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FEATURES OF THE CONSTRUCTION OF DIRECTED DEEP WELLS IN TURKMENISTAN

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EXTENDED ABSTRACT

L'industria del petrolio e del gas in Turkmenistan è cruciale per l'economia della nazione, ma deve affrontare sfide significative a causa della crescente domanda globale di petrolio e della complessità delle sue formazioni geologiche. Per mantenere e aumentare la produzione di petrolio, l'industria è costretta a innovare tutti gli aspetti operativi, in particolare nella trivellazione e nella gestione dei giacimenti. Questo studio esplora l'applicazione e l'impatto della tecnologia Simultaneous Operations (SIMOPS) in Turkmenistan, concentrandosi sulla sua capacità di affrontare queste sfide attraverso perforazioni direzionali avanzate e una gestione efficiente dei giacimenti.

Storicamente, i giacimenti petroliferi del Turkmenistan si sono affidati a tecniche di perforazione convenzionali caratterizzate da pozzi verticali o leggermente inclinati mirati ai singoli strati del giacimento. Questi metodi sono stati meno efficaci nei serbatoi multistrato a causa della loro incapacità di accedere e gestire in modo efficiente più strati, portando a un recupero di idrocarburi non ottimale, a un maggiore impatto ambientale e a costi più elevati. Le questioni chiave includono lo sfruttamento inefficiente delle zone permeabili, gli alti tassi di convogliamento di acqua o gas e la limitata flessibilità nella gestione dei giacimenti, che spesso si traduce nel fatto che importanti riserve rimangono inutilizzate.

La tecnologia SIMOPS rappresenta un cambiamento nelle strategie di perforazione e produzione che permette la perforazione di pozzi che accedono simultaneamente a più strati di giacimento attraverso un unico foro. Questo approccio non solo riduce i costi di perforazione e gli impatti ambientali, ma migliora anche l'efficienza dello sfruttamento dei giacimenti. Integrando strumenti avanzati di fondo pozzo e sistemi di telemetria, SIMOPS consente un controllo preciso della traiettoria del pozzo, ottimizzando il posizionamento dei pozzi e i tassi di produzione. Questa tecnologia fornisce inoltre la flessibilità necessaria per una gestione efficace del giacimento, consentendo agli operatori di adattare dinamicamente le strategie di produzione e mirare a zone specifiche all'interno del giacimento.

L'applicazione di SIMOPS in Turkmenistan, in particolare nel giacimento di North Goturdepe, dimostra miglioramenti significativi nell'efficienza produttiva e nella performance economica. Quest'area è nota per le sue complesse formazioni e strutture geologiche, che offrono sia sfide che opportunità per l'esplorazione e la produzione di petrolio e gas. Il principale giacimento di produzione di petrolio nella regione, la Formazione Nebitdag Goturdepe, mostra una notevole diversità litologica e di facies, contribuendo a una significativa variabilità nelle caratteristiche del giacimento. La sequenza rocciosa sotterranea dell'area, comprende arenarie, scisti e carbonati di vari periodi geologici. Questo assetto strutturale, caratterizzato da una serie di anticlinali e sinclinali, svolge un ruolo cruciale nella distribuzione e nel comportamento degli idrocarburi all'interno dei giacimenti, influenzandone la geometria, la porosità, la permeabilità e dunque la produttività finale. In generale, le arenarie spesso fungono da potenziali zone serbatoio con porosità e permeabilità favorevoli per lo stoccaggio di idrocarburi; gli scisti agiscono come barriere, regolando il movimento dei fluidi nel giacimento, mentre il potenziale serbatoio nei carbonati dipende dalla loro porosità e dallo stato di fratturazione. Inoltre, l'attività tettonica dell'area, compresi pieghe, faglie e sollevamenti, ha un impatto significativo sulla configurazione dei giacimenti e sulla distribuzione degli idrocarburi, sottolineando l'importanza di comprendere questi contesti geologici per un'efficace gestione dei giacimenti e una strategia di produzione.

Confrontando le metodologie convenzionali e SIMOPS, questo studio illustra come SIMOPS può aumentare i tassi di recupero del petrolio, ridurre i tempi di perforazione e minimizzare l'impatto ambientale delle operazioni di perforazione. I risultati sono supportati da dati raccolti da varie operazioni, evidenziando i vantaggi pratici e le sfide incontrate durante l'implementazione di SIMOPS. L'uso del SIMOPS in Turkmenistan ha implicazioni più ampie per l'industria petrolifera globale nello gestire contesti geologici complessi e serbatoi eterogenei migliorando la produzione di idrocarburi e riducendo le spese e i costi operativi per tutta la vita dei giacimenti petroliferi grazie al minor numero di pozzi e all'utilizzo di pozzi direzionali di esplorazione avanzata da pozzi esistenti. Pertanto, sebbene SIMOPS presenti alcuni ostacoli tecnici, rimane vitale per la crescita strategica dell'industria del petrolio e del gas, supportando lo sviluppo sostenibile e l'aumento della produzione di energia a lungo termine come dimostrato nei giacimenti petroliferi del Turkmenistan.

