https://doi.org/10.33271/nvngu/2025-3/021

A. Jangirov[1],
orcid.org/0009-0003-5668-1896,
G. Umirova[2],
orcid.org/0000-0001-5185-3132,
A. Abdullina[*3],
orcid.org/0000-0003-0483-2798,
I. Karpenko[4,5],
orcid.org/0000-0001-7753-9010

1 – "Professional Geo Solutions Kazakhstan" LLP, Almaty, the Republic of Kazakhstan
2 – Satbayev University, Almaty, the Republic of Kazakhstan
3 – Karaganda Technical University, Karaganda, the Republic of Kazakhstan
4 – M. P. Semenenko Institute of Geochemistry, Mineralogy and Ore Formation of the National Academy of Sciences of Ukraine, Kyiv, Ukraine
5 – NJSC "Naftogaz of Ukraine", Kyiv, Ukraine
* Corresponding author e-mail: abdullinakrg@gmail.com

FEASIBILITY STUDY OF SEISMIC AVO-INVERSION AND SEISMIC INVERSION CAPABILITIES IN CONDITIONS OF ACOUSTICALLY WEAK-CONTRAST RESERVOIRS AND HOST ROCKS

Purpose. To improve the accuracy of lithotype classification and reduce uncertainty in hydrocarbon prospecting predictions under conditions of weak contrast in the elastic properties of reservoirs and the surrounding rock by testing a probabilistic approach to seismic data interpretation.

Methodology. The study applies a technological approach that includes:

1. Constructing probability distribution functions for lithotypes based on lithological trend data from wells.
2. Using inversion to create cubes of elastic properties and their further analysis using Bayes' principle.
3. Lithotype classification based on the probabilistic approach by aligning inversion data with probability distributions.

Findings. High-resolution seismic data processing was carried out successfully, which ensured their high resolution. Elastic property volumes were obtained and used to assess the probability of various lithotypes. The Bayesian approach to lithotype classification was implemented, demonstrating improved interpretation accuracy in conditions of low elastic property contrast. Promising structures were identified, confirming the effectiveness of the proposed approach in complex geological settings.

Originality. A probabilistic method for seismic data analysis was tested, based on the integration of probability distribution functions and inversion data. This methodology allows for accounting for lithological variability and uncertainties during interpretation, representing a novel approach for conditions of low elastic property contrast.

Practical value. The developed methodology can be applied in hydrocarbon exploration and field development when reservoir and host rock physical properties exhibit weak contrast. It helps reduce geological risks, optimize drilling site selection, and enhance the economic efficiency of geological exploration.

Keywords: *hydrocarbon deposit, dynamic interpretation, seismic pre-stack inversion, probability-density functions, reservoir*

Introduction. For the economy of the Republic of Kazakhstan, the current priority is not only the discovery of new oil and gas fields but also maintaining the production levels of hydrocarbon resources. The Caspian Sea remains a particularly important region for oil and gas operations, as experts believe the region currently holds significant untapped potential.

Over the past 30 years, the Caspian region has become one of the largest hubs for significant hydrocarbon reserves, influencing the development prospects of the oil and gas sector and attracting attention from the international scientific community and major oil companies. These companies continue to show significant interest in participating in joint projects and investing in oil and gas ventures in Kazakhstan.

Despite the interest of the state and foreign investors in the Caspian Sea, the region has proven challenging in terms of environmental conditions and resource validation. For instance, previously considered promising structures such as Kurmangazy and Satpayev turned out to be less successful. In October 2019, the NCOC consortium abandoned plans to develop and returned the Kalamkas-Sea field to Kazakhstan, and Shell also announced its withdrawal from the Khazar field development project. These decisions were attributed to the low profitability of the projects. These facts highlight the complexity of geological exploration in the area and the region's limited study level for hydrocarbon deposit identification.

To maintain the region's attractiveness to investors, it is necessary to consider the experience of drilling with negative results. Although the Caspian region, including its Kazakh sector, has a sufficient number of structural targets, the average geological risk is about 20 %. This means that only one out of five structures may be successful, while the other four may be "dry". Thus, geological exploration in the Caspian Sea requires significant investments, and the cost of unsuccessful drilling can reach tens of millions of dollars [1, 2].

Given the high drilling costs in this region, prioritization of structures by geological risk should be based on available geological and geophysical data. This includes utilizing advanced algorithms for seismic data analysis to better assess the potential of each structure.

Initial data and methods. The study area is located in the oil and gas-bearing North Caspian, within Kazakhstan's sector of the Caspian Sea. The initial milestone in studying the area's geology was the establishment of the state enterprise “KazakhstanCaspyShelf” in 1993, later transformed into a consortium. Between 1994 and 1997, the consortium successfully implemented a state program of geophysical surveys on Kazakhstan’s shelf, shooting over 26,000 square kilometers of 2D seismic profiles. A sparse profile network with a density of 16×16 km and 8 × 16 km was used. As a result, structures like Kashagan and Kalamkas-Sea were identified, which were subsequently considered significant hydrocarbon deposits [3–5].

