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Prospect forecast for drilling ultra-deep wells in difficult geological conditions of western Turkmenistan

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Abstract

The relevance of the study is related to the growing need for efficient production of hydrocarbons in the difficult geological conditions of western Turkmenistan to ensure energy security and economic development of the region in the changing global oil and gas market. The purpose of the study is to conduct a comprehensive analysis of the geological, technical, and economic aspects of drilling ultra-deep wells in difficult geological conditions of western Turkmenistan to assess their potential feasibility and contribution to the energy infrastructure of the region. The study used analytical, functional, and statistical methods, classification, and synthesis. The prospects for drilling wells in difficult and extreme geological conditions of western Turkmenistan were identified. The analysis of the current state of prospecting and exploration in this region was carried out, while the main attention was paid to the investigation of the main difficulties faced by drillers when working with deep horizons of the reedbeds. As a result of the conducted research, general principles and recommendations aimed at overcoming these problems were developed. Despite the successful introduction of modern technical and technological innovations that meet international standards when drilling deep and ultra-deep wells in the West Turkmen depression, the study emphasized that the existing drilling problems have not yet been eliminated. This study will provide valuable recommendations and information for making informed decisions when developing and implementing projects for drilling ultra-deep wells in difficult geological conditions, contributing to effective resource management and development of the oil and gas industry in western Turkmenistan.

Keywords: Reservoir, Gas generation, Tectonics, Reservoir pressure, Permeability

1. Introduction

The study of the topic of ultra-deep drilling in difficult geological conditions of western Turkmenistan is extremely relevant since the region has a huge potential for the discovery and production of hydrocarbon resources at deep horizons, but at the same time, presents complex technical and geological challenges. This research not only contributes to ensuring energy security and economic development of the country but can also

be important for the global energy market, contributing to the global supply of oil and gas. In addition, the development of advanced technologies and methods for drilling in difficult conditions may have promising applications in other regions of the world where similar challenges are faced, and contribute to the sustainable development of the oil and gas industry in the future.

The problem of the study is that the drilling of ultra-deep wells in difficult geological conditions of western Turkmenistan is associated with several significant challenges and uncertainties. These challenges include a complex geological structure, deep production horizons, high temperatures and pressures, and the need to develop new technologies and engineering solutions to ensure the safety and efficiency of the process. In addition, it is necessary to consider the environmental and social aspects associated with activities in the oil and gas industry in this region. Solving these problems may be of key importance for the successful development of resources and ensuring the sustainable development of the region and the industry as a whole.

According to [1], in western Turkmenistan, there are often problems in the process of drilling multi-layer deposits with abnormally high reservoir pressure with horizons having different reservoir characteristics (reservoir pressure, permeability, porosity, saturation pressure). In addition, each horizon sometimes contains several layers with different characteristics that require an individual approach in the construction of wells. According to [2], the need to create innovative technologies for drilling and servicing wells at great depths at elevated temperatures and pressures represents significant technical challenges that the oil and gas industry in western Turkmenistan must successfully cope with. These challenges can be an incentive for the development of new methods and equipment.

[3] report that due to the increase in drilling depth and the variety of factors influencing the conditions that contribute to the occurrence of complications, a different combination of conditions, both geological and technical, often leads to a deteriorated wellbore condition. Sometimes the quality of the drilling mud, seemingly meeting all previously recognized requirements, turns out to be unsuitable for drilling wells under these conditions for one reason or another. All this shows that the occurrence of complications associated with the effect of the pressure drop is caused by the water release of the solution and the physicochemical properties of the crusts formed under conditions of temperature and pressure drop acting in the well. [4] note that the development of ultra-deep drilling in western Turkmenistan provides economic opportunities for the country, especially in times of changing world oil and gas prices. However, to successfully utilize this potential, it is necessary to invest significant costs and resources in development and technological innovation.

According to [5], the extraction of hydrocarbons at great depths in western Turkmenistan has the potential to influence the global energy market, adding additional energy resources and influencing global energy balances. This can contribute to a more stable energy supply and mitigate fluctuations in global energy markets [6, 7]. [8] note that in order to ensure the sustainable development of the region, it is important to carefully consider the opinions and interests of residents, and ensure their active participation in the decision-making process, which will help prevent possible conflicts and promote harmonious development in this area. This is an important aspect of the socio-environmental sustainability of oil and gas industry projects [9].

The purpose of this study is to comprehensively analyze the geological, technical, and economic aspects of ultra-deep drilling in difficult geological conditions of western Turkmenistan to assess its potential feasibility and impact on the energy infrastructure of this region.

2. Research method

The analytical method allowed for a deeper and more systematic understanding of the complex geological conditions of western Turkmenistan, and their potential impact on hydrocarbon production. This method collected and analyzed data on rock structure, hydrodynamic characteristics, geochemical, and other parameters, which facilitated a more accurate assessment of the risks and opportunities of ultra-deep drilling in this region.

The obtained results will play an important role in the development of strategies for further hydrocarbon production and sustainable development of western Turkmenistan.

Long-term data on hydrocarbon production in western Turkmenistan were studied using the statistical method. This method identified trends and patterns in production activities, assessed the impact of various factors on the volume of production, and allowed the prediction of possible changes in the future. The results obtained have become an important tool for developing optimal strategies for managing production and resources in the region, which, in turn, contributes to more efficient and sustainable exploitation of hydrocarbon deposits.

Using a functional method, changes in the operation of oil wells at deep levels in western Turkmenistan were investigated. This method identified optimal operating strategies, determined the periods of the greatest efficiency of wells, and specified the factors that have the most significant impact on their productivity. The obtained results helped to optimize drilling and maintenance processes, which contributed to an increase in hydrocarbon production and an improvement in the economic performance of projects in the region.

The structural and functional method contributed to a more detailed study of the organization of oil and gas infrastructure in western Turkmenistan. This method identified the key components of the infrastructure and determined their interrelationships and influence on the processes of production and transportation of hydrocarbons. The study of the structure and functions of the infrastructure helped identify bottlenecks and potential improvements in the system, which contributed to a more efficient and sustainable operation of the oil and gas industry in this region.

