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OIL DEPOSITS IN THE FIELD OF TURKMENISTAN: INDUSTRIAL EVALUATION BY STATISTICAL METHOD

AUTHORS:
A. Deryaev[1,*]

AFFILIATIONS:
[1]Department of Well Drilling, Scientific Research Institute of Natural Gas of the State Concern "Turkmengas", Ashgabat, Turkmenistan

***CORRESPONDING AUTHOR:**
Email: annagulyderyaev@gmail.com

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Abstract

The purpose of this study is to analyse and evalute the effectiveness of the statistical method in estimating oil reserves on the example of a field in Turkmenistan. Various methods such as analytical, statistical, correlation tables, moving average, calculation were used to arrive at the conclusion. Residual oil reserves were estimated taking into account different types of wells and cumulative production, which provided a more complete picture of the field's potential. The results of the study showed that the use of statistical method for estimating oil reserves in the Goturdepe field in Turkmenistan is of high importance for effective production management. The analysis of well production data and the application of statistical methods allowed the identification of important trends and patterns in oil production, which is a key step for optimizing the field development process. One of the key findings of the study is the need to account not only for current production, but also to forecast future production. This helps to optimize the field development process and make informed decisions about further investment. Within the framework of this study, it was noted that, given the complex geology of the region, the use of statistical methods is critical to ensure the accuracy and reliability of reserve estimates. This approach allows for the consideration of many factors, including variations in production and geological features, providing more accurate estimation results and informed decision-making in the management of oil production in Turkmenistan. The results of the study confirm the effectiveness of the statistical method for estimating oil reserves in the Goturdepe field, which contributes to effective production management and also allows optimization of the field development process, helping to improve the efficiency and reliability of production in the region.

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1.0 INTRODUCTION

Turkmenistan's oil industry is vital to its economy, generating significant revenue. Accurate reserve estimates are essential for efficient field exploitation, especially given the complex geology and rock diversity in Turkmenistan. Reliable reserve assessments are crucial for informed production and development decisions. Inaccurate estimates can lead to inefficient resource use, missed opportunities, and economic losses. Thus, there is a need for estimation methods that consider Turkmenistan's specific geological conditions to improve reserve accuracy. Research into oil and gas reserve estimation methods can address limitations in current approaches, which often overlook geological complexities. Turkmenistan, like many other regions with significant hydrocarbon reserves, faces challenges associated with the availability of large areas for drilling rigs. The region is characterised by desert terrain and harsh climatic conditions, which may limit the availability and suitability of certain areas for drilling operations [1; 2]. Western Turkmenistan has limited access to large areas suitable for drilling rigs, which may pose challenges to the development and expansion of the oil and gas industry.

Previous studies have emphasised the importance of considering geological structures in estimating hydrocarbon reserves. For example, T. Muter et al. [3] and C. Zou et al. [4] have shown that structural features such as anticlinal folds and reservoir permeability significantly affect hydrocarbon distribution and recoverability. These findings are particularly relevant to the Goturdepe field, where the complexity of the geological structure requires a detailed understanding of subsurface conditions to ensure accurate reserve estimates. The work of J. Li et al. [5] also show that fields with certain geological structures usually have higher reserves and more efficient extraction methods. J. Boak and R. Kleinberg [6] emphasised the impact of innovations such as hydraulic fracturing and horizontal drilling on production efficiency. This is directly applicable to the Goturdepe field, where conventional drilling methods may not be able to cope with the unique challenges of the region. Integrating modern drilling techniques could potentially increase resource recovery and extend the life of the field. Q. Lei et al. [7] and H. Mahmoud et al. [8] also confirm the need for innovation in the oil and gas industry in conducting reserve estimation to achieve more accurate and relevant results. The use of modern techniques becomes essential to achieve competitiveness and sustainable development of the oil industry.

Various methods are widely used for industrial assessment of oil reserves [9; 10]. Thus, the studies of A. Sircar et al. [11] and Z. Caili et al. [12] included statistical methods to identify patterns in production, as well as geological modelling to assess the structural distribution of reserves in the deposits. Engineering modelling to analyse well production parameters was carried out in the works of X. Ma et al. [13] and C. Sun et al. [14]. The results of the studies showed that the use of different methods and their complex analysis contribute to a more accurate and reliable assessment of oil reserves, taking into account many variables. The purpose of this study is to carry out an industrial evaluation of oil reserves in the field of Turkmenistan using the statistical method. The main objectives of the study were to determine the volume of recoverable oil reserves on the example of a specific field, as well as to identify patterns and trends in the process of its exploitation.