Questo studio non solo contribuisce alla comprensione delle tecniche avanzate di perforazione in contesti geologici complessi, ma fornisce anche preziose informazioni per gli *stakeholders* dell'industria globale che puntano a superare sfide simili. Man mano che l'industria avanza, l'integrazione di tali tecnologie sarà vitale per garantire la fattibilità economica e la sostenibilità ambientale della produzione di idrocarburi.

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ABSTRACT

The relevance of the study of construction of directional deep wells in Turkmenistan lies in the application of innovative drilling methods for efficient oil production from hard-to-reach horizons, which is becoming a strategic necessity in the context of the development of the oil industry in this country. The purpose of this study was to analyse the effectiveness of the simultaneous separate operation method in the context of hydrocarbon production in one of the fields of Turkmenistan. In the course of the work the statistical method, comparative method and analysis were used. The results of the study indicated that the introduction of advanced technologies and equipment in the process of drilling and well development in the region of Turkmenistan had a profound impact on oil production. It has led not only to increased efficiency and reduced well construction time, but also increased oil production. The demand for this technology is of particular importance in western Turkmenistan, where directional drilling has become a key factor in the region's economic development and energy security. The gamma ray logging results show fluctuations in natural radiation levels corresponding to different geological formations. Pressure curves plotted as a function of depth demonstrate fluctuations in reservoir pressure. The results of the work are of direct practical significance, allowing to accelerate the development of fields in difficult geological conditions, offshore shallow waters, as well as to reduce drilling costs without requiring changes in oil recovery factor.

Keywords: *reservoir productivity, reserve depletion, profitability, oil inflow, bottomhole, separate operation*

INTRODUCTION

Strong Turkmenistan's oil and gas industry, faced with ever-increasing oil demand, faces the challenge of not just adapting to changing conditions, but actively innovating in all aspects of its operations. Maintaining and increasing oil production is becoming a central challenge, leading to a review and improvement of production methods. Key to this is the introduction of advanced technologies, from the development of new drilling systems to the use of highly efficient equipment that can optimize processes and improve production capabilities at all stages of field development (Fan *et alii*, 2021; Khotsianivskyi & Sineglazov, 2023). This aspect includes not only the search for new resources in existing fields, but also the exploration and development of deep horizons, where resources have proven difficult to access due to geological formations and low-permeability reservoirs, requiring innovative approaches and modern technologies for their extraction. In light of these challenges, innovative approaches to drilling directional deep wells are becoming a key factor for efficient field exploitation and increasing the overall productivity of Turkmenistan's oil industry. This opens up new opportunities for the development and implementation of technological solutions that can ensure sustainable and enhanced oil production from complex geological formations.

Conventional drilling systems have been the cornerstone of oil and gas extraction for decades, but their limitations become apparent when dealing with multilayer reservoirs. These systems typically involve vertical or slightly deviated wells drilled individually to target specific reservoir layers. However, this approach often results in suboptimal recovery rates and inefficient exploitation of reservoirs due to several limitations. One major limitation is the inability to efficiently access multiple reservoir layers with a single well. Conventional drilling systems require separate wells for each layer, leading to increased drilling costs, longer construction times, and higher environmental impact. Moreover, the vertical orientation of these wells may not adequately intersect fractures or permeable zones within the reservoir, limiting hydrocarbon recovery. Another issue is the lack of flexibility in reservoir management. Conventional wells have limited capabilities for adjusting production rates or targeting specific zones within the reservoir. This can result in uneven depletion of reservoirs, leaving behind significant untapped reserves and reducing overall recovery efficiency. Furthermore, conventional drilling systems are often susceptible to issues such as water or gas coning, which occurs when water or gas migrates into the wellbore, displacing hydrocarbons and reducing production rates. These challenges highlight the need for more innovative approaches to maximize hydrocarbon recovery from multilayer reservoirs. In contrast, Simultaneous Operations (SIMOPS) technology offers several advantages over conventional drilling systems. One key benefit is the ability to access multiple reservoir layers simultaneously with a single wellbore. This approach reduces drilling costs, minimizes environmental impact, and accelerates field development by allowing for more efficient exploitation of reservoirs. Additionally, SIMOPS technology enables greater flexibility in reservoir management. Operators can adjust production rates and target specific zones within the reservoir more effectively, leading to optimized hydrocarbon recovery and extended field life. By integrating advanced downhole tools and telemetry systems, engineers can precisely control the trajectory of the wellbore, ensuring optimal placement within the reservoir.

Moreover, SIMOPS technology mitigates the risk of issues such as water or gas coning by optimizing well placement and production techniques. By carefully managing fluid flow and pressure, operators can minimize the influx of water or gas into the wellbore, maintaining stable production rates and maximizing recovery efficiency. However, SIMOPS technology also has its limitations. The initial investment cost may be higher compared to conventional drilling systems due to the need for specialized equipment and advanced downhole tools. Additionally, SIMOPS requires thorough planning and coordination to ensure safe and efficient operations, which can pose logistical challenges for some projects. In summary, while conventional drilling systems have limitations in efficiently exploiting multilayer reservoirs, SIMOPS technology offers a more innovative and effective approach to hydrocarbon production. By simultaneously accessing multiple reservoir layers with a single wellbore and providing greater flexibility in reservoir management, SIMOPS technology represents a significant advancement in the oil and gas industry's quest for optimized recovery and sustainable field development.

