https://doi.org/10.33271/nvngu/2025-4/005

G. G. Djalilov[1],
orcid.org/0000-0001-8778-2719,
B. T. Ratov[*2],
orcid.org/0000-0003-4707-3322,
A. K. Sudakov[3],
orcid.org/0000-0003-2881-2855,
Sh. A. Toshmatov[4],
orcid.org/0000-0002-1269-7904,
I. S. Togaev[4],
orcid.org/0009-0006-8190-7035,
Z. B. Bekeshova[5],
orcid.org/0009-0006-1867-0979

1 – State Institution "Institute of Geology and Exploration of Oil and Gas Fields", Tashkent, Republic of Uzbekistan
2 – Satbayev University, Almaty, Republic of Kazakhstan
3 – Dnipro University of Technology, Dnipro, Ukraine
4 – National University of Uzbekistan named after Mirzo Ulugbek, Tashkent, Republic of Uzbekistan
5 – LLP "OPTIMUM "Design Institute", Aktau, Republic of Kazakhstan
[*] Corresponding author e-mail: b.ratov@satbayev.university

ECONOMIC ASSESSMENT OF HYDROCARBON RESOURCES AND ENHANCEMENT OF THE EFFICIENCY OF GEOLOGICAL EXPLORATION IN THE USTYURT REGION

Purpose. To conduct a comprehensive analysis of the economic efficiency of oil and gas geological exploration activities (GEA) and to identify the main reserves for its improvement. Additionally, the study analyzes the existing planning system for exploration works in the Ustyurt oil and gas region and identifies the correlations between the volumes of deep drilling and the increase in discovered reserves using econometric models.

Methodology. The following methods were employed: comprehensive analysis and systematization of previous research results documented in archives and published sources; analogy and comparison methods – to outline the directions of geological exploration and prioritize sites; the graph-analytical method.

Findings. A forecast of oil and gas potential was performed using the complete set of available geological data to determine both the initial total and prospective hydrocarbon resources, as well as their spatial distribution and accumulation conditions. Applying established methods for estimating prospective hydrocarbon resources – while taking into account the results of geological exploration in the Ustyurt region and the patterns of hydrocarbon deposit distribution in the sedimentary section – enabled the identification of priority directions for near-term GEA, along with an assessment of the profitability of developing these hydrocarbon resources. The forecasted hydrocarbon resources of the Ustyurt region have been substantiated and range from 15.0 (Samsky Gas-and-Oil Region (GOR)) to 249.0 thousand t.o.e./km^2 (Sudochy GOR).

Originality. For the first time, the economic feasibility of developing hydrocarbon resources in the priority areas of the Northern Ustyurt region has been demonstrated. One such area is the Barsakelmes site, where the profitability, considering revenues from domestic-market hydrocarbon sales, reached 147 %.

Practical value. The necessity and effectiveness of carrying out geological exploration in the southeastern part of the Barsakelmes macrodepression have been substantiated. This area has a sedimentary cover thickness similar to that of the Sudochy depression, which was used as an analog to determine the profitability of GEA. Within this depression, the feasibility of planning further exploration on 20 identified structures has been confirmed. Additionally, the profitability of developing the resources of prospective areas has been substantiated.

Keywords: *prospective resources, development, oil and gas potential, gas-oil zoning, profitability*

Introduction. Hydrocarbon resources are quantities of hydrocarbons naturally occurring either on the Earth's surface or in the subsurface. When evaluating resources, both discovered and undiscovered hydrocarbon accumulations are considered. Resource assessments focus on quantities potentially recoverable and marketable through commercial projects.

Forecasting hydrocarbon potential is one of the most critical and responsible stages of geological research. It relies on comprehensive geological information and is conducted to determine initial total and prognostic hydrocarbon resources (HC), their spatial distribution, and depositional conditions.

No mineral deposit should be classified as potential resources unless it can be reliably predicted, discovered, explored, extracted from the subsurface, and profitably marketed domestically or internationally, with total revenues exceeding costs, including those of scientific forecasting.

The depletion of oil reserves in many regions of Uzbekistan and the growing interest of oil and gas companies in acquiring new license areas highlight the priority of identifying prospective hydrocarbon targets to replenish Uzbekistan's hydrocarbon mineral resource base. The primary basis for identifying such targets is the existing hydrocarbon resource base. Concurrently, increased geological exploration activity, especially in recent years, has significantly improved the geological and geophysical understanding of hydrocarbon-prospective areas in Uzbekistan [1].

Despite extensive geological exploration efforts, the development of prognostic hydrocarbon resources in the Ustyurt region faces several scientific-methodological and organizational-economic constraints. One key challenge which remains is the high degree of uncertainty in resource estimation in underexplored areas with limited geophysical data coverage. This is primarily due to the limited representativeness of existing geological and geophysical data and substantial lithological and stratigraphic heterogeneity of sedimentary cover.

Traditional assessment methods – specific density approaches and averaged structural models – do not always yield sufficiently accurate forecasts, particularly in structurally complex areas with significant fluctuations in reservoir parameters. Conversely, the use of volumetric-statistical methods results in wide-ranging estimates, reducing the reliability of calculations and complicating investment decisions.

Additionally, insufficient integration of modern digital technologies in modeling and analysis processes, particularly inadequate use of GIS, machine learning, 3D geological modeling, and probabilistic assessments, limits the capacity to develop more precise and economically justified geological exploration scenarios.

Thus, the challenge lies not only in refining quantitative resource characteristics but also in developing a robust methodological framework that accounts for spatial heterogeneity of geological data, economic efficiency of development, and forecast uncertainty. Addressing this issue requires multidisciplinary approaches involving geology, resource economics, digital modeling, and risk-oriented planning of geological exploration activities.

Literature review. The Ustyurt petroleum region is subdivided into three petroleum-bearing provinces (North Ustyurt, South Ustyurt, and East Aral) and two petroleum-bearing districts (Central Ustyurt and Tuarkyr). Each area's productive sequence is associated primarily with Jurassic deposits (excluding the latter two) and Paleozoic formations. Within Jurassic sediments, prognostic hydrocarbon resources are evaluated for all sections – Upper, Middle, and Lower Jurassic – while pre-Jurassic formations, due to insufficient research, have their resources estimated without detailed subdivision [2, 3].