The deduction method helped in the development of logically sound conclusions and recommendations based on the available information about ultra-deep drilling in western Turkmenistan. The study of data and the use of logical reasoning identified causal relationships and key factors affecting the success or failure of drilling projects at deep levels. The findings became the basis for the development of strategies and action plans aimed at improving the efficiency and sustainability of hydrocarbon production in this region.

The application of the synthesis method was a process of combining various aspects and information obtained from geological, technical, environmental, and economic studies related to drilling at deep levels in western Turkmenistan. This method facilitated an integral and multifaceted understanding of the complex issues of ultra-deep drilling in this region, as well as the identification of the most important factors, the determination of the relationships between them, and potential risks and opportunities. The study, based on the synthesis of these data, served as the basis for the development of integrated strategies and decision-making aimed at optimizing drilling processes, ensuring the stability of hydrocarbon production and rational use of available resources in this region, contributing to the sustainable and efficient development of the oil and gas industry.

3. Results

In recent years, Turkmenistan has been actively showing interest in the introduction of completely new technical solutions in the field of well drilling. The main attention is paid to the improvement of drill bits, the creation of devices for logging when digging without the need to lift drill pipes, and the development of methods for drilling horizontal wells. In addition, the focus is on new top-drive drilling systems and multifunctional drill pipes, which are used for the effective destruction of the face with the help of a variety of high-performance pressure nozzles. Of particular interest are the various designs of the upper drive systems, which differ significantly from conventional power swivels. Previously, power swivels were not widely used due to the difficulties associated with carrying out operations for lowering and lifting drilling tools. Another significant innovation is horizontal drilling, which became possible due to the introduction of top drive systems. Many horizontal wells have been drilled all over the world.

Experts argue with strong arguments that such horizontal wells contribute to an increase in reservoir productivity by 2-3 times and, consequently, increase the efficiency of each investment compared to vertical wells. This is achieved by increasing the length of the section of the productive reservoir, ensuring natural drainage and the

possibility of removing the well from the oil or gas level and creating inert wells that horizontally extend beyond the productive reservoir.

Innovations in the field of drilling require integration into a single system. In modern conditions, it is impossible to achieve high technical and economic efficiency when drilling oil and gas wells without this integration, which is the main source of increasing oil and gas reserves. To extract oil from oil fields, a system of producing wells is used, which can be located in rows or in the form of a regular geometric grid, whether triangular or square. The placement of wells in rows is chosen for the development of highly productive oil fields with good permeability, and in cases where the oil deposit has a complex stratigraphic structure. In other scenarios, wells are placed in a geometric grid. Important parameters are the distances between wells when using a uniform grid and the distances between rows. The determination of optimal intervals between producing wells is based on the laws of underground hydrodynamics, considering the physical and geological characteristics of the productive reservoir. Economic factors are also considered since the choice of distance affects the total number of wells that need to be drilled for the development of oil fields. When designing the development of oil fields, various options for the placement of wells with different intervals between them are considered, and a comparative analysis is carried out to select the most economically feasible option.

The need for further expansion of the oil and gas reserves under study, and an increase in their production, has led to a significant improvement in the quality and efficiency of drilling operations. As a result, there was a need for continuous improvement of technologies and equipment for deepening drilling, increasing the speed of drilling operations, and reducing operating costs. The accuracy and reliability of geological, geophysical, and technical data have become critically important, which allows for more accurate prediction of mining and geological conditions and improving the management of the well drilling process. The need for further improvement of drilling technology stems from the complexity of geological and technical problems that arise in the drilling process. The current technological scheme of deep mechanical drilling will remain unchanged for many years. To increase the speed of mechanical drilling, it is necessary to develop a unified concept of technical solutions that will be adapted to the specific conditions of each well. This also includes an analysis of the economic feasibility of using various methods depending on the characteristics of the well, such as the use of hydraulic or electric downhole motors. There is considerable reason to assume that the volume of directional drilling will increase, including the penetration of horizontal sections of wells through productive formations.

New technologies based on directional drilling have proven their effectiveness in the industrial extraction of hydrocarbon resources in new fields and in areas of fields that previously remained unclaimed due to the presence of ground structures that interfere with vertical drilling.

To achieve the production goals, set for the oil industry, it is necessary to continue to increase the speed of drilling wells [10]. From the standpoint of local features, in the absence of complex seismic surveys to identify the location of oil and gas fields, the main challenges when drilling deep wells in difficult geological conditions include uncertainty and lack of geological data on the structure of the lower layers of reedbed sediments. Stratigraphic ambiguities in underlying sediments, especially in the Mesozoic complex, including uncertainties in the presence or absence of individual stratigraphic units.

Significant errors in the assessment of the depth of stratigraphic complexes, reservoir (pore) pressures, temperature indicators, the spread of tectonic disturbances, and the angle of inclination of deep layers. Regular structural disturbances associated with emissions of a sub-meridional orientation. The West Turkmen depression is dominated by sediments of the Cenozoic era (Figure 1), which covers the last 65 million years of geological history. This includes a variety of geological formations, such as salt and clay shales, sandstones, and clays, which are important for the study of possible hydrocarbon deposits. The main challenges in the field of technical and technological aspects of drilling deep wells are largely related to the use of predictive geological information, but it is necessary to consider the possible presence of uncertainty in this information, which can create difficulties during drilling.