2.0 MATERIALS AND METHODS

A study on commercial oil reserve estimation using the statistical method was carried out in the Goturdepe field in Turkmenistan. The study involved a comprehensive analysis of well production data, focused on identifying relationships between previous and subsequent production rates. This involved the use of correlation tables, in which the production rates of each well were separated and characterized by a series of interval distributions. A moving average was used to smooth the data, which was calculated based on consecutive values of ordinates. In order to simplify subsequent calculations, similar decline rates were combined into three intervals, for each of which the average flow rate of the pre-calculation month was calculated. To determine recoverable oil reserves, the sum of flow rates was calculated.

When justifying the oil recovery factors of the Goturdepe field deposits, it was decided to consider three main options. In the first case, only old wells in operation at the time of the study were considered. In the second case, both old and re-entry wells were considered, and in the third case, old, re-entry and new (design) wells were considered. This made it possible to take into account different field development scenarios and provide a more complete picture of the field's potential. Residual recoverable reserves attributable to return wells and new wells were determined using the same decline rates as for the main wells. This provided a uniform method of analysis and evaluation for all well types, allowing comparison of their performance and contribution to total recoverable reserves. Then, a graph of the behaviour of the average flow rate of one well by year was plotted. Then, the flow rates of new wells that were put into operation in different years were plotted on the same graph. Further, the degree of excess of new wells' flow rates over the average flow rate of the object and changes in this ratio over time were assessed. The data obtained on the ratio of new well production rates at various dates served as a basis for analysing and forecasting their efficiency.

In order to determine the remaining recoverable oil reserves for the existing return wells and new wells, oil reserves were calculated for each well, taking into account their production activities. These values were then summed for all the re-entry and new wells to give the total remaining recoverable oil reserves. Cumulative oil production was then added to this total to determine the initial recoverable oil reserves of the field. This took into account both current oil production and the potential reserves that could be recovered from existing and new wells in the future.

3.0 RESULTS

The statistical method of oil reserves estimation is a comprehensive approach based on a thorough analysis of well flow data. It is based on the study and processing of information on the dynamics of flow rates, which makes it possible to identify patterns and the nature of the relationship between previous and subsequent flow rates. This relationship is established with the help of correlation tables, which allow predicting future flow rates on the basis of available data [15-17]. One of the key aspects of the statistical method is the extrapolation of data to the final conditions of the reservoir development. This means that a model is built from the available flow rate data to predict oil flow rates under different field conditions. In estimating the ultimate recovery of reservoirs, the value of the ultimate oil flow rate is calculated using the formula (1):

$$\rho_f = \frac{3_f + 3_b + 3_{e.}Q_l + 3_{l.}Q + 3_{c.}Q_l + 3_{ot.}Q_l}{365P_c} \quad (1)$$

Where, ρ_f – is the ultimate flow rate of the well, tonnes per day; 3_f – well equipment maintenance and operation costs, manat/sq.m./sq.year; 3_b – basic, additional wages and social insurance contributions, manat./sq.yr; 3_e – energy costs spent on liquid extraction, manat./t; 3_l – expenditures on artificial impact on the reservoir, manat./tм^3 water; 3_c – oil gathering and transportation costs, manat./t of liquid; 3_{ot} – expenses for technical treatment of oil, manat./t of liquid; Q_l – annual liquid production per one well, tonnes; P_c – wholesale (closing) enterprise (or world) price for oil or marginal cost of oil production from marginal wells, manat/t.

The key step in the estimation of oil reserves by statistical analysis is the determination of annual fluid production per well [18-20]. It is important to take into account that this estimate is based on the final water cut of the deposit, which in this case (2) is 97%:

$$Q_l = \frac{365qk}{1-0.97} = 33.3 * 365qk \quad (2)$$

The water cut, which is the ratio of water to oil, plays a significant role in determining production. For each volume of oil produced, a significant amount of water is required, which in turn requires the application of appropriate technologies for its treatment and utilization [21; 22]. The results of calculations based on Equations (1) and (2) made it possible to determine the value of the ultimate flow rate of one well at Goturdepe field. The results obtained were 0.68 tonnes per day, 0.66 tonnes per day and 1.23 tonnes per day, respectively. These values reflect the maximum possible oil production that can be achieved by each well in the field under certain operating conditions. However, it should be noted that these figures are affected by many factors, such as geological features of the reservoir, well specifications and production methods. The process of determining recoverable oil reserves using the statistical method is then examined in detail using specific well data. To begin with, the data on the production rates of each well are systematized into a correlation table, which reflects the relationship between the values of one variable depending on the intervals of another variable (Tables 1 and 2).