In pre-Jurassic formations, the productive complexes are represented by Upper Devonian–Middle Carboniferous terrigenous-carbonate deposits and Upper Carboniferous–Lower Permian terrigenous-volcanogenic sediments [4, 5].

Currently, over a dozen approaches exist for estimating prognostic hydrocarbon resources in categories D1 and D2 [6–8]. Differences among these methodologies are primarily attributable to variations in the geological and geochemical-bituminological understanding of petroleum-bearing basin deposits [9, 10].

Primarily, the evaluation of prognostic resources within petroleum-bearing regions involves delineating zones and areas characterized by distinct tectonic and geological structures of the sedimentary sequence, including productive strata [11, 12]. Within these areas, particular attention is paid to reservoir parameters, seal quality, genetic trap types, and the outcomes of prior oil and gas exploration activities, where applicable. Assessing prognostic hydrocarbon resources is an essential component of oil and gas exploration since this process must rely on comprehensive geological and tectonic knowledge derived from geophysical survey data and deep drilling results [13–15].

The purpose of the study is a comprehensive analysis of the economic efficiency of oil and gas exploration activities and the identification of primary reserves for its enhancement, alongside an examination of the existing system for planning geological exploration activities. Additionally, the study seeks to identify patterns linking deep drilling volumes and the growth of proven reserves through the application of economic-mathematical models. This will facilitate the development of practical scientific recommendations aimed at improving economic efficiency and optimizing the planning of geological exploration in the context of the Ustyurt petroleum region.

Within the framework of this research, particular attention is given to the relationship between geological parameters and techno-economic indicators of field development, including assessments of the sensitivity of profitability to burial depth, lithological composition of reservoirs, and the quality of cap rocks. Furthermore, the study evaluates geological-economic approaches that integrate system analysis methods, geostatistics, and investment modeling. The obtained results can serve as a basis for substantiating governmental licensing priorities, planning geological exploration activities, and evaluating the investment attractiveness of specific areas.

This research aim logically extends the issues addressed previously, emphasizing the necessity of multidisciplinary and integrated approaches to mitigate uncertainties in hydrocarbon resource estimation and exploration strategy planning.

Setting the task. In accordance with methodological guidelines from various years (1983, 2000, 2014), the main approaches used to estimate prognostic hydrocarbon resources include the methods of geological analogs and comparative assessment of the study area with known deposits. For petroleum basins that have been the subject of long-term geophysical and drilling activity, such as those in Uzbekistan, these approaches are considered the most appropriate. Specifically, the methods of specific resource density and averaged structural estimation are widely applied. In contrast, for poorly studied areas and hypothesized productive complexes, the volumetric-statistical method is typically used. This approach was employed, for instance, in assessing Paleozoic resources within the Ustyurt petroleum region (excluding the Kuanish district).

While the first two methods are relatively simple and generally considered reliable, the volumetric-statistical approach often lacks objectivity and may result in significant over- or underestimation of resources. Therefore, estimates obtained using the specific density and averaged structure methods are generally regarded as more credible [16, 17].

In the classification of prognostic hydrocarbon resources, additional categories – localized prognostic resources labeled D1l and D2l – are also distinguished. Category D1l refers to resources within identified structures where the productive complex has been confirmed and assigned to category D1, while D2l applies to areas evaluated under category D2 [18, 19].

The method of specific densities is used within productive complexes that contain identified fields, enabling direct comparison between prospective and proven zones. Fields and tested exploration structures with confirmed non-productivity serve as reference examples. Notably, areas where only one dry well was drilled are excluded from the reference territory. Based on the cumulative initial reserves and total area of fields, including non-productive structures, a specific resource density is determined (in thousand tons/km^2 for oil and million m^3/km^2 for gas).

For each geological zoning unit, resource estimation maps were created, delineating both reference and calculated areas. In the case of the Ustyurt region, geological analogy correction coefficients are applied when transferring the reference resource densities to the target areas. These coefficients consider factors such as tectonic position (uplift or depression), trap type (anticlines, reefs, bioherms), seal quality (e.g., salts and compacted clays as high-quality seals, unconsolidated clays as low-quality), and reservoir characteristics. Typically, the combined analogy coefficient is less than 1.0, reflecting the fact that larger, well-defined structures tend to dominate reference areas.

The calculation of geological prognostic resources for a given area using the geological analogy method is expressed as [20, 21]

$$Q_r = q_r \cdot S_p \cdot k_{an},$$

where Q_r is estimated resources of oil, gas, condensate, or associated gas for the target area; q_r is specific resource density of the reference area (thousand tons/km^2 for oil, million m^3/km^2 for gas); S_p is area of the target zone (km^2); k_{an} is correction coefficient of geological analogy for oil or gas.

The specific density q_r is calculated as

$$Q_z = \frac{Q_z}{S_z},$$

where Q_z is reserves in the reference area; S_z is the area of the reference zone.

Condensate resources are calculated by multiplying gas resources by the condensate content factor

$$Q_{cr} = Q_{gr} \cdot k_r,$$

where Q_{cr} is condensate resources; Q_{gr} is gas resources; k_r is condensate content in the reference gas, g/l.

The specific density method is the primary approach for assessing hydrocarbon resources in well-studied petroleum complexes across Uzbekistan. To verify the reliability of results obtained using this method, the averaged structure method is also applied [22]. This includes the following:

- average reserves (oil, gas, condensate) per field in the reference area;
- average area of identified structures, based on total area divided by the number of structures;
- inter-structural area, depending on tectonic setting (e.g., smaller in orogenic zones than on platforms, typically 75 % of a single structure's area);
- discovery success rate, calculated as the proportion of productive structures among all explored ones.

Using these indicators, the number of potential structures and expected resources in the calculated zone can be estimated.

