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# Prospects for Industrial Extraction of Methane from Coal Seams in the Karaganda Basin: Results of Experimental-Industrial Studies at the Taldykuduk Site

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**ABSTRACT**

The study focuses on assessing the industrial potential of coalbed methane production in the Karaganda Basin based on drilling and testing data from wells T7 and T8 at the Taldykuduk site. The goal is to develop and verify engineering solutions, ensuring efficient methane extraction from unstressed seams under real geological and technical conditions. The research object is the coal seams of the Karaganda suite, characterized by high gas content, developed fracturing, and heterogeneous reservoir structure. Vertical wells were drilled with local enlargement of productive intervals, zone isolation using packers, and controlled hydraulic stimulation. A set of geophysical surveys was conducted, including gamma, density, and neutron logs, caliper logging, inclinometry, gas-geochemical monitoring, and flow tests, to determine reservoir pressure and permeability. Laboratory analyses of core and coal samples examined adsorption–desorption properties, elemental composition, and formation water characteristics, enabling the selection of optimal reagents and gas treatment schemes. Stable methane inflows up to 30 m³/day were obtained under steady depression without water inflow, confirming readiness for pilot-industrial operation. After hydraulic stimulation and optimization of well regimes, an increase in gas flow rate was recorded, confirming the efficiency of reservoir stimulation. Based on pressure and flow curves, technological parameters were defined — perforation intervals, hydraulic treatment conditions, and requirements for gas collection, dehydration, and compression systems. The practical significance of the study lies in substantiating a technological scheme for industrial methane extraction and reducing methane hazards during mining. Implementation of the proposed approach will enable integration of extracted gas into the regional energy balance and reduce uncontrolled methane emissions, providing environmental and economic benefits.

***Keywords:*** methane, degasification, drilling, hydraulic fracturing, industrial production, gas permeability.

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## Introduction

Over recent decades, coalbed methane has evolved from a source of heightened mining hazard into an independent type of hydrocarbon feedstock actively incorporated into the energy balances of many countries. The experience of the United States, China, and Australia confirms that coalbed methane production volumes can reach tens of billions of cubic meters per year, comparable to conventional natural gas production [[1], [2], [3], [4]]. The technologies for its extraction are based on the use of specialized drilling and inflow-stimulation methods—horizontal and directional wells, hydraulic fracturing, mechanical enlargement of productive zones, and optimization of drawdown. These processes are accompanied by geophysical and gas-geochemical monitoring, filtration and desorption modeling, and a system for conditioning the gas for transportation.

In Kazakhstan, interest in industrial coalbed methane production has intensified thanks to the large resources of the Karaganda Basin, whose total potential is estimated at up to 2 trillion m³ [5]. For a long time, degasification activities were carried out mainly to improve the safety of underground operations. Under current conditions of growing gas demand and the transition to low-carbon energy, the key task is to shift from degasification as a safety measure to industrial development of coalbed methane and its integration into the gas-transport infrastructure. The main technological obstacle is the low permeability and pronounced anisotropy of coal reservoirs, which require multistage stimulation methods and precise selection of drainage regimes to prevent water loading and stabilize inflow.

Particular attention is given to the Taldykuduk area of the Karaganda Basin, where pilot-industrial work has been carried out on the construction and testing of vertical wells using technologies for enlarging productive intervals and hydraulic fracturing [6]. Commissioning of well T7 demonstrated a stable methane inflow of about 30 m³ per day, which is comparable to the initial stages of industrial development of analogous fields abroad. The results obtained and the interpretation of pressure and rate curves made it possible to formulate initial technological regulations for selecting exposure intervals, injection parameters, and drawdown management, as well as to determine requirements for gas dehydration, compression, and utilization systems.

The scientific novelty of the study lies in the comprehensive validation of various inflow-stimulation technologies—from mechanical enlargement to hydraulic impact—applied to the geological and technical conditions of the Karaganda Basin. An essential element is the implementation of proprietary solutions protected by patents: a method for advance reduction of natural gas content [7], a method for advanced degasification of a coal seam by an inclined-directed well with branches [8], and a method of degasification using an injection well [9]. These technologies form a unified system—from preliminary reduction of reservoir pressure and redistribution of flows to the formation of high-conductivity channels.

The relevance of the topic is determined by the combination of the Karaganda Basin's substantial resource base, the insufficient maturity of domestic industrial production technologies, and the need to adapt global experience to local conditions. The expected results include an increase in recoverable methane reserves, enhanced energy security, and a reduction in uncontrolled emissions through managed extraction and utilization of gas. Going forward, plans include expanding the network of pilot wells, implementing multistage hydraulic-stimulation technologies, refining geomechanical and flow models, and conducting a techno-economic assessment for the transition to the industrial stage of coalbed methane development in Kazakhstan.

## Experimental part

The methodology applied at the Taldykuduk site was designed to evaluate the industrial potential of methane extraction from coal seams. The work was carried out in stages: preparation and drilling of reference wells, geophysical surveys to identify promising zones, local operations to increase near-wellbore permeability, stepwise inflow tests with pressure-recovery monitoring, and laboratory studies of core and formation water. The approach focuses on result reproducibility and safe technology scaling under conditions of low natural permeability of coal reservoirs.

Field tests were conducted on wells T7 and T8. During drilling, mechanical penetration rate, torque, axial load, drilling fluid flow rate, and density were controlled; productive intervals were selectively exposed for subsequent studies. The suite of geophysical measurements included gamma-ray, density, and neutron logs, acoustic profiling, caliper logging, and inclinometry. Joint interpretation made it possible to determine lithological associations, identify zones of increased fracturing, and assess gas saturation of the rocks.

