DEVELOPMENT OF COALBED METHANE IN RUSSIA: FIRST RESULTS AND PROSPECTS

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Introduction

In the XXI century high natural gas demand and price growth rates together with general resource deterioration proved that the modern energy consumption structure based only on conventional energy sources requires sufficient adjustments. Along with active works on introduction of resource-saving technologies, growing attention is now paid all over the world to researches of unconventional gas sources, especially to coalbed methane.

Russia has huge resources of coal varying in quality (from brown coals to anthracites) and occurring in coal basins of different age and located rather irregularly. As to the territory, 66% of coal resources are located in Western and Eastern Siberia, 28% - in the Far Eastern district and about 6% - in the European part and the Urals. Main large basins are situated in the Asian part of Russia: in Siberian, Far Eastern and Urals Federal Districts. The total resources of coalbed methane of the main coal-bearing basins of Russia are estimated to reach 83.7 trln. m^3 [1].

Growing volumes of coalbed gas production in the world, on the one hand, and gigantic predicted resources of methane in coal basins of Russia, on the other hand, determine relevance and practicability of science researches in this field, so in this connection the Government of the Russian Federation pays much attention to the issue of coalbed methane production in Russia.

Aims

The researches performed were aimed at selecting the sites and assessing the prospects of commercial production of coalbed methane as a separate mineral in Russia.

Methods

Prospects of sites for large-scale methane production are predetermined by geologic development history and geotectonic peculiarities of methane-coal basins and fields. This assessment should be based on the results of their step-by-step study including their ranking and selection of priority sites (fields, areas), based on prospects, for detailed measurements and preparation to gas field development. According to the methodology of oil and gas exploration and depending on the exploration maturity of the coalbed gas content, the appraisal and preparation to commercial development of coalbed methane basins and fields are divided into stages: regional, assessment survey, and exploration.

Dimensions and density (concentration) of coalbed methane, regularity of distribution in layers and stratigraphic regional units, fields, areas and sites are the objective geologic factors of commercial coalbed methane production.

At the regional stage, methane resources are appraised on the basis of general geological regularities and prospect evaluation objects are identified. The main criteria allowing to choose high prospect basins are: availability of large-scale resource base, favourable regional geologic conditions (high gas content of the section, metamorphism and depth of coal layers determining their high gas content), availability of gas consumers close to the supposed production sites and significant social and ecological effect of these works.

Assessment survey is planned based on the outcome of the regional stage. The main objectives of assessment survey are:

- Drilling of structural (prospecting core) wells, logging, and evaluation of coal content, hydrogeological and physical and mechanic properties of the section.
- Core recovery and investigation in order to establish the coalbed reservoir properties.
- Detailed land logging and remote measurements (land CDP 2D reflection seismics, decoding and analysis of aerial and space images to assess the geomechanical condition of the massif).

- Ranking of the surveyed objects based on their prospects for setting exploration works.

In the course of assessment survey, the coalbed methane content in the depths of over 600m was measured following the Russian methodology in prospecting (core) wells including: coal gas sampling by core gas samplers (80 samples), gas desorption by stages (free discharge at room temperature, vacuum desorption, thermal vacuum desorption), analysis of recovered gas, technical analysis of coal. In two wells, coalbed methane content was measured according to the Gas Technology Institute (USA) methodology using equipment from Raven Ridge Resources (USA). Comparison of the results showed good precision.

Formation flow characteristics were studied using KII-65 complex (an analogy of American DST).

Exploration is planned for the areas and fields ranked highly based on prospect evaluation survey.

The main objectives of the exploration stage are:

- Drilling of exploration wells, their completion and pilot operation.
- Finalizing of the processes of drilling, completion and coalbed gas recovery stimulation.
- Identification of the wells' capacity to produce.
- Estimation of the cost of well construction and field development.
- Estimation of coalbed methane reserves.
- Geological and economic evaluation (feasibility study) of the expediency of coalbed methane field development.

Results

. As a result of assessment of coal fields in Russia, a conclusion was made that, generally, prospect coal-bearing basins are characterized by favourable geologic, technologic and economic parameters but either have methane resources restrictions or there are no large methane consumers close to the fields. That is why today it is worth assessing the coalbed methane resources of such basins according to, mainly, factor of meeting local demands of the region. Possibility of conversion of mechanic transport (first of all, coal production enterprises) to gas fuel is of great importance because it will allow to reduce, and, in future, to waive the necessity to supply liquid oil products into these regions. This group consists of Donetsk (Rostov region) (methane resources amount to 97 bln. m^3), Ulugkhemski (40 bln. m^3), South-Yakut (920 bln. m^3), Zyriansk (99 bln. m^3), Sakhalin (40 bln. m^3), Bureinsk (105 bln. m^3) basins, and Kuzbass was determined the first-priority object for further exploration preparation (Table 1).