For poorly studied areas, the volumetric-statistical method is employed, utilizing average sedimentation rates (km^3 per million years). The "Methodological Guidelines..." (2000) recommends the equation developed by I. I. Nesterov, V. V. Poteryaeva, and F. K. Salmanov for assessing prognostic hydrocarbon resources in underexplored basins

$$Q = 3.71\omega - 6.48,$$

where Q is geological resources in million tons of conventional hydrocarbons (CHC); ω is an average volumetric sedimentation rate, km^3/million years.

This method was also applied to estimate Paleozoic resources in the Ustyurt petroleum region.

For the resulting hydrocarbon resource volumes, recovery factors for oil, gas, and condensate are applied as recommended in the "Methodological Guidelines..." (1983, 2014): free gas – 0.85; condensate – 0.65. Oil – based on analogous fields and regions, with an average of 0.25 applied in areas where no oil accumulations have been identified.

Research results and their analysis. In the Ustyurt petroleum region, productive complexes are primarily associated with Jurassic deposits. The migration and accumulation of hydrocarbons in these strata have been complicated by the low lateral and vertical continuity of porous horizons within the Lower and Middle Jurassic sections. As a result, many lithologically confined hydrocarbon accumulations located beyond anticline structures remain undetected due to the lack of appropriate identification methodologies.

The Jurassic sequence is subdivided into Lower, Middle, and Upper intervals. The Lower and Middle Jurassic deposits are composed of swamp, fluvial, and possibly shallow marine sediments, represented by alternating gray and dark gray sandstones, siltstones, and clays containing abundant homogenized plant remains. In contrast, Upper Jurassic deposits were formed under shallow marine conditions and consist mainly of clays and siltstones interbedded with limestones. Toward the top of the Upper Jurassic, the thickness of the limestones increases, and dolomites and anhydrites appear. The limestones, containing terrigenous admixtures, are light gray to nearly white or greenish-gray in color [23, 24].

The thickness of Jurassic deposits, as well as the entire sedimentary cover, varies significantly: from 920 m in the northwestern part of the Shakhpakhty Step and up to 1,030 m in the most elevated area of the Barsakelmes Trough, and from 1,700 to 2,000 m in the Barsakelmes and Sudochye depressions. On uplifts, the total thickness of the sedimentary cover is minimal (Figure).

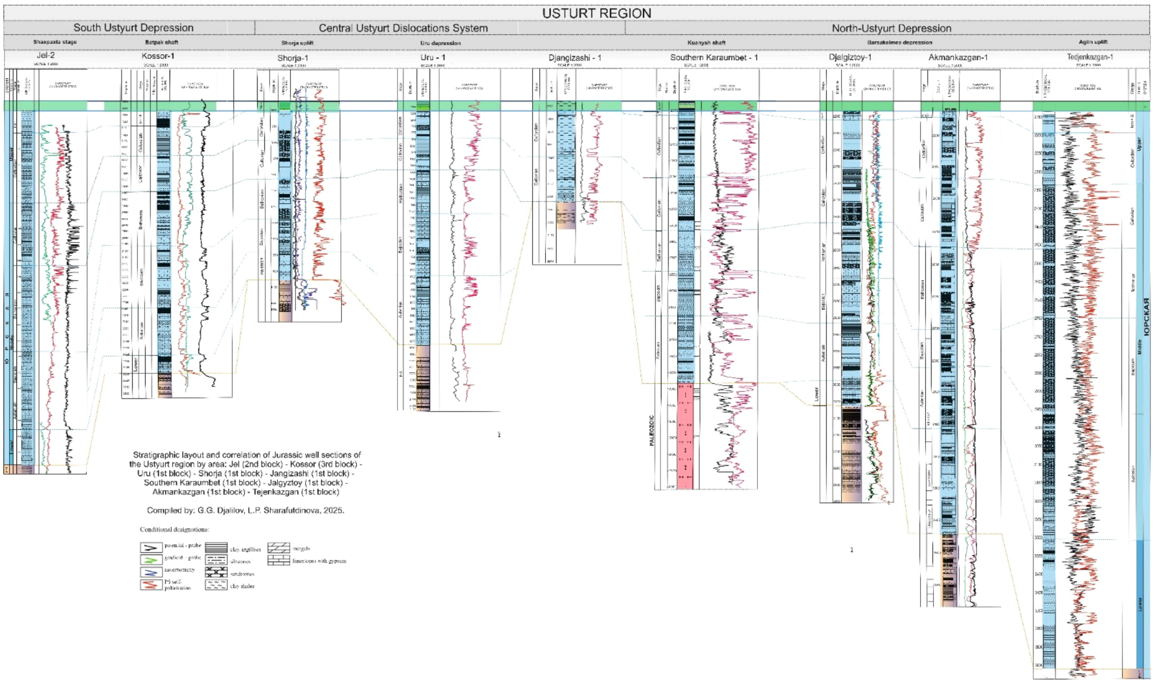

Fig. Stratigraphic subdivision and correlation of Jurassic well sections in the Ustyurt region across the following areas: Dzhel (well 2) — Kossor (well 3) — Uru (well 1) — Shordzha (well 1) — Dzhangyzashchi (well 1) — South Karaumbet (well 1) — Zhalgyztoy (well 1) — Akmankazgan (well 1) — Tedzhenkazgan (well 1) (after Dzhalilov G. G.)

As noted earlier, the Ustyurt petroleum region is subdivided into three petroleum-bearing provinces (North Ustyurt, South Ustyurt, and East Aral) and two petroleum-bearing districts (Central Ustyurt and Tuarkyr). Productive sequences in these regions are associated with Jurassic (excluding the latter two) and Paleozoic formations. Prognostic hydrocarbon resources in the Jurassic are assessed across all three intervals, while in pre-Jurassic formations, due to limited study, estimations are made without further subdivision.

In the Paleozoic, the productive complexes are represented by Upper Devonian—Middle Carboniferous terrigenous-carbonate formations and Upper Carboniferous—Lower Permian terrigenous-volcanogenic deposits. The assessment of resources in both Jurassic and pre-Jurassic strata was conducted using petroleum-geological zoning, based on tectonic subdivision carried out under the direction of O. A. Karshiyev at the Institute of Geology and Exploration of Oil and Gas Deposits (Republic of Uzbekistan).

