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ASSESSMENT OF GEOLOGICAL CONDITIONS AND PROSPECTS FOR METHANE PRODUCTION IN THE KARAGANDA COAL BASIN

ОЦЕНКА ГЕОЛОГИЧЕСКИХ УСЛОВИЙ И ПЕРСПЕКТИВЫ ДОБЫЧИ МЕТАНА В КАРАГАНДИНСКОМ УГОЛЬНОМ БАССЕЙНЕ

ҚАРАҒАНДЫ КӨМІР БАССЕЙНІНДЕ МЕТАН ӨНДІРУДІҢ ГЕОЛОГИЯЛЫҚ ЖАҒДАЙЛАРЫ МЕН ПЕРСПЕКТИВАЛАРЫН БАҒАЛАУ

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Keywords:
methane, coal seams, mining prospects, degassing, industrial, hydraulic fracturing, gas content, permeability..

ABSTRACT
The article explores the prospects for methane extraction at the Taldykuduk and Saran sections of the Karaganda coal basin. It highlights the geological features of these areas, including tectonic structures and varying gas-bearing parameters. Drilling methods, such as vertical drilling with hydraulic fracturing and directional horizontal drilling, are described along with their applicability under specific conditions. The emphasis is placed on the necessity of systematizing and updating geological data, as existing information on the permeability and gas saturation of coal seams is fragmented.
The study underscores the critical role of investigating the physical and mechanical properties of coal and conducting additional isothermal desorption tests to evaluate the critical desorption point. The high potential for methane production at significant depths, where gas content reaches 20 m^3/t or more, is noted, making these sections attractive for pilot project implementation. The combination of hydraulic fracturing and horizontal drilling methods is recommended to enhance productivity in low-permeability conditions.
The article provides conclusions and recommendations for designing drilling operations, emphasizing the need for advanced technologies and the involvement of skilled professionals. It underscores the importance of an integrated approach to studying and developing coalbed methane in the Karaganda basin to achieve sustainable gas extraction.

Түйінді сөздер:
метан, көмір қабаттары, өндіріс перспективалары, газсыздандыру, өнеркәсіптік, гидро жару, газдылық, өткізгіштік..

ТҮЙІНДЕМЕ
Мақалада Қарағанды көмір бассейнінің Талдықұдық және Саран учаскелерінде метанды өндіру перспективалары қарастырылған. Учаскелердің геологиялық құрылымының ерекшеліктері, соның ішінде әртекті тектоникалық құрылымдар және газдылықтың әртүрлі параметрлері ұсынылған. Гидро жарумен тік бұрғылау және бағытталған көлденең бұрғылау сияқты бұрғылау әдістері және олардың жағдайларға байланысты қолданылуы сипатталған. Геологиялық деректерді жүйелеу және өзектендіру қажеттілігіне баса назар аударылады, себебі көмір қабаттарының өткізгіштігі мен

газға қанықтылығы туралы бар ақпарат толық емес. Көмірдің физикалық-механикалық қасиеттерін зерттеудің және десорбцияның критикалық нүктесін бағалау үшін қосымша изотермиялық сынақтар жүргізудің негізгі рөлі көрсетілген. Газдылығы 20 м³/т немесе одан да көп жететін, бұл учаскелерді пилоттық жобаларды іске асыру үшін тартымды ететін елеулі тереңдіктер аймағында метан өндірудің жоғары әлеуеті атап өтілді. Төмен өткізгіштік жағдайында өнімділікті арттыру үшін гидро жару және көлденең бұрғылау әдістерінің үйлесімі ұсынылады. Заманауи технологияларды пайдалану және білікті мамандарды тарту қажеттілігін қоса алғанда, бұрғылау жұмыстарын жобалау бойынша қорытындылар мен ұсынымдар ұсынылған. Жұмыс тұрақты газ өндіруге қол жеткізу үшін Қарағанды бассейнінде көмір метанын зерттеу мен әзірлеуге кешенді тәсілдің маңыздылығын атап көрсетеді.

