GEOLOGY

Z. B. Bekeshova¹,
orcid.org/0009-0006-1867-0979,
B. T. Ratov*²,
orcid.org/0000-0003-4707-3322,
A. K. Sudakov³,
orcid.org/0000-0003-2881-2855,
K. A. Kozhakhmet¹,
orcid.org/0000-0003-1339-7193,
D. A. Sudakova⁴,
orcid.org/0000-0002-8676-4006

1 — Yessenov University, Aqtau, the Republic of Kazakhstan
2 — Satbayev University, Almaty, the Republic of Kazakhstan
3 — Dnipro University of Technology, Dnipro, Ukraine
4 — Ivano-Frankivsk National Technical University of Oil and Gas, Ivano-Frankivsk, Ukraine
* Corresponding author e-mail: b.ratov@satbayev.university

ASSESSMENT OF THE OIL AND GAS POTENTIAL OF THE EASTERN EDGE OF THE NORTHERN USTYURT USING NEW GEOPHYSICAL DATA

Purpose. Detailed substantiation of the geological structure of the eastern edge of the Northern Ustyurt, clarification of modern geological and geophysical data, as well as highlighting the mainstages of evaluating the results of exploration work to confirm the oil and gas potential and subsequent exploitation of the fields.

Methodology. The authors used the following scientific methods: generalization — to systematize scientific provisions; analogy and comparison — to characterize deflection in different periods; analysis and synthesis — to substantiate geological and geophysical data; algorithmmization — to determine conceptual provisions regarding the assessment of the oil and gas bearing capacity of the trough.

Findings. In order to achieve the goals, the indicators of oil and gas capacity in the areas of the eastern side of the Northern Ustyurt of different geological ages were substantiated. The geological and geophysical features of the basin dating back to 2010 compared to modern refinement of geological data were characterized. The productive and unproductive structures of the eastern side of the Northern Ustyurt are characterized, taking into account the showing of oil and gas based on deposits of different geological ages. The importance of conducting geological exploration and creating corresponding cartographic materials is justified, followed by the design of predictive graphical models, geological sections, and a detailed plan of the territory.

Originality. The influence of high hydro carbon generation rates on the further identification of "oil windows" has been substantiated for the first time. The hierarchical levels of predicting the oil and gas content of the trough are identified. The necessity of improving the mechanisms for assessing oil and gas content is substantiated.

Practical value. The substantiation of the features of the assessment of the oil and gas content of the of the eastern edge of the Northern Ustyurt, which should be based on forecasting promising areas of prospecting, is the key to distinguishing between productive and unproductive objects, determining their real scale and directing investment flow precisely to promising areas with minimal environmental and economic losses.

Keywords: *Northern Ustyurt, field, oil, gas, tectonics, section, geology, forecast*

Introduction. The Republic of Kazakhstan is included in the list of the world's leading states in terms of proven reserves of a large number of minerals, including oil and gas. In particular, this applies to the Ustyurt region, which is estimated on the scale of significant oil and gas potential.

It should be noted that the Ustyurt Plateau is divided into troughs, each of which is characterized by a certain percentage of oil and gas content. Thus, the eastern edge of the Northern Ustyurt occupies one of the leading places in terms of oil and gas volumes. However, in recent years there has been a serious threat of depletion of mineral deposits without proper filling and a qualitative assessment of the current situation, as well as future prospects [1].

As noted by representatives of the Ministry of Ecology, Geology and Natural Resources of the Republic of Kazakhstan, important attention should be paid to exploration work with a further forecast to the immediate prospects for the oil and gas potential of the region, as well as the corresponding troughs. According to experts, the eastern edge of the Northern Ustyurt is at least considered the most explored to date; however, there remain territories with unspecified geological and geophysical data without a qualitative level of assessment and predictive indicators at all levels [1].

That is why the assessment of the scale of oil and gas resources and forecast calculations of future production confirm the fact of the suspension of the gradual increase in hydrocarbon reserves and the increase in the level of industrial capacities. After all, first of all, up-to-date data on the resource supply with oil and gas are the key to planning a national, in particular, energy strategy of the country.

It is also important to note that obtaining information about oil and gas deposits through geological exploration is a rather complicated process that requires a high level of logistics. And in modern conditions, when the depth of occurrence of such minerals is increasing, accordingly, exploration work is becoming increasingly difficult.

Moreover, successful geological exploration requires highly skilled specialists and continuous equipment upgrades. Complex geological conditions and the need for advanced technologies add complexity to the process of resource search and evaluation. The successful implementation of such projects can not only improve the quality of hydrocarbon assessment but also lead to the development of new methods that facilitate more accurate predictions and efficient resource use.

It is also important to consider the fact that the modernization of the geological exploration sector and the introduction of new technologies require significant financial investments and integration of international experience. It is crucial not only to attract investments but also to develop scientific and technical personnel capable of effectively addressing modern challenges. Investments in advanced technologies and specialist training are key to achieving long-term success in the field of geological exploration.

However, despite the difficulties of geological exploration, a qualitative assessment of the size of the fields of the eastern edge of the Northern Ustyurt and the potential for oil and gas potential is extremely important for the future of the entire nation, for securing the country's stable position in the global energy market, as well as for attracting appropriate investment flows.

