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Determining and Justifying the Drilling Location of an Experimental Well

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Abstract. *The purpose of the work is to determine and to justify the location of an experimental well for producing coal-bed methane by developing an integrated analytical method of selecting the drilling location of wells. As a result, an assessment of the resource base of the Taldykuduk site of the Karaganda coal basin of the Republic of Kazakhstan has been presented. The method of well drilling has been determined and substantiated. Recommendations have been given for drilling experimental wells. There have been determined the differences in the location and movement of natural gas in conventional porous and fractured reservoirs and methane in coal seams, which predetermine differences in exploration methods and technologies of developing traditional gas fields and coal seams. There have been substantiated objective conditions for the drilling location of wells. The practical value consists in developing methodological recommendations for determining the location of wells.*

Keywords: *methane, coal seams, well site, Taldykuduk area, methane safety, gas production.*

Introduction

There are several natural features that can be used to determine the drilling site of wells for gas production [1-3]. There have been substantiated methodological recommendations for its selecting. For testing the technology of methane production by drilling a well from the surface along a coal seam and substantiating drilling parameters with adaptation to the mining and geological conditions of the Karaganda coal basin, the Taldykuduk site has been selected.

The selection is explained by the following factors [4]:

- a high coal content: 9.5%. The total thickness of the coal seams of the site is about 60 m; most of the layers are sustained in terms of thickness; four layers have the thickness of more than 3.5 m;
- the degree of metamorphism of the coal grades from KZh to OS, which implies a high natural gas content (up to 26 m^3/t d.a.m.). The average density of methane resources, taking into account the normal thickness of the layers, reaches 500-600 million m^3/km^2, and for the depths of 200-1000 m it is 870-1060 million m^3/km^2. When the apparent power is taken into account, it increases by 15-40%. The total resources of methane in coal seams on an area of 65 km^2 are about 29 billion m^3. Methane resources in coal-bearing rocks are about 69 billion m^3;
- significant disturbance of the coal-bearing stratum, which causes the presence of free methane that fills the voids of faults, the crushing zones of coal and rocks, and the development of several systems of multidirectional fracturing, which facilitates the coal gas emission and increases gas permeability of the coal-bearing stratum;
- carbon deposits that are associated with methane formation and methane content of the site, are covered by a cover of Jurassic and Cenozoic gas-tight rocks that are a stratigraphic screen for gases migrating to the daylight surface (mainly methane);
- the presence of anticlinal structures, in the domed uplifts of which the coal-gas-bearing massif is in a somewhat stretched state, as a result of which it has increased gas permeability with practically preserved methane content.

Coal content

The coal content of the Taldykuduk area is confined to the deposits of the Karaganda formation and is the highest in the basin [4]. In the section of the formation there are 25 coal seams, of which 14 are classified as medium and thick (K_{18}^{1}, K_{17}, K_{15}, K_{13}, $K_{13}^{B.C.}$, K_{12}, K_{11}^{1}, K_{11}, K_{10}, K_{7-8}, K_{53}, K_{4}, K_{2}, K_{1}) and 11 as thin (K_{20}, K_{19}^{2}, K_{19}^{1}, K_{19}, K_{18}^{2}, K_{18}, K_{14}, K_{9}, K_{8}^{1}, K_{6}, K_{3}). The coefficient of total coal content is 9.5%. In addition to these layers, layer H_1 of the over-Karaganda formation is of interest.

The distribution of coal seams by thickness is presented in Table 1.

Coal seams with the thickness of more than 0.7 m, where the main coal reserves are concentrated, are characterized by a relatively consistent thickness and

Table 1 – Distribution of seams according to thickness

Thickness, m	Seam index
Thick (3.5 and more)	$К_{13}$, $К_{12}$, $К_2$, $К_1$
Medium (1.2-3.5)	$К_{18}^1$, $К_{17}$, $К_{15}$, $К_{13}$, $К_{11}^1$, $К_{11}$, $К_{10}$, $К_{7-8}$, $К_{53}$, $К_4$
Thin (0.7-1.2)	$Н_1$, $К_{20}$, $К_{19}^2$, $К_{19}^1$, $К_{19}$, $К_{18}^2$, $К_{18}^1$, $К_{14}$, $К_9$, $К_8^1$, $К_6$, $К_3$

structure. There are few rock layers in them and the ash content of coal packs is low (up to 15-25%).