Ключевые слова:
метан, угольные пласты, перспективы добычи, дегазация, промышленное, гидроразрыв пласта, газоносность, проницаемость

АННОТАЦИЯ

В статье рассмотрены перспективы добычи метана на Талдыкудукском и Саранском участках Карагандинского угольного бассейна. Представлены особенности геологического строения участков, включая тектонические структуры и варьирующие параметры газоносности. Описаны методы бурения, такие как вертикальное бурение с гидроразрывом пластов и направленное горизонтальное бурение, и их применимость в зависимости от условий. Акцент сделан на необходимости систематизации и актуализации геологических данных, так как существующая информация о проницаемости и газонасыщенности угольных пластов фрагментарна. Показана ключевая роль исследования физико-механических свойств углей и проведения дополнительных изотермических испытаний для оценки критической точки десорбции. Отмечен высокий потенциал метанодобычи в зоне значительных глубин, где газоносность достигает 20 м³/т и более, что делает эти участки привлекательными для реализации пилотных проектов. Рекомендовано сочетание методов гидроразрыва и горизонтального бурения для повышения производительности в условиях низкой проницаемости. Представлены выводы и рекомендации по проектированию буровых работ, включая необходимость использования современных технологий и привлечения квалифицированных специалистов. Работа подчеркивает значимость комплексного подхода к изучению и разработке угольного метана в Карагандинском бассейне для достижения устойчивой добычи газа.

INTRODUCTION

The development and extraction of methane in the Karaganda coal basin are planned for the Taldykuduk and Saran sections, which are integral parts of the basin. These sections hold a significant volume of geological data collected during the Soviet era, including the drilling of 18–30 wells per square kilometer on the Saran section and 10–15 wells per square kilometer on the Taldykuduk section. However, this historical data has not yet been systematized or utilized for constructing a geological model.

Coal deposits in the Karaganda basin have been developed for many years. Of particular interest for methane extraction is the Karaganda suite, comprising coal-bearing seams and clastic deposits with a total thickness of 780-800 meters. This multilayer sequence includes seams up to 60 meters thick, such as the notable K12 seam, which reaches a thickness of 8.4 meters (Figure 1). The cumulative thickness of coal seams represents a significant positive factor contributing to a high potential methane yield.

According to the literature (Dou X., 2025; Drizhd N.A., Alexandrov A.Yu. & Zhunis G.M., 2020; Xu F., Zhang W. & Zhao G. 2023; Fang H., Li A. & Huang Y. 2023), coal deposits in the Karaganda basin contain substantial volumes of methane, highlighting the need to ensure safety in coal mines. However, no underground mining activities have been conducted to date on the Saran and Taldykuduk sections, allowing these areas to be considered "unrelieved" zones with high potential for methane production.

The coal seams of the Karaganda basin have undergone significant tectonic modifications. Within the project sections, faults, anticline and syncline structures, and zones of structural deformation are observed. Methane emissions have been detected in loose coal near these zones. The metamorphism of coal seams ranges from 1.04 to 1.75, creating favorable conditions for methane accumulation and extraction.

Thus, the combination of geological and tectonic features of the Taldykuduk and Saran sections determines their high potential for methane development, making them promising targets for detailed research and subsequent project implementation.