Within the *North Ustyurt petroleum* province, nine petroleum districts are distinguished, including the Samsky, Kosbulaksky, Ostrovnoy, Aktumsuksky, Muynaksky, Barsakelmes, Kuanish-Koskalinsky, Sudochiy, and Kungrad districts.

The Aktumsuk district is further subdivided into petroleum-bearing areas such as Kassarminsky, Terenkuduksky, Kharoisky, Baychagyr-Yarkynbay, Agyynsky, Shaytankalinsky, Aldansky, and Akmankazgan. Differences are also observed in the density of prognostic hydrocarbon resources across these subregions.

In the Kosbulak depression, the deepest Jurassic sections are located in the eastern part, where seismic and drilling data indicate burial depths exceeding 5,500 m for the Lower Jurassic, 3,600 m for the Middle Jurassic, and 3,000 m for the Upper Jurassic.

The hydrocarbon generation potential of these deposits was confirmed by the discovery of the Zapadny Aral oil and gas field in 2010, with oil accumulations found in the Upper Jurassic and gas in the Middle Jurassic.

A total of 23 oil and gas fields have been discovered in the Northern Ustyurt region: Kushkair, Saikhun, Karachalak, Garb. Barsakelmes, Kokchalak, Tillali, Akchalak, Beskala, Kuanish, Urga, Aral, Aralyk, Dali, Surgil, Arslan, Berdakh-Shim. Berdakh, Kuyy Shark. Berdakh, Shagyrlyk, Shege, West Aral, Kyzyl-Shaly, Kuyy Surgil, and Inam.

Hydrocarbon accumulations have been identified in Paleozoic rocks (Karachalak and Kokchalak) and in Lower Jurassic deposits (Kushkair, Aralyk, Kuyy Surgil, Inam); in Middle Jurassic deposits (West Aral, Tillali, Aral, Shagyrlyk, Shege, Kyzyl-Shaly); in Lower and Middle Jurassic deposits (Garb. Barsakelmes, Kuanish, Saikhun, Beskala, Arslan); in Middle and Upper Jurassic deposits (Dali, Shark. Berdakh); and in Lower, Middle, and Upper Jurassic deposits (Akchalak, Surgil, Berdakh-Shim. Berdakh) [25, 26].

Overall, hydrocarbon resources (categories C3 + D1 + D2) in Jurassic and Paleozoic deposits of the Ustyurt region are estimated at 4,718.2/3,839.3 million tons of oil equivalent (geological/recoverable). Of this, categories D1 + D2 amount to 3,644.2/3,008.8 million tons, and C3 accounts for 1,073.9/830.5 million tons. Resources within Jurassic deposits represent 4,369.8/3,691.7 million tons, while Paleozoic deposits hold 348.2/147.5 million tons. Specifically, D1 + D2 resources in the Jurassic are 3,545.6/2,954.7 million tons, and in the Paleozoic 98.5/54.8 million tons.

The forecast hydrocarbon resources of the Northern Ustyurt petroleum province under categories C3 + D1 + D2 are distributed as follows: in the pre-Jurassic complex, total hydrocarbons amount to

85.8/72.7 million TOE, including free gas — 80.4/69.2 billion m^3 and condensate — 5.4/3.5 million tons; in the Lower Jurassic — 640.7/551.9 million TOE, including free gas — 593.3/520.1 billion m^3 and condensate — 47.4/31.8 million tons; in the Middle Jurassic — 1,645.3/1,400.3 million TOE, including gas — 1,540.3/1,328.1 billion m^3 and condensate — 105.0/72.2 million tons; in the Upper Jurassic — 1,227.2/1,014.1 million TOE, including free gas — 1,136.6/969.6 billion m^3, oil — 37.1/9.3 million tons, and condensate — 53.5/35.2 million tons.

Four areas have been identified as priority targets for hydrocarbon exploration in Jurassic deposits — Kuanish-Koskalin, Kungrad, Sudochye, and Barsakelmes. The territory of the well-studied Sudochye Trough is considered a promising area for further exploration, as it still contains potentially productive zones with hydrocarbon resources in Jurassic formations. In the northern Ustyurt region, hydrocarbon generation centers are associated with depression zones, including the southeastern part of the Barsakelmes Trough.

The southeastern part of the Barsakelmes macrotrough is among the priority areas due to its sedimentary cover thickness, which is comparable to that of the Sudochye Trough. This similarity was taken into account when assessing the economic viability of conducting geological exploration.

The ongoing seismic exploration activities in the southern part of the Kuanish-Koskalin area indicate a low density of structural features. Therefore, the area of a structure together with adjacent inter-structural zones is assumed to be 33.6 km^2. Such structural dimensions are typical for the depressions of the Northern Ustyurt petroleum province. Assuming a conditional field discovery success rate of 0.2 in this area, the identification of 14 prospective targets can be expected. The average gas-bearing area reaches approximately 16 km^2. Based on analog estimates using a coefficient of 0.7 for gas and a condensate yield factor of 117, the average C3 reserves are estimated at 3,200 million m^3 of gas and 400 thousand tons of condensate. With a well spacing of 80 ha/well, 20 production wells with an average depth of 3,450 m will be required.

According to the economic indicators of the performed calculations, the Kuanish-Koskalin area is considered profitable for geological exploration. At current domestic market prices, profitability is estimated at 26 %, while at external market prices it reaches 639 %.

The northern part of the Kungrad petroleum area is among the priority sites for exploration. The profitability of resources in promising structures is estimated at 28 % based on domestic market prices and 702 % based on international market prices.

The northern part of the Sudochye petroleum area is a highly promising and fairly well-surveyed region. The main objective here is to identify new structures and conduct detailed exploration. The Jurassic formations in this depression occur at relatively great depths — between 3.0 and 3.7 km — and have a thickness of 1.7 to 2.0 km according to geophysical data.