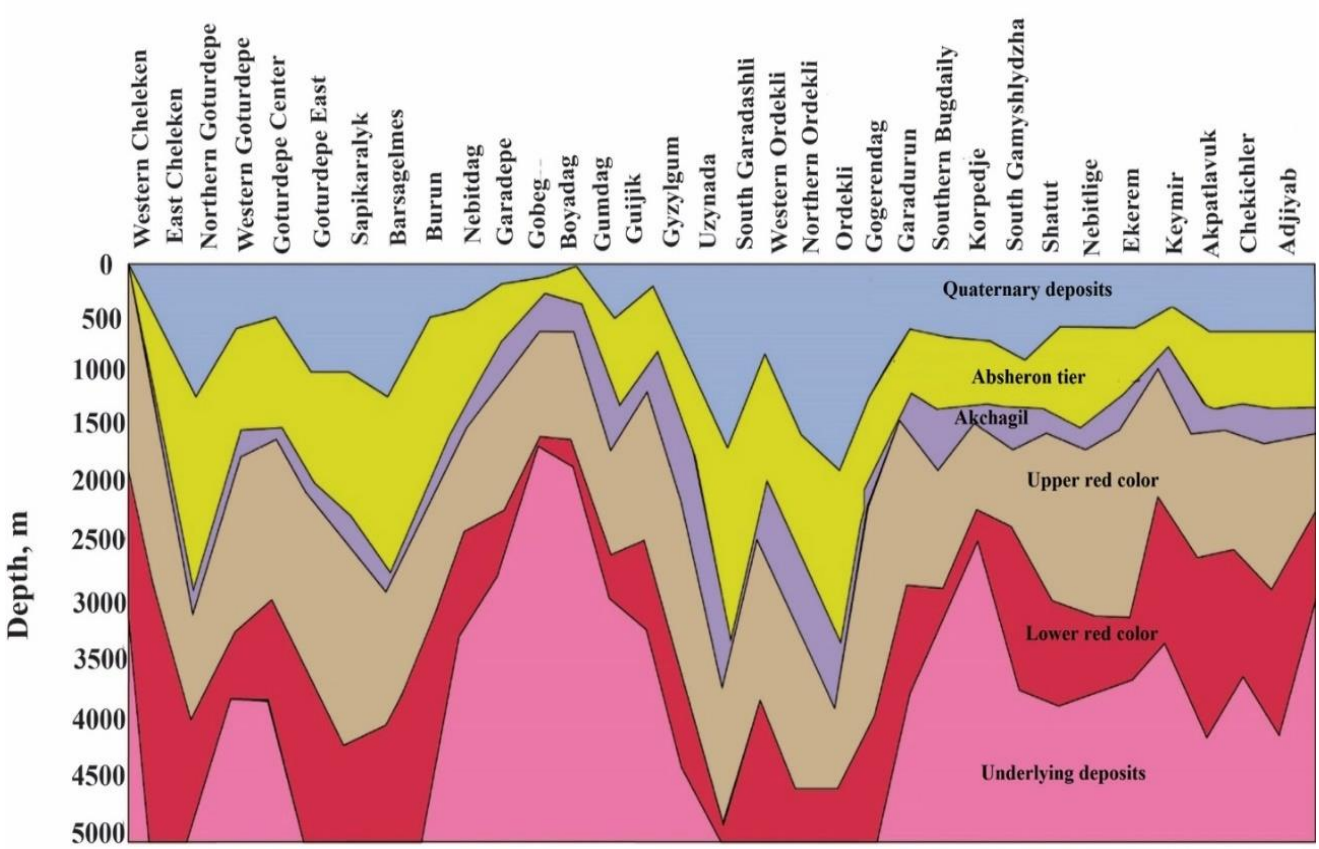

Figure 1. Stratigraphy of the areas of the West Turkmen Depression

Decisions on the choice of technical and technological methods often depend on the presence of zones with abnormally high reservoir (pore) pressures, which increase significantly in the nearest part of the geological section [11]. The application of design solutions when drilling wells using drilling mud, whose density is in the range from 2.35 to 2.4 g/cm³, faces significant difficulties associated with the need to maintain the parameters of the drilling mud within technologically acceptable limits, even when drilling under extreme loads [12].

At the initial stages of drilling wells into deep horizons, the study of geological conditions that determine the stability of a well in reedbeds was carried out. Three types of well sections in sub-reedbed sediments were identified. The first type of section, where there are no extreme values of reservoir (pore) pressures, and the density of the drilling mud does not exceed 2.25 g/cm³, allows drilling without the use of denser fluids. This type of incision includes Upper Cretaceous layers. The second type of section, in which extreme values of reservoir (pore) pressures close to rock pressure are observed, requires the use of drilling muds with a density from 2.3 to 2.45 g/cm³. The features of the section allow for ensuring the long-term stability of the well when using traditional drilling methods. The third type of section is also characterized by extreme values of reservoir (pore) pressures close to rock pressure, but in this case, the well turns out to be unstable, even when using drilling muds with the maximum allowable density, taking into account mining and geological conditions. This instability is explained by the high plasticity, humidity, and low mechanical strength of the clay rocks that make up this section, and complex tectonic conditions in the areas where wells are drilled.

Due to insufficient mechanical strength of rocks, a significant deformation of the borehole occurs, caused by periodic fluctuations in the hydrodynamic pressure of the drilling mud during operations for lowering and lifting tools, and during well flushing and subsequent removal of rocks that can fall into the well and create grooves [13]. Drilling of such sections is further complicated by the fact that they include both dry and fractured potassium clays that can cause collapses, and wet and plastic sodium clays that are prone to swelling and may exhibit plastic flow. In this regard, it is necessary to use various methods and approaches to neutralize them (Figure 2).