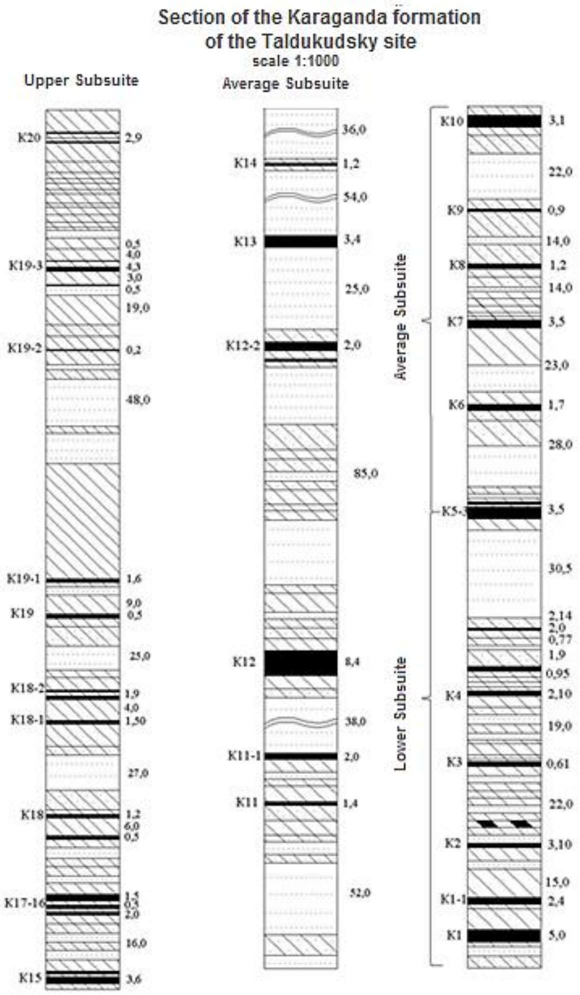

Figure 1. The sequence of strata in the Karaganda formation

Note: compiled by the authors

The study employed a combination of geological, geophysical, and analytical methods to evaluate the methane potential of the Karaganda coal basin, specifically at the Taldykuduk and Saran sites.

Geological data analysis. Archival geological reports and well-logging data from the Soviet period were reviewed and systematized. These data included information on the thickness of coal seams, tectonic structures, and lithological composition. - Geophysical surveys. Borehole geophysical methods (logging, gas content measurements, and cavementry data) were used to identify seam boundaries, permeability indicators, and gas saturation. Laboratory tests. Isothermal desorption analyses were carried out on coal samples to determine the critical desorption pressure (CDP) and methane sorption isotherms. The physical and mechanical properties of coal were also assessed through compression and permeability tests. Analytical modeling. Based on the collected data, gas content versus depth correlations were constructed. Preliminary reservoir modeling was performed to assess the spatial variability of permeability and methane content. This methodology provided the basis for identifying key parameters necessary for evaluating methane production prospects and for selecting appropriate drilling technologies.

MATERIALS AND METHODS

The results of the applied methods demonstrate a consistent increase in gas content with depth, accompanied by significant variability in permeability values. On the Taldykuduk site, maximum gas content reaches 20.2 m³/t, increasing up to 115–125 m³/t in the "methane zone" at depths exceeding 500 m. However, permeability remains highly heterogeneous, ranging from below 0.01 mD to 20–40 mD.

These findings indicate that while the methane resource potential is substantial, extraction efficiency will be strongly constrained by low permeability in certain intervals. Hydraulic fracturing and horizontal drilling are therefore recommended as combined methods to improve productivity.

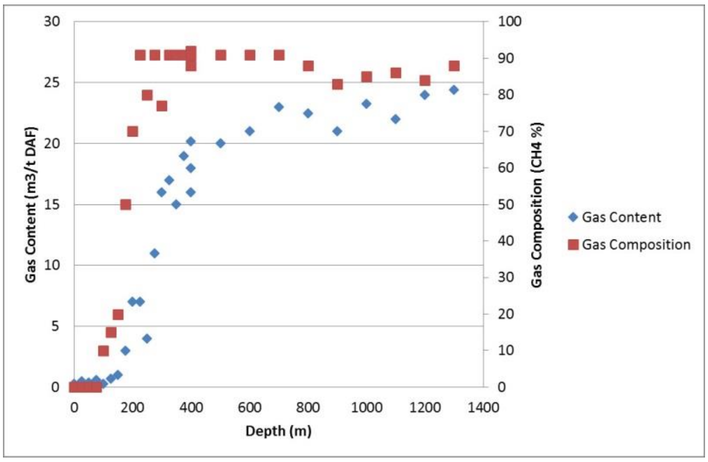

Figure 2. The gas content according to the depth

Note: compiled by the authors

The composition of the gas, characterized by methane content, is displayed on the Y axis. It should be noted an uneven increase in gas concentration with increasing depth and significant methane losses with high hydrocarbon content at depths over 700 m. Tests on the construction of a gas sorption isotherm have not been carried out. Nevertheless, a similar isotherm that best meets the conditions is shown in Fig. 3. According to calculations, coal seams are located near the gas saturation state. However, this conclusion is based on fragmentary and unreliable data obtained during mining activities.