From 2009 to 2015, 2D seismic surveys were conducted in the study area. The purpose of some surveys was to prepare for exploratory drilling on previously identified local structures (1,482.65 linear km), while others aimed to refine the geological structure and detail the most promising structures (additional marine seismic surveys covering 714.3 full-fold kilometers). In 2016, localized areas underwent 3D seismic surveys, covering 606.5 linear kilometers.

As a result, due to several factors, the study area is characterized by relatively low geological and geophysical exploration, particularly in terms of drilling, which does not allow for reliable modeling of geological structures and assessment of oil and gas potential.

In tectonic terms, the study area is located in the southern part of the Pre-Caspian Basin, within the zone of ancient collision between the oceanic crust of the southern East European Plate and the paleo-island arc of the Scythian-Turan Plate, which occurred during the Hercynian orogeny [6, 7]. The investigated region encompasses the junction of the Pre-Caspian Basin and the Karpinsky Ridge, making it particularly interesting in terms of geological structure and hydrocarbon potential (Fig. 1).

According to several researchers, the Karpinsky Ridge is a unique geostructural feature formed at the junction of two platforms of different ages (the East European and Scythian-Turan platforms) and two hydrocarbon-bearing provinces (the Pre-Caspian and North Caucasus-Mangyshlak provinces) [8–10]. To the east of the Karpinsky Ridge lies a similar feature – the Buzachi Arch. While the Karpinsky Ridge is well-studied within the territory of Russia, it remains poorly explored in Kazakhstan.

Geological surveys indicate that the northern Caspian region has a complex geological structure comprising various stratigraphic units formed during different geological epochs. Both marine and continental deposits are present in this area. The geological section of the region features a wide range of deposits spanning from the Paleozoic to the Cenozoic. Hydrocarbon reserves have been confirmed in both Paleozoic and Meso-Cenozoic deposits, highlighting their productivity across different stratigraphic horizons (Fig. 1).

Mesozoic and Cenozoic sediments form the platform cover that overlays Paleozoic and Permian-Triassic rocks. The tectonic features of the platform cover are largely shaped by active salt tectonics, which are particularly prominent along the southern boundary of the Pre-Caspian Basin.

The reservoirs in the studied region include both carbonate-terrigenous Paleozoic deposits and terrigenous Meso-Cenozoic deposits, indicating substantial potential for hydrocarbon exploration and development in this area [11].

The proposed technological approach is aimed at interpreting Meso-Cenozoic deposits, as they are more accessible for drilling. While Paleozoic deposits are also drillable, their economic viability depends on the size of the accumulation rather than the heterogeneity of the section.

The primary tool for lithological analysis of seismic data presented in this study is pre-stack inversion (in the AVO domain), which is based on the contrast in elastic properties between reservoir and non-reservoir rocks, in this case, between sandstones and shales [12]. According to borehole data, the most promising Mesozoic intervals – the Cretaceous and Jurassic – do not always exhibit contrasting elastic properties. Fig. 2 shows the dependency graphs of elastic properties (*P*-wave imped-

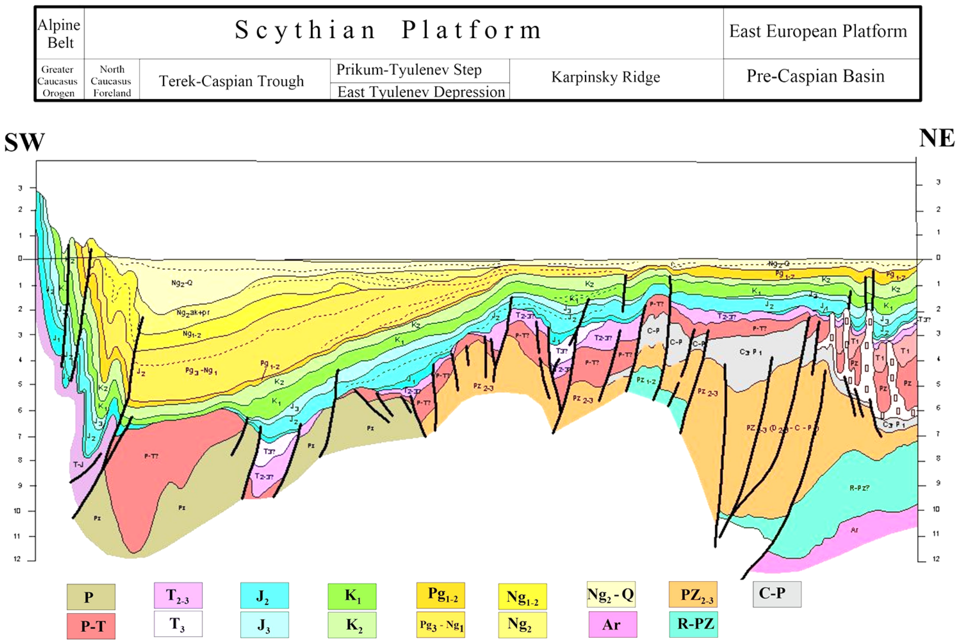

Fig. 1. Geological cross-section of the collision zone between the Scythian-Turan Plate and the East European Plate