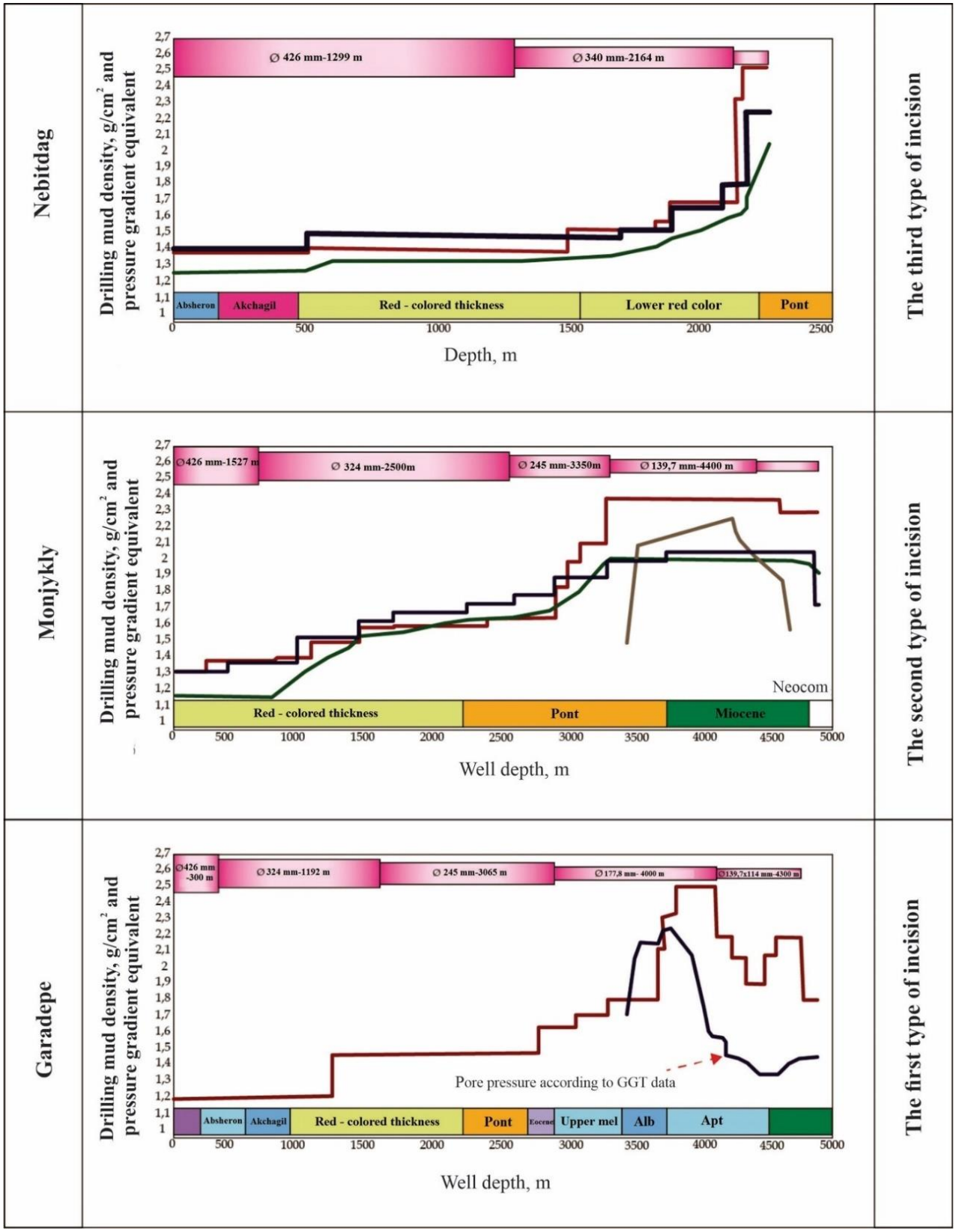

Figure 2. Main types of cross-sections of the deposits of western Turkmenistan

The classification mentioned above, presented earlier, is indicative and predictive, but it is still used to make decisions and assess the possibility of drilling wells through rocks with extreme reservoir (pore) pressures. To ensure that the required speed of new well commissioning is achieved within the current development system, the key factor is the efficient organization of drilling operations, given the limited available time at drilling sites. There are two possible ways to solve this problem of increasing the number of simultaneously operating drilling

rigs or increasing the productivity of the drilling cycle while reducing the number of drilling rigs. This, in turn, contributes to the acceleration of drilling both individual wells and the entire well program. In addition, it is important to strive to reduce capital costs [14]. The successful execution of drilling operations in difficult geological conditions strongly depends on the experience gained during drilling at a certain site. In world practice, the form and scale of drilling projects are often determined by the purpose, complexity (design depth) of wells, the level of knowledge of geological sections, and the requirements of an operating enterprise [15].

Oil companies face new challenges related to the introduction of advanced technologies, modernization and replacement of outdated equipment. It is remarkable that foreign companies focus on solving key technical, technological, and organizational tasks related to the preparation for drilling wells, through the full responsibility of service companies for the condition of the drilling rig (including drilling muds and drilling bits) and ensuring their reliable and successful operation. In addition to the above technical tasks, organizational aspects that are important for the successful completion of the well construction project are also considered. These aspects include thorough preparation of the project and comprehensive scientific, technical, and organizational support of drilling operations, in which all project participants participate. Modern scientific and technical methods used in the development of oil and gas fields are based on a deep and comprehensive study of the characteristics of productive formations and the substances contained in them, as well as on the analysis of complex processes [16, 17]. The process of exploration of deposits begins from the moment of their discovery and continues until the full development of resources that can be extracted with economic benefit. The increase in oil and gas production is closely related to the discovery of new fields and productive horizons, and much depends on the level of development of drilling technology [18].

In recent years, there has been a noticeable tendency to increase the depth of drilling wells, both for the exploration of new and for the development of already-known hydrocarbon deposits. This trend also concerns the exploration of promising horizons for future exploration and exploration. With increasing drilling depth, the impact of various physicochemical and mechanical processes on the condition of the well increases. Increasing the drilling depth is accompanied by more frequent and serious difficulties, which require additional financial costs [19]. To optimize costs in such conditions, it becomes necessary to revise the drilling technology and adapt it to the increasingly complex conditions that are characteristic of deep wells [20]. The main differences between the drilling technology of conventional and deep wells are the significant time and resources spent on preparation for drilling deep and ultra-deep wells [21]. These costs include not only the purchase of the necessary equipment on the surface and in the depths but also a detailed study of the condition's characteristics of drilling at great depths [22, 23]. An important aspect of deep well drilling technology is the use of specialized equipment, for example, to control the pressure at the bottom of the well.

