Equally spaced cleats
Gas conservation	Compression	Adsorption
Transport mechanism	Laminar flow under a pressure gradient (Darcy's law)	The diffusion flux in the coal matrix caused by the concentration gradient (Fick's law of diffusion) and pressure gradient (Darcy's law)
Recovery enhancement	Starts at high speed of formation, and then falls. Weak returns requires waterinitialization	The gas velocity increases with time and then decreases. Mining is initialized mainly by water
The phase state of gas	Free and water-soluble	Sorbed
Gas storing	Gas storage in micropores. The real gas law	Gas storage by adsorption on the surfaces of micropores
Mechanical properties	Young's modulus of ~ 10^6. Compressibility at the expense of pores ~ 10^{-6}	Young's modulus ~ 10^5. Compressibility at the expense of pores ~ 10^{-4}
The gas content	The gas content of the well log data is obtained	The gas content of the well core material is obtained
Gas-water ratio	The ratio of gas to water decreases with time	The ratio of gas to water increases over time with the subsequent steps
Type of a collector rock	Inorganic rock of collector	Organic rock of collector
The pore size	Macropores from 1 mc to 1 mm	The micropores of 4 mc to 80 mc
Collector- parent rock relation	The collector and the parent rock are independent	The collector and the parent rock are the same
The dependence of permeability	The permeability is independent of the stress	Permeability is very strongly dependent on the stress
Permeability and porosity properties	Porosity and permeability do not significantly change during the gas production	Porosity and permeability vary significantly during gas production

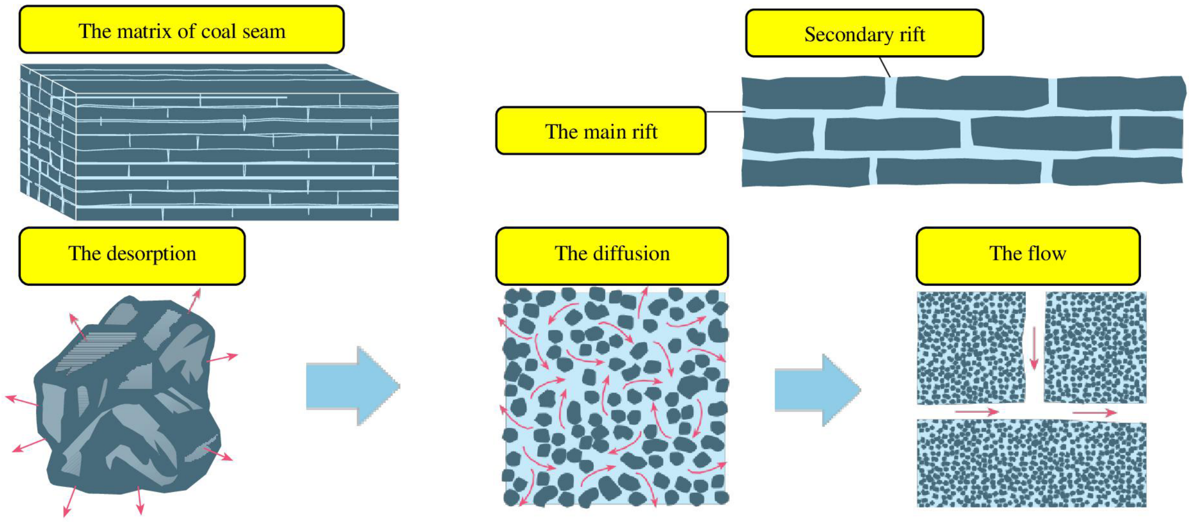

Fig. 3. Coal structure and mechanism of CBM extraction

nal cleavage fractures are formed. Major cracks have an extended character that allows them to provide fluid movement to an open surface, while the perpendicular cracks are perpendicular to the main cleats and are also called the secondary cleavage (Fig. 3). Thus, cleavage fractures provide a level of coal permeability.