All the changes in the thickness and structure of coal seams are caused by the presence of consedimentary disturbances, such as splitting, facies replacement and erosion.

Petrographic studying of coal seams $к_{20}$-$к_1$ and $н_1$ has been carried out on the core material of exploratory wells. Based on studies [4], it has been found that all the seams are stony, humus, predominantly complex and to a lesser extent of a relatively complex and simple structure. Rock layers make up 5-20%, coals are matte to shiny. Semi-shiny and semi-matte coals prevail. The content of vitrinite is from 44 to 91%, the reflectance of vitrinite is from 1.04 to 1.75%.

Gas content of the coal seams

According to the results of testing coal seams at the upper levels with hermetic glasses, it has been found that the zone of demethanization of the seams extends to the depth of 100-150 m from the daylight surface. This depth interval has also been confirmed by the data of testing the layers with core gas collectors.

Sampling by core gas collectors has been carried out from coal seams during exploration work at the upper and lower levels. Th samples have been taken from all the seams and all the tectonic blocks.

The following gas components have been determined in the gas taken from the samples of the core gas collectors: nitrogen, methane, heavy hydrocarbons, hydrogen, carbon dioxide, and helium.

Changes in the component composition of the gas with depth are insignificant, with the exception of methane and its homologues. In the upper group of reservoirs ($к_{18}^2$-$к_{13}$), the methane content increases to the depth of 700 m (91%), and then decreases to 88-83% due to increasing the percentage of heavy hydrocarbons (up to 6.5%). In the $к_{12}^3$-$к_{7\text{-}8}$ seams this boundary runs deeper, to 1100-1300 m, and in the seams of the lower subformation of the Karaganda formation it has not been established, but its depth is more than 1000 m. The carbon dioxide content decreases with depth from 1.9% to 300 m up to 1-0.8% deeper than 1000 m. Hydrogen is practically absent.

For the coal seams of the Taldykuduk area, an intensive increase in methane content from the surface of the methane zone (115-125 m) to the depth of 400 m has been established. In this interval, it increases from 0 to 20.2 m^3/t d.a.m. Deeper, its growth slows down and every subsequent 100 m of the seam deepening, their methane content increases by 0.9-0.1 m^3/t d.a.m. At the depth of 1300 m, the methane content reaches 24.4 m^3/t d.a.m.

The calculation of coal methane-bearing capacity has been based on average interval values, while its highest values, already at depths exceeding 300 m, reached 24-26 m^3/t d.a.m. The maximum values in the calculations cannot be used, since the impact of fault tectonics and overburden deposits on the methane content of coal seams and enclosing rocks has not been fully elucidated in the area. Based on single samples, it has been found that in the eastern part of the field, where the coal seams are overlain by Mesozoic deposits with the thickness of 120 to 260 m, the seams directly below them are in the methane zone, and the methane content of coal often exceeds 10 m^3/t d.a.m.

Sorption capacity of coal seams

The sorption capacity of coal is the ability to hold large volumes of gas at low formation pressures. This property is formed due to the phenomenon of sorption resulting from the impact of weak intermolecular attraction of van der Waals forces. Large volumes of gas in coal can be retained due to the large internal area of coal microporosity [5].

The sorption capacity of coal for gas determined by pressure change is described by the Langmuir sorption isotherm, and the maximum amount of gas that can be retained in coal at a certain temperature is described by the Langmuir isotherm equation.

Determining coal sorption isotherms is carried out in laboratory conditions with full control of thermobaric conditions. As a result of the studies, the relationship between pressure and sorption capacity of coal has been determined at constant values of temperature and humidity.

Laboratory work to determine the sorption capacity of coal for methane at the Taldykuduk site has not been carried out.

Gas content of enclosing rocks

In the enclosing rocks of the coal-bearing strata, the gas content in the sorbed state is extremely low and depends mainly on the presence of organic matter in them. The overwhelming volume of free gas fills the pore space in sandstones and siltstones. Therefore, the quantitative content of gas in rocks is directly dependent on their porosity, fracturing, as well as on the gas pressure in the subsoil [6]. The natural gas content of the rocks has been determined both by core sampling in core gas collectors and by the gas logging method.

The gas content of the enclosing rocks is shown in Table 2.

