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JURASSIC GAS-CONDENSATE RESERVOIRS OF USTYURT (UZBEKISTAN): GEOLOGICAL FEATURES AND PRODUCTIVITY ENHANCEMENT

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Abstract. The Ustyurt region of north-western Uzbekistan is one of the country's principal gas-bearing areas and the feedstock base of the Ustyurt Gas Chemical Complex, yet the decline of national gas production makes both the replacement of reserves and the stabilisation of output from existing fields an urgent task. This study integrates published geological, geophysical and production data on the Shakhpakhty, Surgil, East and North Berdakh fields and the Western Aral discovery with an analytical assessment of gas well deliverability. The reservoirs were compared in terms of porosity, permeability, depth and reported well rates, and the influence of near-wellbore conditions was quantified with the pseudo-steady-state gas inflow equation. The results show that productive intervals are confined mainly to Middle–Upper Jurassic terrigenous reservoirs at depths of about 2.0–3.0 km, whose quality ranges from tight fluvial sandstones with 4–16 % porosity to Callovian reservoirs with permeability of up to 1,500 millidarcy, and that maximum reported well rates differ by an order of magnitude. The channelised, laterally variable architecture of the sandstones, condensate dropout near the wellbore, reservoir pressure depletion and regional water scarcity were identified as the main factors limiting productivity. Calculations indicate that a positive skin factor of +5 reduces the well rate by about 40–45 %, whereas a negative skin of −4 achieved by stimulation raises it 2.2–2.8 times. On this basis, a three-stage programme is proposed that links seismic-driven well placement, horizontal wells with multistage hydraulic fracturing, condensate-bank remediation and compression to reservoir type, and directs further exploration towards the Lower Jurassic and Paleozoic complexes.

Keywords: Ustyurt region, Jurassic reservoirs, gas-condensate fields, condensate banking, skin factor, hydraulic fracturing, horizontal wells, hydrocarbon potential.

Introduction

Natural gas is the backbone of Uzbekistan's energy balance, and for decades the country was among the largest gas producers in Eurasia. In recent years, however, domestic production has declined markedly, and since 2023 Uzbekistan has become a net importer of gas [12]. Under these conditions, two tasks have become equally important for the upstream sector: the replacement of reserves in under-explored areas and the more efficient development of fields that are already in production.

The Ustyurt region, located between the Caspian Sea and the Aral Sea within the Republic of Karakalpakstan, is directly concerned with both tasks. It hosts a number of gas and gas-condensate fields, and the Surgil field together with the East and North Berdakh fields supplies the Ustyurt Gas Chemical Complex (UGCC), which was designed to receive 4.5 billion cubic metres (bcm) of gas per year [6, 15]. Since the complex began operating in 2015 [15], a stable feedstock supply has turned from a regional issue into a matter of national industrial significance. The government has also introduced risk-service contracts, under which partners are rewarded for incremental production from low-yield fields [13]; this creates a demand for well-substantiated technical solutions for such fields.

Previous studies of the region have mostly addressed either its petroleum geology or individual production problems. Regional assessments describe the Jurassic petroleum system and its traps [16], basin modelling has been used to evaluate deeper plays [19], and seismic reservoir characterisation has revealed the complex architecture of Jurassic sandstones [2]. The authors' earlier

work examined the geological and geophysical conditions and the oil and gas potential of the Assakeaudan Trough in southern Ustyurt [10, 11]. At the same time, the link between the geological features of Ustyurt reservoirs and the technological means of raising well productivity has not been considered systematically, although it is precisely this link that determines which technologies are worth piloting in a given field. Bridging this gap is the problem addressed in the present paper.

The aim of the study is to generalise the geological characteristics of the principal Ustyurt fields, to identify the factors that limit exploration success and well productivity in Jurassic gas-condensate reservoirs, and, on this basis, to substantiate a staged set of technologies for increasing gas production and to outline priority directions for deeper exploration.

Materials and methods

The study is based on an analytical review and generalisation of open data. The geological part draws on the regional petroleum-system assessment of the U.S. Geological Survey [16], papers on basin modelling and seismic reservoir characterisation in the Berdakh–Sudochi area [2, 19], industry publications on field discoveries and test results [7, 12, 14, 17], reports on the Surgil field and the UGCC [6, 15], studies of the geological, geophysical and geodynamic conditions of southern Ustyurt [10, 11, 20], and the authors' experience in exploration well completion, testing and gas reserve estimation [1, 9]. The engineering part relies on fundamental works on gas-condensate phase behaviour, well deliverability, stimulation and horizontal well technology [3–5, 8, 18].