In a single determination, made in the vitrinite of the Karaganda coal, open porosity was 15 %, with an average being 9–10 %. Studies performed earlier by Akimbekov A. K. and Makhov A. A. in KSTU calculated permeability values of change from 0.05 to 5.85 · 10^{-2} mD depending on the depth of the coal seams. However, studies in Sherubaynurinsky area in 2015 provided very encouraging data on the permeability of the coal seams of Karaganda suites, varying from 10.7 to 15 mD. One cannot help emphasizing the important fact that many publications clearly confirm the high gas permeability of the coal seams in the US compared to the coal basins of the CIS countries, which explains the high production rates of wells and economically successful experience in coalbed methane production.

The above mentioned leads to the conclusion that the gas permeability of coals in natural conditions depends on the macrostructure of the coal seam, the degree and nature of the filling of the filter pore volume of the natural moisture, on the methane pressure gradient and on the characteristics of rock pressure; coal array has a network of fractures and the matrix, the matrix accumulates volume of gas, the matrix has low permeability, the permeability and porosity of coal are caused by the cleavage; in an intact coal filter array, a carbon skeleton has a high resistivity and relatively low permeability, therefore, the coal seam permeability largely depends on the integrity of the array. "Methane-coal" system is characterized by a certain binding energy representing the energy difference between methane and coal and energy in combination of the same substances, when they are infinitely distant from each other. In a real collector, transition processes of gas from coal structure to the unbound state last over six months. That is to say, even provided sufficiently effective unloading of the reservoir, there remains a "gas barrier" in the transition zone connecting the methane associated with the coal structure, and microcracks, wherein the gas moves in the unbound state.

The strength of these ties is considerably weakened by external, energy impact on coal. This indicates that the "gas barrier" has certain energy and can be destroyed by directed external influence. In particular, by conventional hydrofracturing (fracturing) unloaded coal seam through the borehole from the surface up to 60 % of methane contained in the coal seam at a radius of 120 meters from the well can be removed.

Modern concepts of the relationship of methane and coal are based on theoretical positions and the results of experimental studies in the field of physical chemistry. Because of the existence of a CBM reservoir solid solution, which can contain up to 80 % of the gas, it follows that the equilibrium system consists of only one phase. Therefore, with the help of external radiation it is possible to provide conditions of destabilization of equilibrium.

Thus, most of the gases contained in coal seams in the natural environment, cannot be considered gases in the strict sense, as they do not obey the gas laws being bound; and only those that are in the coal in the unbound state, are. Being in a bound state the "future" gases cannot mplement their internal energy until they are in a free phase, and this requires the gas pressure to decrease or the coal, saturated with gas, to be able to expand. Consequently, the gas showing processes in mining operations in the vast majority are the result of anthropogenic impact.

In this case the porosity of coal does not only determine their properties as a reservoir of methane, but also as a source of gas recovery fracturing and stress-deformable solid natural sorbent. In this connection, evaluation of coal substance as a source of commercial production of methane from the surface of the wells should not be based on the general geologic formations of methane resources, but at commercially recoverable. The main factors determining the composition of the natural gas in coal seams, the amount of general and perspective for independent commercial of its production are: the degree of metamorphism of coal, the value of natural gas permeability and gas content of coal, natural degassing processes deposits, the value of the natural gas pressure in the formation and sizes of the zone of spread of gas deep into subsurface from the surface weathered zone. One should also take into account the features of geodynamics of geological carboniferous structures and arrays, which are the regional determinant factor of developmentof the natural fracturing and permeability of coal seams; moreover, they cause the possibility of using technological methods for increasing the permeability reservoirs, intensification (activation) of gas recovery. Experience of coal and gas mining of the US, Canada, Australia, China and other countries has shown that the use of highly efficient technologies of intensification of gas recovery of coal seams (hydraulic fracturing, pulse pneumatic and hydrodynamic effects on the coal seam in an open hole – cavitation, etc.) contributed to obtaining high production rates of commercial wells extracting methane and up to 80 %.