Table 1: First correlation table

Follow-up (ℓgy)			2.65	2.45	2.25	2.05	1.85	1.65	1.45	1.25	1.05
Flow rate (ℓgy_i)			2.75	2.65	2.35	2.15	1.95	1.75	1.55	1.35	1.15
Previous (ℓgy_{i-1})			-2.55	-2.35	-2.15	-2.95	-1.75	-1.55	-1.35	-1.15	-0.95
Debit (y_i:y_{i-1})			562	2-354	7-223	8-141	2-89	0-56.1-	35.4-	22.3-	14
ℓgx	**$\ell gx_i\ell gx_{i-1}$**	**x_i:x_{i-1}**	-354	8-223	9-141	3-89	1-56	2-35.5	-22.4	-14.1	-8.9
2.65	2.75-2.55	562.2-354.8	22	4							
2.45	2.55-2.35	354.7-223.9	4	22	14						
2.25	2.35-2.15	223.8-141.3		7	52	28	2				
2.05	2.15-1.95	141.2-89.1			16	105	35	1			
1.85	1.95-1.75	89-56.2			1	23	63	24			
1.65	1.75-1.55	56.1-35.5				2	11	30	15	1	
1.45	1.55-1.35	35.4-22.4						5	17	9	2
1.25	1.35-1.13	22.3-14.1							6	16	4
1.05	1.15-0.95	14-8.9								3	4
0.85	0.95-0.75	8.8-5.6									2
0.65	0.75-0.55	5.5-3.5									
0.45	0.55-0.35	3.4-2.2									
0.25	0.35-0.15	2.1-1.4									
0.05	0.15-(-0.05)	1.3-0.9									

Source: developed by the author

Table 2: Second correlation table

Follow-up (ℓgy)		0.85	0.65	0.45	0.25	0.05	Ni	Σ ni yi	Y	Monthly flow rate decline rates		
Flow rate (ℓgy_i)		0.95	0.75	0.55	0.35	0.15	F.					
Previous (ℓgy_{i-1})		-0.75	-0.55	-0.35	-0.15	-0.05						
Debit (y_i:y_{i-1})		8.8-	5.5-	3.4-	2.1-	1.3-				**In log.**	**Smoothed**	**In numbers**
ℓgx	ℓgx_i: ℓgx_{i-1}	x_i:x_{i-1}	-5.6	-3.5	-2.2	-1.4	-0.9					
2.65	2.75-2.55	562.2-354.8						26	68.7			
2.45	2.55-2.35	354.7-223.9						40	96			
2.25	2.35-2.15	223.8-141.3						89	195.25	2.1938-0.0562-0.0324		0.9281
2.05	2.15-1.95	141.2-89.1						157	317.65	2.0232-0.0266-0.0276		0.9384
1.85	1.95-1.75	89-56.2						111	205.55	1.8518-0.0018-0.0273		0.9391
1.65	1.75-1.55	56.1-35.5						59	96.95	1.6432-0.0068-0.0129		0.9453
1.45	1.55-1.35	35.4-22.4						33	46.25	1.4015-0.0485-0.0032		0.9927
1.25	1.35-1.13	22.3-14.1						26	32.9	1.2654-0.0154-0.0082		0.9813
1.05	1.15-0.95	14-8.9	2					9	9.65	1.0722-0.0222-0.0024		0.9945
0.85	0.95-0.75	8.8-5.6	11	4				17	14.05	0.8265-0.0235-0.0327		0.9275
0.65	0.75-0.55	5.5-3.5	4	3	1	1		9	6.05	0.6722-0.0222-0.0252		0.9436
0.45	0.55-0.35	3.4-2.2			1	5	1	7	1.75	0.2500-	0.2	
0.25	0.35-0.15	2.1-1.4			1	2	12	15	1.55	0.1033	0.0533	
0.05	0.15-(-0.05)	1.3-0.9										

Note: F – frequency.
Source: developed by the author.

Table 3: Table of average debits of the pre-settlement month

Group number by flow rate intervals	Intervals of average daily flow rates, tonnes/day	Number of wells in operation as of the calculation date	Average daily flow rate of one well, tonnes/day	Monthly flow rate decline rate
1	562.2-70.8	29	159.9	0.9382
2	70.7-44.7	10	58.5	0.9453
3	44.6-0.9	30	19.1	0.9875
Average daily flow rate per well for the entire facility			88.9	

Source: developed by the author.

Next, the arithmetic mean of the subsequent flow rates, the monthly decline rate in logarithms and its smoothed versions in both logarithms and numbers are calculated. The monthly flow rate decline factor is defined as the ratio of the average monthly flow rate for the subsequent period to the average monthly flow rate for the previous period [23]. The moving average method is used to smooth the dynamics of oil production. In this case, each new value is added to the eight previous values and then the result is divided by 9 [24].

After smoothing, the antilogarithms of the obtained average values are calculated. The antilogarithm is necessary to return to the original absolute flow rate values. Then, based on these values, monthly coefficients are calculated in numbers, which represent the ratio of the average flow rate of the current month to the average flow rate of the previous month. For further analysis and to simplify subsequent calculations, similar flow rates are combined into three intervals. In each of these intervals, the average flow rate of the pre-calculation month is calculated to establish the overall production trend over a period of time (Table 3).