Within the boundaries of the depression, it is still possible to identify up to 20 additional structures. Estimates based on the methodology outlined above show that the development of resources in prospective areas within the Sudochye Trough would yield a profitability of 65 % on the domestic market and 943 % on the external market.

In the South Ustyurt petroleum province, three promising gas-bearing districts are distinguished: Shakhpakhtinsky, Assakeaudansky, and Uzunkuinsky. These districts vary in the degree of drilling maturity. The productivity of Paleozoic and Jurassic deposits within the Shakhpakhtinsky district has been confirmed by two fields — Shakhpakhty and Dzhel — where accumulations have been identified in the Paleozoic as well as in the Lower and Middle Jurassic intervals. In the Assakeaudansky district, accumulations are also present in Paleozoic, Lower, and Middle Jurassic rocks. In contrast, within the Uzunkuinsky district, no hydrocarbon accumulations have been discovered to date, although ten structures have been delineated and prepared for exploratory drilling in Jurassic and Paleozoic deposits.

In total, prognostic hydrocarbon resources (C3 + D1 + D2) for the South Ustyurt petroleum province are estimated at 521.5/295.7 million tons of oil equivalent (geological/recoverable), including 299.9/225.6 million tons in categories D1 + D2, and 221.6/70.1 million tons in category C3. Of this, free gas accounts for 288.5/246.5 billion m^3, oil for 227.4/45.5 million tons, and condensate for 5.6/3.7 million tons [27, 28].

Free gas under category C3 + D1 + D2 is estimated at 3,619.6/3,115.2 billion m^3 (geological/recoverable), including (D1+D2) — 2,909.2/2,472.8 billion m^3, and C3 — 710.4/642.4 billion m^3. Oil under category C3 + D1 + D2 is estimated at 184.9/38.3 million tons, including (D1 + D2) — 56.3/12.6 million tons, and C3 — 128.6/25.7 million tons. Condensate under category C3 + D1 + D2 is estimated at 178.3/119.9 million tons, including (D1 + D2) — 132.2/85.9 million tons, and C3 — 46.1/34.0 million tons.

The resources under category C3 + D1 + D2 are distributed as follows:

- in the pre-Jurassic complex, total hydrocarbons are estimated at 237.6/54.1 million TOE, including free gas — 10.1/8.6 billion m^3, oil — 227.4/45.5 million tons, and condensate — 0.1/0.09 million tons;
- in the Lower Jurassic, total hydrocarbons are estimated at 29.0/24.6 million TOE, including free gas — 28.7/24.4 billion m^3, and condensate — 0.3/0.2 million tons;
- in the Middle Jurassic, total hydrocarbons are estimated at 68.6/58.6 million TOE, including free gas — 68.2/58.3 billion m^3, and condensate — 0.4/0.3 million tons;
- in the Upper Jurassic, total hydrocarbons are estimated at 186.3/158.4 million TOE, including free gas — 181.5/155.2 billion m^3 and condensate — 4.8/3.2 million tons.

The prospective hydrocarbon resources under category C3 across the South Ustyurt petroleum province as a whole amount to 19.6/17.7 million TOE.

The East Aral petroleum province is subdivided into six areas: North Aral, Central Aral, Taldyk, Obruchev, Akkala, and Kinderli. This region is also characterized by low geological and drilling exploration coverage. Additionally, the southern part of the area is marked by reduced thickness of Lower Jurassic deposits, for which no resource estimations have been carried out.

The total forecast hydrocarbon resources under category C3 + D1 + D2 are estimated at 597.5/504.4 million TOE (geological/recoverable), including 512.6/429.6 million TOE under category D1 + D2 and 84.9/74.8 million TOE under category C3. This includes free gas estimated at 559.7/480.0 billion m^3 under category C3 + D1 + D2, and condensate at 37.8/24.4 million tons. Of these, category D1 + D2 accounts for 485.1/412.3 billion m^3 of free gas and 27.5/17.3 million tons of condensate.

The Central Ustyurt dislocation system is among the least explored areas in terms of drilling. In this region, well No. 1 Satbay, located on the Shordzha Arch, encountered for the first time within the Ustyurt area halogenic deposits of Paleozoic age in 2012. Drilling data indicate that the top of the salt layer lies at a depth of 1,630 m, and the base at 3,680 m. As is well known, salt formations possess excellent sealing properties, which positively influences the hydrocarbon potential of the Paleozoic formations in the area [29, 30].

In the Central Ustyurt region, the southeastern part of the Shordzha petroleum prospective area is considered a priority. Across most of the Assakeaudan Trough, where promising Jurassic and Paleozoic deposits occur at depths exceeding 4,000 m, the area is currently not regarded as a priority for exploration. On the Shakhpakhty Step, however, Jurassic and Paleozoic formations lie at relatively shallow depths. The potential for discovering hydrocarbon accumulations in the salt-bearing and subsalt Paleozoic sequences on the southeastern flank of the Central Ustyurt dislocation system is considered high.

A comprehensive analysis of geological and geophysical data has yielded valuable geological insights that have allowed a reassessment of the geological structure and resource potential of the area under study, particularly with regard to the Paleozoic complex. This reevaluation is largely attributed to the discovery of a thick salt-bearing sequence (1,737 m in well No. 1 Satbay) of Kungurian age (Lower Permian), and the underlying terrigenous-carbonate, carbonate, and volcanogenic rocks. Salt formations have been encountered in three exploration wells: Satbay No. 1, Aziya Zholbarysy No. 1, and Khakberdi No. 1.

The Aziya Zholbarysy No. 1 well was successfully drilled, with gas inflow recorded from Paleozoic formations during testing operations. The well confirmed that the Paleozoic formations within the Central Ustyurt uplift have potential for hydrocarbon accumulations.

A certain correlation has been observed between the depth of occurrence and the thickness of the examined sequences. For example, the greater the depth of the salt-bearing sequence, the thinner its thickness tends to be; conversely, the thicker the overlying Permian and Permo-Triassic deposits covering the salt, the thinner the salt-bearing sequence itself.