The world experience and relative comparison of geological and structural conditions, quality and metamorphism of coals of the Karaganda basin productive areas and the US coal basins (San Juan) and Russia (Kuznetsk), where projects of methane extraction from coal seams are successfully implemented, showed the occurrence of such areas in the Karaganda basin that are similar to the above-mentioned fields regarding geological and productivity criteria such as coal thickness and coal-bed methane, methane concentration of resources; this gives grounds to refer the coal basin to promising ones for the development and implementation of the project of extracting methane of coal beds (Table 2) [2]. The Karaganda basin is considered to be one of the most gas-bearing in the world. Origin of hydrocarbon gases in the Karaganda basin is connected with regional metamorphism of coal. Coals are characterized by high natural methane content of 25–35 m^3/t, which is proved by a large volume of gas sampling (1700 samples). The highest gas content occurs in different layers of Ashlyarikskaya and Karagandinskaya suites. At depths of about 400 m in the Karaganda basin in the main reservoirs, Karaganda suite quantity of gas reaches 22–25 m^3/t, increasing in Sherubaynurinsky and Teneksky areas up to 25–27 m^3/t. Gas weathering zone in this area is at a depth of 120–175 and 130–160 m, respectively. Coalbed methane increases with the depth of their occurrence.

Table 2

Comparative analysis of geological and technological parameters of CBM fields prospects for commercial production of methane from coal seams

Assesment criteria	The Karaganda basin (Kazakhstan)	The San Juan basin (USA)	The Kuznetsky basin (Russia)
Geological age	Carbon	Mel-Paleogene	Carbo-Permian
Area	$3.6 \cdot 10^3$ km^2	$19.5 \cdot 10^3$ km^2	$26.7 \cdot 10^3$ km^2
Tectonics	Gently dipping coal seams up to 10–25° with a slight development of faults. Overall, two-thirds of the reserves are located in the basin areas of relatively simple tectonic structure	The coal seams are sustained over a large area and usually feature quiet, almost horizontal bedding of up to 1°	Diverse structural conditions of occurrence of coal seams: the broken folds of numerous breaks in the northern part of the basin, the shortest linear folds with steep rocks bedding complicated by thrusts and reverse faults in the extreme western part, intact bracha folds in the center and sloping monoclinal occurrence in the southern part of the basin
Carboniferous	80 coal seams Σ capacity of up to 110 m	6 coal seams Σ capacity of up to 34 m	135coal seams Σ up to 350 m
Petrographic composition	G, Zh, K, OS	D, G, Zh, K	D, G, Zh, K, OS, T, A
The reflectance of vitrinite	Vitrinite	Vitrinite	Vitrinite, fyuzenit
Permeability	0.77–1.3 %	0.7–1.5 %	0.6–3.0 %
Methane content	Up to 15 mD	Up to 50 mD	Up to 80 mD
Coal reserves	Up to 35 m^3/t.	Up to 20 m^3/t.	Up to 30 m^3/t.
Methane Resources	33.4 billion tons	200 billion tons	524.4 billion tons
Petrographic composition	1 trillion m^3	2.4 trillion m^3	13.1 trillion m^3
The depth of resource assesment	1800 m	1980 m	1800 m
The resource density	400–800 mln m^3/km^2	300–1000 mln m^3/km^2	500–3500 mln m^3/km^2

Evaluation of coalbed methane resources, made by the results of the study of gas-bearing coal seams in the exploration of coal deposits of Kazakhstan scientists, as well as on the basis of many years of research scientists of Karaganda M. A. Yermekov, N. S. Umarhodzhieva has been confirmed by the world's largest specialists. Kazakhstan has huge potential resources of methane from coal deposits and its reserves of more than 8 trillion m^3 which put us on the 9th place among the countries that have coal reserves. Therefore, the Karaganda basin is not only a coal basin, but also a major coal mine methane with the specific conditions of distribution methane in the coal-bearing strata.

Taking into account the large areas and large reserves of methane, exploration and extraction of coal bed methane must be initiated timely which could realistically solve the energy problems by 2020, not only in the Karaganda region, and become alternative gasification of all the Central Kazakhstan

The development of CBM fields in Kazakhstan will allow:

- radically improving the safety of mining operations that will reduce deaths and injuries at work underground and in the long run making it possible to increase production of coking coal;
- producing 3–4 billion m^3 of methane per year, and providing all the needs of Central Kazakhstan and Astana city for gas for over 50 years and can be a basis for the development of new energy industry;
- using coal bed methane in the industries to produce electricity by burning it in mobile gas power plants, boilers. CHP (experience of using methane in the boiler is available in Karaganda); for domestic purposes for centralized maintenance of the population and retail as fuel – gas in the apartment and as a fuel for motor vehicles; in the metallurgical industry and chemical industry for use as a fuel, and in the production of synthetic materials;
- reducing the environmental component by decreasing the amount of gas emitted into the atmosphere.