Three groups of methods were applied. First, a comparative analysis of reservoir parameters (depth, porosity, permeability and maximum reported well rate) of the principal fields and discoveries was carried out, with all data brought to common units. Second, the elements of the Jurassic petroleum system – source rocks, reservoirs, seals and traps – were generalised, and the exploration maturity of individual stratigraphic complexes was assessed qualitatively. Third, the influence of near-wellbore conditions on well productivity was evaluated analytically using the pseudo-steady-state inflow equation for a gas well written in field units [3]:

$$q = \frac{k\,h(p_r^2 - p_{wf}^2)}{1422\,T\,\mu\,z\,[ln(r_e/r_w) - 0.75 + S]} \quad (1)$$

where q is the gas rate, Mscf/day; k is permeability, mD; h is net pay thickness, ft; p_r and p_{wf} are the average reservoir pressure and the bottomhole flowing pressure, psia; T is reservoir temperature, °R; μ and z are the gas viscosity, cP, and the compressibility factor at average pressure; r_e and r_w are the drainage and wellbore radii, ft; S is the total skin factor.

Since the flow capacity kh, pressures and fluid properties vary from well to well and are not fully available in open sources, the analysis was performed in dimensionless form. Dividing Eq. (1) written for an arbitrary skin factor S by the same equation for an undamaged well (S = 0) under identical reservoir and drawdown conditions gives the relative rate:

$$\frac{q_S}{q_0} = \frac{ln(r_e/r_w) - 0.75}{ln(r_e/r_w) - 0.75 + S} \quad (2)$$

Values of $\ln(r_e/r_w)$ between 7.0 and 8.0 were adopted, which corresponds to a wellbore radius of about 0.1 m and drainage radii of roughly 110–300 m. The skin factor was varied from −5 to +10, covering the range from stimulated to severely damaged wells. Following [5], condensate banking was treated as an additional positive skin caused by the reduction of gas relative permeability in the near-wellbore region.

Results

Geological setting and petroleum system. The North Ustyurt basin has a triangular outline and is bounded on all sides by late Paleozoic and Triassic fold belts. Its sedimentary cover consists of predominantly clastic Jurassic–Tertiary rocks from several hundred metres to about 5 km thick, overlying Devonian–Carboniferous carbonates and Permian–Triassic clastic and volcanic sequences

[16]. The main source rocks are lacustrine shales and coals of the continental Jurassic sequence, and oil and gas accumulations occur mainly in Jurassic clastic reservoirs in structural traps at depths of 2.5–3 km [16]. In the southern part of the region, the Assakeaudan Trough, whose northern flank includes the Shakhpakhty step, is regarded as a promising area [10, 11]; faults cutting the basement and extending into the Jurassic section are considered a possible decisive factor in the formation of Jurassic hydrocarbon accumulations there [20].

Main fields. The generalised characteristics of the principal fields and discoveries of the Uzbek part of Ustyurt are given in Table 1.

Table 1 – Main gas and gas-condensate fields of the Uzbek part of the Ustyurt region

Field / discovery	Reservoir and key parameters	Status and significance
Shakhpakhty	Jurassic clastics; Callovian reservoir with 12–16 % porosity and 100–1,500 mD permeability; well rates up to 1.5 million m³/day [7]	About 1.5 trillion cubic feet (≈42 bcm) of gas [7]; one of the oldest fields of the region
Surgil	Jurassic gas-condensate reservoirs	Discovered in 2006; reserves of about 120 bcm; main feedstock source for the UGCC [6, 15]
East and North Berdakh	Jurassic terrigenous reservoirs; the Berdakh well tested 150,000 m³/day in 1990 [7]	Supplement Surgil gas to the UGCC, whose total intake capacity is 4.5 bcm/year [15]
Western Aral	Middle Jurassic terrigenous reservoirs at 2,000–3,000 m; maximum test rate about 580,000 m³/day [14]	First commercial gas in the Uzbek part of the Aral Sea (2010) [14]
Kuanysh, Akchalak, West Barsakelmes	Jurassic reservoirs	Discovered accumulations awaiting development [7]

Maximum reported well rates of the region are compared in Figure 1. They differ by an order of magnitude, from 150 to 1,500 thousand m³/day. The highest rates are associated with the high-quality Callovian reservoir of Shakhpakhty, whereas the Berdakh well produced ten times less from Jurassic deposits; this spread reflects differences in reservoir quality and stratigraphic level.