4. Discussion

The forecast of the prospects for drilling ultra-deep wells in the difficult geological conditions of western Turkmenistan plays a critical role in the strategic planning of the development of the oil and gas industry in this region. Western Turkmenistan is characterized by a complex geological structure, where the presence of various rocks and formations requires in-depth research. Accurate determination of the structure and properties of underground formations plays a crucial role in choosing the location of wells and determining the optimal drilling depth [24-25]. Successful drilling of ultra-deep wells requires access to advanced technologies and high-tech drilling equipment. This also includes training of highly qualified specialists capable of effectively managing such drilling operations. Drilling ultra-deep wells is an expensive undertaking, and the study of economic factors, such as energy prices and projected production volumes, is of critical importance [26]. It is necessary to assess how investments in such drilling will be justified from an economic standpoint. Drilling ultra-deep wells can have an impact on the environment. It is necessary to conduct an environmental assessment to prevent or minimize negative consequences and develop plans to eliminate possible damages. The outlook analysis should consider potential technological innovations and cooperation with international partners who

can provide access to best practices and experience in the field of drilling [27]. It is important to consider forecasting the prospects for drilling ultra-deep wells as part of the overall strategy for the development of the oil and gas industry in western Turkmenistan. This will ensure the consistency and sustainability of the development of the regional oil and gas industry.

According to the results of recent studies by [28], technologies for drilling deep and ultra-deep oil and gas wells are experiencing amazing progress and provide huge prospects for the oil and gas industry [29]. One of the significant breakthroughs in this area is the possibility of reaching much greater depths when drilling. Previously inaccessible resources are becoming available, which contributes to an increase in oil and gas reserves [30]. This factor is of particular importance, given the growing demand for energy resources in the world [31]. Horizontal drilling also plays a critical role in the progress of well drilling. It allows extracting hydrocarbons from productive formations as much as possible, while reducing the impact on the environment. This method not only increases the efficiency of production but also helps to reduce the number of drilling sites, which, in turn, saves resources and decreases the negative impact on nature. It is worth noting that modern technologies also raise an important issue of sustainability and environmental safety [32]. Research and development are aimed at minimizing negative impacts on the environment, including the prevention of emissions and pollution of groundwater. This ecological orientation not only meets modern standards but also reflects the importance of a responsible attitude to nature and the preservation of ecosystems for future generations [33].

According to [34], the progress in the development of technologies to increase the speed of jet drilling and the mechanism of rock destruction for deep wells is an important step in the development of the oil and gas industry. These innovations promise to significantly increase the efficiency of the drilling process and improve well productivity. One of the significant achievements in this field is the development of advanced drilling pumps and nozzles capable of creating high-speed jet streams. This allows increasing the drilling speed and significantly reducing the time spent on drilling deep wells [35]. Such innovations contribute to more efficient use of resources and reduce environmental impact. It may be added that the new rock-breaking mechanisms allow handling harder and more complex rocks at deeper depths. This opens access to resources that were previously unavailable due to technical limitations. Improved productivity and efficiency of drilling deep wells not only contribute to an increase in oil and gas production but also reduce operating costs, which is important for the economic sustainability of the industry [36]. As a result, these technological advances represent great prospects for the future development of deep well drilling and the growth of energy resource production.

[37] determined that the management of downhole heat during the drilling of shallow and ultra-deep high-enthalpy geothermal wells is a complex task that requires careful design and innovative technologies. Geothermal energy is becoming increasingly in demand as a clean energy source, and the development of such wells plays an important role in this process. When drilling shallow geothermal wells, it is important to consider the thermal loads that may occur inside the well, as they can cause equipment wear and lead to a decrease in efficiency [38, 39]. Technical solutions such as insulation and cooling systems can help manage thermal processes and improve operational reliability [40]. Ultra-deep, high-enthalpy geothermal wells pose an even greater challenge since temperatures and pressures at deep depths are much higher. It is important to develop unique materials and technologies for drilling and operating such wells. The management of thermal processes and heat exchange is becoming a priority, and engineers must work to develop specialized solutions to ensure sustainable and efficient production of geothermal energy [41, 42].

[43] determined that the use of deep learning methods in geophysical and oil and gas research is becoming more common, and the use of this technique to predict the bottom-hole pressure drop in the eccentric annulus of an ultra-deep well is a relevant area of research. Deep learning methods, such as neural networks and deep learning algorithms, have the potential to analyze huge amounts of data, which makes them an ideal tool for processing information obtained from geophysical research [44, 45]. These methods can reveal complex patterns and relationships between different parameters, which helps to predict the bottom-hole pressure drop more accurately. However, it is worth noting that the application of deep learning in this area also presents challenges,

such as the need for high-quality data and computing resources [46]. In addition, careful training of models and their constant updating is necessary to achieve accurate results. Despite these difficulties, the use of deep learning methods in predicting pressure in ultra-deep wells promises a significant improvement in accuracy and efficiency in this field of research.

[47] have shown by their work that studies related to the use of glycerin emulsions in olefins as components of drilling muds for oil wells are an interesting area of research. Glycerin, a chemical component with high viscosity and low toxicity, can be used to improve the properties of drilling mud [48, 49]. When it is mixed with olefins, it can create emulsions capable of increasing drilling efficiency. However, for a critical assessment of the use of such emulsions, it is important to consider several factors. It is necessary to conduct detailed laboratory studies to determine the optimal concentrations of glycerin and olefins to create stable emulsions that will work well in drilling conditions. It is also important to consider issues related to the stability of emulsions to high temperatures and pressures that can occur in deep wells.