Conclusions. All this confirms that the organization of large-scale production of coalbed methane is a modern, socially necessary and environmentally feasible project. However, in order to make mining of coal bed methane a new dynamic sector of the country, as well as to attract investment into the industry from abroad, it is necessary to develop a National Program of coal methane industry in Kazakhstan, which will provide concessional taxation, investment preferences and other events be within the framework of state support.

References / Список літератури

1. Drizhd, N. A., Akhmatnurov, D. R., Musin, R. A. and Zamaliev, N. M., 2016. Modern problems and prospects of development Karaganda coal basin, *Trudy Universiteta,* No. 2, pp. 37–42.

2. Zolotyih, S. S., Arnautov, V. S. and Surin, E. V., 2015. *Iz nedr kuzbasskih kladovyih – goryuchiy gaz metan* [From the bowels of Kuzbass stores – combustible methane gas], Kemerovo: Kuzbassvuzizdat.

3. Mihajlov, V. A., 2013. *Unconventional sources of hydrocarbons of Ukraine*. In: Coalbed methane, gas hydrates, impact structures and superimposed depressions of the Ukrainian shield, Kiev: Nika-Tsentr.

4. Dumenko, S. S., 2014. Priority objects for gas exploration within Donbas, *Naukovyi visnyk Natsionalnoho hirnychoho universytetu*, No. 6, pp. 28–32.

5. Grigorev, G. A. and Afanaseva, T. A., 2012. Prospects for the industrial development of unconventional gas resources in Russia, *Neftegazovaja geologija. Teorija i praktika,* Vol. 7, No. 2, pp. 1–19.

6. Storonskiy, N. M., Hryukin, V. T., Mitronov, D. V. and Shvachko, E. V., 2008. Unconventional resources of methane coal-bearing strata, *Rossiyskiy himicheskiy zhurnal*, Vol. LII, No. 6, pp. 63–72.

Мета. Попередня оцінка ресурсів метану вугільних пластів. Обгрунтування актуальності розвитку паливно-енергетичного комплексу Республіки Казахстан на основі вивчення та використання нетрадиційних джерел енергетичної сировини, серед яких одним з найважливіших є метан вугільних пластів.

Методика. Методичною основою був збір, аналіз і узагальнення результатів світового досвіду промислового видобутку метану вугільних пластів з визначенням характеристик колекторів метану вугільних пластів у порівнянні з традиційним газом і геолого-технологічних параметрів перспективності метановугільних родовищ для промислового видобутку метану.

Результати. Представлено аналіз світової та вітчизняної літератури з питань досвіду розробки метану вугільних пластів. Розглянуті питання технології вилучення метану, оцінки ресурсної бази вугільних родовищ Республіки Казахстан. Обгрунтована доцільність промислового видобування метану в Карагандинському басейні. Проведено порівняльний аналіз і зіставлення геологічних параметрів вугільних родовищ Республіки Казахстан та інших країн, де успішно реалізуються проекти видобутку метану вугільних пластів.

Наукова новизна. Полягає в наступному:

- встановлені відмінності в умовах знаходження та переміщення природних газів у традиційних порових і тріщинних колекторах та метану у вугільних пластах, що спричиняють відмінності технологій розвідки й розробки традиційних газових і метановугільних родовищ;
- визначені особливості та критерії промислової значущості ресурсів метану вугільних пластів для промислового видобутку;
- обгрунтовані об'єктивні умови перспективності розвитку технологій і видобутку метану з вугільних пластів у Карагандинському басейні.

Практична значимість. Полягає у створенні в Республіці Казахстан нової газовидобувної галузі, заснованої на комплексному освоєнні газоносних вугільних родовищ, для вирішення цілого ряду соціальних, енергетичних і екологічних проблем Центрального Казахстану.