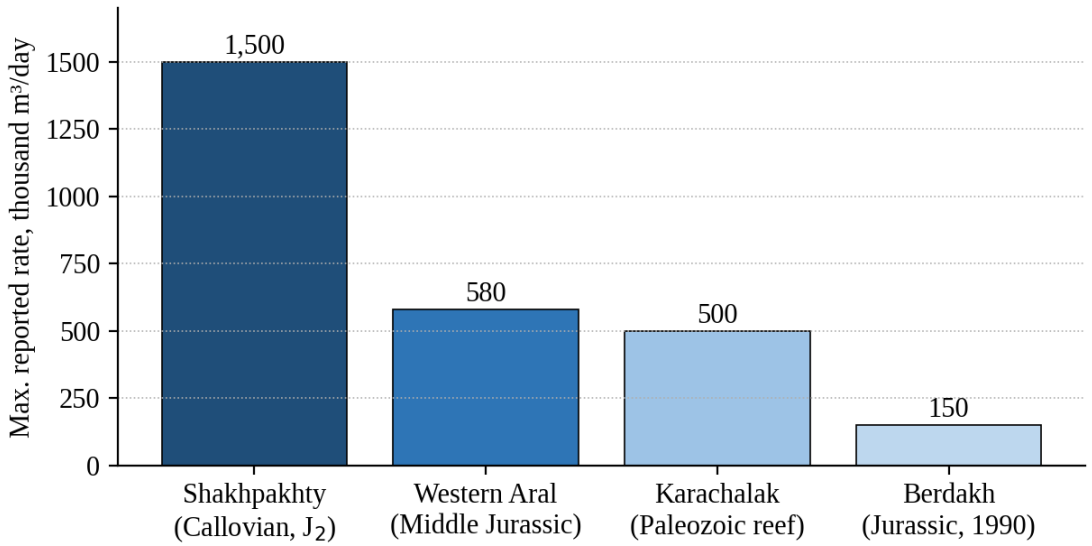


Figure 1 – Maximum reported well flow rates in the Ustyurt region (compiled from [7, 14])

Reservoir heterogeneity. The Early–Middle Jurassic fluvial sandstones of the Ustyurt plateau have open porosity of only 4–16 %, whereas the Callovian reservoir of the Shakhpakhty field

combines 12–16 % porosity with permeability reaching 1,500 mD [7]. Such a wide range reflects the alternation of continental and coastal-marine depositional environments during the Jurassic. Seismic reservoir characterisation of the Sudochi depression and the Berdakh high showed that exploration and production wells there had long been placed on the assumption of conformable, laterally continuous reservoirs, whereas the actual architecture is dominated by laterally variable channel and facies bodies [2]. This mismatch was identified as one of the causes of low drilling success and declining gas production [2]. In practical terms, the same stratigraphic interval may be highly productive in one well and nearly tight in an adjacent one, so the placement of each new well becomes a key decision.

Deeper plays. Exploration in Ustyurt has historically focused on Middle and Upper Jurassic targets. Basin modelling of the Berdakh–Sudochi area has been used to assess the potential of the deeper, poorly explored Lower Jurassic sequences [19], and in 2025 the state explorer Yangi Kon began drilling the UDG-1 well on the former Aral Sea floor specifically to test Lower Jurassic strata [12]. The Paleozoic section is also of interest: the Karachalak reef tested gas at about 500,000 m³/day from Paleozoic limestones at 3,521 m, and oil was obtained from the Karakuduk reef [7]. Although the core porosity of Paleozoic limestones is low (around 3 %), some samples are cavernous, which suggests that permeable intervals may be under-represented in the existing cores [7]. The potential of great depths was confirmed in 2025, when drilling in Ustyurt reached 6,500 m for the first time and a very large gas accumulation was announced, whereas earlier exploration had been limited mainly to depths of 2,500–3,000 m [17].