In the study of Arabov *et alii* (2021), the authors emphasize the great importance of directional drilling of deep wells for the progress of the oil industry. According to the findings, this method is designed to optimize production processes, especially in complex geology where conventional methods may not be effective. It is noted that it can open up opportunities to effectively exploit previously inaccessible reservoir areas to maximize the benefits of their potential for oil production.

In his work, Ataev (2015) confirms that directional drilling of deep wells has great potential to increase oil production in complex geological conditions. This method allows for better adaptation to variable geological formations and more efficient extraction of hydrocarbons from deep reservoirs. It is also noted that this method can optimize the use of resources and minimize the impact on ecosystems, as fewer wells are used to extract more oil, reducing the overall impact on natural resources.

According to Romanenko *et alii* (2022), the use of simultaneous operations method (SIMOPS) allows production from different horizons of one well, applying different technologies for each section of the reservoir. This allows increasing production efficiency by minimizing the number of wells and optimizing hydrocarbon production processes. However, it is noted that to realize the full potential of this method, additional technical studies and refinement of the technique to maximize its efficiency are required.

According to Anishchenko & Atrushkevich (2020), one of the important aspects of the SIMOPS method is its ability to effectively manage oil production from multilayer reservoirs, providing the ability to regulate the pressure and fluid flow in each layer independently of each other. This is achieved through the use of multi-stage tubing units that regulate the pressure in each section of the well, providing optimum production conditions for each layer. It is emphasized that this individual control of production processes allows hydrocarbons to be extracted more efficiently and allows processes to be tailored to the characteristics of each reservoir, increasing the overall productivity of the field.

Since the above-mentioned studies have not paid enough attention to the practical application of the simultaneous separate operation method in hydrocarbon production, the purpose of this paper is to analyse its real application on the example of oil fields in Turkmenistan. The main objective is to study the effectiveness of this method, its impact on technological and economic indicators of production, as well as to identify the peculiarities and problems arising from its use in this regional environment.

This research holds significant importance for the international community due to its exploration of advanced drilling techniques and their application in complex geological settings, specifically in the North Goturdepe field of Turkmenistan. By addressing the challenges posed by heterogeneous reservoirs and intricate structural settings, the study highlights innovative approaches to enhance hydrocarbon production efficiency. The findings underscore the efficacy of advanced directional drilling techniques, such as horizontal wellbores and SIMOPS, in optimizing reservoir development and increasing oil recovery rates. By demonstrating the success of these methods in a real-world context, the paper offers valuable insights for oil and gas industries worldwide facing similar geological complexities. Moreover, the study's emphasis on technological advancements and their integration into field operations resonates with a broad audience interested in enhancing energy exploration and production strategies. The implications extend beyond Turkmenistan, influencing global efforts to maximize hydrocarbon recovery, minimize environmental impact, and ensure energy security. In essence, this paper contributes to the collective knowledge base of the international scientific and industrial community, offering practical solutions and strategic insights for addressing the challenges of reservoir management and oil production in complex geological environments.

MATERIALS AND METHODS

This study reviewed the experience of directional drilling by Turkmenneft State Concern, using the latest advanced technologies, in the North Goturdepe field (Turkmenistan). This included the study of geophysical survey diagrams as well as pressure plots for the wells in the field (Deryaev, 2023). The focus on reservoir pressure, in particular, distinguishes from other types of pressure like lithostatic or hydraulic, providing a direct link to the field's production dynamics and the effective management of reservoirs.

The methodologies employed in this research were rooted in statistical analysis and comprehensive data evaluation to decipher trends in oil production advancements and the efficacy of various drilling technologies. Specifically, statistical methods were pivotal for processing and interpreting geological characteristics of wells, reservoir parameters, productivity, and the success of novel drilling technologies. These methods facilitated a rigorous assessment of the reservoirs' parameters, identifying patterns in production metrics relative to technical well aspects or geological attributes. Such evaluations underpin conclusions on technology efficiencies and guide the optimization of drilling processes. A critical component of the statistical approach was the use of principal equations to analyze the data. One key equation used was:

$$P=\rho gh \quad (1)$$

where P represents the reservoir pressure, ρ – the fluid density, g – the acceleration due to gravity, and h – the depth of the fluid column. This equation was fundamental in calculating the pressure at various depths, providing insights into the reservoir's behavior under different operational conditions. Another principal equation focused on the statistical analysis of production data:

$$Q=A*e^{(-Dt)} \quad (2)$$

where Q represents the rate of oil production, A – the initial production rate, D – the decline rate, and t – the time. This equation helped in forecasting production rates and evaluating the effectiveness of drilling and extraction techniques over time.