As noted by [50], the detection of adjacent wells around the ultra-deep electromagnetic logging while drilling (LWD) instrument is an important technical study that is of great importance in the geophysical and petroleum industries. Ultra-deep wells, as a rule, are drilled to great depths and present special technical and geological challenges. As mentioned above, one of the key aspects of this study is the development and application of advanced methods for detecting nearby wells using LWD technology. This reduces the risk of collisions with neighboring wells and potential problems such as cross-contamination or mutual impact on hydrocarbon production. In addition, such technology can improve drilling accuracy and efficiency, which is important to reduce time and costs.

In conclusion, the analysis of the prospects for drilling ultra-deep wells in western Turkmenistan requires an integrated approach that considers many factors. With proper preparation and consideration of all aspects, it is possible to fulfill the development potential of the oil and gas industry in this region in the best possible way.

5. Conclusions

Forecasting the prospects for drilling ultra-deep wells in difficult geological conditions of western Turkmenistan is an important aspect of strategic planning for the production of hydrocarbon resources in this region. In conditions where the drilling depth is becoming increasingly significant and geological factors can introduce serious limitations and cause difficulties in the production process, it is necessary to conduct in-depth studies and assessments of the drilling potential at deep levels. Western Turkmenistan has rich hydrocarbon reserves, and effective drilling of ultra-deep wells can significantly increase production and contribute to the development of the oil and gas industry in the region. It is important to consider both the technical aspects of such activities, as well as environmental and social issues related to the development of hydrocarbon deposits on deep geological horizons. Therefore, further research and evaluation should include a multi-faceted analysis to ensure the sustainable and productive development of these resources. An important factor that makes western Turkmenistan unique is its complex mountain and geological nature. This region is characterized by the presence of various types of rocks, including clay and sand deposits, and the presence of zones with high pressure and temperature. These features create significant technical and engineering challenges for drilling ultra-deep wells.

However, despite the complexity of the conditions, western Turkmenistan has significant reserves of oil and gas at a depth that requires drilling ultra-deep wells. This creates prospects for additional extraction of these valuable resources. It is predicted that the development of drilling technologies, including the use of modern equipment and methods, as well as the professional development of specialists, will effectively develop and extract energy resources at great depths. This also implies the need for geological studies to more accurately determine deposits and optimal drilling sites. Investments in research and development of technologies for drilling ultra-deep wells will be of strategic importance for ensuring the energy security of the region and meeting the growing demand

for oil and gas. An additional area of research may be the analysis of the experience and best practices of other countries, especially in the field of drilling under high geological stresses. Potential innovative methods and technologies that can improve the efficiency of ultra-deep drilling in western Turkmenistan should also be further explored.

Declaration of competing interest

The author declare that they have no known financial or non-financial competing interests in any material discussed in this paper.

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References

[1] A. R. Deryaev, "Well trajectory management and monitoring station position borehole," *SOCAR Proceedings*, vol. S2, pp. 1-6, 2023.

[2] Sh. Gurbannyyazov, "The role of information modeling technology in the digitalization of the construction industry," *International Scientific Journal Symbol of Science*, vol. 3, no. 1, pp. 54-56, 2023.

[3] A. R. Deryaev, "Selection of drilling mud for directional production and evaluation wells," *SOCAR Proceedings*, vol. 3, pp. 51-57, 2023.

[4] A. R. Annaeva, Sh. M. Allabaev and G. D. Ashirov, "Development of the oil and gas industry and growth prospects," *In Situ*, vol. 2, pp. 16-18, 2023.

[5] Kh. R. Akhmedov, H. A. Panzhiev and A. P. Eshmurolov, "Forecasting the oil and gas content of the Paleozoic deposits of the Bukhara-Khiva region of the Turan oil and gas province." *Interscience*, vol. 15, no. 49, pp. 5-6, 2018.

[6] A. Tanchak, K. Katovsky, I. Haysak, J. Adam, and R. Holomb, "Research of spallation reaction on plutonium target irradiated by protons with energy of 660 MeV," *Scientific Herald of Uzhhorod University. Series "Physics"*, no. 52, pp. 36-45, 2022. https://doi.org/10.54919/2415-8038.2022.52.36-45

[7] R. D. Selvakumar, J. Wu, I. Afgan, Y. Ding and A. K. Alkaabi, "Melting performance enhancement in a thermal energy storage unit using active vortex generation by electric field," *Journal of Energy Storage*, no. 67, 107593, 2023. https://doi.org/10.1016/j.est.2023.107593

[8] A. Byashimov, M. Ishanov, A. Berdieva and N. Ozbekov, "Some aspects of environmental safety in the oil and gas industry of Turkmenistan," *Colloquium Journal*, vol. 7, no. 166, pp. 30-31, 2023.

[9] R. Narmanova, A. Tapalova, R. Zhapparbergenov and N. Appazov, "Biological Products for Soil and Water Purification from Oil and Petroleum Products," *Evergreen*, vol. 10, no. 2, pp. 688-695, 2023. https://doi.org/10.5109/6792815

[10] J. C. Kurnia, M. S. Shatri, Z. A. Putra, J. Zaini, W. Caesarendra and A. P. Sasmito, "Geothermal energy extraction using abandoned oil and gas wells: Techno-economic and policy review," *International Journal of Energy Research*, vol. 46, no. 1, pp. 28-60, 2022. https://doi.org/10.1002/er.6386

[11] C. Peng, *et al.*, "Predicting rate of penetration in ultra-deep wells based on deep learning method," *Arabian Journal for Science and Engineering*, vol. 48, no. 12, pp. 16753-16768, 2023. https://doi.org/10.1007/s13369-023-08043-w

[12] S. Davoodi, M. Al-Shargabi, D. A. Wood, V. S. Rukavishnikov and K. M. Minaev, "Synthetic polymers: A review of applications in drilling fluids," *Petroleum Science, (in press)*. https://doi.org/10.1016/j.petsci.2023.08.015

[13] N. Reppas, C. T. Davie, Y. Gui, B. Wetenhall and S. P. Graham, "The effects of cooling on fine-grained sandstone in relation to wellbore injection of carbon dioxide," *Rock Mechanics and Rock Engineering*, vol. 56, no. 10, pp. 7619-7637, 2023. https://doi.org/10.1007/s00603-023-03446-5