Methane resources

Methane resources in total with heavy hydrocarbons in the subsoil of the Taldykuduk site have been calculated over its entire area, excluding the areas of formation demethanization and areas where the methane content is less than 5 m^3/t d.a.m. The boundaries for assessing methane resources for its independent production are as follows:

- the upper limit is the position of the isomet 5 or 10 m^3/t d.a.m.;
- the lower limit is the lower limit of assessing reserves or resources of coal: the absolute mark minus 800.

Table 3 shows methane resources, both for individual reservoirs and for the site as a whole. Methane resources were calculated in the central

Table 2 – Gas content of enclosing rocks

Lithological differences	Methane content (m^3/t in the intervals of depths (m)						
	700-800	800-900	900-1000	1000-1100	1100-1200	1200-1400	700-1400
Siltstones	2.8	4.2	1.2	2.7	-	-	1.2-4.2
Sandstones	0.03	0.03	0.9	0.08	0.11	0.1	0.03-0.11

Table 3 – Methane resources in coal seams of the Taldykuduk site

Seam index	To the depth of 1000 m	Total methane resources with the coal mass thickness over 0,5 м, methane content over 5 m^3/t d.a.m. to the depth of 1300 m, mln m^3
Н$_1$	110.1	226.3
К$_{20}$	91.7	159.6
К$_{19}^{2}$	67.9	67.9
К$_{19}^{1}$	143.2	143.2
К$_{19}$	88.4	88.4
К$_{18}^{2}$	66.3	66.3
К$_{18}^{1}$	327.4	327.4
К$_{18}$	665.4	808.4
К$_{17}$	281.0	317.7
К$_{15}$	1410.7	1670.5
К$_{14}$	465.5	569.8
К$_{13}^{в.с.}$	773.6	1098.2
К$_{13}$	1230.1	1404.8
К$_{13}^{н.с.}$	281.8	617.9
К$_{12}$	3907.7	5505.0
К$_{11}^{1}$	553.3	810.1
К$_{11}$	537.4	771.3
К$_{10}$	1549.8	2200.0
К$_{9}$	156.2	238.9
К$_{8}^{1}$	249.5	363.1
К$_{7-8}$	1372.0	2231.5
К$_{6}$	385.2	607.1
К$_{5}^{3}$	1342.4	1692.9
К$_{4}$	596.1	846.4
К$_{3}$	375.9	475.2
К$_{2}$	1796.2	2495.2
К$_{1}$	1626.7	2050.8
Total	**20451.5**	**27853.9**

and northern parts of the Taldykuduk area in several options: with the coal thickness of more than 0.7 m and 0.7-0.5 m, as well as with its methane content of more than 10 m^3/t d.a.m. and more than 5 m^3/t d.a.m.

Therefore, methane resources are proposed for approval with the coal mass thickness of 0.5 meters or more and a methane content of 5 m^3/t d.a.m. and more (Table 3), which in the area of the entire Taldykuduk area are estimated at 27.8 billion m^3.

In connection with the fact that due to the heterogeneity of the structural structure of the Taldykuduk area and numerous faults, the occurrence of coal seams is variable, the density of methane resources is also variable, determined by the total thickness of the coal mass (more than 0.5 m) of the seams intersected by a particular well.

The density of methane resources at the depths of 200-1000 m horizontally varies on average from 400 to 700 million m^3/km^2, reaching 870-1060 million m^3/km^2 in the southwestern part of the field.

In total at the Taldykuduk site 27.8 billion m^3, including that to the depth of 1000 m 20.5 billion m^3.

Coal strata permeability

Targeted studies to determine the permeability of coal and rocks have not been carried out. However, based on the significant dislocation of the coal-bearing strata of the area, it should be assumed that there are various kinds of cracks and voids in it, in which the gas is in the free state under pressure equal to hydrostatic pressure. In addition, open pores of vitrinite serve as good channels for filtration and diffusion of gases, which is due to the presence of mutually perpendicular separation cracks in it, cutting the vitrinite perpendicular to the layering into prismatic pieces. According to individual determinations made in the vitrinite of Karaganda coals, open porosity reaches 15% and average porosity is 9-10%.