An important stage in assessing the potential of a field and planning its further development is also the calculation of recoverable oil reserves. It is necessary to take into account both current well flow rates and their dynamics of change over time, which are presented in Equation (3):

$$Q = 30_n R_e \sum S \quad (3)$$

Where, Q – residual oil reserves; 30 – number of days in a month; n – number of wells; R_e – exploitation coefficient; S – sum of monthly average daily flow rates for one well.

The sum of monthly average daily flow rates for a single well is an important indicator that reflects the overall production dynamics over a certain time interval [25; 26]. This indicator is calculated by expression (4):

$$S = \frac{q_1 - q_n R}{1 - R} - q_1 \quad (4)$$

Where, q_1 – input flow rate (at the beginning of calculations average daily flow rate of one well), tonnes per day; q_n – minimum flow rate of the interval, tonnes per day; R – decline coefficient.

This formula allows taking into account the dynamics of oil production changes over time and obtaining the total value of production for the entire period of well operation. Such an assessment allows determining more accurately the potential of the field and making informed decisions on its development and exploitation [27]. Then for the first group of 29 wells

– for the first, the second and the third interval of flow rates accordingly:

$$S_1' = \frac{159.9-70.8*0.9382}{1-0.9382} - 159.9 = 1352.6\ \text{t},$$
$$S_2' = \frac{70.7-44.7*0.9453}{1-0.9453} - 70.7 = 449.3\ \text{t},$$
$$S_3' = \frac{44.6-0.66*0.9875}{1-0.9875} - 44.6 = 3471.4\ \text{t}.$$

Next, the residual reserves of the wells are determined. This makes it possible to estimate how much oil can be produced from wells after they have already worked for a certain time [28; 29]. In this case, the statistical method is used to analyse and predict production on the basis of available data and to establish general patterns in its dynamics. Thus, the residual reserves will be:

$$Q_1 = 30.29 * 0.976\,(1352.6 + 449.3 + 3471.4) = 4477664\ \text{t}.$$

The sum of monthly average daily flow rates for the next group of 10 wells and their remaining reserves is determined in the same way:

$$S_2'' = \frac{58.5-44.7*0.9453}{1-0.9453} - 58.5 = 238.6\ \text{t},$$
$$S_3'' = \frac{44.6-0.66*0.9875}{1-0.9875} - 44.6 = 3471.4\ \text{t},$$
$$Q_2 = 30.1 * 0.976(238.6 + 3471.4) = 1086288\ \text{t},$$

as well as for the third group of wells:

$$S_3''' = \frac{19.1-0.66*0.9875}{1-0.9875} - 19.1 = 1456.9\ \text{t},$$

Thus, total remaining recoverable oil reserves for the entire production fund will be as follows:

$$Q_{1^1} = Q_1 + Q_2 + Q_3 = 6843693\ \text{t}.$$

When justifying oil recovery factors, different development scenarios must be considered. For fields with established core stocks, the approach differs from that used for new fields [30-32]. A suboptimal calculation method for new reservoirs may be unproductive for long-term fields. Thus, in Southwest Turkmenistan, the statistical method is used to justify recovery factors under three development scenarios: 1 – Old wells only: Estimates production potential using only existing wells. 2 – Old and return wells: Includes previously shut-in or suspended wells, estimating production potential with reactivated wells. 3 – Old, Return, And New Wells: Considers all wells, including future projects, providing a comprehensive view of the field's potential and optimizing development strategies. Decline rates [33-35] are used to predict future production changes based on production dynamics. Aggregating well flow rates into intervals simplifies analysis and enhances the accuracy of predicting remaining recoverable reserves:

$$S_1^{HB} = \frac{88.9-70.8*0.9382}{1-0.9382} = 364.1\ \text{t}.$$

A special method is used to determine the initial production rates of new and return wells, which takes into account the dynamics of their production over time. First, a graph is plotted showing the behaviour of the average production rate per well over the years of operation. This graph makes it possible to assess the general trend in production over time (Figure 1).

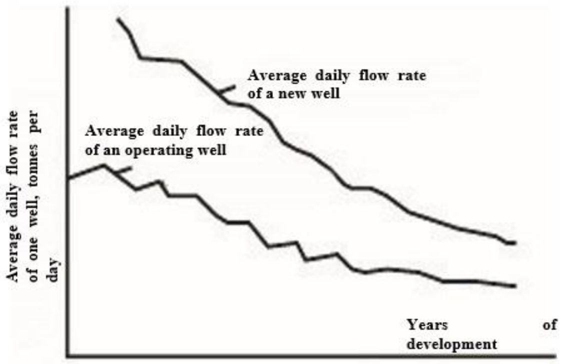

Figure 1: Graph comparing average daily flow rates of new and operating wells **[***Source: developed by the author*]