Productivity-limiting factors. The generalisation of the data allows four groups of factors limiting well productivity to be distinguished. The first is the heterogeneity of the Jurassic reservoirs described above, which reduces drilling success and the effective pay penetrated by a vertical well. The second is condensate banking. When the bottomhole pressure in a gas-condensate reservoir falls below the dew point, liquid condensate drops out around the wellbore [4, 18]. Three flow regions then form in the reservoir, and it is the near-well region, where both gas and condensate are mobile and the gas relative permeability is reduced, that controls most of the loss of deliverability [5]. This loss can be considerable even in reservoirs with moderate condensate content [4]. The third factor is the decline of reservoir pressure in long-producing fields, which reduces the drawdown term in Eq. (1). The fourth group comprises environmental and logistical constraints: the fields lie in a remote desert area close to the drying Aral Sea, where fresh water is scarce, which limits water-intensive operations such as conventional hydraulic fracturing [3].

Inflow analysis. The relative rates calculated from Eq. (2) are given in Table 2, and their dependence on the skin factor is shown in Figure 2.

Table 2 – Relative gas well rate q_S/q_0 calculated from Eq. (2)

Skin factor S	$\ln(r_e/r_w) = 7.0$	$\ln(r_e/r_w) = 7.5$	$\ln(r_e/r_w) = 8.0$
−4	2.78	2.45	2.23
−2	1.47	1.42	1.38
0	1.00	1.00	1.00
+2	0.76	0.77	0.78
+5	0.56	0.57	0.59
+10	0.38	0.40	0.42

At a given drawdown, the well rate is proportional to the flow capacity kh and inversely proportional to the term $[\ln(r_e/r_w) - 0.75 + S]$. As follows from Table 2, a positive skin of +5, caused by formation damage or a condensate bank, reduces the rate by 41–44 %, whereas a negative skin of −4, typical of a successfully fractured well, increases it 2.2–2.8 times relative to an undamaged well. The dependence is strongly non-linear (Figure 2): reducing the skin from 0 to −4 gives a much larger

gain in rate than the loss caused by an equal positive skin. The sensitivity is also higher at smaller $\ln(r_e/r_w)$, i.e. for densely spaced wells.

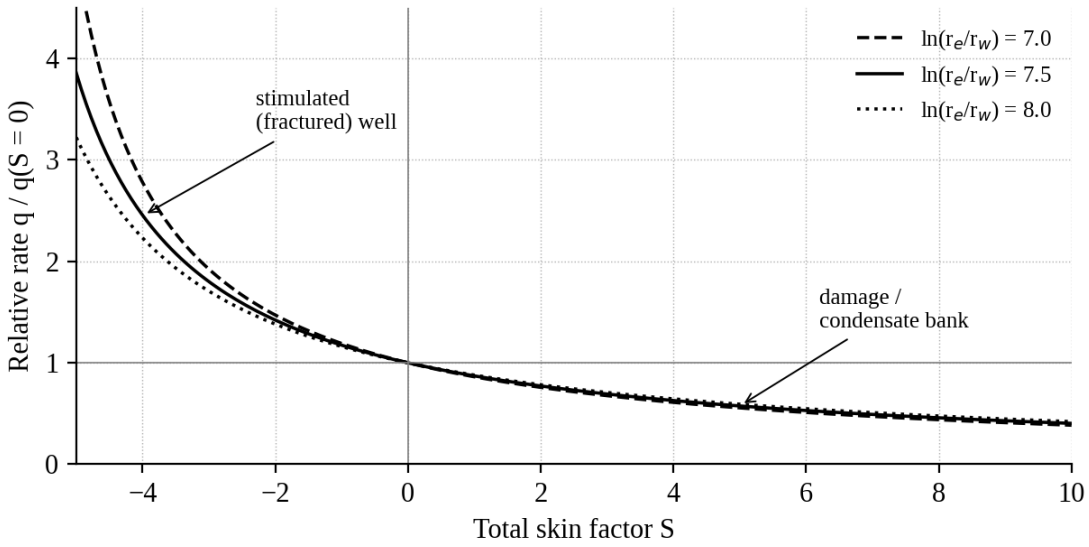


Figure 2 – Relative gas well rate versus total skin factor, calculated from Eq. (2)

It follows that in the Ustyurt reservoirs the management of the near-wellbore zone and the increase in effective reservoir contact are the most direct levers for raising well productivity. A horizontal well acts in the same direction: its larger contact with the reservoir is equivalent to a negative pseudo-skin [8], which is particularly valuable in thin and laterally variable Jurassic sandstones.