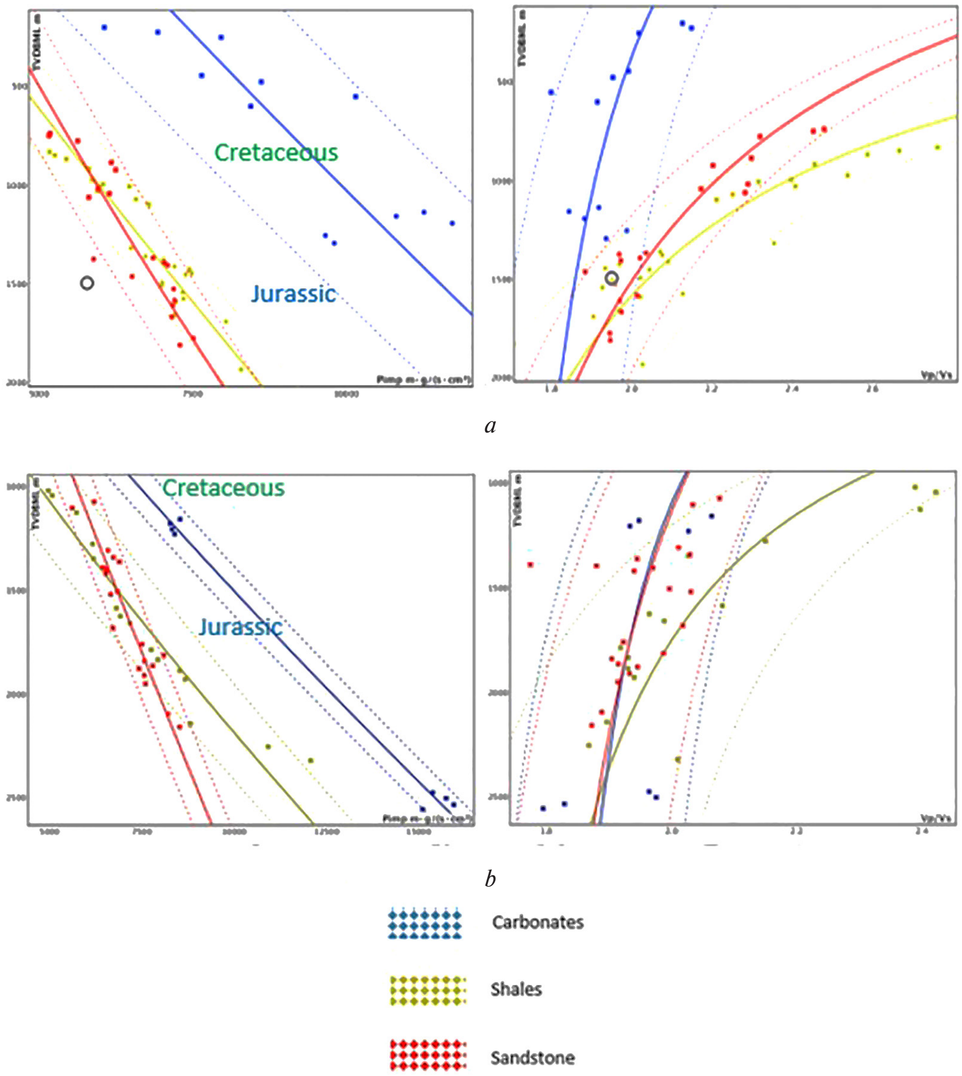

Fig. 2. Statistical distribution of elastic properties in the Mesozoic section:
a – North Caspian (south of Precaspian Basin); b – Mid Caspian (Mangyshlak, Buzachi)

ance and V_p/V_s ratio) for two distant regions: the northern Caspian-southern Pre-Caspian Basin (Fig. 2, *a*) and the central Caspian-Mangyshlak region (Fig. 2, *b*).

The analysis of the graphs indicates either an elevated impedance of Cretaceous sandstones compared to shale impedance or a close range of their values. The Jurassic section also demonstrates significant overlap in impedance. This situation arises in cases of sandstone clayification or the influence of cementation. Conditions of weak contrast between reservoirs and surrounding rocks are widespread across the vast territories and basins of Kazakhstan, posing a challenging factor for lithology evaluation using seismic data.

The article discusses the practical application of a probabilistic approach in the analysis of seismic data and inversion results. High-quality processing is required to obtain seismic data with a broad range of offsets and high resolution [12]. Deterministic inversion was also performed, as this procedure allows predicting the volumetric distribution of various petrophysical parameters of productive formations in interwell space using physically and mathematically sound algorithms.

The probabilistic approach to analyzing seismic data and inversion results involves a comprehensive examination of regional wells to understand the behavior of elastic properties [13].

The authors of the article have previously noted that to achieve high-quality reservoir identification against a low-contrast background of surrounding rocks, seismic data processing must be performed at a high level. This includes achieving 3D data with a high signal-to-noise ratio and maximum horizontal and vertical resolution [14]. The main parameters of field acquisition are presented in Table 1.