The flow rates of new wells drilled in different years are plotted together to compare them with the average flow rate of the facility and observe changes over time. Currently, there are 52 return wells, and since the existing network does not cover all field zones, an additional 15 wells are planned to enhance coverage and access under-explored reserves. This expansion aims to improve field productivity and long-term exploitation. The initial flow rate for both new and returning wells is 88.9 tonnes/day. The residual reserves for these wells are:

$$S_2^{HB} = \frac{70.7-44.7*0.9453}{1-0.9453} = 70.7 = 449.3\ \text{t},$$
$$S_3^{HB} = \frac{44.6-0.66*0.9875}{1-0.9875} = 44.6 = 3471.4\ \text{t}$$
$$Q_1^{HB} = 30(52+15) * 0.976(364.1 + 449.3 + 3471.4) = 8405749.2\ \text{t}.$$

Remaining recoverable oil reserves from existing return wells and new wells will be as follows:

$$Q_{res.rec.} = Q_1^1 + Q_1^{HB} = 15249000.4\ \text{t}$$

By summing these reserves with cumulative oil production, initial recoverable oil reserves are determined:

$Q_{rec.} = Q_{res.rec.} + Q_o$.

This approach is crucial for field development planning and production strategy [36; 37]. Applying the statistical method to a field in Turkmenistan provided a detailed analysis of production data, revealed trends and patterns, and determined initial well rates and recoverable reserves. In Southwest Turkmenistan, oil and gas reserves are estimated using various methods: the volumetric method, which relies on geological data and reservoir geometry; the material balance method, which uses production data and residual reserves to track volume changes over time [38-43], and the statistical method, which analyzes production data and forecasts future production.

4.0 DISCUSSION

Research into the commercial evaluation of oil and gas reserves is crucial for the energy industry, given their significant role in the global economy. This need arises from the rapidly changing production conditions and their substantial effects on the economy, environment, and public safety. Reliable data enable optimization of operations, risk reduction, and maximization of resource benefits. This study at the Goturdepe field in Turkmenistan validated the effectiveness of the statistical method for estimating oil reserves, demonstrating its accuracy and applicability in complex geological settings. The findings align with those in the work of S. Bhattacharyya and A. Vyas [44], which highlighted the method's ability to account for various production factors, including well flow rate changes and geological features. This study, however, further underscores the importance of forecasting future production and considering different development scenarios to optimize the development process and guide investment decisions.

Findings of T. Afeni et al. [45] and M. Mallick et al. [46] highlighted that geostatistical methods improve accuracy and reliability by accounting for spatial correlations and geological features. This study complements their work by emphasizing the importance of diverse estimation methods and focusing on a specific field in Turkmenistan. A. Radwan et al. [47] evaluated conventional and unconventional gas resources using various estimation methods, including geological and statistical. While both studies address oil reserve estimation, Radwan et al. examine multiple resource types and methods, whereas this study provides a detailed analysis of a specific field using the statistical method, demonstrating its relevance for field management. M. Wang et al. [48] demonstrated that the accuracy of shale oil resource estimation relies on proper consideration of geological structure and field operation specifics. Their study complements this research by providing additional insights into the application of statistical methods for oil reserve estimation, enhancing the understanding of different methodologies in various contexts. A. Altowilib et al. [49] highlighted the importance of using multiple calculation methods to account for diverse geological and technical factors in hydrocarbon production from coal seams. A. Banerjee and R. Chatterjee [50] focused on calculating reserves for coalbed methane reservoirs. While their work underscores the value of statistical methods in reserve estimation, this study specifically addresses oil reserves in the Goturdepe field in Turkmenistan, reinforcing the significance of statistical approaches in oil reserve estimation, as noted by Altowilib et al. [49] and Banerjee and Chatterjee [50].

Thus, all such studies are critical to the development of the oil and gas industry and exploration. Such research can enable developers and engineers to develop more accurate and reliable production and field management strategies, ultimately contributing to the efficient utilization of energy resources and overall energy security.

5.0 CONCLUSIONS

This study highlights the importance of using sophisticated drilling techniques to efficiently exploit oil fields, especially in complex geological environments such as the Goturdepe field. The use of statistical techniques to estimate oil reserves highlights the critical importance of accurate and proactive drilling operations to optimise production efficiency. However, it is important to consider the wider implications of drilling in such environments. Drilling in regions with complex geological formations, such as western Turkmenistan, often requires the use of advanced technologies such as directional drilling, hydraulic fracturing and enhanced oil recovery techniques. These techniques increase the availability of hydrocarbons in hard-to-reach areas and help reduce the risks associated with drilling in unstable or unexpected geological formations. The use of these sophisticated techniques can lead to the adoption of more environmentally friendly drilling operations, which can minimise environmental impact and maximise the efficiency of resource extraction.