**Figure 1** – General view of the U/Reamer MOT 7-1/2 in × 22 in

Mechanical enlargement was used as a gentle method for increasing permeability without applying proppant. A U Reamer 7-1/2 × 22-inch reamer provided uniform enlargement of the borehole diameter within the productive layer under controlled axial load and rotation frequency. The effectiveness of the operation was confirmed by changes in caliper profiles without excessive ovality. To prevent clogging of the fracture–pore space, circulation flushing with low-salinity water and an inhibitor additive was used to reduce coal fines dispersion. This ensured preservation of the filtration properties of the rock mass and stability of the obtained results (Figure 1).

Hydraulic fracturing was performed in well T8 within a specially isolated coal interval. Injection parameters were selected based on calculations of the minimum horizontal stress derived from acoustic and density measurements, using empirical relationships characteristic of coal rocks. The operations were carried out in stages: interval sealing with packers, initiation of the injection stage, main stage of fracture opening and formation of a conductive channel, followed by controlled closure. Pressure and flow rate were recorded with high temporal resolution, which allowed, through interpretation of the closure curves, to estimate the conductivity of the created channel and the expected productivity increase. The layout and sequence of operations are shown in Figure 2.

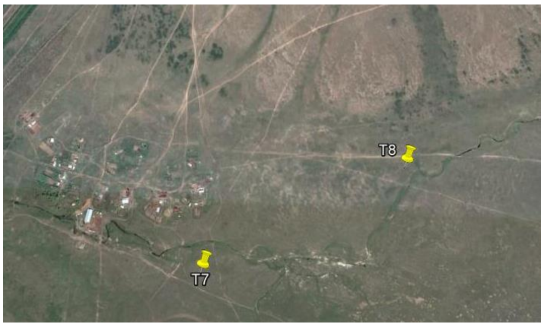


**Figure 2** – Location of wells T7 and T8

Inflow tests were performed using a stepwise scheme with sequential increases in drawdown followed by stabilization of the flow rate. Reservoir pressure was determined using buildup periods, which made it possible to calculate the permeability–thickness product (kh), skin factor, and drainage radius from logarithmic and derivative diagnostics. After hydraulic fracturing, the linear-flow component was additionally analyzed using square-root-of-time analysis, allowing estimation of the fracture half-length and effective conductivity.

Laboratory studies included determination of bulk and grain density, porosity by helium pycnometry, gas content from desorption canisters, and methane adsorption characteristics from Langmuir isotherms—capacity and saturation pressure. Gas permeability was measured under steady-state and quasi-steady-state conditions while varying effective stress and orientation relative to bedding [10]. Mechanical tests were carried out on dry and wetted specimens under uniaxial compression and Brazilian tension; the resulting static moduli were compared with dynamic values calculated from acoustic data [11]. The ranges of the obtained parameters are summarized in Table 1 for subsequent calibration of flow models.

**Table 1** – Results of laboratory studies and test intervals of coal seams in well T7

| № | Seam No. | Roof, m | Floor, m | Total thickness, m | Purpose |
|---|---|---|---|---|---|
| 1 | 8 | 186.6 | 210.3 | 23.7 | For methane gas inflow |
| | 9 | 212.0 | 216.3 | 4.3 | For methane gas inflow |
| 2 | 5 | 154.2 | 165.1 | 10.9 | For methane gas inflow |
| | 6 | 165.1 | 176.6 | 11.5 | For methane gas inflow |
| | 7 | 176.6 | 182.1 | 5.5 | For methane gas inflow |
| 3 | 3 | 119.2 | 121.1 | 1.9 | For methane gas inflow |

The chemical composition of formation waters was determined using certified methods, including analysis of ionic composition, total mineralization, and assessment of the medium's tendency to form scale and corrosion. The data obtained were used in selecting inhibitor programs, gas dehydration schemes—adsorption or glycol—and in choosing compression parameters, which made it possible to avoid technological flow-rate limitations at the early stage of development.

Interpretation of hydrodynamic data was performed taking into account gas supercompressibility by transforming to pseudopressure, as well as the two-component structure of the coal seam, represented by the matrix and a fracture system with active desorption–diffusion exchange. Exchange parameters were determined from the character of the early and late segments of the pressure-buildup curves and from the behavior of the derivative function. Matching of calculated and actual data was carried out iteratively on the basis of the set of rate–pressure relationships, with laboratory results used as a priori constraints. To assess parameter uncertainty, bootstrap analysis and Bayesian regularization were applied.

Quality control included preliminary calibration of pressure, temperature, and flow sensors, as well as inter-operational checks. Geophysical instruments were verified on control intervals, and calipers on standard calibration rings. Operational logs contained detailed entries on depth, regimes, and the tools used, which ensured accurate tracing of operations and made it possible to promptly identify the causes of possible discrepancies.

The efficiency criteria were stable gas inflow at moderate drawdown, a decrease in skin factor after stimulating treatments, absence of early water breakthrough, and reproducibility of results in repeated test cycles. The flow rates obtained at well T7, on the order of several tens of cubic meters of gas per day under a stable regime, make it possible to consider this approach as a basis for expanding the pilot network with the use of multistage stimulation technologies.

## Results and Discussion

Well T7: drilling, enlargement, and completion.