Applicable technologies. Matching the identified factors with the available technological solutions leads to the scheme presented in Table 3.

Table 3 – Correspondence between productivity-limiting factors and technological solutions

Limiting factor	Technological solution	Expected effect
Lateral heterogeneity, channel reservoirs	Seismic reservoir characterisation (spectral decomposition, inversion) for well placement; geosteering [2]	Higher drilling success; wells placed in the best facies
Low permeability, thin pay	Horizontal and multilateral wells; multistage hydraulic fracturing [3, 8]	Larger reservoir contact; negative skin; higher rate per well
Condensate bank near the wellbore	Keeping bottomhole pressure above the dew point where possible; solvent and methanol treatments; hydraulic fracturing to reduce drawdown [4, 5]	Restored gas relative permeability; slower productivity decline
Pressure depletion	Wellhead and field booster compression; gas cycling in condensate-rich zones [18]	Extended production plateau; higher condensate recovery
Water scarcity, remote location	Water-saving fracturing fluids (foamed, energised, recycled produced water); pad drilling [3]	Lower water demand and infrastructure cost

Staged approach. It is proposed to implement these technologies in three stages. At the first stage, existing seismic and well data are re-interpreted to build facies-based reservoir models and to select pilot areas; reserves are re-estimated by complementary methods [9], well completion and testing practices are reviewed [1], and basin models are updated to rank the Lower Jurassic and Paleozoic targets [19]. At the second stage, pilot horizontal wells with multistage fracturing are drilled

in low-permeability zones, condensate-bank remediation is tested on producing wells with declining rates, and dedicated exploration wells are drilled to the deeper complexes. At the third stage, successful solutions are scaled up, including within risk-service contracts in which the contractor's remuneration depends on incremental production [13]. Such a sequence reduces technical and financial risk and allows the effect of each technology to be measured against a baseline.

Conclusion

The Ustyurt region remains one of the most promising gas areas of Uzbekistan, and its proven accumulations are associated mainly with Middle–Upper Jurassic terrigenous reservoirs of highly variable quality. The study has shown that the channelised, laterally variable architecture of these reservoirs is a key factor limiting drilling success, while well productivity in the developed fields is further reduced by near-wellbore condensate accumulation, reservoir pressure depletion and environmental constraints such as water scarcity. The analysis based on the gas inflow equation demonstrates that controlling the skin factor and increasing reservoir contact are the most effective ways to raise deliverability: stimulation that brings the skin to −4 can more than double the well rate, whereas an unremedied condensate bank may cut it by almost half. A staged introduction of seismic-driven well placement, horizontal wells with multistage fracturing using water-saving fluids, condensate-bank remediation and compression, supported by risk-service contracts, can therefore stabilise gas supply to the Ustyurt Gas Chemical Complex. Future growth of the resource base is linked to the Lower Jurassic and Paleozoic complexes, as confirmed by the 2025 deep discovery, and requires integrated seismic reservoir characterisation, basin modelling and dedicated deep exploration wells. Together, these measures can help offset the decline in national gas production.

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ҮСТІРТТІҢ (ӨЗБЕКСТАН) ЮРА ГАЗ-КОНДЕНСАТ КОЛЛЕКТОРЛАРЫ: ГЕОЛОГИЯЛЫҚ ЕРЕКШЕЛІКТЕРІ ЖӘНЕ ӨНІМДІЛІКТІ АРТТЫРУ