Literature review. The author P. Khmyrov studies the historical stages of the main exploration work on oil and gas deposits in the Ustyurt region, as well as the dynamics, current state, and amount of hydrocarbons in the deposits [2]. The scientist notes that the beginning of active exploration work on the territory of the Ustyurt plateau is characterized by the discovery of a large number of oil and gas fields.

The scientist H. Abilkhasimov explored the geological structure of the North Ustyurt trough system in the context of comparison with other oil and gas regions. In this case, he notes the prospects of oil and gas deposits dating back to the Palaeozoic and Triassic. The author also notes that centres of generation of hydrocarbons are concentrated precisely in the territory of the Kosbulak and Samsky troughs. It is the comprehensive studies of the Ustyurt Plateau that make it possible to obtain data on the existing potential of the oil and gas potential of the territories located in the direction of the Kosbulak depression [3].

Researchers G. Abdullaev, et al. explored the current state and development prospects of the Ustyurt region by studying all phases of deposits in terms of stratigraphic and tectonic accessories. In particular, the predictive assessment of the resource base of hydrocarbons with in the stratigraphic complexes: Upper, Middle and Lower Jurassic, as well as the Palaeozoic, is substantiated. Based on the results of comprehensive studies, the need for investment in future exploration work using the latest, progressive technologies has been proven once again [4].

The scientist M. G. Yuldasheva in her works analyses the features of the geological section of the Samsko — Kosbulak trough with a generalization of actual data and future prospecting, in particular, data from deep drilling of the relevant areas [5].

The author has formed a geological model of the study area with details of all geochemical and filtration parameters of deposits, as well as geological age (Jurassic, Palaeozoic).

The purpose of the study. The purpose of the work is to summarize the geological and geophysical data for the eastern edge of the Northern Ustyurt, to justify the need for a qualitative assessment of the prospects for oil and gas at all forecast levels in order to strengthen the main aspects of the country's energy security.

Setting the task. The information base of the study was made up of statistical data, reports of the Ministry of Ecology, Geology and Natural Resources of the Republic of Kazakhstan, the Ministry of Digital Development, Energy and Industry of the Republic of Kazakhstan, materials of the review of analytics by Kaz Inform MIA and the Energy Aspects of Kazakhstan Centre. In particular, cartographic information on the prospects of oil and gas basins was considered in detail through stratigraphic and tectonic data, as well as the dynamics, current state, and amount of hydrocarbons in sedimentary rocks, as well as the resource base of hydrocarbons with in the stratigraphic complexes: Upper, Middle and Lower Jurassic, as well as the Palaeozoic.

The study of problematic aspects of the research topic involved utilizing a range of sciences related to the material composition and structure of the Earth's crust, its movements, developmental history, and the patterns of mineral formation and distribution. The analysis included works by Canadian, Chinese, American, Kazakh, Ukrainian, British, Nigerian, and Brazilian scientists in this field. The research examined the characteristics of developing and implementing an integrated intelligent system for calculating key indicators of regional hydrocarbon potential, the current state of the legislative framework regarding the specifics of geological exploration and the quality of assessing mineral extraction prospects at all forecasting levels, as well as actual data and future exploration efforts, particularly deep drilling data for relevant subsidence areas. Additionally, the study assessed the investment attractiveness of future geological exploration using the latest progressive technologies.

To achieve the goal of scientific work, asset of general scientific research methods was used, in particular:

- method of analysis — for identification geographical features of the eastern edge of the Northern Ustyurt within the Ustyurt region; determination of the structural strength of the deflection in the context of deposits of different geological age;

- generalization method — for systematization of the main scientific provisions, the establishment of theoretical aspects and features of exploration work on the oil and gas potential of promising areas in the context of forecasting the future development of the country's fuel and energy sector;

- the method of analogies and comparisons — for substantiation of studies of the geological and geophysical characteristics of the eastern edge of the Northern Ustyurt in different periods of the late 20th and early 21st centuries to the present; study of the features of the structure of the tectonic zone of the Kosbulak basin and the identification of signs of modern paleotemperatures and the depth of the sedimentary strata;

- synthesis method — for identification of the main types of deposits in different directions of the eastern edge of the Northern Ustyurt and their detailed characterization, followed by generalization of the current state of sediment accumulation throughout the zone, which was initially characterized by stable compensated subsidence;

- induction method — for the study of certain theoretical and methodological aspects of assessing the oil and gas potential of specific areas using data obtained as a result of prospecting; substantiation of the need to carry out predictive calculations of oil and gas content at different levels to identify all the objects of the trough — from the most promising and generally unproductive.

- abstract-logical method — when clarifying the essence of the basic concepts, definitions and categories in the field of studying all phases of deposits in terms of stratigraphic and tectonic affiliation, as well as when summarizing and drawing conclusions;

- the method of algorithmization is the definition of conceptual provisions on the features of a qualitative assessment of oil and gas content and forecasting the further exploitation of fields through indicators of the potential resource base, industrial productivity, and future seismic surveys.

Thus, the proposed methodology enables a comprehensive approach to the research, taking into account both current scientific advances and practical aspects of oil and gas exploration and development.