In June 2016, drilling began on the vertical pilot-production well T7 at the Taldykuduk site (Figure 2). The wellbore design included a direction with a diameter of 340 mm, a 244.5 mm conductor, and a 140 mm production casing with full cementing to the surface. This scheme ensured borehole stability within the section of argillites and siltstones, as well as the possibility of selective exposure of coal interbeds. Low-mineralized water with an inhibitor preventing the dispersion of coal fines was used as the drilling fluid. Drilling regimes were selected with limits on axial load and torque, with continuous control of mechanical penetration rate and fluid flow rate, which made it possible to minimize near-wellbore damage.

To increase the contact area between the borehole walls and the coal seam, as well as to open microfracturing, a U Reamer MOT 7-1/2 × 22-inch (559 mm) reamer was used. The increase in effective filtration area was confirmed by caliper logging results (Figure 2).

The suite of geophysical surveys conducted before and after mechanical enlargement made it possible to identify, within the 154–216 m interval, coal interbeds with reduced apparent density (1.59–2.21 g/cm³) and increased specific electrical resistivity (15.3–118.4 Ω·m). In combination with acoustic characteristics, these data indicate high gas saturation and low wettability of the rocks. Joint interpretation of gamma-ray, density, and neutron logs with the caliper results was used to refine test boundaries and select sections for mechanical enlargement (Tables 2–3). Caliper profiles confirmed uniform diameter increase within the target intervals without signs of ovality or loss of borehole wall stability.

**Table 2** – Main physical parameters of the rock skeleton and fluids in the section of well T7.

| **Rock skeleton** | **σ, g/cm³** | **ΔT, μs/m** |
|---|---|---|
| Sandstone | 2.65 | 165 |
| Clay | 2.40-2.55 | 275-325 |
| Limestone | 2.71 | 155 |
| Fresh water | 1.00 | 610 |
| Saline water | 1.05 | 590 |

The technological sequence of operations included borehole cleaning, enlargement of productive zones, repeat geophysical surveys, isolation of seams using packers, and a series of stepwise inflow tests. During mechanical enlargement, axial load and tool rotation frequency were controlled, and continuous circulation of low-mineralized water ensured efficient removal of cuttings and coal dust. To prevent secondary clogging of the fracture–pore space, a specially selected inhibitor was used that accounted for the ionic composition of formation waters; the parameters of its selection are provided in the summary materials. According to control caliper logging, a uniform diameter increase of 20–60 mm was recorded within the target intervals while maintaining the proper cylindrical shape of the borehole.

Well cleanup and commissioning were carried out according to the standard scheme: initial cleaning, gradual reduction of bottomhole pressure, stabilization of flow rate, and a final pressure-buildup stage. During the cleaning stage, a short-term removal of drilling fluid and fine coal was observed, after which gas inflow became stable. The series of stepwise tests showed a regular increase in flow rate with growing drawdown; at the control step, a stable methane inflow of about 30 m³ per day was obtained under a moderate pressure differential and with no signs of water breakthrough [12]. Analysis of pressure-buildup data made it possible to determine integral permeability, skin factor, and drainage radius. A decrease in the skin parameter relative to the initial values confirmed the positive effect of mechanical enlargement of the productive interval, which is consistent with the results presented in Table 3.

**Table 3** - Results of interpretation of open-hole well-logging data for well T7 in the Taldykuduk area.

a – Geophysical and geometric parameters of coal seams.

| № | Top, m | Base, m | H, m | ΔS, mm | GZ3, Ω·m | GZ3B, Ω·m | GR, μR/h |
|---|---|---|---|---|---|---|---|
| 1 | 112.9 | 113.9 | 1.0 | 242 | 75.3 | 38.7 | 6.5 |
| 2 | 114.8 | 117.0 | 2.2 | 289 | 54.4 | 34.2 | 6.3 |
| 3 | 119.2 | 121.1 | 1.9 | 286 | 27.7 | 29.0 | 5.1 |
| 4 | 144.2 | 145.1 | 0.9 | 254 | 44.1 | 34.7 | 7.5 |
| 5 | 154.2 | 165.1 | 10.9 | 289 | 118.4 | 113.4 | 2.5 |
| 6 | 165.1 | 176.6 | 11.5 | 359 | 45.9 | 41.7 | 1.9 |
| 7 | 176.6 | 182.1 | 5.5 | 324 | 75.2 | 50.7 | 1.5 |
| 8 | 186.6 | 210.3 | 23.7 | 381 | 36.2 | 33.7 | 3.7 |
| 9 | 212.0 | 216.3 | 4.3 | 312 | 26.4 | 36.0 | 4.7 |
| 10 | 248.5 | 251.7 | 3.2 | 314 | 30.6 | 21.0 | 7.8 |
| 11 | 266.8 | 268.6 | 1.8 | 311 | 25.6 | 30.1 | 8.1 |
| 12 | 280.5 | 282.4 | 1.9 | 298 | 27.3 | 27.6 | 8.5 |
| 13 | 284.5 | 286.4 | 1.9 | 235 | 31.9 | 35.0 | 7.9 |
| 14 | 299.3 | 308.5 | 9.2 | 436 | 15.7 | 15.3 | 7.0 |
| 15 | 309.9 | 316.3 | 6.4 | 444 | 16.1 | 20.0 | 6.4 |