Continued advances in drilling equipment are improving well control and minimising downtime. The results of the study show that using an integrated methodology that combines traditional statistical approaches with modern technological advances can provide more accurate reserve estimates and improve field development strategies. Given the potential for technical breakthroughs in drilling, oil companies can enhance their ability to strategically prepare for long-term field development and investment. Ultimately, the efficiency of drilling operations in fields such as Goturdepe is largely dependent on the continuous development of drilling technology. Future research should focus on exploring the possibility of applying sophisticated drilling techniques along with statistical analysis to improve the accuracy of reserve estimation and optimise oil production in Turkmenistan and other regions facing similar geological obstacles.

REFERENCES

[1] Mamonov, K., Dobrokhodova, O., and Kanivets, O. "Features of land use: Monitoring aspects", *Journal of Kryvyi Rih National University*, vol. 21, no. 2, pp. 94-98, 2023.

[2] Deryaev, A.R. "Drilling fluids for drilling wells in complex geological conditions in oil and gas fields of Turkmenistan", *Neftyanoe Khozyaystvo - Oil Industry*, vol. 2024, no. 4, pp. 32-36, 2024.

[3] Muther, T., Qureshi, H.A., Syed, F.I., Aziz, H., Siyal, A., Dahaghi, A.K., and Negahban, S. "Unconventional hydrocarbon resources: Geological statistics, petrophysical characterisation, and field development strategies", *Journal of Petroleum Exploration and Production Technology*, vol. 12, no. 6, pp. 1463-1488, 2022.

[4] Zou, C., Qiu, Z., Zhang, J., Li, Z., Wei, H., Liu, B., Zhao, J., Yang, T., Zhu, S., Tao, H., Zhang, F., Wang, Y., Zhang, Q., Liu, W., Liu, H., Feng, Z., Liu, D., Gao, J., Liu, R., and Li, Y. "Unconventional petroleum sedimentology: A key to understanding unconventional hydrocarbon accumulation", *Engineering*, vol. 18, pp. 62-78, 2022.

[5] Li, J., Yang, X., Dong, C., Li, J., Xu, Z., Zhang, L., and Zhang, W. Characteristics of orderly hydrocarbon accumulation of deep reservoirs in Kuqa Depression and its exploration implications. *Geological Journal*, vol. 58, no.11, pp. 4103-4120, 2023.

[6] Boak, J., and Kleinberg, R. Shale gas, tight oil, shale oil and hydraulic fracturing. In: *Future Energy* (pp. 67-95). London, Elsevier, 2020.

[7] Lei, Q., Xu, Y., Cai, B., Guan, B., Wang, X., Bi, G., Li, H., Ding, B., Fu, H., Tong, Z., Li, T., and Zhang, H. "Progress and prospects of horizontal well fracturing technology for shale oil and gas reservoirs", *Petroleum Exploration and Development*, vol. 49, no. 1, pp. 191-199, 2022.

[8] Mahmoud, H., Hamza, A., Nasser, M.S., Hussein, I.A., Ahmed, R., and Karami, H. "Hole cleaning and drilling fluid sweeps in horizontal and deviated wells: A comprehensive review", *Journal of Petroleum Science and Engineering*, vol. 186, article number 106748, 2020.

[9] Moldabayeva, G.Zh., Suleimenova, R.T., Turdiyev, M.F., Shayakhmetova, Zh.B., and Karimova, A.S. "Scientific and technical substantiation of reducing oil viscosity", *International Journal of Engineering Research and Technology*, vol. 13 no. 5, pp. 967-972, 2020.

[10] Tanekeyeva, G.D., Abeuov, E.A., Makhmudov, D.R., Musin, R.A., and Balabas, A.Yu. "Study of the geomechanical conditions for carrying out and maintaining surface mine workings", *Ugol*, no. 2, pp. 31-33, 2023.

[11] Sircar, A., Yadav, K., Rayavarapu, K., Bist, N., and Oza, H. "Application of machine learning and artificial intelligence in oil and gas industry", *Petroleum Research*, vol. 6, no. 4, pp. 379-391, 2021.

[12] Caili, Z., Xinshe, L., Yajuan, Y., Jian, Y., Tianyou, H., and Yan, Z. "Petroleum exploration history and enlightenment of Changqing oilfield in Ordos Basin", *Xinjiang Petroleum Geology*, vol. 42, pp. 17-39, 2021.

[13] Ma, X., Cai, X., Yun, L., Li, Z., Li, H., Deng, S., and Zhao, P. Practice and theoretical and technical progress in exploration and development of Shunbei ultra-deep carbonate oil and gas field, Tarim Basin, NW China. *Petroleum Exploration and Development*, vol. 49, no. 1, pp. 1-20, 2022.