The processing flow includes kinematic procedures (such as data quality assessment, geometry assignment, compensation for spherical divergence, velocity analysis, etc.) and dynamic procedures (such as noise suppression, multiple wave suppression, surface-consistent amplitude correction, surface-consistent deconvolution, etc.). A separate stage of the processing flow consists of migration transformations, which were performed in the pre-stack domain.

During the seismic data processing, multiple waves were suppressed, which significantly contributed to enhancing the low-frequency component of the amplitude spectrum of the data.

Table 1

Field seismic acquisition main parameters

I. Pattern parameters		
1	Full fold	168
	Fold in the direction of receiver lines (RL)	14
	Fold in the direction orthogonal to RL	12
2	Bin size, m × m	25 × 25
	Bin size along receiver lines (RL), m	25
	Bin size orthogonal to RL, m	25
3	Number of receiver lines (RL) in the template	6
4	Number of receiver points (RP) per receiver line	168
5	Spacing between receiver points (RP) on RL, m	50
6	Interval between receiver lines, m	300
7	Channel distribution	84–0–84
8	Offset distribution, m	4,175–0–4,175
9	Maximum value of minimum offsets, m	389
10	Maximum “source-receiver” offset, m	6,011

Results. In this study, seismic data were processed using a wide range of modern procedures, both in the time and depth domains. The application of advanced techniques in different sorts allowed for the effective suppression of linear noise as well as low-speed, low-frequency noise observed at shallow depths. Special attention was given to the suppression of multiples to improve the reliability of constructing a depth-velocity model in the subsequent processing stages in the depth domain and refining the structural map on depth sections. As a result of the processing, a conditioned dataset was obtained for structural and dynamic (inversion transformations, AVO analysis, etc.) interpretation. The seismic data demonstrate high resolution, with dynamic reflection horizons clearly defined and well-traced across various structural levels.

To implement the principles of probabilistic interpretation, elastic property cubes were initially obtained based on inversion algorithms.

The probabilistic approach is based on Bayes’ theorem, also known as Bayes’ formula, which is a key theorem in elementary probability theory. Using this approach, one can recalculate the probability of a specific event by considering both prior data and new observations. Bayes’ formula is based on the concept of conditional probability, which represents the probability of one event occurring given that another event has already occurred.

With Bayes’ formula, we can estimate the probability that a particular event was caused by a specific reason. Bayes’ theorem reflects the relationship between the probability of event A and the probability of event B, the conditional probability of event A occurring given event B, and the conditional probability of event B occurring given event A. Suppose the prior probability of an oil-saturated sandstone is 30 %. We also have information that the probability of a good reservoir in the area is 50 %. It is also evident that with 100 % oil-saturated sandstone, the probability of good reservoir properties is 100 %, because an oil-saturated reservoir without good reservoir properties does not exist.

In the given example, the Bayesian approach is as follows: $P(A)$ = probability of oil-saturated reservoir = 30 %; $P(B)$ = probability of reservoir = 50 %; $P(B|A)$ = probability of a reservoir given oil-saturated sandstone = 100 %.

If drilling results show a reservoir with good elastic properties, it is necessary to update the probability of oil-saturated sandstone. The formula used to solve this task is

$$P(A \mid B) = P(A) \cdot P(B \mid A)/P(B),$$

where the updated probability of oil-saturated sandstone is the initial probability of oil-saturated sandstone multiplied by the probability of a good reservoir given

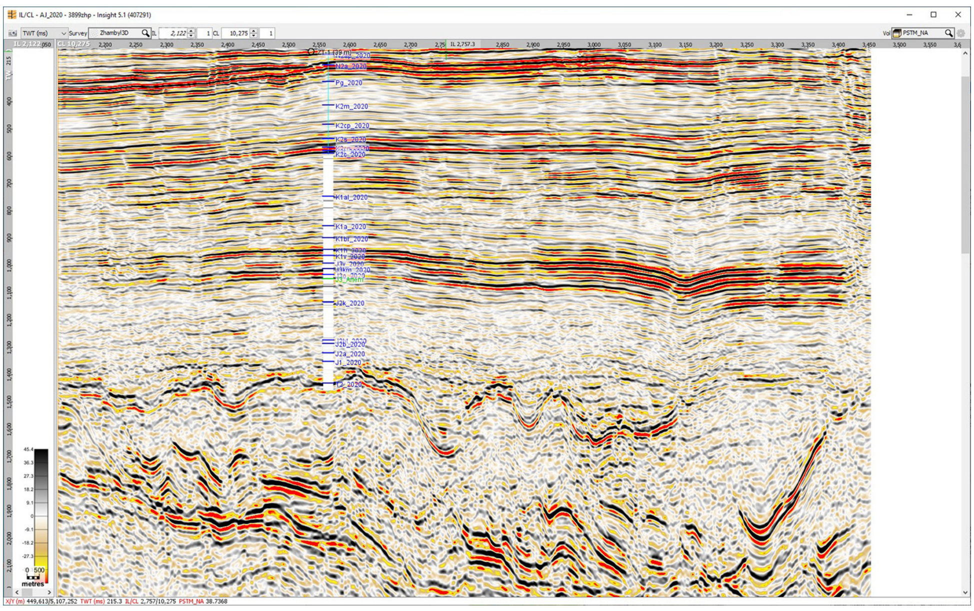

Fig. 3. Example of seismic data

oil-saturated sandstone, divided by the probability of a good reservoir. That is, %

$$(30 \cdot 100) \div 50 = 60.$$

Ultimately, considering the presence of a competent reservoir, the probability of encountering oil-saturated sandstone is 60 %.