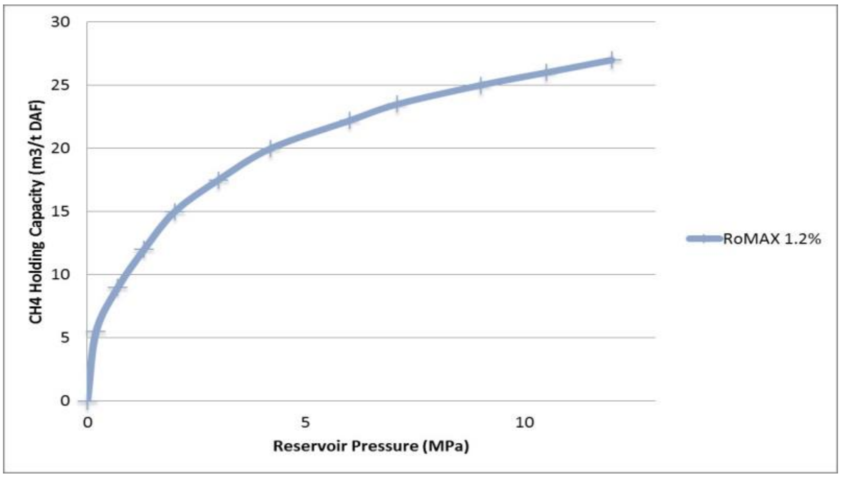

Figure 3. Prognostic isotherm for coals of the Karaganda basin
Note: compiled by the authors

To refine gas saturation parameters, it is recommended to conduct additional studies aimed at determining the critical desorption pressure (CDP) and the corresponding reservoir pressure for key seams, such as seam K12 (Wang Z., Fu X. & Zhou H. 2023; Reddy B.R., Ashok I. & Vinu R., 2020).

Sorption isotherm calculations should be performed exclusively for methane (CH4), aligning with the most applicable methodologies for the Karaganda coal basin. Accurate isotherm data are essential for estimating the required water removal volume to reach the level at which gas extraction becomes feasible, as well as for determining the capacity of pumping equipment. These parameters are crucial for the efficiency of drilling operations in coal seams, particularly when using directional drilling methods, as planned for the Karaganda basin. Currently, reliable data on coal seam permeability are lacking. However, based on scattered reports, permeability values are estimated to range from less than 0.01 mD (extremely low permeability) to 20–40 mD (good permeability). For coal seams, permeability in the range of 20–40 mD is considered sufficient for extraction, while values below 0.01 mD significantly hinder or render extraction unfeasible. Globally, no successful commercial coalbed methane (CBM) projects have been documented at permeability levels below 1 mD. Low permeability remains a major challenge for CBM project implementation in several countries, including China, India, the United Kingdom, Australia, and the United States (Zhang X., Cai Y. & Kang J. 2023). Available data suggest that the coal seams of the Karaganda basin may also exhibit extremely low permeability, posing a significant challenge for successful project execution. While permeability generally increases at shallower depths, it remains low in dense coal seams.

Reservoir pressure is assumed to be hydrostatic; however, no reliable confirmation is available. In certain cases, overpressure has been observed. No permeability measurements under pressure conditions have been conducted on Karaganda coal cores, nor have the directions of prevailing stress fields been studied. Permeability anisotropy is widespread, limiting the planning of optimal azimuths for directional drilling (Rabatuly M., Musin R.A. & Kenetaeva A.A. 2023). Detailed studies are required to determine the directions of tectonic stress fields and coal seam cleat orientations, which are critical components of ongoing reservoir evaluations. The current dataset is insufficient for comprehensive pilot project planning. The primary objective of data collection is to determine an optimal extraction strategy that balances maximizing permeability with adequate gas content in the seams.

Drilling depth parameters, according to international practices, range from 300 to 600 m. Successful projects are rare at depths exceeding 800 m. On the Saran site, hydraulic fracturing was performed at a depth of 830 m in seam K12, but the results were unsatisfactory (gas flow rates of 30,000-40,000 m³/day for a short duration). The next pilot project is planned for the Taldykuduk site, using directional drilling on one of the thick coal seams. The Atlas Copco RD20 rig, with a capacity of 40 tons, will be employed. The drilling plan includes setting the conductor casing at 10 m, intermediate casing at 80 m, deviating the wellbore at 120 m, followed by horizontal drilling along the seam for approximately 300 m (Jianguang W., 2019). The project's goal is to achieve a stable gas flow rate of 5,000–6,000 m³/day (up to 200,000 m³/month) over a prolonged operational period.