b - Physical and petrophysical parameters of coal seams

| № | ρ, g/cm³ | Kclay, % | Kp, % | Lithology |
|---|---|---|---|---|
| 1 | 2.17 | 45.8 | 6.5 | Carbonaceous argillite |
| 2 | 2.09 | 44.3 | 6.3 | Carbonaceous argillite |
| 3 | 1.64 | 32.0 | 2.6 | Coal |
| 4 | 2.18 | 60.1 | 6.5 | Carbonaceous argillite |
| 5 | 1.63 | 9.1 | 1.2 | Coal |
| 6 | 1.59 | 5.4 | 0.8 | Coal |
| 7 | 1.59 | 3.1 | 0.4 | Coal |
| 8 | 1.66 | 17.9 | 2.4 | Coal |
| 9 | 1.73 | 27.0 | 3.8 | Coal |
| 10 | 1.93 | 64.9 | 9.2 | Carbonaceous argillite |
| 11 | 1.79 | 69.4 | 9.9 | Carbonaceous argillite |
| 12 | 2.21 | 76.6 | 10.9 | Carbonaceous argillite |
| 13 | 2.05 | 65.3 | 9.3 | Carbonaceous argillite |
| 14 | 1.68 | 54.3 | 7.7 | Carbonaceous argillite |
| 15 | 1.62 | 45.4 | 6.2 | Carbonaceous argillite |

Laboratory studies for T7 included porosity (helium pycnometry), gas content (desorption canisters), adsorption parameters from Langmuir isotherms, and gas permeability under steady-state/quasi-steady-state conditions with control of effective stress. The obtained ranges were used as a priori inputs for calibration of flow models and were compared with well-logging density and acoustic indicators; the consistency of field and laboratory estimates confirms the correctness of interval selection. Formation-water analysis (ionic composition, mineralization) was applied to select inhibitor programs and gas dehydration schemes at the compression-preparation stage, which removed technological flow-rate limitations during the commissioning period [13].

The following operational recommendations were formulated for well T7: maintain stable, moderate drawdowns without abrupt changes in wellhead pressure; in case of increasing hydraulic resistance, perform preventive flushing of the near-wellbore zone; provide for gas dehydration using glycol or adsorption systems, taking into account moisture-content fluctuations; upon the appearance of local signs of water breakthrough, adjust offtake regimes and, if necessary, perform targeted isolation of water inflow. Overall, the combination of mechanical enlargement with a gentle operating regime ensured stable gas inflow at an early stage without increasing geomechanical risks and can be considered a baseline scheme for analogous coal seams at the pilot-industrial development stage.

During T7 operation, a stable methane inflow of about 30 m³ per day was recorded, which, under moderate drawdown, confirms the industrial potential of the site. The liquid rate was in the range of 0.9–5.6 m³ per day, which is associated with the removal of residual drilling fluid and partial inflow of formation waters from adjacent interbeds [14]. Chemical analysis revealed elevated mineralization—about 12.5 g/L of dry residue with chloride concentration up to 7.5 g/L. Such an ionic signature is characteristic of the participation of formation waters and indicates well-developed natural fracturing that provides hydraulic communication of coal interbeds with water-bearing intervals (Tables 2, 3). Taking into account the chloride–sodium type of water, the use of corrosion-resistant materials and inhibitor programs with control of pH and hardness is recommended; for gas conditioning—glycol dehydration with control of salt deposition in heat-exchange units. According to pressure-buildup analysis, a decrease in the skin parameter relative to the initial values was noted, which confirms the effect of mechanical enlargement. The "soft" operating regime was recognized as optimal: gradual increase in drawdown, maintenance of balance between the gas and liquid phases at the wellhead, preventive flushing with low-mineralized water with an inhibitor additive preventing dispersion of coal fines (Figure 2; Tables 2, 3).

Well T8: drilling and preparation for hydraulic fracturing.

In August 2016, a vertical pilot-production well T8 was drilled at the Taldykuduk site (Figure 2). The design included a direction with a diameter of 340 mm, a 244.5 mm conductor, and a 140 mm production casing run to a depth of about 550 m with cementing to the surface, which ensured borehole stability and reliable isolation of non-productive intervals at the stage of subsequent stimulation. The suite of geophysical studies identified priority coal interbeds with low apparent density (1.75–1.89 g/cm³), elevated specific resistivity (25.4–197.1 Ω·m), and increased P-wave transit time (428–627 μs/m)—Tables 4–7. These indicators correspond to slightly wetted, highly gas-saturated reservoirs with low natural permeability, where formation of an artificial conductive system is required to ensure stable inflow.

Taking into account geophysics, caliper logging, and geomechanical constraints, hydraulic fracturing was planned in T8 within the priority intervals (Tables 6, 7). The preparatory stage included refinement of the minimum horizontal stress from acoustic and density data, determination of a safe pressure range, a diagnostic injection to evaluate breakdown pressure, leakoff coefficient, and closure character, as well as verification of cement quality and tightness of the packered zone. In addition, the working fluid was selected with regard to the ionic composition of formation waters to minimize the risks of swelling and plugging [15]. Based on the diagnostic injection, volumes and injection rate were refined, as were the parameters of the selected proppant—preferably a lightweight fine fraction with good transportability and moderate requirements for pressure and rate.

The technological sequence of hydraulic fracturing provided for interval isolation with packers, initiation of the injection stage, the main stage of conductive fracture formation with control of bottomhole pressure and rate, and controlled closure with recording of the pressure-falloff curve. From sections of linear and radial flow on time and logarithmic plots, effective conductivity and fracture half-length were determined. Comparison with pressure-buildup results after the operation made it possible to assess the decrease in skin parameter and the increase in integral permeability.