[14] Sun, C., Nie, H., Dang, W., Chen, Q., Zhang, G., Li, W., and Lu, Z. "Shale gas exploration and development in China: Current status, geological challenges, and future directions", *Energy & Fuels*, vol. 35, no. 8, pp. 6359-6379, 2021.

[15] Huang, Y., Li, X., Liu, X., Zhai, Y., Fang, F., Guo, W., Qian, C., Han, L., Cui, Y., and Jia, Y. "Review of the productivity evaluation methods for shale gas wells", *Journal of Petroleum Exploration and Production Technology*, vol. 14, no. 1, pp. 25-39, 2024.

[16] Xue, L., Liu, Y., Xiong, Y., Liu, Y., Cui, X., and Lei, G. "A data-driven shale gas production forecasting method based on the multi-objective random forest regression", *Journal of*

Petroleum Science and Engineering, vol. 196, article number 107801, 2021.

[17] Oryngozhin, Y.S., Moldabayeva, G.Z., and Igembaev, I.B. Innovative method of high-viscosity oil production. In: *12th International Multidisciplinary Scientific GeoConference and EXPO - Modern Management of Mine Producing, Geology and Environmental Protection, SGEM 2012* (pp. 463-470). 2012.

[18] Epelle, E.I., and Gerogiorgis, D.I. "A review of technological advances and open challenges for oil and gas drilling systems engineering", *AIChE Journal*, vol. 66, no. 4, article number e16842, 2020.

[19] Koroviaka, Ye.A., Mekshun, M.R., Ihnatov, A.O., Ratov, B.T., Tkachenko, Ya.S., and Stavychnyi, Ye.M. "Determining technological properties of drilling muds", *Naukovyi Visnyk Natsionalnoho Hirnychoho Universytetu*, vol. 2, pp. 25-32, 2023.

[20] Nesterov, V. "Integration of artificial intelligence technologies in data engineering: Challenges and prospects in the modern information environment", *Bulletin of Cherkasy State Technological University*, vol. 28, no. 4, pp. 82-92, 2023.

[21] Deryaev, A.R. "Features of forecasting abnormally high reservoir pressures when drilling wells in areas of south-western Turkmenistan", *Innovaciencia*, vol. 11, no. 1, 2023.

[22] Iskandarov, E.K., Ismayilova, F.B., and Farzalizade, Z.I. "Oil Leaks Diagnosis in Pipelines Based on Artificial Neuron Technologies", *Lecture Notes in Networks and Systems*, vol. 912, pp. 313-323, 2024.

[23] Patzek, T.W., Saputra, W., Kirati, W., and Marder, M. "Generalised extreme value statistics, physical scaling, and forecasts of gas production in the Barnett shale", *Energy & Fuels*, vol. 33, no. 12, pp. 12154-12169, 2019.

[24] Imangozhina, Z.A. "The current state of the gas industry of the Republic of Kazakhstan", *Bulletin of Turan University*, vol. 1, pp. 201-208, 2021.

[25] Lee, K., Lim, J., Yoon, D., and Jung, H. "Prediction of shale-gas production at Duvernay formation using deep-learning algorithm", *SPE Journal*, vol. 24, no. 6, pp. 2423-2437, 2019.

[26] Rusho, M.A., Azizova, R., Mykhalevskiy, D., Karyonov, M., and Hasanova, H. "Advanced earthquake prediction: unifying networks, algorithms, and attention-driven lstm modelling", *International Journal of GEOMATE*, vol. 27, no. 119, pp. 135-142, 2024.

[27] Ning, Y., Kazemi, H., and Tahmasebi, P. "A comparative machine learning study for time series oil production forecasting: ARIMA, LSTM, and Prophet", *Computers & Geosciences*, vol. 164, article number 105126, 2022.

[28] Tokarev, V.I., Akhmet, A.A., and Garifov, A.K. "Evaluation of the efficiency of horizontal wells", *Bulletin*, vol. 4, no. 1, pp. 28-38, 2022.

[29] Dzhalalov, G.I., Kunayeva, G.E., and Moldabayeva, G.Zh. "Fluid influx to a battery ofincomplete horizontally branched wells in deformed formation", *News of the National Academy of Sciences of the Republic of Kazakhstan, Series of Geology and Technical Sciences*, vol. 3, no. 447, pp. 29-33, 2021.

[30] Mahmoud, A.A., Elkatatny, S., Chen, W., and Abdulraheem, A. "Estimation of oil recovery factor for water driven sandy reservoirs through applications of artificial intelligence", *Energies*, vol. 12, no. 19, article number 3671, 2019.

[31] Moldabayeva, G., and Abileva, S. "Study and determination of regularities in variability of oil rheological properties to enhance oil recovery", *Periodicals of Engineering and Natural Sciences*, vol. 9, no. 4, pp. 44-60, 2021.