The statistical method also enabled a refined classification of reservoir geological characteristics, aiding in pinpointing each reservoir's unique attributes. This analysis was crucial for tailoring drilling and development strategies to each reservoir's specific needs, thereby enhancing the overall efficiency of production processes.

Furthermore, the study employed comparative methodologies to evaluate new drilling technologies against the backdrop of geological data from wells and reservoirs. This facilitated a nuanced comparison of deposit parameters and unravelled the nuances of the production process as influenced by well technical specifics. Consequently, optimal operational methods were identified for each reservoir based on the efficacy of new technologies, thereby augmenting the data pool for well design analysis and operational efficiency in resource development.

RESULTS

The study area, located in the southwest part of Turkmenistan, encompasses the North Goturdepe field, situated partially in the maritime zone of the Caspian Sea within the Balkhan Gulf. This region is characterized by complex geological formations and structural settings, presenting unique challenges and opportunities for oil and gas exploration and production. The geological framework of the study area comprises the Nebitdag Goturdepe Formation, which constitutes the primary reservoir for oil production in Turkmenistan. This formation exhibits significant lithological and facies variability, resulting in a high degree of heterogeneity in reservoir-filtration characteristics. The sedimentary succession in the subsurface consists of various lithological units, including sandstones, shales, and carbonates, deposited during different geological periods. The structural setting of the study area is characterized by a series of anticlines and synclines, reflecting the tectonic history of the region. The North Goturdepe field is situated within this structural framework, with geological structures influencing the distribution and behavior of hydrocarbons in the reservoirs. These structural features have a significant impact on reservoir geometry, porosity, and permeability, affecting reservoir performance and hydrocarbon production.

The rocks intercepted in the well at the North Goturdepe field exhibit diverse lithologies and facies characteristics. The sedimentary succession includes sandstones, shales, and carbonates, with varying thicknesses and properties. Sandstone intervals typically represent potential reservoir units, characterized by good porosity and permeability, conducive to hydrocarbon accumulation and production. Shale intervals act as sealing or confining units, controlling fluid flow within the reservoir. Carbonate rocks may exhibit reservoir properties depending on their porosity and fracturing. The structural setting of the study area is influenced by tectonic processes, including folding, faulting, and regional uplift. Anticlines and synclines are prominent structural features, affecting the geometry and distribution of reservoirs. Faults may compartmentalize reservoirs, influencing fluid flow and reservoir connectivity. Understanding the structural setting is crucial for reservoir characterization and development planning, as it dictates the distribution of hydrocarbons and the effectiveness of production techniques. In summary, the study area in southwest Turkmenistan encompasses complex geological formations and structural settings, posing challenges and opportunities for oil and gas exploration and production. The Nebitdag Goturdepe Formation serves as the primary reservoir, exhibiting significant lithological variability and structural complexity. Understanding the geological framework, structural setting, and characteristics of rocks intercepted in wells is essential for successful reservoir management and hydrocarbon production in this region.

Deposits of the Nebitdag Goturdepe Formation, which constitute the main reserve for stabilization of oil production in Turkmenistan, represent a unique complex with pronounced lithological and facies variability. This contingent of rocks is characterized by an extraordinary variety of structures and properties, creating a high degree of heterogeneity in the reservoir-filtration characteristics of productive formations. This entails significant challenges in oil and gas field development, presenting engineers and geologists with complex puzzles that seemingly have no easy solution at times. This heterogeneity of geological formations requires innovative approaches and careful analysis to successfully exploit and extract the unique energy resources contained in these deep geological formations (Al-Khdheeawi *et alii*, 2017; Ghassemi & Garzanti, 2019). However, it has been proven in practice that the application of advanced directional drilling techniques, especially when using telemetric downhole communication and logging channels during directional and horizontal wells, can significantly accelerate field development with minimal costs and in a much shorter time (Stavychnyi *et alii*, 2023). The effectiveness of such drilling techniques has demonstrated a new reality in the exploitation capabilities of wells, especially those that recover oil from Lower Redwood deposits.

The integration of horizontal wells successfully drilled and brought into production has led to a radical change in the understanding of the potential of these fields. Their productivity was not just within expectations, but many times higher than anticipated before these innovative techniques. This emphasizes the importance of new drilling techniques and approaches to oil production, opening up new opportunities and previously inaccessible or undervalued reserves, leading to new prospects for the upstream industry. The south-western part of Turkmenistan is a unique region with oil and gas fields, where about 95 per cent of the existing reservoirs have a multilayer structure (Fig. 1). This means that each productive reservoir has its own unique geological characteristics, including reservoir pressure, permeability, saturation pressure and water cut (Raimondi, 2019).

Fig. 1 - Overview map of Western Turkmenistan and location of the North Goturdepe field; spatial scale: 1:250000

This feature of the geological structure creates challenges and, at the same time, provides unique opportunities for the oil production industry. The varied characteristics of each reservoir require an individualized approach to its exploitation and development, as well as a high degree of technical adaptability in drilling and well development. Understanding these characteristics becomes the key to effective production management, as each reservoir has its characteristics that affect its potential and operational capabilities (Sun *et alii*, 2019). The productive reservoirs in this region are characterized by various capacities, which represents an important geological feature. These formations are exploited according to the bottom-up sequence principle, considering their unique characteristics. The example of well No. 29 North Goturdepe illustrates a geophysical survey diagram showing the layered structure and different reservoir intervals in this area (Fig. 2).