Among the priority areas for geological exploration is the southeastern part of the Shordzha uplift, located to the northeast of the Assakesaudan Trough.

The southeastern part of the Shordzha petroleum district is identified as a priority target. Based on an assumed success ratio of 0.1, the discovery of 12 new structures is projected. Profitability of geological exploration on the Shordzha site is estimated at 40 % under domestic market conditions and up to 478 % on the external market.

Total prognostic resources (C3 + D1 + D2) for the Central Ustyurt region are estimated at 348.6/149.6 million tons of oil equivalent, including 144.9/94.4 million tons in D1 + D2 and 203.7/55.2 million tons in C3. These include 118.8/102.6 billion m^3 of free gas, 227.4/45.4 million tons of oil, and 2.4/1.6 million tons of condensate.

The results obtained for petroleum provinces, districts, and local targets have been used to characterize the density of hydrocarbon resources (in thousand t.o.e./km^2). The highest density in the North Ustyurt petroleum province is observed in the Sudochiy district, with 249.0 thousand t.o.e./km^2, while the lowest is in the Samsky district – 15.0 thousand t.o.e./km^2.

Resource development across the Ustyurt region averages 8.0 %, with the North Ustyurt province also at 8.0 %, the South Ustyurt province at 29 %, and zero development reported to date in the East Aral province and the Central Ustyurt district. Notably, the vast majority (94.5 %) of prognostic hydrocarbon resources in Jurassic formations of the Ustyurt region are located at depths up to 4 km, whereas only 5.5 % of Paleozoic resources are found at depths between 4–5 km.

Conclusions. Within the North Ustyurt region, four areas have been identified as priority targets for the exploration of hydrocarbon accumulations in Jurassic deposits: Kuanish-Koskalinsky, Kungrad, Sudochiy, and Barsakelmes. Among them, the southeastern part of the Barsakelmes macro-depression stands out due to its comparable sedimentary cover thickness with the Sudochiy depression, which was used as a geological analog in the assessment of the feasibility of exploration activities. Six structural prospects are expected to be identified within the Barsakelmes area. The profitability of prospective resources in these structures is estimated at 147 % under current domestic market conditions and up to 1,758 % based on export pricing.

In the South Ustyurt petroleum province, three gas-bearing districts – Shakhpakhtinsky, Assakeaudansky, and Uzunkuinsky – are considered promising, though they exhibit varying degrees of exploration maturity. Completion of exploratory drilling is required to enhance forecasting reliability.

In the Central Ustyurt region, the southeastern part of the Shordzhin petroleum district is classified as a priority area. Based on the economic analysis performed, the Barsakelmes site appears to be the most cost-effective among the priority zones of North Ustyurt, with a domestic market profitability rate reaching 147 %.

According to the authors, the application of the proposed methodology allows for an objective assessment of both the necessity and the effectiveness of initiating geological exploration programs in the study area. It also enables a comprehensive geological and economic evaluation of prognostic targets, including assessments of budgetary efficiency and investor return potential.

Thus, the prioritization of specific areas within the Ustyurt region is substantiated by both geological-structural features and economic feasibility calculations. The Barsakelmes area, with its favorable combination of burial depth, sedimentary cover thickness, and geophysical attributes, demonstrates high profitability even under domestic pricing, making it a reference example of viable exploration and development. Its comparison with the Sudochiy depression further justifies the use of geological analogy methods in exploration planning.

Despite the presence of promising structures, the South and Central Ustyurt zones require further exploration and geophysical support, particularly to refine stratigraphic frameworks and reservoir characterization. Nevertheless, even at the preliminary evaluation stage, several areas demonstrate signs of high investment attractiveness, underscoring the need for a systematic approach to exploration planning.

The methodology proposed in this study has proven effective as a tool for integrated evaluation of both geological and economic parameters. This is especially critical under conditions of high geo-economic uncertainty. Its application supports the development of a scientifically grounded subsoil use model capable of sustaining long-term mineral resource base replenishment in the region.

References.