At the stage of substantiating, choice and arrangement of sites that have prospects for exploration and assessment works according to the criteria of assessment and degree of exploration maturity, the prospect of coalbed methane production of geologic and economic districts of Kuzbass was examined. 21 geologic and economic districts (178 fields and areas) were studied. On the basis of prospect criteria the first-priority objects for prospecting and appraisal works were chosen. The results of coalbed methane reserves' assessment by Kuzbass districts are given in table 2.

Based on the assessment survey of prospect Kuzbass objects the Taldinskoe coalbed methane field was ranked top priority for exploration.

The Taldinskoe field is confined to the namesake brachysyncline having an area of about 70 km^2. The geological structure of the Taldinskoe field includes Palaeozoic deposits represented there by late-Permian Kolchuginsky sedimentary complex, which, according to accumulation chronology and conditions, is divided into Kuznetsk, Il'insk, and Erunakovsky sub-series. The Leninsky set coalbed of the Erunakovsky sub-series has been judged prospective for methane production. The Leninsky set thickness equals to 620-650 m and its section contains up to 19-20 coalbeds (from bed 60 to bed 39) having the total thickness of about 42 m. Single bed thickness varies between 1 and 6 m. The formations are continuous and relatively continuous. The coal petrographic composition is classified as vitrinite. Vitrinite content equals to 82-88%. Coal metamorphism regularly grows with the stratigraphic depth of occurrence. Vitrinite reflection index Ro varies from 76% (bed 60-59) to 0.98% (bed 39).

Exploration maturity of the natural methane bearing capacity of the Taldinskoe area has allowed reasonable establishing of the main regularities of the dynamics of gas weathering and coalbed methane bearing capacity depending on the depth of occurrence and coal metamorphism.

The main component of Taldinskoe coalbed natural gases free of gas weathering (de-methanization) is methane. Its concentration in the coalbed natural gas mixture within the metamorphogene gas zone amounts to 80-99%. The admixtures (up to 10-12%) include unevenly distributed methane homologues (heavy hydrocarbon gases), also occasionally small concentrations (up to 1.0-3.0%) of hydrogen occur.

The coalbed gas weathering zone (GWZ) is the subsurface part of the coal-bearing strata where methane migration to the daylight surface takes place concurrently with counter flow of surface water and atmospheric gases to the depth resulting in replacement of methane in coal formations with nitrogen or carbon dioxide. Coalbed methane concentration in the gas weathering zone varies from 1-3 to 70-80%. In the gas weathering zone, coalbed methane-bearing capacity does not exceed 3-5 m^3/ton of coal. Thickness of the gas weathering zone varies in different mining and geological conditions from the first meters to 300-400 meters featuring drastic variations within comparatively short distances. Gas weathering zone thickness depends on a number of geological, geomorphological, tectonic, and hydrogeological factors. The hypsometric depth of the border between the gas weathering zone and methane gas zone is the coordinate of regular increase of coalbed gas-bearing capacity with depth, determining, in turn, different gas-bearing capacity of formations in horizons.

GWZ thickness within the Taldinskoe syncline varies from 100-150 to 400-450m. The minimal GWZ thickness is observed in the eastern and north-eastern flanks of the syncline, where it is adjacent to the Zhernovskoe anticline. There the methane zone border occurs at the depth of 150-200m and its thickness amounts to 100-200m approximately. The GWZ thickness increases in the southern direction. In the southern part of the Taldinskoe syncline, the methane zone surface occurs at the depth of 150 to 50m and its thickness equals to 200-300m. In the central part of the Taldinskoe area, coal beds of the Tailugansky series, including bed 78, occur in the gas weathering zone that is 300-350m thick. The maximal GWZ thickness (up to 400-450m) is noted in the north-eastern part of the Taldinskoe syncline near large overlap fault #7 in its lower limb. There the methane zone surface occurs at datum +/-0 to -150m. Such local subsidence of the methane zone is explained by that cropping out coal beds 69 to 60-59 are separated with the dislocation surface of overlap fault #7 from deeper horizons allowing intensive methane migration to air without its inflow from the depth.