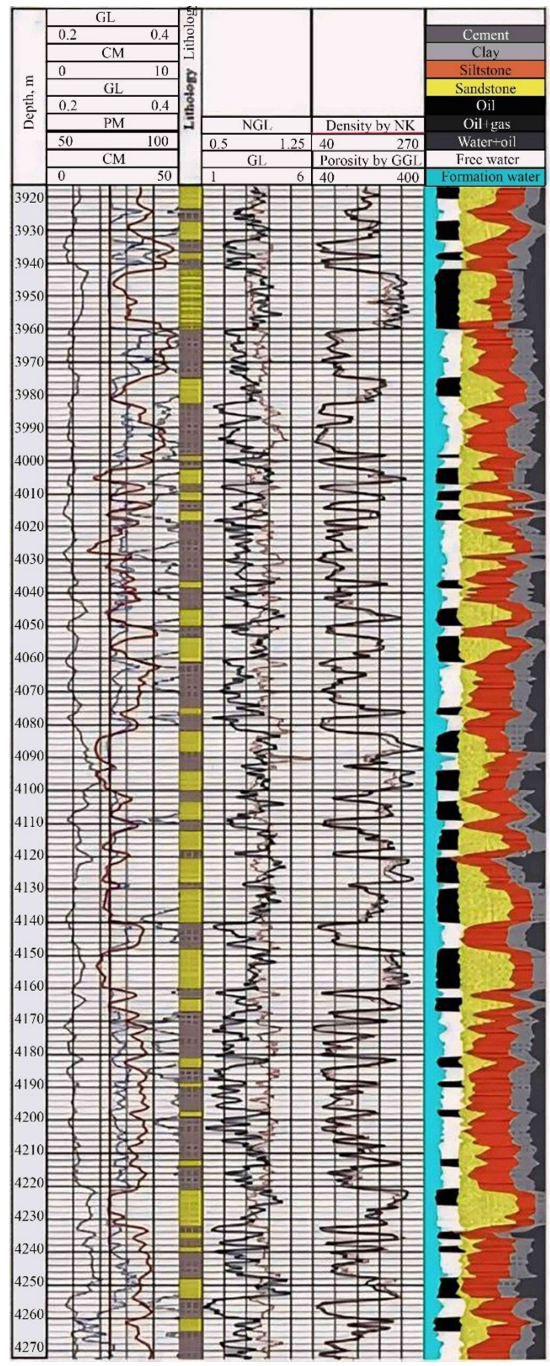

Fig. 2 - Fragment of logging diagram for well No. 29 North Goturdepe

For cavernometry, the data indicates a range of cavern sizes across the surveyed area, with depths varying from approximately 2000 meters to 4500 meters. Profiles show variations in surface topography, with notable features such as ridges and valleys correlating with subsurface caverns and formations. Gamma-ray logging reveals fluctuations in natural radiation levels corresponding to different geological formations, with peaks indicating the presence of certain mineral compositions. Neutron logging data illustrates changes in neutron counts indicative of lithological changes and porosity variations within the formations. Pressure curves plotted as a function of depth demonstrate fluctuations in reservoir pressure, with depths ranging from approximately 1000 meters to 5000 meters. These curves provide valuable insights into reservoir behavior and potential hydrocarbon accumulation zones.

The horizontal wireline technology is an effective method of eliminating the negative effects of vertical wellbores. This method reduces the risk of underbalance holes, which can promote the intensive movement of water or gas from the upper gas-bearing layers towards the well. Such processes significantly reduce the life of the well, lead to underproduction of part of the reserves, and require compaction of field development (Guan *et alii*, 2021). However, the use of horizontal drilling in productive strata demonstrates the slowing down of these negative processes. This allows more efficient oil production from reservoirs with lower thickness. In the case of reservoirs with high permeability, horizontal wellbores allow increasing oil flow into the well several times. In fractured and heterogeneous reservoirs, horizontal wellbores provide access to areas of increased permeability and porosity. Drilling horizontal wellbores from existing wells allows efficient extraction of oil that remains in some parts of the reservoir after long-term operation, increasing the overall production efficiency and extending the life cycle of the field (Mahmoud *et alii*, 2020; Loreto *et alii*, 2022).

Innovative methods and technical solutions are used when drilling wells with different deviated wellbores at new and existing fields. This includes the use of special devices for wellbore trajectory control, as well as downhole telemetry systems that provide precise control and monitoring of drilling direction. Such systems are equipped with advanced software that allows engineers and geologists to carefully plan and control not only the depth and angle of the well, but also its direction in the required geological horizon. These technological solutions allow the well trajectory to be precisely adjusted, creating the right deviation of the wellbore to achieve specific geological objectives. For example, in old fields, these systems allow for additional drilling to recover remaining oil or gas reserves, and in new fields, they optimize exploration and development of new areas given the complex geological conditions. This significantly improves drilling efficiency, minimizes risks and ensures more accurate execution of the specified technological parameters of wells (Deryaev, 2023).