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Аңдатпа. Өзбекстанның солтүстік-батысындағы Үстірт аймағы елдің негізгі газды аудандарының бірі және Үстірт газ-химия кешенінің шикізат базасы болып табылады, алайда ұлттық газ өндірісінің төмендеуі қорларды толықтыруды да, игеріліп жатқан кен орындарынан өндірісті тұрақтандыруды да өзекті міндетке айналдырады. Зерттеуде Шахпахты, Сургиль, Шығыс және Солтүстік Бердах кен орындары мен Батыс Арал ашылымы бойынша жарияланған геологиялық, геофизикалық және кәсіпшілік деректер газ ұңғымаларының өнімділігін аналитикалық бағалаумен біріктірілді. Коллекторлар кеуектілік, өткізгіштік, тереңдік және ұңғымалардың шығымы бойынша салыстырылды, ал ұңғыма маңы аймағы жағдайларының әсері газ ағынының псевдотұрақталған теңдеуі арқылы сандық тұрғыда бағаланды. Нәтижелер өнімді горизонттардың негізінен шамамен 2,0–3,0 км тереңдіктегі орта–жоғарғы юра терригендік коллекторларымен байланысты екенін көрсетті; олардың сапасы кеуектілігі 4–16 % тығыз флювиалдық құмтастардан өткізгіштігі 1500 миллидарсиге дейін жететін келловей коллекторларына дейін өзгереді, ал ұңғымалардың ең жоғары шығымдары бір ретке ерекшеленеді. Өнімділікті шектейтін негізгі факторлар ретінде құмтастардың арналық, латералды өзгермелі құрылымы, ұңғыма түбі маңында конденсаттың түсуі, қабат қысымының төмендеуі және аймақтағы су тапшылығы анықталды. Есептеулер +5

оң скин-фактор ұңғыма шығымын шамамен 40–45 %-ға азайтатынын, ал қабатты қарқындату арқылы қол жеткізілген −4 теріс скин-фактор оны 2,2–2,8 есе арттыратынын көрсетті. Осы негізде сейсмикалық деректерге сүйеніп ұңғымаларды орналастыруды, қабатты көп сатылы гидравликалық жарумен көлденең ұңғымаларды, конденсат тығынын жоюды және компримирлеуді коллектор түрімен байланыстыратын үш сатылы бағдарлама ұсынылды, сондай-ақ барлау жұмыстарын төменгі юра және палеозой кешендеріне бағыттау қажеттігі негізделді.

Түйін сөздер: Үстірт аймағы, юра коллекторлары, газ-конденсат кен орындары, конденсат тығыны, скин-фактор, қабатты гидравликалық жару, көлденең ұңғымалар, көмірсутек әлеуеті.

ЮРСКИЕ ГАЗОКОНДЕНСАТНЫЕ КОЛЛЕКТОРЫ УСТЮРТА (УЗБЕКИСТАН): ГЕОЛОГИЧЕСКИЕ ОСОБЕННОСТИ И ПОВЫШЕНИЕ ПРОДУКТИВНОСТИ

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Аннотация. Устюртский регион на северо-западе Узбекистана является одним из основных газоносных районов страны и сырьевой базой Устюртского газохимического комплекса, однако снижение национальной добычи газа делает актуальными как восполнение запасов, так и стабилизацию добычи на разрабатываемых месторождениях. В исследовании опубликованные геологические, геофизические и промысловые данные по месторождениям Шахпахты, Сургиль, Восточный и Северный Бердах и открытию Западный Арал объединены с аналитической оценкой продуктивности газовых скважин. Коллекторы сопоставлены по пористости, проницаемости, глубине залегания и дебитам скважин, а влияние условий призабойной зоны количественно оценено с помощью уравнения псевдоустановившегося притока газа. Результаты показали, что продуктивные горизонты приурочены преимущественно к средне-верхнеюрским терригенным коллекторам на глубинах около 2,0–3,0 км, качество которых изменяется от плотных флювиальных песчаников с пористостью 4–16 % до келловейских коллекторов с проницаемостью до 1500 миллидарси, а максимальные дебиты скважин различаются на порядок. Основными факторами, ограничивающими продуктивность, определены русловое, латерально изменчивое строение песчаников, выпадение конденсата в призабойной зоне, истощение пластовой энергии и дефицит воды в регионе. Расчёты показывают, что положительный скин-фактор +5 снижает дебит примерно на 40–45 %, тогда как отрицательный скин-фактор −4, достигаемый интенсификацией притока, увеличивает его в 2,2–2,8 раза. На этой основе предложена трёхэтапная программа, увязывающая размещение скважин по данным сейсморазведки, горизонтальные скважины с многостадийным гидроразрывом пласта, удаление конденсатной пробки и компримирование с типом коллектора, а также обоснована необходимость направить дальнейшие геологоразведочные работы на нижнеюрский и палеозойский комплексы.

Ключевые слова: Устюртский регион, юрские коллекторы, газоконденсатные месторождения, конденсатная пробка, скин-фактор, гидроразрыв пласта, горизонтальные скважины, углеводородный потенциал.

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