Figure 4 illustrates an example of changes in coal seam gas content with depth. The optimal depth for methane extraction is not determined by maximum gas content but rather by the zone where a balance is achieved between required gas content and permeability indicators.

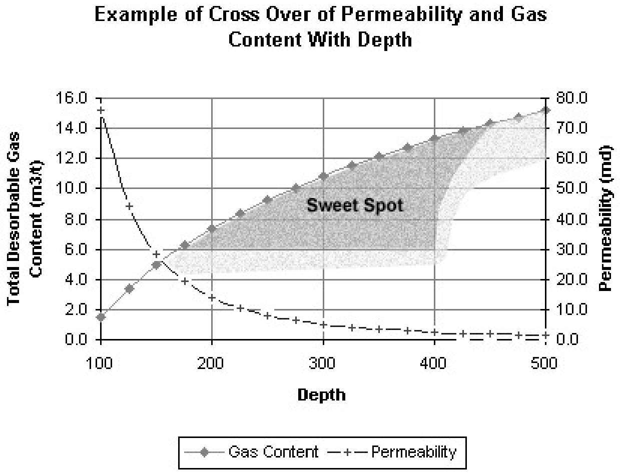

Figure 4. Changes in the gas content of coal seams depending on the depth
Note: compiled by the authors

Commencing operations without obtaining precise data on reservoir properties is highly risky and economically unjustifiable. The main challenges associated with the use of hydraulic fracturing and the design of horizontal drilling are outlined below.

The selection of a depth of 830 m for hydraulic fracturing virtually guarantees low reservoir permeability and, consequently, insufficient well productivity. This case exemplifies an approach where the complex process of coalbed methane extraction is initiated before conducting detailed reservoir studies.

International experience indicates that projects employing hydraulic fracturing at such depths are exceedingly rare. Even in cases where they are implemented, reservoir permeability is typically higher than that in the Karaganda basin. Furthermore, in most coal deposits, hydraulic fracturing is not used as a standard completion method. For instance, in Australia, the share of such projects is only 5–8% (Zhou W., Wang H. & Liu, X.2019).

The proposed horizontal drilling design represents an "absorbing column" that does not intersect the vertical pump bore (Figure 5). International coalbed methane development practices typically involve the use of separate vertical production wells equipped with pumps and gas collection systems (Figure 6). An example of multi-seam implementation is shown in Figure 7.

To enhance efficiency, it is recommended to drill a pressure monitoring well calibrated to the reservoir pressure.

The planned length of the horizontal wellbore is 300 m, which falls significantly short of international standards. This limitation reduces the well's impact on the reservoir and constrains the potential gas production volume.

The diameter of the proposed well is 168 mm, making it one of the largest diameters used for coalbed methane extraction. However, the increased diameter reduces the flexibility of the drilling equipment, which may complicate trajectory control.

Precise targeting of the seam is a critical aspect of successful drilling. Insufficient information on seam positioning increases the risk of an overly steep entry, potentially requiring additional drilling at the seam base to adjust the trajectory. This factor significantly elevates technical risks, particularly under conditions of limited understanding of the site's geological structure.

Effective seam drilling management requires specialized equipment and the involvement of highly skilled professionals with experience in coalfield operations. To achieve more precise control, intentional deviation of the drill stem trajectory is recommended, allowing for the determination of the optimal position of the drilling tool within the seam.