Research results and their analysis. Full-fledged research on oil and gas deposits on the territory of the Ustyurt plateau began in the second half of the 20th century. The fundamental studies were carried out on the basis of the common depth point seismic survey method. Subsequent exploration work was carried out in order to clarify the location of promising oil
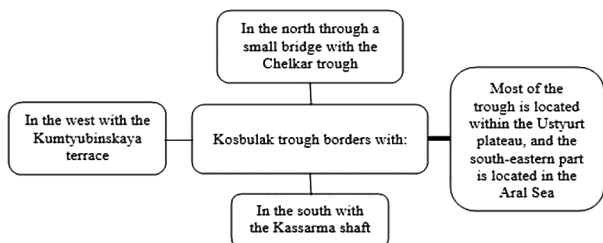
Fig. 1. Characteristics of the geographical features of the location of the eastern edge of the Northern Ustyurt [3]

and gas fields in several horizons – Lower Middle Jurassic and Palaeozoic [5].

In recent decades, there has been a significant expansion and development of geological exploration methods, driven by the growing need for effective use of energy resources and the necessity to optimize the processes of resource search and evaluation. Modern approaches include the implementation of new technologies, such as automated data analysis systems, which enhance the accuracy and efficiency of predictions. It is important to note that integrating modern technologies into geological exploration also requires the improvement of educational programs and the training of specialists in this field.

In 1991, there arose a need to determine the quantity of energy and fuel resources on the Ustyurt Plateau, which by that time had become part of Kazakhstan and Uzbekistan. This, in turn, required an enhancement of the quality of geological exploration and the clarification of geological and geophysical data.

In 1998, at the legislative level, further directions for the search for promising oil and gas deposits were fixed [5].

In the first half of the 20th century, fairly intensive exploration work made it possible to identify new locations of oil and gas in the western part of the eastern edge of the Northern Ustyurt, the northern part of the Ustyurt region, in which, taking into account various parts of the basin, in particular the Kulazhat, Koltik and Samsko-Beyneus inflections, a high level of hydrocarbon generation is observed [6] (Fig. 1).

It should be noted that pre-Jurassic deposits in the eastern edge of the Northern Ustyurt have no showing of oil and gas potential (Fig. 2).

If it is considered that the deposits of the Upper Devonian and Lower Carboniferous in the northern part of the trough, then their oil and gas source rocks with a high genetic potential for productivity (Fig. 3).

The structural plans of the Upper Jurassic, pre-Jurassic deposits and the crystalline basement prove that the development of the eastern edge of the Northern Ustyurt is inherited (Fig. 4).

Analysing Fig. 4, it is necessary to add that there is a selection of the area where the greatest immersion of the roof of the Upper Jurassic deposits is observed. This area is marked at the north-eastern border of the Ustyurt plateau and is minus 3,000 m.

Considering the Jurassic deposits, one should pay attention to the enrichment in dispersed organic substances, the content of which varies from 1.0 to 3.94 %.

These substances are found in the humus type and with agas-generating classification. In particular, the Jurassic deposits are characterized by strong facies variability in planar

Fig. 2. Delimitationof the belonging of the subsoil of the eastern edge of the Northern Ustyurt to deposits of different geological age [3]
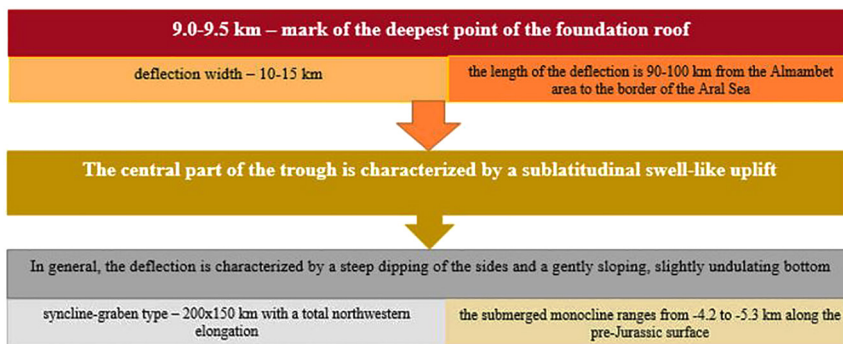

Fig. 3. Geological and geophysical characteristics of the eastern edge of the Northern Ustyurt, completed by 2010 [4]
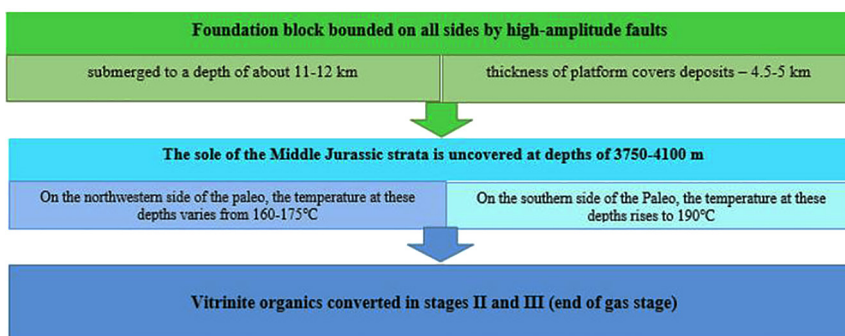

Fig. 4. Geological and geophysical characteristics of the eastern edge of the Northern Ustyurt, completed after 2015 [4]

and geological sections, where sandy reservoirs are replaced by clayey differences [7, 8].

Subsequently, closer to 2020 (Fig. 4), it was studied that a high level of industrial productivity of the Middle Jurassic deposits of the Kosbulak trough was recorded in the section of one field. The deposits of the Upper Jurassic layers of the Kosbulak trough, the boundaries of which are defined along the Takhtakairs well and the Shazpakhty stage, were also studied separately.