Discussion. Bayes' principle in the interpretation of seismic inversion results, it is necessary to construct probability distribution functions for each lithotype based on well log lithological trends (Figs. 2, 4). These functions depend on three key parameters: depth, longitudinal impedance, and the ratio of longitudinal and shear wave velocities (V_p/V_s). Depth determines the position of the trend, the central value of the trend characterizes the main range of values, and twice the standard deviation reflects the spread of values around the central trend. This approach allows for accounting for variations in the elastic properties of reservoirs and host rocks depending on depth, which is particularly important for interpreting complex geological structures [13].

After constructing the probability distribution functions, the values obtained from seismic data inversion

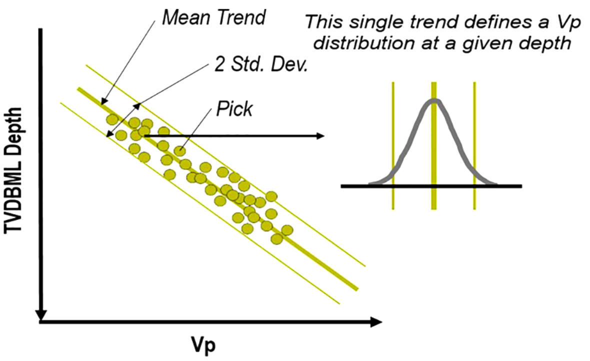

Fig. 4. The principle of transforming depth lithological trends into probability distribution functions

are compared with the probabilistic distributions for the corresponding depth [15–17]. For example, in Fig. 4, the process of classifying a single inversion value for a depth of 900 meters is shown. The distance from the actual inversion value to the center of each class on the distribution function determines the probability that this value corresponds to a specific lithotype. In this example, the inversion value is closest to the water-saturated sandstone, giving it the highest probability (55 %), followed by clay (40 %), with the remaining 5 % distributed among other lithotypes.

This classification scheme, although presented in a simplified form, requires the use of several parameters in practice to improve accuracy. In addition to impedance, the V_p/V_s ratio plays an important role, as well as depth, which is taken into account when constructing probability distributions. Thus, the three-dimensional array of inversion results, including cubes of longitudinal impedance and V_p/V_s ratios, is transformed into probabilistic values for lithotype classes.

This approach not only allows for the classification of rock types considering uncertainty but also enables a more accurate interpretation of seismic data, especially in conditions of weak contrast in elastic properties [18]. The use of Bayes' principle in interpreting inversion results helps improve the quality of predictions and reduce risks when drilling exploration wells.

Conclusion. The application of the probabilistic approach to interpreting seismic data in conditions of weak contrast in the elastic properties of reservoirs and host rocks is a key step toward improving the accuracy of lithotype classification. This method accounts for interpretation uncertainties, reducing the risk of incorrect conclusions and errors in evaluating geological characteristics. An important part of this approach is the construction of probability distribution functions based on well log lithological trends. These functions help more accurately describe the probabilistic distribution of lithotypes, based on data obtained from seismic inversion.

The principles of the Bayesian approach to interpreting seismic inversion results have been success-