The success criteria were the formation of stable gas inflow at moderate drawdown, absence of increased water inflow at an early stage, and reproducibility of flow rate in repeated tests. To manage risks, online monitoring of pressure and rate with high temporal resolution was used, adjustment of injection rate in the presence of signs of unstable opening, and post-operation analysis of closure mechanics with evaluation of the leakoff-to-storage ratio [16].

Post-fracturing startup was carried out according to a gentle scheme: minimal drawdowns during the first day, control of gas humidity and composition of produced fluid, gradual increase in offtake under stable dynamics. At the initial stage, a predominance of linear inflow with a gradual transition to a quasi-radial regime is expected as the fracture is cleaned and the filtration properties of the near-wellbore zone stabilize (Tables 4–7). If signs of water breakthrough appear, regrouping of intervals, reduction of drawdown, selective isolation of water inflow, or adjustment of the working-fluid composition during repeated treatments is envisaged. Overall, the strategy implemented at T8 logically complements the results obtained for T7: mechanical enlargement made it possible to ensure rapid inflow startup, while hydraulic fracturing creates conditions for long-term conductivity and a stable gas regime while maintaining controlled geomechanical risks (Figure 2; Tables 4–7).

**Table 4** - Suite of open-hole geophysical studies for well T8 in the Taldykuduk area.

a – Electrical methods

| **Parameter** | **1** | **2** | **3** |
|---|---|---|---|
| Method | KS (N0.5M2A; A2M05N) | SP | BK |
| Mnemonic | GZ3B, GZ3 | SP | LL3 |
| Depth scale | 1:500 | 1:500 | 1:500 |
| Logging interval, m | 146.3–506.0 | 146.3–502.0 | 146.3–508.5 |
| Instrument | EK-73 | EK-73 | EK-73 |
| Data quality | Good | Good | Good |

b – Radioactive methods

| Parameter | 4 | 5 | 6 |
|---|---|---|---|
| Method | GR | NK | GGK-p |
| Mnemonic | GR | RFTN, RNTN, TRNP | RHOB |
| Depth scale | 1:500 | 1:500 | 1:200 |
| Logging interval, m | 146.3–509.5 | 146.3–511.0 | 146.3–511.0 |
| Instrument | 2NNK-73 | 2NNK-73 | PK-73 |
| Data quality | Good | Good | Good |

c – Other methods

| Parameter | 7 | 8 | 9 | 10 |
|---|---|---|---|---|
| Method | Caliper, Profilometry | Inclinometry | Acoustic logging (AK) | Cement-bond log (AKC) |
| Mnemonic | CALI, C1, C2 | AZIM, DEVI | DTP, DTS | CBL |
| Depth scale | 1:500 | 1:500 | 1:200 | 1:500 |
| Logging interval, m | 146.3–511.0 | 0.0–510.0 | 146.3–509.5 | 0.0–146.3 |
| Instrument | 4PM-73 | IN-73 | 2AK | 2AK |
| Data quality | Good | Good | Good | Good |

The presented suite of geophysical studies made it possible to obtain a complete understanding of the lithological structure, fracturing, and gas saturation of the coal seams. The use of a combination of electrical, radioactive, and acoustic methods ensured high interpretation accuracy of the section and identification of priority intervals for stimulation operations. Data from gamma, density, and neutron logs were used in constructing correlation models and determining the dynamic properties of the reservoirs.

**Table 5** - Main physical parameters of the rock skeleton and fluids in the section of well T8.

| Rock skeleton | ρ, g/cm³ | ΔT, µs/m |
|---|---|---|
| Sandstone | 2.65 | 165 |
| Clay | 2.40–2.55 | 275–325 |
| Limestone | 2.71 | 155 |
| Fresh water | 1.00 | 610 |
| Saline water | 1.05 | 590 |

The data in the table illustrate the ranges of density and acoustic parameters used in the interpretation of geophysical survey results. Comparison of these values with field measurements made it possible to refine rock types, assess gas and water saturation of the coal seams, and adjust reservoir boundaries.

**Table 6** - Testing recommendations.

| № | Seam № | Roof, m | Floor, m | Total thickness, m | Purpose |
|---|---|---|---|---|---|
| 1 | 7 | 314.1 | 324.9 | 10.8 | For methane gas inflow |
| | 8 | 325.9 | 326.8 | 0.9 | For methane gas inflow |
| | 9 | 328.2 | 330.5 | 2.3 | For methane gas inflow |
| 2 | 1 | 150.2 | 158.7 | 8.5 | For methane gas inflow |

**Table 7** - Results of interpretation of open-hole geophysical logging data for well T8 at the Taldykuduk area

a - Coal intervals (well T8, open hole)

| Parameter | 1 | 7 | 8 | 9 |
|---|---|---|---|---|
| Seam № | 1 | 7 | 8 | 9 |
| Roof, m | 150.2 | 314.1 | 325.9 | 328.2 |
| Bottom, m | 158.7 | 324.9 | 326.8 | 330.5 |
| Total, m | 8.5 | 10.8 | 0.9 | 2.3 |
| DS, mm | 477 | 295 | 256 | 249 |
| BK, Ω·m | 59.5 | 159.5 | 197.1 | 158.2 |
| GK, µR/h | 2.7 | 2.7 | 3.3 | 3.0 |
| W, % | 58.6 | 54.0 | 50.3 | 52.3 |
| GGKp, g/cm³ | 1.77 | 1.76 | 1.89 | 1.75 |
| AK, µs/m | 627.32 | 445.17 | 429.72 | 428.39 |
| Kgl, % | 8.6 | 9.1 | 13.0 | 10.8 |
| Kp GGKp, % | 2.7 | 2.6 | 4.2 | 3.4 |
| Kp NK, % | 1.2 | 1.2 | 1.7 | 1.4 |
| Kp AK, % | 1.6 | 1.4 | 2.4 | 1.8 |
| Lithology | Coal | | | |