Studies of the features of the geological and geophysical features of the Kosbulak trough, which exist today, indicate a gradual increase in the paleotemperature regime in the places of the largest trough, reaching 175 °C. Such an increase in paleotemperature can be traced to the east of the Beineu depression [9].

In the end, the so-called Kosbulak depression was formed, which occupies the largest area of the basin. To date, an increase in modern reservoir temperatures is noted on the territory of the Kosbulak depression. For example, in the deep intervals of the Shikuduk range, the level of formation temperatures is constantly increasing, ranging from 155 to 175 °C, which is a coincidence with the maximum paleotemperature indicators. Thus, modern studies of the geological and geophysical characteristics of the Kosbulak basin indicate that the Jurassic-Paleogene deposits led to the current state of sediment accumulation in the area, which from the very beginning was characterized by stable compensated subsidence, in which there were no processes of significant up lifts and breaks. That is, at the moment the tectonic zone of the basin has two fundamental features:

- the level of the modern depth of the sedimentary sequence of the Jurassic deposits is characterized by maximum subsidence;

- the level of modern paleotemperature indicators is the maximum for the entire historical period of geological exploration.

For example, an increase in paleotemperature parameters reaching 200 °C is observed at the largest subsidence of the Middle Jurassic deposits, namely, 4.5 km [10].

In the eastern part, the Kosbulak depression, which is part of the Aral Sea, has the characteristics of a monoclinal uplift of the Jurassic sequence. However, to date, the features of the formation of sedimentary rocks in this part of the depression have not been sufficiently studied.

The north-western part of the Kosbulak depression, the Aktumsitskaya depression, is characterized by low thermal regime indicators caused by a rapid decrease in the level of paleo isotherms. That is, at the moment, paleotemperature indicators are sharply decreasing in the near-edge parts of the depression from 160 to 75 °C in the North Ustyurt area.

It should be noted that the micro components of fossil coal or vitrinites of the Jurassic deposits with in the North Ustyurt area of the Kosbulak depression is 65 % at a depth of 2,300—2,500 m, which indicates the drilling stage of transformation. At such deep deposits, the reservoir temperature regime is 72 °C, which corresponds to the maximum indicators of these deposits. At the same time, indicators are considered standard conditions at which the thermal regime is equal to 0.01 W/m^2 with the dominance of types II and III of kerogen, and the content of organic substances varies from 1.3 to 2.3 % at the highest level of maturity of the Lower Jurassic and Triassic oil source rocks [3].

Under such conditions, it is impossible to accurately determine the change in hydrocarbon movement; however, it can be assumed that such migration was over the entire area of the section, both vertically and in area. In fact, an increase in the level of oil saturation is formed above the Paleogene strata; however, as evidenced by recent studies, oil deposits are observed in the Upper Triassic complex. The error and discrepancy between the calculations and the real situation is due to the so-called hydrocarbon flow in to the Eocene strata due to crack sand faults, as well as through trigger rocks. Although

the risks of disagreements are necessarily taken into account in the corresponding calculations [7].

At the present stage of development, the Middle Jurassic oil source rocks with in the Kosbulak trough are identified as an "oil window" with increased hydrocarbon generation rates. At the same time, the remaining types of sedimentary rocks are still characterized by the initial stage of maturity of source rocks, and the calculated conversion factor has an indicator of more than 50 %, which predicts a rather low potential of source rocks in general. Al though the forecast values do not always coincide with the actual indicators, as mentioned earlier.

Therefore, studies of the geological and geophysical features of oil and gas deposits should include a qualitative assessment of the oil and gas content of the subsoil. In turn, such an assessment is aimed at substantiating the data obtained during prospecting, aimed at identifying favourable areas of potential oil and gas accumulation with appropriate zoning, differentiation by degrees of potential and further prospects with the choice of optimal prospecting and exploration work. Also, a fundamental aspect is the study of the main criteria for oil and gas content with a detailed consideration of spatial configurations, features of the movement of organic substances [8].

After the actual analysis and assessment of the oil and gas potential, cartographic material is created indicating the predicted graphical models with special symbols in the form of a geological section or a detailed plan of the territory where oil and gas promising objects are located. At the final stage, the assessment of oil and gas content also includes recommendations for prospective exploration work in a specific area. In predictive calculations of the oil and gas content of the subsoil, the following objects are identified [9]:

- new oil and gas fields with in insufficiently explored territories;

- new accumulations of oil and gas with in the basins for which geological exploration has already been carried out;

- confirmation of previously discovered oil and gas bearing regions;

- identification of new productive horizons in previously confirmed oil and gas regions.

It should also be noted that, depending on the level of quality of geological exploration and the assessment of the oil and gas potential of specific areas, the corresponding predictive directions for the development of the country's fuel and energy sector in the context of integrated socio-economic development and ensuring national interests will be formed. Forecast as an integral element of the assessment of oil and gas potential of deposits has a certain hierarchy, namely [10]:

- regional forecast — provinces, types and orders of their structures, the largest objects, basins, as well as lithological and stratigraphic complexes are studied;

- zonal forecast — individual objects of the province are studied, classified according to the second type of order;

- local forecast — specific structures are estimated locally, including reservoirs and groups of unseparated reservoirs.