[14] L. Santos, A. D. Taleghani and D. Elsworth, "Repurposing abandoned wells for geothermal energy: Current status and future prospects," *Renewable Energy*, vol. 194, pp. 1288-1302, 2022. https://doi.org/10.1016/j.renene.2022.05.138

[15] K. Abdelaal, K. Atere, K. LeRoy, A. Eddy and R. Smith, "Holistic real-time drilling parameters optimization delivers best-in-class drilling performance and preserves bit condition – A case history from an integrated project in the Middle East," in *SPE Canadian Energy Technology Conference*. Calgary: Society of Petroleum Engineers, p. SPE-208958-MS, 2022. https://doi.org/10.2118/208958-MS

[16] A. Sircar, K. Yadav, K. Rayavarapu, N. Bist and H. Oza, "Application of machine learning and artificial intelligence in oil and gas industry," *Petroleum Research*, vol. 6, no. 4, pp. 379-391, 2021. https://doi.org/10.1016/j.ptlrs.2021.05.009

[17] I. H. Zinchenko and O. V. Lavdanska, "MODERN TECHNOLOGIES FOR EVALUATING THE EFFECTIVENESS OF DIGITALIZATION," *Bulletin of Cherkasy State Technological University*, no. 2, pp. 34-42, 2022. https://doi.org/10.24025/2306-4412.2.2022.263563

[18] K. Mudryk, T. Hutsol, M. Zablodskiy, D. Sorokin and S. Usenko, "A study of electrothermomechanical converter for technological purposes with nonlinear changes in the loading and cooling medium," *Machinery & Energetics*, vol. 14, no. 2, pp. 9-22, 2023. https://doi.org/10.31548/machinery/2.2023.09

[19] O. Riabchuk, O. Panasiuk, V. Tarashchenko, T. Bilobrovenko and K. Saliamon-Mikhieieva, "Problems and prospects of state financial control and analysis of local budget execution," *Scientific Horizons*, vol. 25, no. 11, pp. 102-110, 2022. https://doi.org/10.48077/scihor.25(11).2022.102-110

[20] Y. Ghorbani, *et al.*, "Moving towards deep underground mineral resources: Drivers, challenges and potential solutions," *Resources Policy*, vol. 80, p. 103222, 2023. https://doi.org/10.1016/j.resourpol.2022.103222

[21] Iu. M. Shynkariuk, "Alternative representation of space and time: Geometric solution of problems of relativity theory," *Scientific Herald of Uzhhorod University. Series "Physics"*, no. 51, pp. 74-82, 2022. https://doi.org/10.54919/2415-8038.2022.51.74-82

[22] M. Akkurt, S. O. Yildirim, N. Q. Shikhaliyev, N. A. Mammadova, A. A. Niyazova, V. N. Khrustalev and A. Bhattarai, "Crystal structure and Hirshfeld surface analysis of (E)-2-(4-bromophenyl)-1-[2,2-dibromo-1-(4-nitrophenyl)ethenyl]diazene," *Acta Crystallographica Section E: Crystallographic Communications*, vol. 78, pp. 732-736, 2022. https://doi.org/10.1107/S205698902200620X

[23] S. M. Ozdoyev and N. Tileuberdi, "The geological prerequisites for increasing oil production at the North Karamandybas field. News of the National Academy of Sciences of the Republic of Kazakhstan," Series of Geology and Technical Sciences, vol. 4, no. 424, pp. 276-280, 2017.

[24] Kh. Z. Rasulov, E. S. Toshmatov and D. Zh. Artykbaev, "Earthquake-Resistant Steepness of Slope Structures," *AIP Conference Proceedings*, vol. 2612, 020006, 2023. https://doi.org/10.1063/5.0113268

[25] K. Baibolov, D. Artykbaev, Z. Aldiyarov and G. Karshyga, "Experimental investigations of the coarse-grained soil in the dam of the pskem hep," *News of the National Academy of Sciences of the Republic of Kazakhstan, Series of Geology and Technical Sciences*, vol. 1, no. 451, pp. 21-32, 2022. https://doi.org/10.32014/2022.2518-170X.136

[26] Ya. Hrechko, I. Sereda, Ie. Babenko and M. Azarenkov, "Thermionic coating method with preliminary bombardment of the substrate surface with a stream of low energy ions," *Scientific Herald of Uzhhorod University. Series "Physics"*, no. 53, pp. 9-8, 2023. https://doi.org/10.54919/physics/53.2023.09

[27] V. F. Dyomin, A. T. Batyrkhanova, A. N. Tomilov, A. Ye. Zhumabekova and U. E. Abekov, "Developing technological schemes of driving workings with controlled resistance of contours," *Naukovyi Visnyk Natsionalnoho Hirnychoho Universytetu*, vol. 2019, no. 3, pp. 22-28, 2019. https://doi.org/10.29202/nvngu/2019-3/2

[28] H. Wang, H. Huang, W. Bi, G. Ji, B. Zhou and L. Zhuo, "Deep and ultra-deep oil and gas well drilling technologies: Progress and prospect," *Natural Gas Industry B*, vol. 9, no. 2, pp. 141-157, 2022. https://doi.org/10.1016/j.ngib.2021.08.019

[29] A. Kobets, E. Aliiev, H. Tesliuk and O. Aliieva, "Simulation of the process of interaction of the working bodies of tillage machines with the soil in Simcenter STAR-CCM+," *Machinery & Energetics*, vol. 14, no. 1, pp. 9-23, 2023. https://doi.org/10.31548/machinery/1.2023.09

[30] N. Tileuberdi, G. Z. H. Zholtayev, D. Zh. Abdeli and S. M. Ozdoev, "Investigation of drainage mechanism of oil from pores of oil saturated rocks using nitrogen at the laboratory condition," *News of the National Academy of Sciences of the Republic of Kazakhstan, Series of Geology and Technical Sciences*, vol. 5, no. 449, 146-152, 2021. https://doi.org/10.32014/2021.2518-170X.108