The pilot wells in the eastern part of the Taldinskoe field established that the methane gas zone border there occurs at a depth of 100-150 m (close to datum 50 to +/ –0 m, subsea), where the natural coalbed methane-bearing capacity amounts to 4-7 m^3/ton of coal. The maximal natural methane-bearing capacity at a depth of 800-900 m reaches 22.5 m^3/ton of coal. Sorption coal analysis has shown that the ultimate methane-bearing capacity of coals in these beds at pressures of 14-15 MPa does not exceed 27.5 m^3/ton of coal. The equation used to predict the methane-bearing capacity is as follows:

$$M=27.5 - 5174.51/(306,8-H)$$

where M is the predicted methane-bearing capacity, m^3/ton of coal

A is the ultimate methane-bearing capacity of coals in the explored site at the maximal appraised depths, m^3/ton of coal (Langmuir volume).

B and C are empirical factors.

H is the bed occurrence depth, m (subsea).

Factor A is determined based on sorption analysis of coals of the explored site. Factors B and C are determined based on actual testing.

Coalbed permeability according to well measurements varied between 1 and 20-30 mD.

In the course of exploration in the eastern part of the Taldinskoe field 8 exploration wells were drilled to the depth of 600 to 900 m. Coalbeds opened by those wells were subjected to hydraulic fracturing using proppant 20/40 mesh in the volume of 8 to 25 tons per operation. During well completion, after dynamic water level was reduced by 80-120 m (depression 0.8-1.2 MPa), intensive gas emission from the wells started. In two wells the peak flow rates equaled to 8 to 6 thousand m3/day; in four – 1.2-2.5 thousand m3/day; two wells were dry. For the first year of operation 6 wells had a yield of more than 6 million m3 of methane. As to the composition, the produced gas was almost pure methane (98-99%). The gas is used for power generation and car filling. At present, two gas piston power plants of 2.3MW capacity are running and up to 50 cars a day are filled with compressed gas.

On the basis of geologic exploration works and taking into account foreign experience of coalbed methane production and geologic and commercial parameters of prospect coal and methane fields in Kuzbass, the possible methane production volumes are forecasted for the period by the year 2030.

It is planned to prepare first-priority areas in Kuzbass to commercial production of methane to the volume of 4.5 bln. m^3/year for the period by 2020 to organize gas supply to the consumers of Kemerovo region. In future, production possibilities of first-priority areas, evaluated on the basis of the most possible forecasted well debits, their location schemes and resource conversion into commercial categories resources index and methane production index, will amount to no less than 10 bln. m^3/year.

The commercial production ranges will be presumably created, first of all, around the experimental wells to allow continuous update of the basin capacity to produce. However, the forecasted production levels in the mentioned period will be defined by gas consumption of the Kemerovo region and competitive ability of coalbed methane at the regional energy market rather than by production possibilities.

As to the further prospect by 2030, the methane potential in Kuzbass and forecasted economic effectiveness indices of its production and transportation will allow to meet the gas demands of neighbouring regions situated in the south of Western Siberia to the volume of 20 bln. m^3/year.

Further production growth during 2020 – 2030 can be determined economically by export supplies to Asian-Pacific countries.

Conclusions

The geologic exploration works and pilot production of methane in Taldinskoe methane and coal field in Kuzbass performed by JSC «Gazprom promgaz» unveiled high potential and economic effectiveness of this yet new and weakly developed sphere of industry.

An important factor of successful exploration of methane and coal fields is the development of science basics of coal-gas-bearing capacity forecasting, improvement of coal-and-methane fields' exploration and development methods, as well as legal base of subsoil use during the development.

Effectiveness of methane production will be defined by relation of methane production cost and market price which (especially at the initial stage) largely depends on the existing taxation system and chosen methane recovery method.

Coal methane field choice and preparation strategy for commercial production of coalbed methane is aimed at the solution of the abovementioned problems. Strategy effectiveness is confirmed by the first results that give us hope to successful development of coal methane industry in Russia.