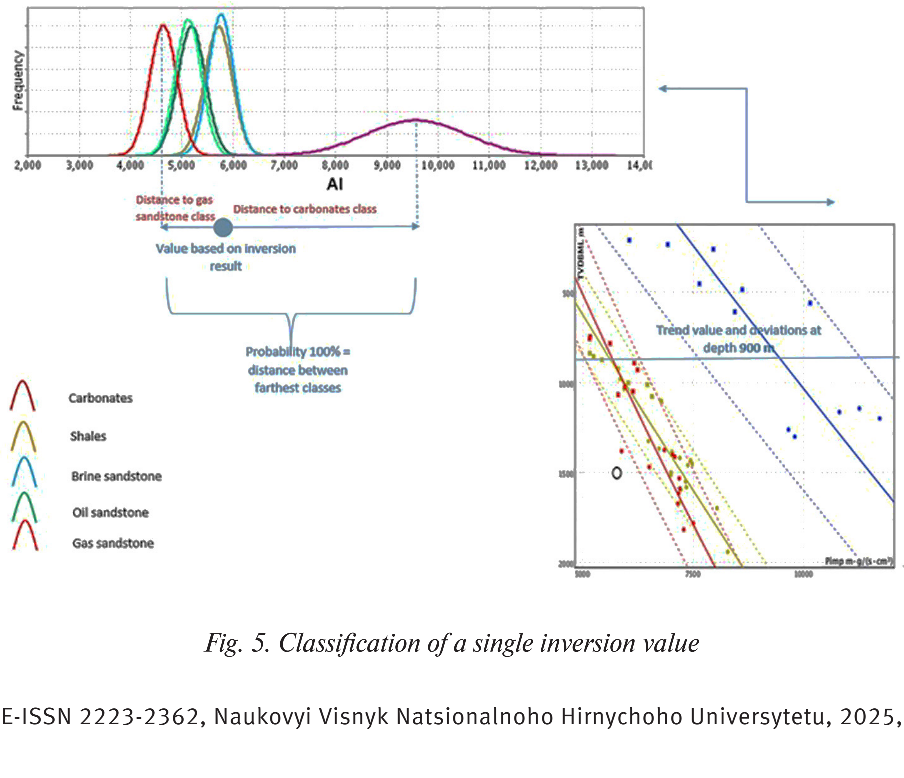

Fig. 5. Classification of a single inversion value

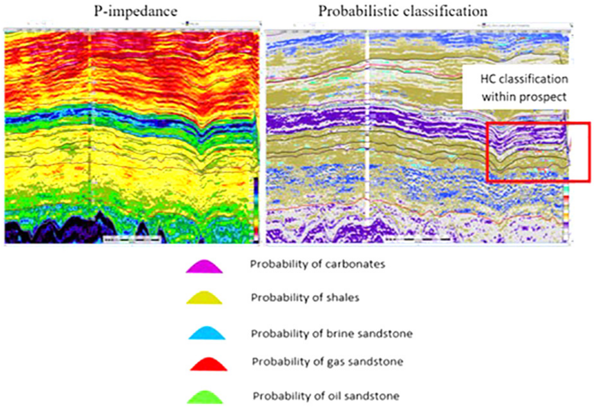

Fig. 6. Classification of seismic data

fully applied in the work by M. G. Lamont and co-authors [13], where a technological flow for identifying gas sandstones is presented. In their paper, M. G. Lamont and colleagues emphasized that the goal of quantitative interpretation is to predict lithology and fluid saturation in the inter-well space. This process should rely on all available data, rather than considering well and seismic data separately. The various geological data play a crucial role in selecting informative seismic attributes and obtaining reliable inversions. Throughout all stages of the analysis, uncertainty must be taken into account in order to assess risks and increase confidence in the resulting predictions. The use of a probabilistic approach allows for the inclusion of all relevant data, such as geological model features, into a probabilistic forecast that accounts for uncertainty and quantitatively evaluates risk. The work by M. G. Lamont and co-authors was conducted for the Mungaru formation, which is one of the main exploration targets in the Carnarvon Basin on the shelf of Western Australia. The success of this study lies in the identification of new gas-bearing sandstones based on the probabilistic approach. It is important to note that gas saturating sandstones often forms an acoustically contrasting environment, which significantly simplifies the interpretation task. However, in this study, the main focus is on weakly contrasting boundaries, which increases uncertainties in data interpretation compared to the results presented in the study by M. G. Lamont, et al. [13].

The seismic section shown in Fig. 3 primarily reflects the structural features of the studied region. Two structures are identified on the section, one of which has been studied through drilling. The article analyzes the possibility of using data from this well to extrapolate to the neighboring structure or adjacent area. The goal is to assess the probability of reservoir presence, and ideally, to determine fluid saturation.

Seismic inversion results typically do not provide a definitive answer, but the use of probabilistic classification of inversion products allows for an assessment of the likelihood of detecting various lithotypes and their saturation. If, based on the seismic section data, the presence of a second structure is confirmed in addition to the already studied structure, the analysis of the elastic properties of rocks, conducted based on the available well data, reveals probabilistic dependencies between lithological characteristics, fluid saturation, and inversion results.

The conclusions obtained for the new structure indicate that, in addition to the positive structural factor, it is characterized by favorable elastic properties, suggesting the likelihood of a reservoir. Furthermore, the probabilistic interpretation demonstrates potential hydrocarbon saturation in the form of oil and gas (Fig. 3).

The proposed approach is particularly important when analyzing series of geological objects formed by anticline traps, where a decision must be made regarding the priority of drilling structures. In the case of a series of anticlines, the considered structure is distinguished by lower risks due to a combination of positive factors: favorable elastic properties identified during inversion and the results of probabilistic interpretation. This makes it more promising for further exploration and development of hydrocarbon fields, significantly increasing the reliability of seismic data.

Like any method of quantitative interpretation, the presented approach is based on a number of key factors that determine its effectiveness and reliability. First and foremost, it depends on the quality and completeness of the initial data. This includes the availability of high-resolution well logs, their accurate and comprehensive petrophysical interpretation, as well as proper integration with lithological and fluid characteristics. The quality of field seismic data acquisition also plays a significant role – the choice of optimal acquisition parameters (resolution, frequency range, and the geometry of source and receiver placement) directly impacts the final result. Equally important is the quality of subsequent seismic data processing, which should preserve amplitude, phase, and frequency composition, ensuring precise correlation between seismic responses and geological features.

Alongside this, the elastic properties of rocks themselves are of crucial importance – specifically, the degree of physical contrast between different lithotypes and fluid-saturated zones. The greater the difference in elastic parameters (V_p, V_s, density), the more reliably they can be differentiated using seismic methods.