[31] V. Kaplun, R. Chuenko and S. Makarevych, "Investigation of energy parameters of a compensated asynchronous motor in the mode of repeated short-term starts," *Machinery & Energetics*, vol. 13, no. 3, pp. 25-33, 2022. https://doi.org/10.31548/machenergy

[32] S. Atanasov, "State-of-the-art technologies for remote sensing of crops water status and nutrients in agriculture: A review," *Scientific Horizons*, vol. 26, no. 9, pp. 167-177, 2023. https://doi.org/10.48077/scihor9.2023.167

[33] N. Voloshyna, O. Voloshyn, D. Sushko, D. Dubinskyi and Yu. Karpenko, "Ecological mechanisms of sus scrofa population regulation in modern conditions," *Scientific Horizons*, vol. 25, no. 2, pp. 65-75, 2022. https://doi.org/10.48077/scihor.25(2).2022.65-75

[34] T. Fang, F. Ren, H. Liu, Y. Zhang and J. Cheng, "Progress and development of particle jet drilling speed-increasing technology and rock-breaking mechanism for deep well," *Journal of Petroleum Exploration and Production Technology*, vol. 12, no. 6, pp. 1697-1708, 2022. https://doi.org/10.1007/s13202-021-01443-4

[35] G. I. Dzhalalov, G. E. Kunayeva and G. Zh. Moldabayeva, "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.

[36] N. Trusova, N. Kotvytska, A. Sakun, T. Pikhniak, M. Pavlova and S. Plotnichenko, "Attracting foreign investment in cyclic imbalances of the economy," *Scientific Horizons*, vol. 25, no. 5, pp. 101-116, 2022. https://doi.org/10.48077/scihor.25(5).2022.101-116

[37] M. S. Khaled, N. Wang, P. Ashok and E. van Oort, "Downhole heat management for drilling shallow and ultra-deep high enthalpy geothermal wells," *Geothermics*, vol. 107, p. 102604, 2023. https://doi.org/10.1016/j.geothermics.2022.102604

[38] K. Martynova and O. Rogacheva, "Thermal conductivity of solid solutions of Bi2(Te1-xSex)3 (x = 0-0.07)," *Scientific Herald of Uzhhorod University. Series "Physics"*, no. 52, pp. 9-15, 2022. https://doi.org/10.54919/2415-8038.2022.52.9-15

[39] M. Ali, A. K. Alkaabi, S. A. Alameri and M. Alrwashdeh, "Effect of thermal energy storage integration on overall nuclear power plant efficiency," *Transactions of the American Nuclear Society*, no. 121, pp. 1097-1098, 2019. https://doi.org/10.13182/T30837

[40] N. Repnikova, Yu. Berdnyk and V. Hnyp, "Improving control accuracy in multi-connected digital systems," *Scientific Horizons*, vol. 25, no. 7, pp. 55-64, 2022. https://doi.org/10.48077/scihor.25(7).2022.55-64

[41] I. Yakymenko, V. Lysenko and K. Witaszek, "Methodology of development of intellectual energy efficient system of control of temperature-humidity regime in industrial heat," *Machinery & Energetics*, vol. 13, no. 1, pp. 18-25, 2022. https://doi.org/10.31548/machenergy

[42] D. Mozharivskyi, L. Titova, O. Nadtochiy and P. Dasic, "Aspects of expert system of engineering management of technical condition of grain harvesters," *Machinery & Energetics*, vol. 13, no. 1, pp. 60-66, 2022.

[43] S. Krishna, S. Ridha, S. U. Ilyas, S. Campbell, U. Bhan and M. Bataee, "Application of deep learning technique to predict downhole pressure differential in eccentric annulus of ultra-deep well," in *Proceedings of the ASME 2021 40th International Conference on Ocean, Offshore and Arctic Engineering. Volume 10: Petroleum Technology*. New York: American Society of Mechanical Engineers, p. OMAE2021-62621, V010T11A072, 2021. https://doi.org/10.1115/OMAE2021-62621

[44] A. Danylkovych, O. Sanginova and A. Shakhnovsky, "Computer simulation and optimization of the composition of the hydrophobising mixture," *Bulletin of Cherkasy State Technological University*, no. 2, pp. 100-110, 2023. https://doi.org/10.24025/2306-4412.2.2023.277295

[45] T. O. Prokopenko and Y. Povolotskyi, "A system of criteria for evaluating the efficiency of projects in the field of information technologies," *Bulletin of Cherkasy State Technological University*, no. 4, pp. 23-30, 2022. https://doi.org/10.24025/2306-4412.4.2022.271448

[46] L. Nykyforova, N. Kiktev, T. Lendiel, S. Pavlov and P. Mazurchuk, "Computer-integrated control system for electrophysical methods of increasing plant productivity," *Machinery & Energetics*, vol. 14, no. 2, pp. 34-45, 2023.

[47] K. N. Celino, E. A. de Souza and R. de Carvalho Balaban, "Emulsions of glycerol in olefin: A critical evaluation for application in oil well drilling fluids," *Fuel*, vol. 308, p. 121959, 2022. https://doi.org/10.1016/j.fuel.2021.121959

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

[49] G. Z. Moldabayeva, G. P. Metaxa and Z. N. Alisheva, "Theoretical bases for the implementation of the processes to reduce viscosity in the conditions of natural reservation," *News of the National Academy of Sciences of the Republic of Kazakhstan, Series of Geology and Technical Sciences*, vol. 5, no. 437, pp. 138-143, 2019.

[50] N. Clegg, *et al.*, "Detection of offset wells ahead of and around an LWD ultra-deep electromagnetic tool," in *SPWLA 62nd Annual Logging Symposium*. Boston: Boston Chapter, SPWLA, p. SPWLA-2021-0039, 2021. https://doi.org/10.30632/SPWLA-2021-0039

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