Table 1 Prospects of Methane and Coal Basins and Fields of Russia for Coalbed Methane Production

Seq. No.	Basin, Field	Age	Workable Coal Beds		Coal Rank	Coal Resources, bln. ton (within appraisal of methane resources)	Methane-Bearing Capacity, m^3/ton of coal	Mine Methane-Bearing Capacity, m^3/ton of daily output	Methane Resources, bln. m^3
			Number	Single Bed Thickness, m					
High-Prospect (First-Priority) Basins and Fields for Commercial Coalbed Methane Production at Present									
1.	Kuznetsky	C, P	135	0.7-24	G-A	615.0	up to 35	up to 70	13100
2.	Pechorsky	C	up to 40	0.7-8	B-A	235.0	up to 33	up to 60	1942
3.	Apsatskoe	J	6	1-20	KZh, K	2.2	up to 30	n.p.	55
									Total 15097
Prospect Basins and Fields for Ancillary and Independent Methane Production for Local Gas Supply									
4.	Donetsky (the Rostov Region)	C	up to 40	0.6-2	G-A	20.1	up to 28	up to 75	97
5.	Kizelovsky	C_1	4	0.7-2	GZh,Zh	0.3	up to 32	up to 22	3
6.	Uligkhemsky	J	6	1-15	G, Zh,K	15.2	over 5 *	n.p.	40
7.	Yuzhno-Yakutsky	J, K	40	1-60	G-T	46.2	up to 25*	n.p.	920
8.	Bureinsky	K	9	3-5	D,G	12.0	up to 18	n.p.	105
9.	Partizansky	K	33	0.7-10.5	G-T	1.5	up to 20	up to 65	22
10.	Sakhalinsky	K-N	80	1-22	D-G	3.2	up to 22	up to 100	40
11.	Zyryansky	K	85	1-14	D-K	29.2	over 15	n.p.	99
12.	Arkagalinsky	K	5	1-20	D-G	0.95	up to 12	up to 13	0.5
13.	Omsukchansky	K	18	0.6-6	T-A	0.7	10 *	up to 10	0.2
14.	Anadyrsky	Pg	5	1-3	B,D,G	42	10 *	n.p.	0.2
15.	Beringovsky	K, Pg	10	0.7-5	D-Zh	4	up to 14	up to 5	10
16.	Podgorodnenkoe field	T-K	10	1-4	T	0.2	up to 11	up to 39	2.3
									Итого 1339.2
Non-Prospect Basins and Fields for Coalbed Methane Production at Present									
17.	Yuzhno-Uralsku	Pg-N	4	10-140	1B	1.2	?	?	?
18.	Bulanash-Elkinsky district	T	32	1-7	D, G	0.16	4-6 *	5-10	less than 1
19.	Tyrminsky district	K	4	0.7-3.7	G	0.25	over 5 *	n.p.	2
20.	Irkutsky (Novometelkinskoe)	J	15	1-21	G, GZh	6.7	?	?	?

21.	Amuro-Zeisky	J, K	3-14	1-3	D-T	1.0	?	?	?
22.	Sredne-Amursky	Pg-N	20	0.7-15	1B-2B	10.6	?	?	?
23.	Bikino-Ussuriisky	Pg-N	10	1-36	1B-3B	2.7	?	?	?
									Total 3 (?)

Table 3.2. continued

Basins and Fields of Unclear Prospect, i.e. Where Methane Production Prospect May Be Estimated After Additional Survey									
24.	West-Siberian	C-N	До 80	0.5-32	1B-PA	3300	up to 20	?	33000
25.	Tungussky	C, P	50	1-25	K-A	1873	up to 30	up to 30	20000
26.	Lensky	J, K	40	1-12	2B-K	836	5	-	3000
		P	20	1-4	G-A	700	15	-	7000
27.	Kansko-Achinsky	J	18	1-5	G	1.3	over 5 *	n.p.	5 (?)
28.	Taimyrsky	C, P	18	1-6	D-A	185.0	?	?	4000
29.	Chelyabinsky	T, J	до 40	1-200	3B,D	0.44	up to 9 *	up to 20	более 2
30.	Gorlovsky	P	15	1-30	A	4.5	up to 23	up to 30	50
31.	Minusinsky	P	40	1-17	D, G	20.0	up to 10 *	n.p.	50
32.	Kamskaya area	C_1	5	1-20	D, G	12.4	10 *	-	100
33.	Herbikano-Ogodzhinsky district	K	12	1-33	D-A	2.1	up to 15	n.p.	30
34.	Uglovsky	Pg, N	25	1-20	2B-3B	1.1	up to 12	up to 45	1
35.	Razdol'nensky	K	10	1-17	G, Zh, T	0.5	?	?	?
36.	Yuzhno-Primorsky district	T	9	1-5	Zh-T	0.7	?	?	?
37.	Kamchatka fields	K-N	5	0.6-10	3B-D	1.0	?	?	?
38.	Egorshinskoe	C_1	10	1-12	OS,T,A	0.12	6 and more*	14.4	1 (?)
39.	Makhnevskoe	C_1	27	1-14	T, A	0.13	over 10 *	up to 58	1 (?)
									Total 67240
									GRAND TOTAL 83679