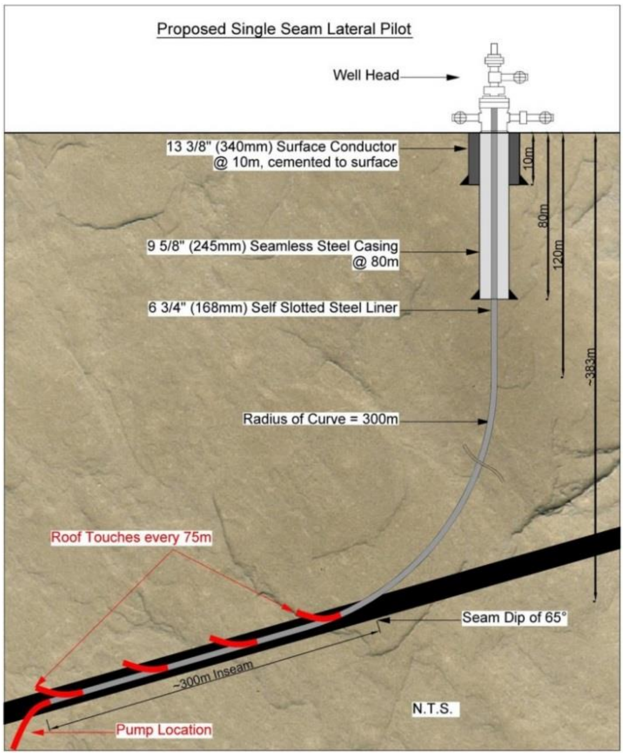

Figure 5. Horizontal directional drilling well

Note: compiled by the authors

At the Taldykuduk site (highlighted in gray), the proposed intersections with the roof of the coal seam and the final placement of the pump are marked in red.

Given the anticipated low permeability of the coal seams in the Karaganda Basin, achieving production goals and accessing resources will require either hydraulic fracturing or a combination of hydraulic fracturing and horizontal drilling. General recommendations include:

For gas permeability below 5 mD, a multilateral well is required.

For gas permeability ranging from 5 to 20 mD, it is advisable to combine hydraulic fracturing with horizontal drilling.

Figure 6 illustrates an example of a horizontal well commonly used in global coalbed methane extraction practices. The key features of this design include the production section of the wellbore positioned at a specified depth and a pressure-monitoring well located near the target seam.

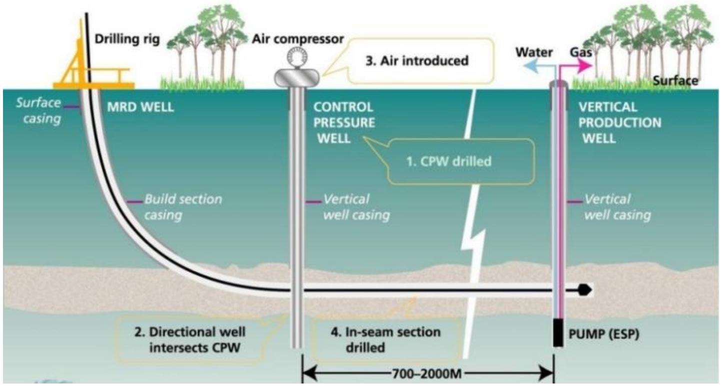

Figure 6. Simple horizontal wells

Note: compiled by the authors

Figure 7 presents an example of a multilateral well. Its key features include the placement of the pump at the point of angle buildup and the orientation of the borehole upward along the dip of the coal seam. This method is based on utilizing gas pressure to drive water upward (highlighted in yellow) toward the main wellbore (marked in red).