b - Carbonaceous argillite (shallower)

| **Parameter** | **2** | **3** | **4** | **5** | **6** |
|---|---|---|---|---|---|
| Seam № | 2 | 3 | 4 | 5 | 6 |
| Roof, m | 177.5 | 181.2 | 183.8 | 199.6 | 201.7 |
| Bottom, m | 178.5 | 182.3 | 185.2 | 200.4 | 202.9 |
| Total, m | 1.0 | 1.1 | 1.4 | 0.8 | 1.2 |
| DS, mm | 467 | 460 | 329 | 465 | 425 |
| BK, Ω·m | 19.6 | 19.3 | 23.7 | 10.6 | 25.4 |
| GK, µR/h | 5.0 | 5.5 | 5.2 | 6.7 | 4.3 |
| W, % | 57.0 | 48.5 | 45.6 | 53.1 | 46.8 |
| GGKp, g/cm³ | 1.75 | 1.76 | 1.99 | 1.76 | 1.75 |
| AK, µs/m | 612.03 | 440.46 | 297.77 | 500.75 | 596.56 |
| Kgl, % | 26.6 | 30.9 | 28.3 | 44.7 | 20.4 |
| Kp GGKp, % | 8.5 | 9.9 | 9.0 | 14.3 | 6.5 |
| Kp NK, % | 3.8 | 4.4 | 4.0 | 5.7 | 2.9 |
| Kp AK, % | 5.0 | 5.7 | 5.3 | 8.3 | 3.8 |
| Lithology | Carbonaceous argillite | | | | |

c - Carbonaceous argillite (deeper)

| **Parameter** | **10** | **11** | **12** |
|---|---|---|---|
| Seam № | 10 | 11 | 12 |
| Roof, m | 334.5 | 384.6 | 389.5 |
| Bottom, m | 336.8 | 388.2 | 390.6 |
| Total, m | 2.3 | 3.6 | 1.1 |
| DS, mm | 293 | 399 | 245 |
| BK, Ω·m | 107.2 | 21.2 | 21.5 |
| GK, µR/h | 5.5 | 7.9 | 8.5 |
| W, % | 47.7 | 51.8 | 41.8 |
| GGKp, g/cm³ | 1.81 | 1.76 | 1.91 |
| AK, µs/m | 445.01 | 380.95 | 299.11 |
| Kgl, % | 31.4 | 59.0 | 69.0 |
| Kp GGKp, % | 10.0 | 18.9 | 22.1 |
| Kp NK, % | 4.5 | 8.3 | 9.8 |
| Kp AK, % | 5.5 | 10.8 | 12.8 |
| Lithology | Carbonaceous argillite | | |
| **Parameter** | **13** | **14** | **15** |
| Seam № | 13 | 14 | 15 |
| Roof, m | 412.2 | 434.0 | 497.4 |
| Bottom, m | 416.8 | 438.4 | 499.3 |
| Total, m | 4.6 | 4.4 | 1.9 |
| DS, mm | 307 | 277 | 276 |
| BK, Ω·m | 28.8 | 25.9 | 45.4 |
| GK, µR/h | 7.8 | 8.6 | 8.4 |
| W, % | 41.5 | 49.7 | 41.7 |
| GGKp, g/cm³ | 1.77 | 1.86 | 1.81 |
| AK, µs/m | 288.82 | 283.13 | 289.79 |
| Kgl, % | 58.0 | 69.7 | 66.5 |
| Kp GGKp, % | 18.6 | 22.3 | 21.3 |
| Kp NK, % | 8.0 | 9.9 | 9.4 |
| Kp AK, % | 10.8 | 13.0 | 12.4 |
| Lithology | Carbonaceous argillite | | |

Comparison of the data for wells T7 and T8 makes it possible to identify two different approaches to the opening and development of the coal seams of the Karaganda Basin. At well T7, mechanical enlargement of the productive intervals was used, which ensured a rapid transition to a gas regime and a stable methane inflow of about 30 m³ per day. At the same time, the inflow of mineralized waters with a high chloride content was recorded, indicating the presence of natural fractures and a hydraulic connection between the coal and aquifer interbeds. This feature increases drainage efficiency but requires the use of corrosion-resistant materials and inhibitor programs to prevent salt deposition and equipment degradation.

In contrast, at well T8, a strategy of hydraulic fracturing aimed at creating an artificial filtration system under conditions of low natural permeability was implemented. The method requires precise geomechanical calculations, diagnosis of the formation state, and selection of the composition of working fluids and proppants. Despite greater technological complexity and costs, hydraulic stimulation ensures expansion of the drainage radius and the formation of a stable conductive system, which in the future increases the stability of gas deliverability and reduces the skin factor.

The mechanical enlargement applied at T7 is effective for the rapid initiation of flow and confirmation of seam productivity, whereas the hydraulic treatment at T8 provides long-term conductivity and a more uniform drainage of the formation. A comprehensive analysis of the results of both wells demonstrates the possibility of adapting different stimulation methods depending on geological conditions and the technological objectives, and lays the groundwork for transitioning to an industrial level of methane production from the coal seams of the Karaganda Basin.