A key aspect of modern quantitative interpretation approaches is accounting for depth trends in the variation of rock physical properties. Incorporating information about trends with depth not only improves the prediction of saturation and lithology but also significantly reduces the uncertainty of results. This is especially important when analyzing poorly studied intervals where direct well data are absent.

The use of statistical methods for studying elastic properties, including stochastic modeling and Bayesian approaches, broadens forecasting capabilities. Such methods allow for the consideration of parameter variability within the studied area and the prediction of reservoir properties that have not yet been encountered through drilling. This applies both to deeper formations and intervals that differ in porosity and fluid saturation from those already observed in wells. Therefore, quantitative interpretation involving depth trends and statistical estimates becomes a powerful tool for assessing geological uncertainty and making informed decisions during drilling.

However, the quantitative use of depth trends in seismic data interpretation significantly increases their predictive value and narrows the uncertainty of results. Studying elastic properties of rocks using statistical methods enables the inclusion of the potential to predict parameters not yet determined by deep drilling, as well as the expected variability of physical parameters. This concerns both deeper formations and rocks that differ in porosity and fluid saturation from those encountered so far in wells.

The practical application of the probabilistic seismic data analysis and inversion methodology is especially important when evaluating reservoirs in conditions of low contrast in elastic properties. In such situations, traditional approaches may yield less accurate results, while probabilistic analysis provides more accurate forecasts of reservoir distribution and their characteristics. This approach is a valuable tool for the exploration and development of oil and gas fields, increasing the likelihood of successful drilling and optimizing mineral resource exploration processes. Future research may focus on improving probabilistic classification models and adapting them to various geological conditions, with the presented interpretation technology being adaptable to other oil and gas fields.

References.

1. Bekeshova, Z., Ratov, B., Sudakov, A., Kozhakhmet, K., & Sudakova, D. (2024). Assessment of the oil and gas potential of the eastern edge of the northern Ustyurt using new geophysical data. *Naukovyi Visnyk Natsionalnoho Hirnychoho Universytetu*, (5), 5-11. https://doi.org/10.33271/nvngu/2024-5/005

2. Fedorov, B., Ratov, B., & Sharauova, A. (2017). Development of the model of petroleum well boreability with PDC bore bits for Uzen oil field (the Republic of Kazakhstan). *Eastern-European Journal of Enterprise Technologies, 3*(1(87)), 16-22. https://doi.org/10.15587/1729-4061.2017.99032

3. Nuranbayeva, B. (2024). The techno-economic justification of the effectiveness of developing the Kashagan oil field in the Caspian Sea shelf using the shaft-well method. *Vestnik KazUTB, 2*, 23. https://doi.org/10.58805/kazutb.v.2.23-431

4. Nugmanov, B. H., Eminov, A. Sh., & Ragimov, F. V. (2017). Sensitivity analysis and assessment of geological risks while estimation of reserves of the Kalamkas field. *SOCAR Proceedings, 3*, 4-8. https://doi.org/10.5510/OGP20170300318

5. Karamurzaeva, A. B. (2011). Clarification of the geological structure of lower cretaceous deposits in the eastern part of the "Kalamkas" deposit. *SOCAR Proceedings, 4*, 25-31. https://doi.org/10.5510/OGP20110400089

6. Volozh, Yu. A., Antipov, M. P., Brunet, M.-F., Garagash, I. A., Lobkovskii, L. I., & Cadet, J.-P. (2003). Pre-Mesozoic geodynamics of the Precaspasian Basin (Kazakhstan). *Sedimentary Geology, 156*(1-4), 35-58. https://doi.org/10.1016/S0037-0738(02)00281-6

7. Abilkhassimov, Kh. (2020). Oil and gas potential of paleozoic deposits of the eastern flank of the Caspian basin. *Kazakhstan journal for oil & gas industry, 2*, 3-13. https://doi.org/10.54859/kjogi95615

8. Krashakova, A. V., Ostroukhov, S. B., & Bochkarev, A. V. (2013). The role of the Karpinsky Ridge in the formation of hydrocarbon deposits in the Caspian Sea. European Association of Geoscientists & Engineers. *Geomodel 2013 – 15th EAGE science and applied research conference on oil and gas geological exploration and development*. https://doi.org/10.3997/2214-4609.20131503

9. Taskinbaev, K. M. (2022). Geodynamics of the junction zone of plates of different ages in western Kazakhstan and adjacent territories. *Oil and gas, 1*(127), 46-58. https://doi.org/10.37878/2708-0080/2022-1.03

10. Zholtaev, G. Zh. (2018).Theoretical framework of hydrocarbon potential assessment in Palaeozoic sedimentary basins of Kazakhstan. *News the national academy of sciences of the Republic of Kazakhstan. Series of geology and technical sciences, 2*(428), 185-193.

11. Iskaziyev, K. O., Syngaevskyi, P. E., & Khafizov, S. F. (2020). Ultra-deep oil: comparison of oil and gas bearing basins and prospects for exploration for ultra-deep deposits (Sichuan, Tarim, Permian, Canning and Precaspian basins). *Kazakhstan journal for oil and gas industry, 4*(5), 3-19.