The hierarchical relationship between predictive levels is very important, because the calculations and data obtained at one level are the starting point for research at the next level. In turn, the results of subsequent studies are verification for the previous level and for determination of the need for additional clarification. The assessment of the oil and gas content of the Kosbulak trough was primarily carried out at the regional level by comparing the geomorphological structure of similar objects in the Ustyurt region. In particular, it was determined that the geological structure of the oil and gas fields of the study area is characterized by the presence of hydrocarbons in the Jurassic deposits with tectonic elements in the inversion stage of development. At the same time, Palaeozoic sedimentary phenomena are located at a considerable depth, forming troughs reaching 8—9 km with the formation of new conditions for the generation of hydrocarbons migrating to the traps of the true Palaeozoic and Jurassic [7].

That is, the results of the study indicate that, taking into account the location of the zones of oil and gas deposits in the context of sedimentation, there is a high potential for generating large troughs — East Aral, Samsky, Chelkar and Kosbulak. In particular, the forecasts were confirmed in the north-western part of the plateau — the Kosbulak trough, the Minsualmas degree and in the southern part — the Barsakelme and Sudochy trough. These objects are characterized by high rates and scales of sediment accumulation [5].

Accordingly, the result of a regional predictive assessment is the formation of an oil and gas accumulation zone with Palaeozoic, Jurassic and Cretaceous deposits, including Paleogene ones. At the zonal forecast level, it was found that the assessment of the oil and gas potential in Palaeozoic deposits includes a positive criterion, determined due to weak metamorphization and relatively low deformation. At the same time, the impossibility of a more detailed study due to the need for too deep drilling was revealed as a negative criterion. However, the development of these deposits is predicted at an acceptable drilling depth in the zones of the boundary of the southern side of the Kosbulak trough with the Aktumsut complex. Under this condition of the articulation of several objects, the nature of the wave field and the seismicity of the geological section are observed, which makes it possible to assume the existence of Palaeozoic carbonate deposits. The local predictive assessment made it possible to find that the eastern part of the marginal part of the Kosbulak trough contains a section of the basement roof, which is submerge data depth of − 8.8 km, in which there is a local uplift or inflection according to the Upper Jurassic age of the deposits [5].

Therefore, in general, the assessment of the oil and gas potential of the eastern edge of the Northern Ustyurt indicates the following factors:

1. The potential resource base of the trough is characterized by a high resource potential, which is estimated at about 400 Mtce [5].

2. In the part of the junction of the Kosbulak trough and the Kessarmas well, there is a change in the industrial productivity of the Paleogene, Cretaceous, and Jurassic deposits, which determine the creation of favourable conditions for the formation of lithological traps [2].

3. Seismic exploration in the southern part of the eastern edge of the Northern Ustyurt will make it possible to identify promising areas in the Upper, Middle and Lower Jurassic zones with preparatory work for drilling at considerable depths.

The current stage of development of the world fuel and energy complex testifies to the combination of global oil and gas geopolitics with intensive investment flows in improving geological exploration and improving the quality of assessing the oil and gas content of certain regions. Under such conditions, global oil and gas cooperation requires compliance with several aspects of interaction: improvement of the material and technical base for the training of industry specialists and current geopolitical trends regarding strategies for the development of an environmentally friendly fuel and energy complex; establishing and complying with obligations for the lawful use of offshore oil fields and increasing the concentration of oil and gas assets and creating multi-stable supply bases; implementing the transition from integrated cooperation to the development to full chain of the oil and gas industry.

Researchers from the Republic of Kazakhstan T. Jurayev, et al. study an experimental development on the use of a new integrated intelligent control system for a gas chemical complex with in the Ustyurt region [6].

This management system unites five diversified industrial enterprises through a single hardware and software platform. The authors also note that the modern innovative approach makes it possible to predict the implementation of future industrial infrastructure projects based on the discovery of new oil and gas areas in the region or the clarification of data on existing facilities.

The authors of the study did not consider the peculiarities of applying innovative approaches in assessing the oil and gas bearing areas of the area and clarifying their geological and geophysical features; however, they fully agree with the need for a detailed description of new methods of exploration and prospecting. After all, a priori studying the features of the structure of oil and gas fields were distinguished by the constant improvement of geological research methods, which were always influenced by the level of ability of investment flows.

Scientists from China and Canada W. Wang, et al. study the main problems that arise during the exploration of new deposits oil and gas [11]. At the same time, detailed attention is paid to improving the directions of forecasting and evaluating oil and gas bearing areas and avoiding professional errors when drilling at great depths. The authors considered and substantiated the features of the discovery of the Anyue gas field in 2013 in the Sichuan basin. At that time, this was the first large-scale discovery of a natural gas field in Precambrian reservoirs. However, significant difficulties arose during the exploration work, since forecasting the prospects for the oil and gas potential of the Lower Palaeozoic deposits is quite difficult. That is why, in a detailed review of the Anyue gas field, scientists identified four functional elements that should guide the forecast calculations of oil and gas potential: source rock (S), paleo uplift (U), reservoir sedimentary facies (D) and regional rock, which is the upper layer in the study of the geological section (C). These elements in combination control the accumulation of hydrocarbons with in the Lower Palaeozoic deposits. Due to the fact that the mechanical movements of the earth's crust can damage the reservoirs of oil and gas formed before this movement, scientists have formed a model for calculating the probability indicators of the preservation of a hydrocarbon reservoir. It was also found that the prospects for oil and gas potential in the Lower Palaeozoic can be predicted by combining the model of accumulation and storage of hydrocarbons. Therefore, 137 wells drilled in the Sichuan Basin indicate that 88.9 % of the oil and gas bearing areas were in deed located in the predicted zones.