[32] Lialiuk, O., and Osypenko, R. "Features of the implementation of artificial intelligence in construction", *Modern Technologies, Materials and Structures in Construction*, vol. 35, no. 2, pp. 172-176, 2023.

[33] Fu, Y., Dehghanpour, H., Motealleh, S., Lopez, C.M., Hawkes, R. 2019. Evaluating fracture volume loss during flowback and its relationship to choke size: Fastback vs. slowback. *SPE Production & Operations*, 34(3), 615-624.

[34] Cao, C., Moussa, T., Dehghanpour, H. "Parent well characterization by comparative analysis of initial and second flowback", https://doi.org/10.2118/212368-MS, Accessed on April 16, 2024.

[35] Drizhd, N., Mussin, R., and Alexandrov, A. "Improving the Technology of Hydraulic Impact Based on Accounting Previously Treated Wells", *IOP Conference Series: Earth and Environmental Science*, vol. 272, no. 2, 022031, 2019.

[36] Tamala, J.K., Maramag, E.I., Simeon, K.A., and Ignacio, J.J. "A bibliometric analysis of sustainable oil and gas production research using VOSviewer", *Cleaner Engineering and*

Technology, vol. 7, article number 100437, 2022.

[37] Doroshenko, Yu., Liuta, N., and Lisafin, D. "Improving the standardisation of oil product losses", *Prospecting and Development of Oil and Gas Fields*, vol. 23, no. 3, 24-33, 2023.

[38] Deryaev, A. "Prospect forecast for drilling ultra-deep wells in difficult geological conditions of western Turkmenistan", *Sustainable Engineering and Innovation*, vol. 5, no. 2, pp. 205-218, 2023.

[39] Pang, X.Q., Chen, Z.H., Jia, C.Z., Wang, E.Z., Shi, H.S., Wu, Z.Y., Hu, T., Liu, K.Y., Zhao, Z., Pang, B., and Wang, T. "Evaluation and re-understanding of the global natural gas hydrate resources", *Petroleum Science*, vol. 18, no. 2, pp. 323-338. 2021.

[40] Ismayilov, G.G., Fataliyev, V.M., and Iskenderov, E.K. "Investigating the impact of dissolved natural gas on the flow characteristics of multicomponent fluid in pipelines", *Open Physics*, vol. 17, no. 1, pp. 206-213, 2019.

[41] Doroshenko, Yu. "Predicting oil product losses from evaporation at petrol stations", *Prospecting and Development of Oil and Gas Fields*, vol. 23, no. 2, pp. 33-40, 2023.

[42] Deryaev, A.R. "Drilling of directional wells in the fields of Western Turkmenistan", *SOCAR Proceedings*, vol. 2023, pp. 22-31, 2023.

[43] Ismailova, J., Abdukarimov, A., Delikesheva, D., Mombekov, B., and Ismailov, A. "Application of fusion property estimation within the multisolid wax prediction model on Kazakhstani crude", *Heat Transfer*, vol. 53, no. 2, pp. 533-557, 2024.

[44] Bhattacharyya, S., and Vyas, A. "Application of machine learning in predicting oil rate decline for Bakken shale oil wells", *Scientific Reports*, vol. 12, no. 1, article number 16154, 2022.

[45] Afeni, T.B., Akeju, V.O., and Aladejare, A.E. "A comparative study of geometric and geostatistical methods for qualitative reserve estimation of limestone deposits", *Geoscience Frontiers*, vol. vol. 12, no. 1, pp. 243-253, 2021.

[46] Mallick, M.K., Choudhary, B.S., and Budi, G. "Geological resource modelling and mine planning of a surface limestone deposit", *Journal of Mines, Metals & Fuels*, vol. 71, no. 6, pp. 734-737, 2023.

[47] Radwan, A.E., Wood, D.A., Mahmoud, M., and Tariq, Z. Gas adsorption and reserve estimation for conventional and unconventional gas resources. In: *Sustainable geoscience for natural gas subsurface systems* (pp. 345-382). London, Gulf Professional Publishing, 2022.

[48] Wang, M., Li, M., Li, J.B., Xu, L., and Zhang, J.X. "The key parameter of shale oil resource evaluation: Oil content", *Petroleum Science*, vol. 19, no. 4, pp. 1443-1459, 2022.

[49] Altowilib, A., AlSaihati, A., Alhamood, H., Alafnan, S., and Alarifi, S. "Reserves estimation for coalbed methane reservoirs: A review", *Sustainability*, vol. 12, no. 24, article number 10621, 2020.

[50] Banerjee, A., and Chatterjee, R. "A methodology to estimate proximate and gas content saturation with lithological classification in coalbed methane reservoir, Bokaro field, India", *Natural Resources Research*, vol. 30, no. 3, pp. 2413-2429, 2021.