For production companies, the attractiveness of drilling horizontal wells and simultaneous separate operation is associated with a number of the following factors, which represent a significant advantage in optimizing oil and gas production processes:

1. The ability to increase oil flow rates allows for faster field development without increasing the oil withdrawal rate. This is an effective solution to increase productivity without overconsumption of resources.
2. Also increasing production rates without the threat of shortening the life of wells, due to possible gas or water breakthroughs through underbalanced funnels, represents a significant economic benefit and minimizes the risks associated with loss of well efficiency (Qutob & Byrne, 2015).
3. Another factor is the decompaction of the well placement grid in new fields. This optimizes the number of production wells required, ensuring more efficient use of the field.
4. Conducting directional drilling from old wells in depleted fields is also a strategic solution to prevent the need for new wells to densify the grid (Elgaddafi *et alii*, 2021).

This simultaneous separation programme receives significant support from manufacturing companies specializing in downhole devices. Their developments and technical solutions play a key role in ensuring the efficiency and safety of this method of oil and gas production.

Turkmenneft State Concern endeavours to build on international experience to effectively apply the SIMOPS method of multiple horizons in a single well. For this purpose, preference is given to specialized equipment capable of working in several productive formations simultaneously. One of the key elements of such equipment is a packer, which ensures isolation of formations from each other, as well as the presence of gas lift valves for gas supply when using the gas lift method of production, as well as separate channels to bring oil to the surface. In our study the utilization of packers plays a pivotal role, particularly in the context of Westbay technology applications. Westbay systems, known for their modular multilevel monitoring capabilities, have been integrated with packer technology to isolate and evaluate different production zones within a single well. This integration allows for precise control and assessment of reservoir performance at various depths. In the field, packers equipped with Westbay technology were strategically positioned to seal off sections of the well, enabling discrete sampling and pressure measurements across the multilayer structure of the reservoirs. This approach not only enhanced the accuracy of our geological and reservoir analyses but also significantly improved the efficiency of well testing and development processes. For example, in well No. 201, we deployed a dual-packer system with Westbay modules to isolate and test specific intervals at depths exceeding 4000 meters. This setup provided crucial data on the reservoir's pressure behavior and fluid composition, demonstrating the efficacy of combining Westbay technology with packers in optimizing well construction and evaluation in complex geological settings.

The technical requirements for the equipment for separate operations must ensure that the same technological measures can be taken as with wells producing these formations separately. This includes the need for workover and process operations, pressure and temperature control, and the ability to adjust production processes in each reservoir. The focus is on the development and application of high-tech equipment that can not only ensure safe and efficient operation of multiple reservoirs simultaneously, but also has the flexibility and adaptability to perform a wide range of technical operations, presenting engineers and specialists with high technological and engineering challenges.

The North Goturdepe field is a unique site for practical testing of advanced technologies in oil production. Its peculiarity is its partial location in the maritime zone of the Caspian Sea, in the waters of the Balkhan Gulf. This unique context of the field is conditioned not only by geological peculiarities, but also by peculiarities of operation, which makes it an ideal place for testing the latest technologies in oil production (Deryaev, 2022). In the North Goturdepe field, several field tests have been carried out in which several wells numbered 37, 147, 200 and 201 have been developed – using the SIMOPS method. These wells were the subject of attention during both the design phase and actual implementation, providing valuable data on the actual designs and performance of each well. Table 1 provides information on the design and actual performance of these wells.

In developing and justifying the design of exploration well No. 201 in the North Goturdepe field, several key factors were considered to ensure the safety and efficiency of drilling in the region. The specific design of the No. 201 well was based on information obtained from previously drilled wells in the field. The decision on the well configuration was determined by the intervals of compatibility of the well section with drilling conditions in this geological context. This included the analysis of predicted reservoir and fracture pressure curves, which allowed anticipation of well conditions at different depths and geological levels (Temizel *et alii*, 2018). The choice of well design No. 201 was focused on ensuring maximum safety and optimal oil production efficiency, considering the specific requirements of the geological formations and reservoir characteristics of this field. This made it possible to create a well design technically justified and adapted to the field conditions for successful implementation of production operations.

Based on the information provided, a decision was made to form a well design in accordance with the specified parameters and requirements:

1. An elongated direction with a diameter of 530 mm is installed at a depth of 30 m to prevent erosion of unstable rocks in the upper part when drilling the well through the conductor. Cement is poured to the top of the borehole without passing it through the wellhead and then pressurized.
2. The design of the conductor with diameter 426 mm assumes its lowering to the depth of 600 m to protect from the upper unstable parts of sandy-clayey quaternary deposits. Installation of the anti-kickback equipment OP1-425×210 according to scheme 1 at the wellhead is intended for effective control over the well in case of possible gas manifestations. Cement filling is carried out up to the wellhead during water pressure testing under the pressure of 70 kg/cm^2.
3. The first intermediate casing of 323.7 mm diameter is run to a depth of 2800 m to block the collapse-prone black-clay deposits of the Apsheron Stage. This will also reduce the openhole interval when the second 244.5 mm intermediate string is advanced. On the surface, a blowout preventer system OP2-350×350 according to scheme 2 is installed to control the well effectively in case of gas blowout using specialized equipment. Cementing is carried out up to the wellhead at a water pressure of 350 kg/cm^2.