Table 2 Prospects of Kuzbass Disricts for Assessment Survey

Seq. No.	Geological-Industrial District	Methane Resources, bln.m^3 — Age of Deposits — Kolchuginsky Series (P_2kl) — Appraisal Interval, m, subsea					Upper Balakhonsky Subseries (P_1bl) — Appraisal Interval, m, subsea					Lower Balakhonsky Subseries ($C_{2-3}bl$) — Appraisal Interval, m, subsea					**Total Districts**
		above +/-0	from +/-0 to -300	from - 300 to-900	from -900 to -1500	Total	above +/-0	from +/-0 to -300	from - 300 to-900	from -900 to -1500	Total	Above +/-0	from +/-0 to -300	from - 300 to-900	from -900 to -1500	**Total**	
Type 1. Most Prospective (Top-Priority) Districts for Exploration at Present																	
1	Erunakovsky	46.9	221.7	1128.8	1 537.9	**2935.3**											**2 935.3**
2	Tom'-Usinsky		48.9	230.3	179.7	**458.9**	57.5	96.9	318.3	460.3	**933.0**	7.2	10.8	20.9	29.5	**68.4**	**1 460.3**
3	Tersinsky	94.8	127.7	358.3	87.3	**668.1**	21.1	33.6	101.3	151.7	**307.7**	0.9	1.0	16.2	21.6	**39.7**	**1 015.5**
4	Mrassky						45.4	62.1	207.7	151.6	**466.8**	1.1	1.1	2.6	3.2	**8.0**	**474.8**
Type 2. Prospective Districts for Appraisal Survey																	
5	Leninsky		208.3	594.9	370.1	**1173.3**											**1 173.3**
6	Belovsky	13.5	27.5	31.7	10.2	**82.9**	0.3	0.6	4.8	12.7	**18.4**						**101.3**
7	Kemerovsky							124.6	149.3	131.5	**405.4**		31.7	128.9	144.3	**304.9**	**710.3**
8	Prokop'evsky-Kiselevsky						65.2*	121.4*	242.6*	171.7*							**601.0**
Type 3. Hardly Prospective Districts for Appraisal Survey at Present																	
9	Anzhersky												10.9	17.4	5.7	**34.0**	**34.0**
10	Zav'yalovsky							5.2	5.8	2.9	**13.9**		4.4	12.1	17.3	**33.8**	**47.7**

11	Titovsky							28.4	100.8	170.5	**299.7**		15.6	42.2	48.7	**106.5**	**406.2**
12	Aralichevsky						5.5	28.2	152.5	296.3	**482.5**				15.5	**15.5**	**498.0**
13	Kondomsky						52.6	107.2	374.0	358.0	**891.8**	7.4	13.7	24.5	29.9	**75.5**	**967.3**
14	Bunguro-Chumyshsky						65.2	112.9	252.7	230.9	**661.7**	18.8	25.6	32.5	20.3	**97.2**	**758.9**
																	Table 1-4 continued
	Type 4. Districts Which Prospects May Be Estimated After Additional Survey																
15	Bachatsky						12.5	15.4	6.3	0.9	**35.1**	0.4	0.6	1.2	0.7	**2.9**	**38,0**
16	Uskatsky	23.5	16.0	7.8		**47.3**			1.0	115.0	**116.0**						**163,3**
17	Baidaevsky	15.5	29.2	22.4	0.9	**68.0**				39.9	**39.9**						**107,9**
18	Osinovsky	2.6	23.2	29.1		**54.9**				3.4	**3.4**						**58,3**
19	Saltymakovsky				287.1	**287.1**		2.1	20.1	47.3	**69.5**		1.4	23.0	56.1	**80.5**	**437,1**
20	Krapivinsky							53.3	45.2	7.9	**106.4**		78.7	142.8	90.3	**311.8**	**418,2**
21	Plotnikovsky		54.3	129.5	218.3	**402.1**											**402,1**
Total Basin		**196,8**	**756.8**	**2 532.8**	**2 691.5**	**6 177.9**	**325.3**	**791.90**	**1982.4**	**2352.5**	**5452.1**	**35.8**	**195.5**	**464.3**	**483.1**	**1 178.7**	**12 808.8**

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