1. Abdullaev, G. S., Bogdanov, A. N., & Eidelnant, N. K. (2019). *Oil and gas fields of the Republic of Uzbekistan*. Tashkent: IGIRNIGM.
2. Bogdanov, A. N. (2019). Current state and structure of the hydrocarbon base of the Republic of Uzbekistan. *Oil province*, *4*(20), 36-48. https://doi.org/10.25689/NP.2019.4.36-48
3. Yuldasheva, M. G., Mukhutdinov, N. U., Akramova, N. M., & Akhmedzhanova, L.S. (2019). Assessment of oil and gas potential of the Lower Jurassic deposits of the central part of the Ustyurt region based on geological and geochemical data. *Oil and Gas Geology. Theory and Practice, 14*(1). Retrieved from http://www.ngtp.ru/rub/2019/8_2019.html
4. Abetov, A. E., Yessirkepova, S. B., & Ma, J. C. (2022). Gravity field transforms at the exploration for hydrocarbon field in the Southern part of the Ustyurt region. *News of the National Academy of Sciences of the Republic of Kazakhstan, Series of Geology and Technical Sciences, 3*(453), 17-31. https://doi.org/10.32014/2022.2518-170X.177
5. Yessalina, S. A., Gulamov, R. A., & Mallaev, S. E. (2024). Revealing new exploration plays in the deeper parts of the Ustyurt region in Uzbekistan. SPE-219312-MS. *GOTECH, Dubai, UAE*. https://doi.org/10.2118/219312-MS
6. Shaikhina, D., Yessalina, S., Muratov, A., Muratov, A. S., Muminov, M. N., Kuvanyshev, A. M., ..., & Ashimov, Z.Y. (2024). Distribution of jurassic clastic reservoirs in the Sudochi depression of the East Ustyurt Basin (Uzbekistan) based on the results of seismic reservoir characterization. SPE-219283-MS. *GOTECH, Dubai, UAE*. https://doi.org/10.2118/219283-MS
7. Ratov, B., Borash, A., Biletskiy, M., Khomenko, V., Koroviaka, Y., Gusmanova, A., ..., & Matyash, O. (2023). Identifying the operating features of a device for creating implosion impact on the water bearing formation. *Eastern-European Journal of Enterprise Technologies, 5*(1(125)), 35-44. https://doi.org/10.15587/1729-4061.2023.287447
8. Zholbassarova, A. T., Bayamirova, R. Y., Ratov, B. T., Khomenko, V. L., Togasheva, A. R., Sarbopeyeva, M. D., ..., & Koroviaka, Ye. A. (2024). Development of technology for intensification of oil production using emulsion based on natural gasoline and solutions of nitrite compounds. *SOCAR Proceedings*, 2, 48-55. https://doi.org/10.5510/OGP20240200965
9. Kosenko, A., Khomenko, O., Kononenko, M., Myronova, I., & Pazynich, Yu. (2024). Raises advance using borehole hydraulic technology. *E3S Web of Conferences, 567*, 01008. https://doi.org/10.1051/e3sconf/202456701008
10. Abetov, A. E., Yessirkepova, S. B., & Barbosa, J. C. M. (2023). Remote sensing at the study of the thermal field of the South Ustyurt region to find hydrocarbon deposits. *News of the National Academy of Sciences of the Republic of Kazakhstan, Series of Geology and Technical Sciences, 2023*(2), 6-16. https://doi.org/10.32014/2023.2518-170X.275
11. Khomenko, V. L., Ratov, B. T., Pashchenko, O. A., Davydenko, O. M., & Borash, B. R. (2023). Justification of drilling parameters of a typical well in the conditions of the Samskoye field. *IOP Conference Series: Earth and Environmental Science, 1254*(1). https://doi.org/10.1088/1755-1315/1254/1/012052
12. Piriverdiyev, P. I., Sarbopeyeva, M. D., & Asadova, G. S. (2019). Analysis of modeling and decision-making processes for drilling wells under uncertainty. *News of the National Academy of Sciences of the Republic of Kazakhstan, Series of Geology and Technical Sciences, 1*(433), 23-31. https://doi.org/10.32014/2019.2518-170X.2
13. Hryhoriev, Y., Lutsenko, S., Systierov, O., Kuttybayev, A., & Kuttybayeva, A. (2023). Implementation of sustainable development approaches by creating the mining cluster: the case of MPP "Inguletskiy". *IOP Conf. Series: Earth and Environmental Science, 1254*, 012055. https://doi.org/10.1088/1755-1315/1254/1/012055
14. Ratov, B. T., Chudyk, I. I., Fedorov, B. V., Sudakov, A. K., & Borash, B. R. (2023). Results of production tests of an experimental diamond crown during exploratory drilling in Kazakhstan. *SOCAR Proceedings, 2*, 023-029. https://doi.org/10.5510/OGP20230200842
15. Rakishev, B. R., Auezova, A. M., Kuttybayev, A. Ye., & Kozhantov, A. U. (2014). Specifications of the rock massifs by the block sizes. *Naukovyi Visnyk Natsionalnoho Hirnychoho Universytetu*, (6), 22-27.
16. Sudakov, A., Dreus, A., Ratov, B., Sudakova, O., Khomenko, O., Dziuba, S., ..., & Ayazbay, M. (2020). Substantiation of thermomechanical technology parameters of absorbing levels isolation of the boreholes. *News of the National Academy of Sciences of the Republic of Kazakhstan, Series of Geology and Technical Sciences*, *2*(440), 63-71. https://doi.org/10.32014/2020.2518-170X.32
17. Sudakov, A., Dreus, A., Ratov, B., & Delikesheva, D. (2018). Theoretical bases of isolation technology for swallowing horizons using thermoplastic materials. *News of the National Academy of Sciences of the Republic of Kazakhstan, Series of Geology and Technical Sciences, 2*(428), 72-80. Retrieved from http://geolog-technical.kz/images/pdf/g20182/72-80.pdf
18. Baibatsha, A., Omarova, G., & Shakirova, G. (2019). Innovative technologies of mineral resources predictioin on covered territories. *International Multidisciplinary Scientific GeoConference Surveying Geology and Mining Ecology Management, SGEM, 19*(1.1), 271-278. https://doi.org/10.5593/sgem2019/1.1/S01.033
19. Zholtaev, G. Z., Mussina, E. S., Fazylov, E. M., & Aliakbar, M. (2019). Prospects for discovering new unconventional hydrocarbon deposits in the caspian sedimentary basin (Shale oil and gas). *International Multidisciplinary Scientific GeoConference Surveying Geology and Mining Ecology Management, SGEM, 19*(1.1), 465-474. https://doi.org/10.5593/sgem2019/1.1/S01.057
20. Issagaliyeva, A. K., Istekova, S. A., & Aliakbar, M. M. (2021). Geophysical data complex interpretation techniques for studies of the earth crust deep horizons in the North Caspian region. *News of the National Academy of Sciences of the Republic of Kazakhstan, Series of Geology and Technical Sciences, 5*(449), 61-67. https://doi.org/10.32014/2021.2518-170X.99
21. Falshtynskyi, V., Dychkovskyi, R., Khomenko, O., & Kononenko, M. (2020). On the formation of a mine-based energy resource complex. *E3S Web of Conferences, 201*, 01020. https://doi.org/10.1051/e3sconf/202020101020
22. Wu, J., Chen, X., Yao, H., Gao, L., Chen, Y., & Liu, M. (2017). Non-linear relationship of hydrological drought responding to meteorological drought and impact of a large reservoir. *Journal of Hydrology, 551*, 495-507. https://doi.org/10.1016/j.jhydrol.2017.06.029
23. Feng, Y., Ren, Y., Qu, H., Wang, Y., & Jiang, T. (2021). Permian hydrocarbon accumulation factors in the Jimunai-Zaysan basin, China-Kazakhstan border. *Dizhi Xuebao/Acta Geologica Sinica, 95*(6), 1935-1948. https://doi.org/10.19762/j.cnki.dizhixuebao.2020194
24. Zhu, X., Shen, C., Zhao, B., Hu, S., Ge, X., & Wang, L. (2022). Multi-stage hydrocarbon migration and accumulation of Permian petroleum system in the Zaysan Basin, NE Kazakhstan. *Journal of Petroleum Science and Engineering, 208*. https://doi.org/10.1016/j.petrol.2021.109291
25. Ziyong, Z., Hangyu, Y., & Xiaodan, G. (2018). Fuzzy fusion of geological and geophysical data for mapping hydrocarbon potential based on GIS. *Petroleum Geoscience, 24*(1), 131-141. https://doi.org/10.1144/petgeo2016-100
26. Khattab, H., Hamdy, A., El-Hoshoudy, A. N., & Gomaa, S. (2024). Assessment of biopolymers rheological properties and flooding results under reservoir conditions for enhanced oil recovery processes. *Egyptian Journal of Chemistry, 67*(9), 431-444. https://doi.org/10.21608/EJCHEM.2024.258404.9090
27. Yessendossova, A., Mykhailov, V., Maussymbayeva, A., Portnov, V., & Mynbaev, M. (2023). Features of the Geological Structure and Polymetallic Mineralization of the Uspensky (Central Kazakhstan) and Dalnegorsky (Far East) Ore Districts. *Iraqi Geological Journal, 56*(2F), 44-60. https://doi.org/10.46717/igj.56.2F.3ms-2023-12-9
28. Umirova, G., Togizov, K., Muzapparova, A., & Kisseyeva, S. (2023). Preparation of calculation parameters according to logging data for 19-24 productive horizons of the Uzen field. *International*