12. Avseth, P., Mukerji, T., & Mavko, G. (2005). *Quantitative Seismic Interpretation: applying rock physics tools to reduce interpretation risk*. Cambridge University Press. https://doi.org/10.1017/CBO9780511600074

13. Lamont, M. G., Thompson, T. A., & Bevilacqua, C. (2008). Drilling success as a result of probabilistic lithology and fluid prediction – A case study in the Carnarvon Basin, WA. *APPEA Journal, 48*(1), 31-42. https://doi.org/10.1071/AJ07004

14. Litavrin, I., Danko, D., Svetlichniy, A., Jangirov, A., Shestakov, A., & Iskaziev, K. (2020). Compensation Methodology of Upper-Layer Anomalies Related to the Surface Relief on the Dynamic Characteristics of Seismic Data. *European Association of Geoscientists & Engineers*, 1-5. https://doi.org/10.3997/2214-4609.202053243

15. Jangirov, A. (2010). Probabilistic Rock Physics – A Step Forward in Seismic Reservoir Characterization, An Example from the Precaspian Basin. *European Association of Geoscientists & Engineers, 1st EAGE International Geosciences Conference on Kazakhstan*. https://doi.org/10.3997/2214-4609.20145726

16. Jangirov, A. (2012). From Rock Physics Study through Inversion to Seismic Litho/fluid Prediction – A Case Study from Precaspian Basin. *European Association of Geoscientists & Engineers*. https://doi.org/10.3997/2214-4609.20143612

17. Jangirov, A., Balabekov, Y., Busk, H., & Kudaikulov, K. (2011). Probabilistic Approach in Seismic Reservoir Characterization – Case Studies from Pre-Caspian Basin. European Association of Geoscientists & Engineers. Atyrau 2011. *First EAGE Caspian Region Workshop*. https://doi.org/10.3997/2214-4609.20144359

18. Shikeruk, K., Jangirov, A., & Shestakov, A. (2012). Review of Modern Methods of Prestack Seismic Data Analysis. *European Association of Geoscientists & Engineers. 2nd EAGE International Conference KazGeo*. https://doi.org/10.3997/2214-4609.20142900

Вивчення можливостей AVO-аналізу та сейсмічної інверсії в умовах акустично неконтрастних колекторів і вміщувального середовища

А. Н. Джангіров[1], *Г. К. Умірова*[2], *А. К. Абдулліна*[*3], *І. О. Карпенко*[4,5]

1 – ТОО «Professional Geo Solutions Kazakhstan», м. Алмати, Республіка Казахстан

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

3 – Карагандинський технічний університет імені Абилкаса Сагінова, м. Караганда, Республіка Казахстан

4 – Інститут геохімії, мінералогії та рудоутворення імені М. П. Семененка НАН України, м. Київ, Україна

5 – НАК «Нафтогаз України», м. Київ, Україна

[*] Автор-кореспондент e-mail: abdullinakrg@gmail.com

Мета. Підвищення точності класифікації літотипів і зниження невизначеності прогнозів нафтогазоносності в умовах слабкого контрасту пружних властивостей колекторів і вміщувальної породи на основі апробації ймовірнісного підходу до інтерпретації сейсмічних даних.

Методика. У роботі застосовано технологічний підхід, що включає:

1. Побудову функцій розподілу ймовірностей для літотипів на основі даних про літологічні тренди свердловин.

2. Використання інверсії для створення кубів пружних властивостей і їх подальшого аналізу за допомогою принципу Байєса.

3. Класифікацію літотипів за ймовірнісним підходом на основі узгодження даних інверсії з розподілами ймовірностей.

Результати. Виконана якісна обробка сейсмічних даних, що забезпечила їх високу роздільну здатність. Отримані куби пружних властивостей, використані для оцінки ймовірності наявності різних літотипів. Реалізовано байєсівський підхід до класифікації літотипів, що продемонстрував підвищення точності інтерпретації в умовах низького контрасту пружних властивостей. Виявлена перспективність ряду структур, що підтверджує ефективність запропонованого підходу до розробки родовищ вуглеводнів у складних геологічних умовах.

Наукова новизна. Апробовано ймовірнісний метод аналізу сейсмічних даних, заснований на поєднанні функцій розподілу ймовірностей і даних інверсії. Методика дозволяє врахувати варіативність літологічних характеристик і невизначеності під час інтерпретації, що є сучасним підходом для умов слабкого контрасту пружних властивостей порід.

Практична значимість. Розроблена методика може бути використана при розвідці й розробці родовищ вуглеводнів за умов слабкого контрасту фізичних властивостей колекторів і вміщувальної породи. Вона дозволяє знижувати геологічні ризики, оптимізувати вибір ділянок для буріння й підвищувати економічну ефективність геологорозвідувальних робіт.

Ключові слова: *родовища вуглеводнів, динамічна інтерпретація, сейсмічна інверсія, функції розподілу ймовірності, колектор*

The manuscript was submitted 29.01.25.