The authors fully support the importance of the main research topics of scientists from China and Canada, because a qualitative assessment and forecast of the oil and gas content of the basin ensures the development of the fuel and energy sector of the country as a whole. In this article, scientists emphasize the need for a detailed predictive calculation at the regional, zonal and local levels. Afterall, the results of one predictive level are the basis for research at the next level. Conversely, step-by-step results at each of the forecast levels allow us to confirm or refute the indicators obtained a teach of the fundamental stages of geological exploration.

Scientists from the Republic of Kazakhstan Y. Abuov, et al. investigate the actual oil and gas potential of the field sand in the future to verify compliance with the terms of the Paris Agreements, according to which the fuel and energy complex must comply with the Green Economy trend program with a significant reduction in greenhouse gas emissions up to 2 years. It should be noted that the current situation of environmentally safe functioning of the energy complex requires more serious control and application of various technologies, in particular Carbon Capture and Storage (CCS). For further implementation of this technology, six sedimentary basins located on the territory of Kazakhstan were selected, in particular, the Caspian, Mangishlak, South Torgai, Ustyurt, Chu − Sarisuy and Zaisan basins were considered for the assessment and ranking of oil and gas reservoirs, as well as in terms of localization and capacity. The reservoir efficiency of oil, gas reservoirs and salt aquifers was assessed for each basin using the CALF and US DOE methods. As a result of the assessment, it was possible to determine that the Caspian basin is most suitable for the geological storage of carbon dioxide, followed by the Mangishlak, South Torgai and Ustyurt basins. It also found that the four sedimentary basins have the potential to signifi-

cantly reduce greenhouse gas emissions in line with the specific decarbonisation needs of the national economy in order to achieve the goals set by the Paris Agreements [12].

The authors did not consider in their studies the environmental aspect in the predictive assessment of the oil and gas potential of the basins of Kazakhstan. However, they fully support the view that this principle should be studied in more detail in the context of environmental conservation. Afterall, the functioning of oil and gas reservoirs should be assessed in the context of meeting the needs of the fuel and energy sector with energy resources and in the context of complying with decarbonisation directions by storing an excessive amount of greenhouse gases.

Researchers from China Z. Wang, et al. analyse the distribution of world reserves of oil and gas field sand the main reasons why individual oil and gas fields are not fully explored and are not used [13]. In particular, the authors studied the features of the modern assessment of residual oil and gas reserves and the prospect of oil and gas potential of individual global fields. The current state and characteristics of world oil and gas production were also substantiated in the context of international oil and gas cooperation [14]. Thus, in 2021, a number of unproductive oil and gas fields were assessed, the number of which was large-scale [15]. In turn, oil fields were discovered that had been undeveloped for quite a long time and had rich reserves and significant oil and gas potential [16]. Such evaluation results once again confirmed the need for large investment flows in the oil and gas business, as well as periodic geological exploration [17].

The authors fully support the research directions of scientists from China, because the article also separately notes the fact that the assessment of the oil and gas potential of the area should be comprehensive with the corresponding refinement of data on fields that are in operation or promising sedimentary rocks or completely unproductive areas [18]. Afterall, the study of the elements of the basin, which carry different geological information, makes it possible to predict the directions of future research and further exploitation to meet the fuel and energy needs of the country as a whole [19]. Thus, the rapid development of technologies that regulate the use of mineral resources, such as oil and natural gas, is one of the main aspects of the functioning of the global financial market [20]. The accumulation of oil and gas is a key link in the national economy of the countries of the world and energy security in general. Forecasting and assessing the prospects for oil and gas potential has always caused great concern for people [21]. However, the methods of geological exploration of oil and gas have undergone significant changes, have become more and more complex, and exploration of the deposit has shifted to ever greater depths [22]. That is why, with the continuous accumulation of an impressive data base, innovative automated methods for classifying oil and gas deposits are increasingly being used, followed by forecasting a favourable combination of deposits.

Based on the conducted analysis, it can be concluded that modern research methods and technologies have a significant impact on the assessment of hydrocarbon potential. Specifically, the implementation of automated systems and innovative technologies greatly improves the accuracy of predictions and the evaluation of potential. These changes in research methodology also reflect the need to adapt to evolving conditions and industry requirements. Modern approaches to geological exploration open new opportunities for identifying and developing promising oil and gas resources, highlighting the importance of continuous improvement of methods and tools in this field.

Conclusions. The Republic of Kazakhstan ranks among the leading countries in the world in terms of mineral reserves, particularly oil and gas. To conduct a thorough evaluation of hydrocarbon potential, including accumulation, systematization, cartography, and updating of data on the geological structure and hydrocarbon potential of the region, modernization of the geological exploration industry is necessary.

With this aim, since 2020, there has been a significant increase in government funding for the exploration of new fields. Government support for the geological exploration sector is crucial for the development of the fuel and energy sector with the attraction of global investments.

In the course of substantiating the geological and geophysical data of the Kosbulak region, a high level of actual oil and gas content was established. Nevertheless, in the future, oil and gas content indicators should be determined using the following geological tasks: accumulation of an information base on the geological structure of the basin; regular search work; determination of the geological structure and geographically economic conditions; study of the scale of the object.