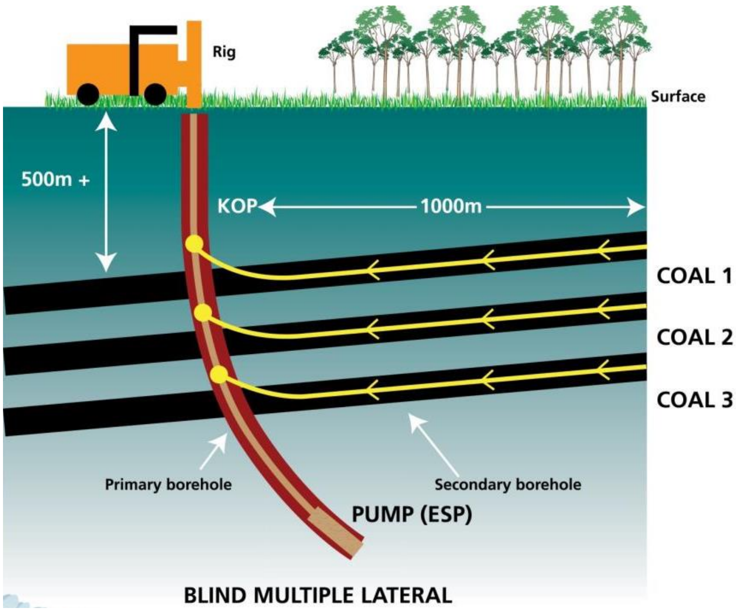

Figure 7. Multi-barrel wells

Note: compiled by the authors

The development of coalbed methane extraction in the Karaganda Basin holds significant potential. Despite the limited availability of field data, preliminary assessments suggest that total methane resources at the Saran and Taldykuduk sites may range from 2 to 10 trillion cubic feet, with the K12 seam alone potentially containing up to 1 trillion cubic feet. According to international standards, these represent exceptionally large gas reserves (Zhou D., Chen G. & Liu, Z. 2022; Xu F., Yan X. & Mei Y. 2022).

However, the quality of the data supporting these estimates remains unsatisfactory, necessitating prioritized research. Specifically, clarifications are required in the following areas:

Absolute permeability and its distribution with depth;

Degree of gas saturation in the seams;

Relationship between gas content and depth within the seams;

Geological structure of the sites.

Permeability is the key factor determining the success of methane extraction operations. Before commencing pilot drilling, it is recommended to gather comprehensive and reliable data on these parameters. Additionally, studying the continuity of coal seams at selected depths is crucial, as this remains insufficiently explored.

During drilling, it is advisable to intersect the horizontal well with a vertical well equipped with a pump. It is unlikely that an absorbing well design will be successful. Early challenges include trajectory adjustments, achieving the correct angle of entry into the seam, and maintaining the wellbore trajectory within the seam.

To minimize risks from the outset, it is essential to engage highly qualified specialists and employ reliable directional drilling equipment. A significant concern remains the possibility of extremely low gas output, even with successful drilling execution.

While coalbed methane extraction in the Karaganda Basin presents promising prospects, its realization requires a systematic approach. This involves first collecting accurate data and subsequently determining the most effective extraction methods. Furthermore, the experience gained from these operations will be valuable for further degassing of coal seams in the region.

CONCLUSION

The development and extraction of methane in the Karaganda coal basin, particularly at the Taldykuduk and Saran sites, demonstrate substantial potential. However, the current limitations in geological and gas-related data present several technical and organizational challenges. Key issues include the low permeability of coal seams, the lack of systematic data on geological structure and tectonic features, and insufficient information on reservoir pressure and gas saturation parameters.

To achieve efficient and stable methane production, comprehensive studies are recommended to refine the key characteristics of the coal seams, including their permeability, gas content, and depth correlation. Optimal development methods are recognized to include directional drilling and hydraulic fracturing, applied according to the properties of the target areas.

The success of projects in the Karaganda Basin will depend on the implementation of modern exploration techniques, the adaptation of international experience, and the development of specialized technical solutions tailored to local geological conditions.

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REFERENCES

Dou, X. (2025). Simulation Research On Space-ranging Vector Guidance System Of Tubular Magnetic Sources. Journal of Applied Science and Engineering, 28(6), 1287–1297. https://doi.org/10.6180/jase.202506_28(6).0011

Drizhd, N.A., Alexandrov, A.Yu., Balniyazova, G., Zhunis, G.M. (2020). Результаты освоения опытных скважин на участке Шерубай-Нуринского месторождения Карагандинского угольного бассейна. Научно-технический, промышленный и экономический журнал «Уголь», №06, 36-40. // Drizhd, N.A., Alexandrov, A.Yu., Balniyazova, G., Zhunis, G.M. Rezultaty osvoeniya opytnykh skvazhin na uchastke Sherubay-Nurinskogo mestorozhdeniya Karagandinskogo ugol'nogo basseina. [Results of development of pilot wells at the Sherubainurinsky site of the Karaganda coal basin]. Moscow: Publishing House of Rolix LLC. (In Russ.)