Column name	Well numbers							
	147		37		200		201	
	Des.	Fact.	Des.	Fact.	Des.	Fact.	Des.	Fact.
Direction	30	30	30	30	30	30	30	30
Conductor	600	598	600	596	600	595	600	597
First intermediate column	2700	2696	2800	2784	2000	1997	2800	2796
Second intermediate column	4148*	4141	4800	4766	4500	4186	4800	-
Production column	-	4247	5200	4686-4902	4900	4182-4330	4700-5100	-

*Tab. 1 - Well designs at the North Goturdepe field, Turkmenistan; * correspond to vertical depth*

The 324 mm technical string is run in stages. The initial part of the first section is installed in the stable area of the open hole at depths from 1700 to 2300 m, and then adjustments are made to the logging data. A second intermediate string of 244.5 mm diameter is run to a depth of 4800 m to prevent absorption by drilling mud with a density of 2.05 g/cm^3 and to avoid entrapment of drilling equipment during pressure changes. The upper part of the well is equipped with the OP2-280×700 scheme 2 blowout preventer system for effective control in case of abnormal situations using special equipment. This process is completed by lifting the cement up to the wellhead during pressure testing with water at a pressure of 660 kg/cm² (Ali *et alii*, 2022). The 245 mm diameter technical string is lowered in two stages. The initial part of the first section is installed with penetration of 50-100 m into the area of the "shoe" of 323.7 mm diameter of the intermediate column. The 139.7 mm diameter "shank" is lowered to a specified depth between 4600 and 5100 m. Its purpose is to provide conditions for testing of productive formations. The height to which the cement is lifted is 500 metres. The pressure used for pressure testing is 504 kg/cm². OKKZ-700-140×245×324×426 elements and AFK6-80/65-700 flowing equipment are installed at the top of the well. Fig. 3 shows a visualization of the North Goturdepe field pressure data (well No. 201).