The results of commissioning well T7 and drilling well T8 at the Taldykuduk site of the Karaganda Basin make it possible to perform a comparative analysis of the effectiveness of the applied technologies against international practice. In the United States—in the San Juan and Powder River basins—industrial methane production from coal seams is based on drilling horizontal and inclined-directional wells with multistage hydraulic fracturing. This approach provides stable gas rates on the order of 30–80 thousand m³ per day and higher [[17], [18], [19], [20]]. In China, vertical and horizontal hydraulic stimulation methods, as well as directional drilling technologies, are developing rapidly, which has made it possible to raise annual methane production to more than 10 billion m³ [21], [22]. The Australian experience shows that combining vertical and horizontal wells with hydraulic fracturing forms the most stable drainage system, especially in low-permeability coals [[23], [24], [25]].

Against this backdrop, research in Kazakhstan is still at the stage of pilot-industrial testing; however, the methane inflow of about 30 m³ per day at well T7 can be regarded as a significant achievement for the initial stage of development. Similar figures were recorded in the early stages of coal seam development in the United States and China. The application of mechanical enlargement at T7 confirmed its effectiveness in increasing the filtration surface, but also revealed an accompanying issue—the inflow of mineralized waters that partially reduces the net gas rate. Meanwhile, the hydraulic fracturing implemented at well T8 is aimed at forming a long-term network of drainage channels capable of ensuring a more stable and higher level of performance [26].

For the geological conditions of the Karaganda Basin, the most rational option appears to be a combined approach that includes preliminary mechanical enlargement of productive zones followed by multistage hydraulic fracturing. Such a combination makes it possible to unite the advantages of both technologies: rapid engagement of coal interbeds in gas release and the subsequent stable development of the drainage system. These solutions logically continue the results of the pilot-industrial works and provide a basis for scaling up production while controlling risks associated with rate nonuniformity and water inflow.

Overall, a comparison of global and domestic experience confirms that the Karaganda Basin has high potential for industrial development of coal seam methane. Further progress requires improving inclined-directional drilling technologies, introducing multistage hydraulic fracturing, and integrating domestic patented solutions into a unified technological complex, which will enable a transition from the experimental level to industrial-scale production.

## Conclusions

Field work carried out at the Taldykuduk site in the Karaganda Coal Basin has convincingly confirmed the possibility of shifting from traditional degasification measures—aimed mainly at ensuring the safety of underground mining—to industrial production of methane from coal seams. Testing of the T7 pilot-production well showed a stable gas inflow of about 30 m³ per day already at the initial stage of commissioning. This result indicates the high gas content of the Karaganda Suite seams and confirms the site's prospects for scaling industrial methane production technologies.

Analysis of the effectiveness of various opening and stimulation methods showed differences in the mechanisms of formation impact and in operational outcomes. The mechanical enlargement applied at well T7 significantly increased the filtration surface and enabled a rapid transition to a gas regime. This approach is distinguished by implementation simplicity and high reproducibility of results while minimizing risks to the geomechanical stability of the borehole. At the same time, an inflow of mineralized waters with a high chloride content was recorded, indicating the involvement of formation horizons in the drainage process. The water factor—especially during long-term operation—requires the introduction of specialized inhibitor programs, the use of corrosion-resistant materials, and monitoring systems that ensure control of the near-wellbore zone condition and the stability of the hydrodynamic regime.

Hydraulic fracturing of the seam, prepared for implementation at well T8, is a more expensive and technologically complex operation, but it provides different operational advantages. By creating an artificial network of fractures, a stable filtration system is formed in a coal mass with low natural permeability, capable of maintaining a steady gas inflow. An increase in the drainage radius and a reduction in the skin parameter contribute to the long-term stability of the flow rate and to bringing low-permeability seams into production. Global practice—primarily the experience of China, the United States, and Australia—confirms that this method is key in moving from the experimental level to industrial-scale methane production.

Of particular importance is the possibility of integrating mechanical enlargement and hydraulic fracturing with domestic engineering solutions protected by patents No. 8188, No. 10961, and No. 10923. The combined use of these technologies creates a technologically flexible system that makes it possible to adapt impact methods to specific geological and technical conditions. Comprehensive application of the methods ensures effective reduction of reservoir pressure, redistribution of flows, and formation of high-conductivity zones, thereby increasing the system's overall energy return.

The practical value of the results obtained lies in creating the prerequisites for organizing, on the basis of the Karaganda Basin, a pilot-industrial test site for methane production from coal seams. Implementation of such a complex will not only diversify Kazakhstan's fuel and energy balance and reduce dependence on imported natural gas, but also raise the level of industrial safety of coal enterprises through controlled reduction of gas hazard and prevention of sudden outbursts.

Overall, the results of studies on wells T7 and T8 confirm the technological and economic feasibility of industrial development of coal seam methane in the Karaganda Basin. Combining stimulation methods, applying innovative engineering solutions, and adapting best international practices form the basis for establishing a new coalbed methane industry in Kazakhstan. This industry can not only strengthen the country's energy independence, but also ensure sustainable regional development through more environmentally friendly and rational use of hydrocarbon resources.

***Conflicts of interest.*** On behalf of all authors, the corresponding author states that there is no conflict of interest.