The result of thorough exploration work is: the formation of historical-geological and tectonic models of the study area; assessment of the resource base of oil and gas; determination of priority and most promising areas of prospecting; calculation of the possible economic effect from prospecting work with the calculation of indicators of growth of reserves and volumes of obtaining promising production of oil and gas volumes; development of an effective complex of prospecting works adapted to the modern conditions of the region's development.

Modern advancements in geological exploration and data analysis technologies play a crucial role in enhancing the accuracy of hydrocarbon assessments. The integration of innovative methods, such as automated monitoring systems and machine learning, significantly improves the process of data collection and interpretation, which in turn leads to a more precise evaluation of resource potential. The successful application of such technologies requires continuous updating of research methods and training of specialists, underscoring the importance of educational programs and scientific research in this field. The implementation of advanced technologies and approaches in geological exploration creates the foundation for more efficient and sustainable development of the country's energy sector.

The following areas of research in the field of improving the quality of oil and gas potential assessment can be considered: improvement of the complexity and calculation of indicators, according to the geological and economic assessment, of the volumes of oil, natural gas; adaptive assessment of profitability indicators of mining — oil and gas with the corresponding associated useful components; detailed consideration of indicators of possible industrial capacity as a result of discovered deposits; constant updating of cartographic information reflecting the efficiency and oil-gas saturation of the sedimentary stratum, as well as formations with the highest productivity and a feasibility study scheme for testing each of the horizons.

References.
1. *Kazakhstan resumes active search for new mineral deposits* (2022). Retrieved from https://nangs.org/news/upstream/kazakhstan-vozobnovlyaet-aktivnyj-poisk-novykh-mestorozhdenij-poleznykh-iskopaemykh.
2. Sadovenko, I., Zagrytsenko, A., Podvigina, O., & Dereviagina, N. (2016). Assessment of environmental and technical risks in the process of mining based on numerical simulation of geofiltration. *Mining of Mineral Deposits, 10*(1), 37-43. https://doi.org/10.15407/mining10.01.037.
3. Abilkhasimov, H. (2019). On new prospects for the oil and gas potential of Northern Ustyurt based on the results of basin modeling. *Neft i Gaz, 1*(109), 37-57.
4. Sudakov, A., Dreus, A., Ratov, B., Sudakova, O., Khomenko, O., Dziuba, S., Sudakova, D., Muratova, S., & Ayazbay, M. (2020). Substantiation of thermomechanical technology parameters for isolating absorbing levels of the boreholes. *News of the National Academy of Sciences of the Republic of Kazakhstan, 2*(440), 63-71. https://doi.org/10.32014/2020.2518−170X.32.
5. Jurayev, T., Khudayarov, B., Yusupbekov, N., Adilov, F., & Ivanyan, A. (2016). Experience of development and implementation of an integrated intelligent control system for the Ustyurt gas-chemical

complex. *Procedia Computer Science, 2016*, 485-489. https://doi.org/10.1016/j.procs.2016.09.431.

6. Clancy, S., Worrall, F., Davies, J., & Gluyas, J. (2018). An assessment of the footprint and carrying capacity of oil and gas well sites: The implications for limiting hydrocarbon reserves. *Science of the Total Environment, 618*, 586-594. https://doi.org/10.1016/j.scitotenv.2017.02.160.

7. Zhang, G., Yang, S., Mo, C., & Zhang, Z. (2022). Experimental research on capacity expansion simulation of multi-cycle injection-production in the reconstruction of oil reservoirs to underground gas storage. *Journal of Energy Storage, 54.* https://doi.org/10.1016/j.est.2022.105222.

8. 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.

9. Goudarzi, A., Meckel, T., Seyyed, H., & Treviño, R. (2019). Statistical analysis of historic hydrocarbon production data from Gulf of Mexico oil and gas fields and application to dynamic capacity assessment in CO_2 storage. *International Journal of Greenhouse Gas Control, 80*, 96-102. https://doi.org/10.1016/j.ijggc.2018.11.014.

10. Ebuka, N., & Iyeke, S. (2022). Analyzing the impact of oil and gas local content laws on engineering development and the GDP of Nigeria. *Energy Policy, 163*, 112836. https://doi.org/10.1016/j.enpol.2022.112836.

11. Wang, W., Pang, X., Chen, Z., Chen, D., Zheng, T., Luo, B., Li, J., & Yu, R. (2019). Quantitative prediction of oil and gas prospects of the Sinian-Lower Paleozoic in the Sichuan Basin in central China. *Energy, 174*, 861-872. https://doi.org/10.1016/j.energy.2019.03.018.

12. Lee, W., Abuov, Y., & Seisenbayev, N. (2020). CO_2 storage potential in sedimentary basins of Kazakhstan. *International Journal of Greenhouse Gas Control, 103*, 103186. https://doi.org/10.1016/j.ijggc.2020.103186.

13. Wang, Z., Fan, Z., Zhang, X., & Liubxichen, B. (2022). Status, trends and enlightenment of global oil and gas development in 2021. *Petroleum Exploration and Development, 49*(5), 1210-1228. https://doi.org/10.1016/S1876-3804(22)60344-6.