Multidisciplinary Scientific GeoConference Surveying Geology and Mining Ecology Management, SGEM, 23(1.1), 729-741. https://doi.org/10.5593/sgem2023/1.1/s06.87

29. Baibatsha, A. A. B., Omarova, G. M., & Baibatchayeva, Z. T. (2022). Tailings are a Reliable Source of Mineral Reserves (Kazakhstan). *Advances in Science, Technology and Innovation.* https://doi.org/10.1007/978-3-030-72547-1_81

30. Xayitov, O. G., Zokirov, R. T., Agzamov, O. A., Gafurov, S. O., & Umirzoqov, A. A. (2022). Classification of hydrocarbon deposits in the South-Eastern part of the Bukhara-Khiva region, justification of its methodology and analysis of the results. *News of the National Academy of Sciences of the Republic of Kazakhstan, Series of Geology and Technical Sciences, 2022*(1), 46-52. https://doi.org/10.32014/2022.2518-170X.139

Економічна оцінка ресурсів вуглеводнів і підвищення ефективності геологорозвідувальних робіт в умовах Устюртського регіону

Г. Г. Джалілов[1], *Б. Т. Ратов*[*2], *А. К. Судаков*[3], *Ш. А. Тошматов*[4], *И. С. Тогаєв*[4], *Ж. Б. Бекешова*[5]

1 – ГУ «Інститут геології та розвідки нафтових і газових родовищ», м. Ташкент, Республіка Узбекистан

2 – НАТ «Казахський національний дослідницький технічний університет імені К. І. Сатпаєва», м. Алмати, Республіка Казахстан

3 – Національний технічний університет «Дніпровська політехніка», м. Дніпро, Україна

4 – Національний університет Узбекистану імені Мірзо Улугбека, м. Ташкент, Республіка Узбекистан

5 – ТОВ «Проєктний інститут «OPTIMUM», м. Актау, Республіка Казахстан

[*] Автор-кореспондент e-mail: b.ratov@satbayev.university

Мета. Комплексний аналіз економічної ефективності геологорозвідувальних робіт (ГРР) на нафту і газ та виявлення основних резервів її підвищення, а також аналіз існуючої системи планування геолого-розвідувальних робіт в умовах Устюртського газонафтоносного регіону й виявлення закономірностей зв'язку між обсягами глибокого буріння та приростом розвіданих запасів із застосуванням економіко-математичних моделей.

Методика. Використані методи: комплексного аналізу й систематизації результатів попередніх досліджень, висвітлених у фондових і опублікованих роботах; аналогії й порівняння – схеми спрямування геологорозвідувальних робіт із виділенням першочергових ділянок; графоаналітичний метод.

Результати. Виконане прогнозування перспектив нафтогазоносності, що базується на використанні всієї суми геологічної інформації з метою визначення кількості початкових сумарних і прогнозних ресурсів вуглеводнів, їх просторового розміщення й умов залягання накопичень. Із використанням існуючих методів оцінки прогнозних ресурсів вуглеводнів, з урахуванням результатів геологорозвідувальних робіт в Устюртському регіоні, закономірностей розміщення покладів вуглеводнів у розрізі осадової товщі обґрунтовані пріоритетні напрямки ГРР на найближчу перспективу з оцінкою рентабельності. Обґрунтовані прогнозні ресурси Устюртського регіону, що варіюється від 15,0 (Самський нафто-газовий регіон (НГР)) до 249,0 тис.т.у.т/км^2 (Судочий НГР).

Наукова новизна. Уперше обґрунтована економічна доцільність освоєння ресурсів вуглеводневої сировини із ділянок, виділених як пріоритетні на території Північно-Устюртського регіону. Такою ділянкою є Барсакельмеська, де відсоток рентабельності з урахуванням прибутку, одержаного від реалізації вуглеводнів за цінами внутрішнього ринку, становив 147 %.

Практична значимість. Обґрунтована необхідність та ефективність постановки геологорозвідувальних робіт на південно-східній частині Барсакельмеського макропрогину, що, за потужністю осадового чохла, схожа на Судочий прогин, у зв'язку із чим він послужив аналогом при визначенні рентабельності проведення ГРР. У межах прогину обґрунтована можливість проєктування ГРР ще на виявлених 20-ти структурах. Обгрунтована рентабельність освоєння ресурсів перспективних площ.

Ключові слова: *прогнозні ресурси, освоєння, нафтогазоносність, газонафтове районування, рентабельність*

The manuscript was submitted 30.01.25.