Gas permeability of rocks in the massif is very low: tenths and hundredths of millidarcy. Gas permeability of coals is higher, up to 10-15 millidarcies at the depths up to 250-300 m, but it sharply decreases with depth and at the depths of 600-700 m it amounts to hundredths and thousandths of millidarcies according to single data. Despite the absence of direct measurements of absolute permeability, the level of water filtration and the nature of water chemistry in the basin indicate that coals, like enclosing rocks, are saturated with water and are water-permeable therefore, they are gas-producing at small pressure differences.

The drilling location of experimental exploration well T1 has been selected on the basis of analyzing the geological conditions of the site, taking into account the tectonic situation in the licensed area, as well as the maps of the predicted methane content of coal seams of the Karaganda formation, a grid of drilled exploration wells of prospecting and appraisal work on the lower horizons of the Taldykuduk section of the Karaganda basin in 1989 and based on the situation in the licensed area. The latter factor played an important role in adjusting the drilling location of the well, since the site has farmland, forest areas, and a railway passes in the central part of the site. So, the location of the well has been selected taking into account the maximum gas content and the situation.

The current gas content of coal seams and enclosing rocks largely depends on the tectonic conditions of the area. The structure of coal-bearing deposits and the degree of their tectonic disturbance are the main factors determining the gas saturation of the coal-bearing strata. Tectonically, the Taldykuduk area is a complex structure confined to the locking part of the southern flank of the Karaganda syncline, with intensely manifested plicative and disjunctive faults. Large and small folds are complicated by faults, diverse both in size and type.

Exploration work at the Taldykuduk site was carried out in the periods of 1982-1989 and in 2006. During preliminary detailed exploration, and then during prospecting and evaluation work, coal seams of the Karaganda formation were opened and the folded structure complicated by faults was established. In total, 94 disturbances of a predominantly reverse fault nature were identified at the site, the disturbances with amplitudes from 15 to 50 m predominated. This indicates a significant disturbance of the coal-bearing stratum, which causes the presence of free methane that fills the voids of faults, zones of collapse of coal and rocks and the development of several systems of multidirectional fracturing, which facilitates gas recovery of coal and increases gas permeability of the coal-bearing strata.

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Сынамалық ұңғыманы салу нүктесін анықтау және негіздеу

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***Аңдатпа.** Жұмыстың мақсаты – ұңғымалардың орналасу орнын таңдау үшін кешенді аналитикалық әдісті әзірлеу әдісімен көмір қабаттарының метанын өндіру үшін сынамалық ұңғыманы салу, орнын анықтау және негіздеу. Нәтижесінде Қазақстан Республикасы Қарағанды көмір бассейнінің Талдықұдық учаскесінің ресурстық базасын бағалау ұсынылған. Ұңғымаларды салу әдістемесі анықталды және негізделген. Тәжірибелік ұңғымаларды салу бойынша ұсыныстар берілді.Табиғи газ кен орындары мен көмір қабаттарын барлау әдістері мен игеру технологияларындағы айырмашылықтарды алдын ала анықтайтын көмір қабаттарында кәдімгі кеуекті және жарылған коллекторларда табиғи газдың және метанның орналасуы мен қозғалысында айырмашылықтар анықталды. Ұңғымаларды салу нүктесіне объективті жағдайлар негізделген. Тәжірибелік құндылық ұңғымалардың орналасу орнын анықтау үшін әдістемелік ұсыныстар жасау болып табылады.*

***Кілт сөздер:** метан, көмір қабаттары, ұңғымаларды төсеу, Талдықұдық учаскесі, метан қауіпсіздігі, газ өндіру.*

Определение и обоснование точки заложения экспериментальной скважины

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***Аннотация.** Целью работы явилось определение и обоснование места заложения экспериментальной скважины для добычи метана угольных пластов методом разработки комплексного аналитического метода для выбора места расположения скважин. В результате представлена оценка ресурсной базы Талдыкудукского участка Карагандинского угольного бассейна Республики Казахстан. Определена и обоснована методика заложения скважин. Даны рекомендации по закладыванию экспериментальных скважин. Определены различия в расположении и движении природного газа в обычных пористых и трещиноватых коллекторах и метана в угольных пластах, которые предопределяют различия в методах разведки и технологиях разработки традиционных месторождений газа и угольных пластов. Обоснованы объективные условия для точки заложения скважин. Практическая ценность заключается в создании методической рекомендации для определения места заложения скважин.*

***Ключевые слова:** метан, угольные пласты, бурение скважин, Талдыкудукский участок, метанобезопасность, добыча газа.*

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