Xu, F., Zhang, W., Li, Z., Zhang, L., Zhang, J., How, W., Change, Q., (...), Zhao, G. (2023). Coalbed methane reservoir description and enhanced recovery technologies in Bad block, Ordos Basin. Natural Gas Industry, 43(1), 96-112. https://doi.org/10.3787/j.issn.1000-0976.2023.01.010

Fang, H., Li, A., Sang, S., Gu, C., Yang, J., Li, L., Liu, H., (...), Huang, Y. (2023). Numerical analysis of permeability rebound and recovery evolution with THEM multi-physical field models during CBM extraction in crushed soft coal with low permeability and its indicative significance to CO2 geological sequestration. Energy, Part A, 262, 125395. https://www.journals.elsevier.com/energy doi:10.1016/j.energy.2022.125395

Drizhd, N.A., Mussin, R.A., Alexandrov, A.Yu. (2019). Improving the Technology of Hydraulic Impact Based on Accounting Previously Treated Wells. International science and technology conference "Earth science", IOP Conf. Series: Earth and Environmental Science, 272, 022031. https://doi.org/10.1088/1755-1315/272/2/022031

India Coal Mine Methane Market Study. (2019, February 22). https://www.globalmethane.org/documents/India

Yang, W., Wang, L., Yang, K., Tian, C., Pan, R. (2023). Molecular insights on influence of CO2 on CH4 adsorption and diffusion behaviour in coal under ultrasonic excitation. Fuel, 355, 129519. https://doi.org/10.1016/j.fuel.2023.129519

Li, W., Yang, K., Deng, D., Zhao, C., Yang, S., Cheng, Y., Lu, S. (2023). A lattice Boltzmann model for simulating gas transport in coal nanopores considering surface adsorption and diffusion effects. Fuel, 340, 127507. http://www.journals.elsevier.com/fuel/ doi:10.1016/j.fuel.2023.127507

Wang, Z., Fu, X., Hao, M., Li, G., Pan, J., Niu, Q., Zhou, H. (2021). Experimental insights into the adsorption-desorption of CH4/N2 and induced strain for medium-rank coals. Journal of Petroleum Science and Engineering, 204, 108705. http://www.sciencedirect.com/science/journal/09204105/81 doi:10.1016/j.petrol.2021.108705

Reddy, B.R., Ashok, I., Vinu, R. (2020). Preparation of carbon nanostructures from medium and high ash Indian coals via microwave-assisted pyrolysis. Advanced Powder Technology, 31(3), 1229-1240. https://doi.org/10.1016/j.apt.2019.12.017

Zhang, X., Cai, Y., Zhou, T., Cheng, J., Zhao, G., Zhang, L., Kang, J. (2023). Thermodynamic characteristics of methane adsorption on coals from China with selected metamorphism degrees: Considering the influence of temperature, moisture content, and in situ modification. Fuel, 342, 127771. http://www.journals.elsevier.com/fuel/ doi:10.1016/j.fuel.2023.127771

Rabatuly, M., Musin, R.A., Demin, V.F., Usupaev, Sh.E., Kenetaeva, A.A. Improving the efficiency of methane extraction from coal seams. Kompleksnoe Ispolzovanie Mineralnogo Syra, 324

Kang, Y., Yan, X., Huangfu, Y., Zhang, B., Deng, Z. (2023). Concept and main characteristics of deep oversaturated coalbed methane reservoir. Shiyou Xuebao/Acta Petrolei Sinica, 44(11), 1781-1790. https://doi.org/10.7623/syxb202311003

Jianguang, W. Technology Process of China's CBM Exploration and Development. https://usea.org/sites/default/files/event. 29.08.2019

Zhou, W., Wang, H., Zhang, Z., Chen, H., Liu, X. (2019). Molecular simulation of CO2/CH4/H2O competitive adsorption and diffusion in brown coal. RSC Advances, 9(6), 3004-3011. http://pubs.rsc.org/en/journals/journal/ra doi:10.1039/c8ra10243k

Zhou, D., Chen, G., Chen, Z., Liu, Z. (2022). Exploration and development progress, key evaluation parameters and prospect of deep CBM in China. Natural Gas Industry, 42(6), 43-51. https://doi.org/10.3787/j.issn.1000-0976.2022.06.004

Xu, F., Yan, X., Lin, Z., Li, S., Xiong, X., Yan, D., Wang, H., (...), Mei, Y. (2022). Research progress and development direction of key technologies for efficient coalbed methane development in China. Meitiandizhi Yu Kantan/Coal Geology and Exploration, 50(3), 1-14. https://doi.org/10.12363/issn.1001-1986.21.12.0736

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