14. Wang, Z., Shi, Y., Wen, L., Jiang, H., Jiang, Q., Huang, S., Xie, W., ..., & Yan, Z. (2022). Exploring the potential of oil and gas resources in the Sichuan Basin with Super Basin Thinking. *Petroleum Exploration and Development, 103*, 977-990. https://doi.org/10.1016/S1876-3804(22)60326-4.

15. Ratov, B. T., Fedorov, B. V., Sudakov, A. K., Taibergenova, I., & Kozbakarova, S. M. (2021). Specific features of drilling mode with extendable working elements. *E3S Web of Conferences, 230*, 01013. https://doi.org/10.1051/e3sconf/202123001013.

16. Kimiagari, S., Mahbobi, M., & Toolsee, T. (2023). Attracting and retaining FDI: Africa gas and oil sector. *Resources Policy, 80.* https://doi.org/10.1016/j.resourpol.2022.103219.

17. Ding, M., Li, Q., Yuan, Y., Wang, Y., Zhao, N., & Han, Y. (2022). Permeability and heterogeneity adaptability of surfactant-alternating-gas foam for recovering oil from low-permeability reservoirs. *Petroleum Science, 19*(3), 1185-1197. https://doi.org/10.1016/j.petsci.2021.12.018.

18. Chudyk, I., Biletskiy, M., Ratov, B., Sudakov, A., & Borash, A. (2024). A new method of well completion employing the implosion effect. *V International Conference "Essays of Mining Science and Practice" IOP Conference Series: Earth and Environmental Science, 1348*(2024), 012056. IOP Publishing. https://doi.org/10.1088/1755-1315/1348/1/012056.

19. Xu, X., Huang, H., Zhang, S., & Hu, S. (2019). Gas generation potential and processes of Athabasca oil sand bitumen from gold tube pyrolysis experiments. *Fuel, 239*, 804-813. https://doi.org/10.1016/j.fuel.2018.11.077.

20. Liu, G., Hu, W., Li, X., & Zhang, B. (2022). The division of oil and gas accumulation assemblage in the Sichuan Basin and the construction of a favorable accumulation assemblage prediction model. *Energy Reports, 8*, 14716-14725. https://doi.org/10.1016/j.egyr.2022.10.373.

21. Fu, G., Liang, M., Guo, H., Xu, H., & Li, Q. (2021). Prediction method of favorable positions of transporting oil and gas capacity configuration in different periods of faults. *Journal of Natural Gas Geoscience, 6*(2), 101-109. https://doi.org/10.1016/j.jnggs.2021.05.002.

22. Sheng, J., Voldsund, M., & Ertesvåg, I. (2023). Advanced exergy analysis of the oil and gas processing plant on an offshore platform: A thermodynamic cycle approach. *Energy Reports, 9*, 820-832. https://doi.org/10.1016/j.egyr.2022.12.021.

Оцінка перспектив нафтогазоносності східного борту Північного Устюрту з використанням нових геофізичних даних

Ж. Б. Бекешова[1], *Б. Т. Ратов*[*2], *А. К. Судаков*[3], *К. А. Кожахмет*[1], *Д. А. Судакова*[4]

1 — Каспійський університет технологій та інжинірингу імені Ш. Єсьонова, м. Актау, Республіка Казахстан
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 — Івано-Франківський національний технічний університет нафти та газу, м. Івано-Франківськ, Україна
* Автор-кореспондент e-mail: b.ratov@satbayev.university

Мета. Обґрунтування геологічної будови східного борту Північного Устюрту, уточнення сучасних геолого-геофізичних даних, а також виділення основних етапів оцінки результатів пошукових робіт щодо підтвердження нафтогазоносності й подальшої експлуатації родовищ.

Методика. Авторами були використані такі наукові методи: узагальнення — систематизація наукових положень; аналогія й порівняння — характеристика прогину в різні періоди; аналіз і синтез — обґрунтування геолого-геофізичних даних; алгоритмізація — визначення концептуальних положень щодо оцінки нафтогазоносності прогину.

Результати. Для досягнення цілей були обґрунтовані показники нафтогазоносності на ділянках східного борту Північного Устюрту різного геологічного віку. Охарактеризовані геолого-геофізичні особливості басейну, що датуються на 2010 рік порівняно із сучасним уточненням геологічних даних. Охарактеризовані продуктивні й непродуктивні структури східного борту Північного Устюрту з урахуванням ознак нафти та газу на основі залягань різного геологічного віку. Обґрунтована важливість проведення геологорозвідувальних робіт і створення відповідних картографічних матеріалів із подальшим проєктуванням прогнозних графічних моделей, геологічних розрізів і детального плану території.

Наукова новизна. Уперше обґрунтовано вплив високих показників генерації вуглеводнів на подальшу ідентифікацію нафтових вікон. Виділені ієрархічні рівні прогнозування нафтогазоносності прогину. Обґрунтована необхідність удосконалення механізмів оцінки нафтогазоносності.

Практична значимість. Аргументована особливість оцінки нафтогазоносності східного борту Північного Устюрту, яка має базуватися на прогнозуванні перспективних напрямів пошукових робіт, що є запорукою розмежування об'єктів на продуктивні й непродуктивні, визначення їх реальних масштабів і спрямування інвестиційних потоків саме на перспективні ділянки з мінімальними еколого-економічними темпами.

Ключові слова: *Північний Устюрт, родовище, нафта, газ, тектоніка, розріз, геологія, прогноз*