Ключові слова: *метан, вугільний пласт, дегазація, перспективи видобутку, промислове використання, метанобезпека, газовіддача*

Цель. Предварительная оценка ресурсов метана угольных пластов. Обоснование актуальности развития топливно-энергетического комплекса Республики Казахстан на основе изучения и использования нетрадиционных источников энергетического сырья, среди которых одним из важнейших является метан угольных пластов.

Методика. Методической основой был сбор, анализ и обобщение результатовмирового опыта промышленной добычи метана угольных пластов с определением характеристик коллекторов метана угольных пластов в сравнении с традиционным газом и геолого-технологических параметров перспективности метаноугольных месторождений для промысшленной добычи метана.

Результаты. Представлен анализ мировой и отечественной литературы по вопросам опыта разработки метана угольных пластов. Рассмотрены вопросы технологии извлечения метана, оценки ресурсной базы угольных месторождений Республики Казахстан. Обоснована целесообразность промышленного извлечения метана в Карагандинском бассейне. Проведен сравнительный анализ и сопоставление геологических параметров угольных месторождений Республики Казахстан и друзих стран, где успешно реализуются проекты добычи метана угольных пластов.

Научная новизна. Заключается в следующем:

- установлены различия в условиях нахождения и перемещения природных газов в традиционных поровых и трещинных коллекторах и метана в угольных пластах, предопределяющие различия технологий разведки и разработки традиционных газовых и метаноугольных месторождений;
- определены особенности и критерии промышленной значимости ресурсов метана угольных пластов для промысловой добычи;
- обоснованы объективные условия перспективности развития технологий и добычи метана из угольных пластов в Карагандинском бассейне.

Практическая значимость. Заключается в создании в Республике Казахстан новой газодобывающей отрасли, основанной на комплексном освоении газоносных угольных месторождений, для решения целого ряда социальных, энергетических и экологических проблем Центрального Казахстана.

Ключевые слова: *метан, угольный пласт, дегазация, перспективы добычи, промышленное использование, метанобезопасность, газоотдача*

Рекомедовано до публікації докт. техн. наук Т. К. Ісабеком. Дата надходження рукопису 27.09.15.

UDC 553.981.2:551.735(477.5)

Y. M. Zelenko,
O. V. Dziuba,
O. M. Karpenko, Dr. Sc. (Geol.), Prof.

Taras Shevchenko National University of Kyiv, Educational-scientific institute “Institute of Geology”, Kyiv, Ukraine, e-mail: zelenko.yuri@gmail.com; geoinformatic@ukr.net; alexbrig@inbox.ru

ASSESSING THE PROSPECTS OF CARBONIFEROUS ROCKS OF THE SOUTHEASTERN PART OF THE DNIEPER-DONETS BASIN ON GAS DEPOSITS OF UNCONVENTIONAL TYPE

Ю. М. Зеленко,
О. В. Дзюба,
О. М. Карпенко, д-р геол. наук, проф.

Київський національний університет імені Тараса Шевченка, навчально-науковий інститут „Інститут геології“, м. Київ, Україна, e-mail: zelenko.yuri@gmail.com; geoinformatic@ukr.net; alexbrig@inbox.ru

ОЦІНКА ПЕРСПЕКТИВНОСТІ КАМ’ЯНОВУГІЛЬНИХ ТОВЩ ПІВДЕННО-СХІДНОЇ ЧАСТИНИ ДНІПРОВСЬКО-ДОНЕЦЬКОЇ ЗАПАДИНИ НА ПОКЛАДИ ГАЗУ НЕТРАДИЦІЙНОГО ТИПУ

Purpose. The study of the thermal maturity of organic matter-rich coal strata of a transition zone between the Dnieper-Donets depression and Donetsk folded structure to assess their gas generation potential and prospects of gas content assessment.

Methodology. The use of mathematical and statistical system for analysis and evaluation of katagenetic and thermal maturity of organic matter. Forecasting oil-gas strata distribution according to contents of organic matter and vitrinite reflectivity of core samples in the study area.

Findings. The thermal maturity of the studied species corresponds to the main phase of gas generation based on application criteria and predictive signs, supplemented by statistical data on vitrinite reflectivity depending on the depth. The most favorable depths for generation and location of unconventional gas reservoirs are defined.