***CRediT author statement:*** **R. Mussin**: Conceptualization, Methodology; **D. Akhmatnurov**: Data curation, Writing draft preparation, Visualization; **N. Zamaliyev:** Validation, Reviewing and Editing; **N. Issina:** Investigation, Supervision, Software.

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# Қарағанды көмір бассейнінің көмір қабаттарынан метанды өнеркәсіптік өндірудің перспективалары: Талдықұдық учаскесіндегі тәжірибелік-өндірістік зерттеулер нәтижелері

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**ТҮЙІНДЕМЕ**
Зерттеу Қарағанды көмір бассейніндегі Талдықұдық учаскесіндегі Т7 және Т8 ұңғымалары бойынша бұрғылау және сынақ деректері негізінде көмір қабаттық метанын өнеркәсіптік өндіру әлеуетін бағалауға арналған. Жұмыстың мақсаты — нақты геологиялық-техникалық жағдайларда жүктемесі түсірілмеген қабаттардан метанды тиімді өндіруді қамтамасыз ететін инженерлік шешімдерді әзірлеу және тексеру. Зерттеу нысаны — жоғары газдалған, біртекті емес фильтрация-сыйымдылық құрылымымен, өте жарықшақтылықпен сипатталатын Қарағанды свитасының көмір қабаттары. Өнімді интервалдарды жергілікті кеңейте отырып, пакерлерді пайдалану арқылы аймақтық оқшаулау және бақыланатын гидравликалық стимуляция қолданылған тік ұңғымалар бұрғыланды. Гамма-, тығыздық және нейтрондық каротаж, кавернометрия, инклинометрия, газ-геохимиялық мониторинг және қабат қысымы мен өтімділігін анықтау үшін ағындық сынақтардан тұратын геофизикалық зерттеулер кешені орындалды. Керн мен көмір үлгілерінің зертханалық талдаулары адсорбция–десорбция қасиеттерін, элементтік құрамын және пласт суларының сипаттамаларын қамтыды, бұл оңтайлы реагенттер мен газды дайындау схемаларын таңдауға мүмкіндік берді. Тұрақты депрессия жағдайында тәулігіне 30 м³-ге дейін ағымды метан сусыз алынды, бұл тәжірибелік-өндіріске пайдалануға дайын екенін растады. Гидравликалық стимуляция және ұңғымалар жұмыс режимдерін оңтайландырудан кейін газ дебитінің артуы тіркелді, бұл қабатқа әсер етуді және тиімді екенін дәлелдеді. Дебит және қысым қисықтары бойынша перфорация аралықары , гидроөңдеу шарттары, сондай-ақ газды сығымдау, сусыздандыру жинақтау жүйелеріне қойылатын технологиялық параметрлер айқындалды. Жұмыстың практикалық маңыздылығы өнеркәсіптік метан өндірудің технологиялық схемасын негіздеуде және тау-кен жұмыстары кезінде метан қаупін азайтуда Ұсынылған тәсілді іске асыру өндірілген газды аймақтық энергетикалық балансқа және бақыланбайтын метан шығарындыларын азайтуға мүмкіндік береді, экологиялық әрі экономикалық пайда әкеледі.

***Түйін сөздер:*** метан, дегазация, бұрғылау, қабатты гидроажырату, өнеркәсіптік өндіру, газ өткізгіштік.

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# Перспективы промышленной добычи метана из угольных пластов Карагандинского бассейна: результаты экспериментально-промышленных исследований на Талдыкудукском участке

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**АННОТАЦИЯ**

Исследование посвящено оценке промышленного потенциала добычи метана из угольных пластов Карагандинского бассейна на основе данных бурения и испытаний скважин Т7 и Т8 на Талдыкудукском участке. Цель работы — разработать и верифицировать инженерные решения, обеспечивающие эффективное извлечение метана из неразгруженных пластов в реальных геолого-технических условиях. Объект исследования — угольные пласты карагандинской свиты, характеризующиеся высокой газоносностью, развитой трещиноватостью и неоднородной фильтрационно-ёмкостной структурой. Пробурены вертикальные скважины с локальным расширением продуктивных интервалов, зональной изоляцией с применением пакеров и контролируемой гидравлической стимуляцией. Выполнен комплекс геофизических исследований, включающий гамма-, плотностной и нейтронный каротаж, кавернометрию, инклинометрию, газогеохимический мониторинг и приточные испытания для определения пластового давления и проницаемости. Лабораторные анализы керна и угля охватывали адсорбционно-десорбционные свойства, элементный состав и характеристики пластовых вод, что позволило выбрать оптимальные реагенты и схемы подготовки газа. Получены устойчивые притоки метана до 30 м³/сут при стабильной депрессии и отсутствии притока воды, что подтверждает готовность к опытно-промышленной эксплуатации. После гидростимуляции и оптимизации режимов работы скважин зафиксировано увеличение дебита газа, подтверждающее эффективность воздействия на пласт. По кривым давления и дебита определены технологические параметры — интервалы перфорации, условия гидрообработки и требования к системам сбора, осушки и компримирования газа. Практическая значимость работы заключается в обосновании технологической схемы промышленной добычи метана и снижении метаноопасности при ведении горных работ. Реализация предложенного подхода позволит интегрировать добытый газ в региональный энергобаланс и уменьшить неконтролируемые выбросы метана, обеспечивая экологические и экономические преимущества.

***Ключевые слова:*** метан, дегазация, бурение, гидроразрыв пласта, промышленная добыча, газопроницаемость.

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