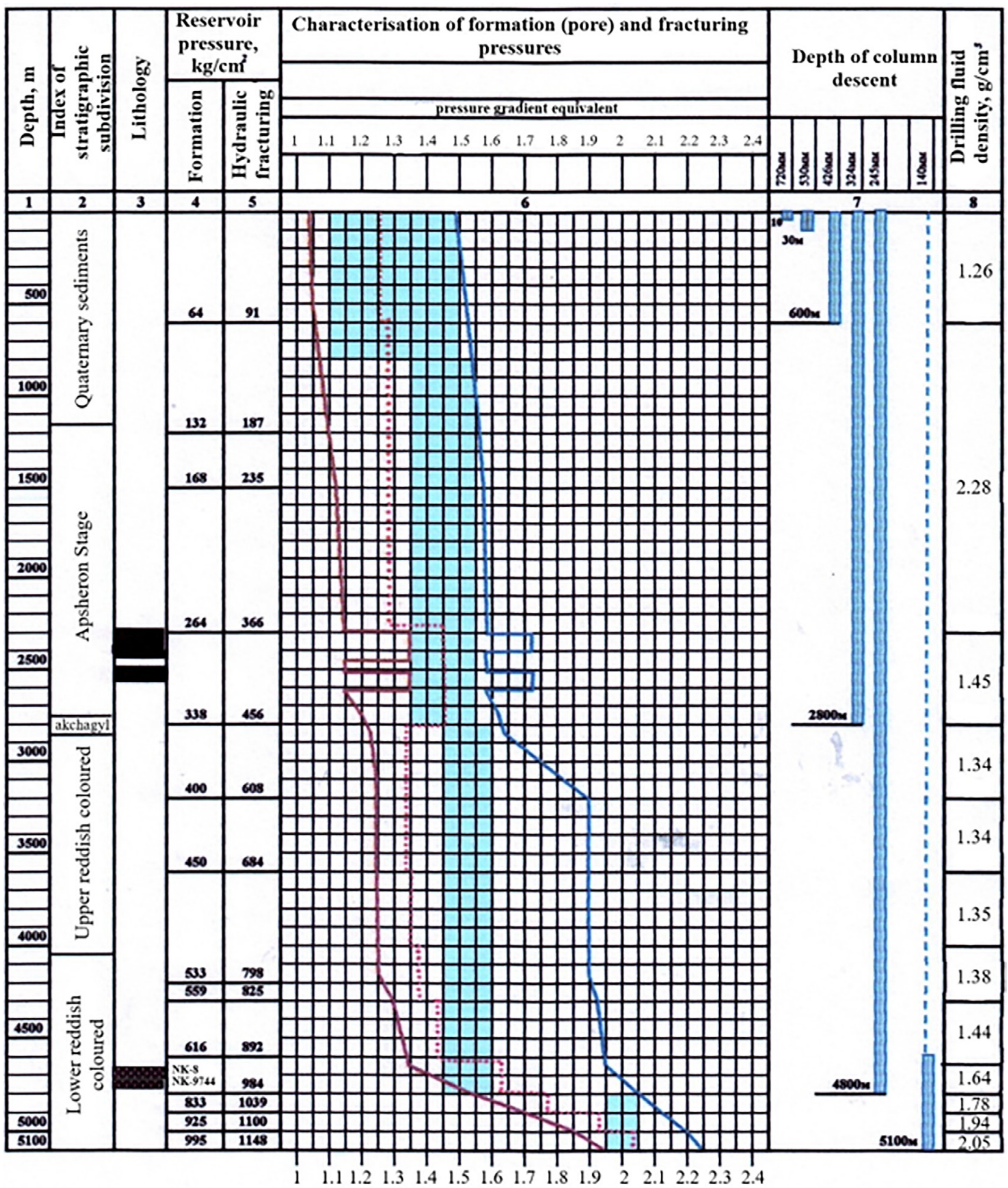

Fig. 3 - Schematic diagrams of double-lift tubing hangers: a) Well No. 37; b) Well No. 147; c) Well No. 201 (design)

The Goturdepe field, which has been actively developed for a long time, has undergone significant changes due to the introduction of advanced technologies, which has allowed not only to maintain its exploitation but also to increase oil production. This significant progress is largely attributable to the use of advanced drilling equipment and technologies, which are being actively mastered by experienced specialists from the State Concern. These innovations have been key to improving the productivity and efficiency of the production process at this field, helping to maintain its importance and prospects in an ever-changing oil market (Bozorgian, 2020). The schematic diagrams of the dual-lift tubing hangers for wells 37, 147 and 201 are shown in Fig. 4.

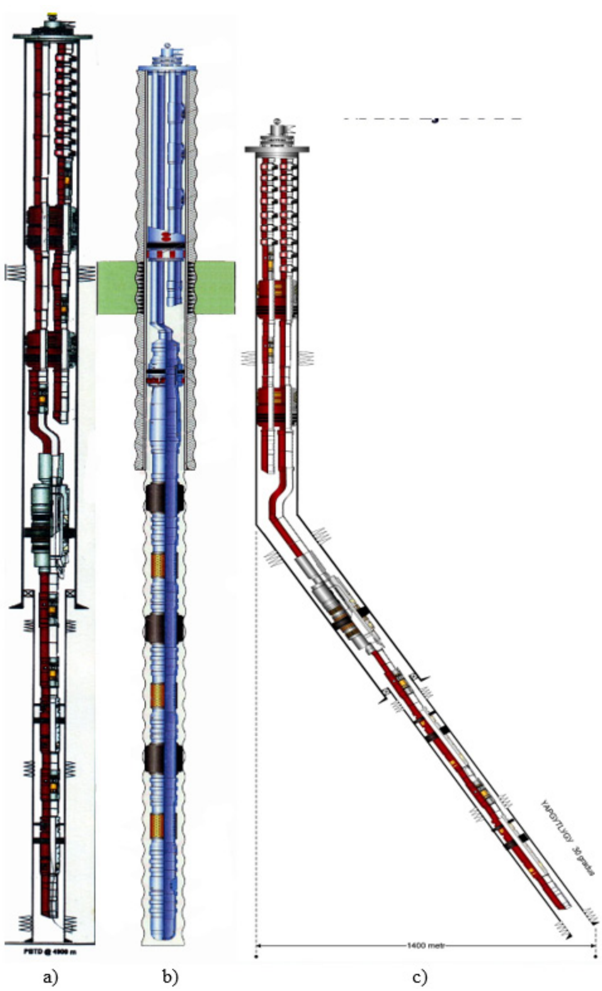

Fig. 4 - Schematic diagrams of double-lift tubing hangers: a) Well No. 37; b) Well No. 147; c) Well No. 201 (design)

Our analysis reveals that wells with deviations, such as those illustrated in Figure 4a, offer a unique advantage in geological observation. By drilling at various angles, we can achieve a more comprehensive and less biased view of the subsurface geology, particularly the network of fractures. This method allows for the 3D representation of fracture networks with reduced bias, providing a more accurate depiction of the geological formations we are exploring. The deviation in well trajectories enables us to intersect fractures at different angles, enhancing our understanding of their spatial distribution and connectivity. This insight is crucial for optimizing extraction strategies and improving the efficiency of hydrocarbon recovery. Such an approach not only refines our geological models but also contributes significantly to the precision of our reservoir simulations and the overall success of field development projects.

Thus, the introduction of advanced technologies and equipment in the drilling and well development process in the region has had a profound impact on oil production. This has led not only to improved efficiency and reduced well construction time, but also to increased oil production. This success carries important implications, especially for western Turkmenistan, where directional drilling has become a special factor in the region's economic development and energy security. This technology optimizes the hydrocarbon production process, contributes to cost reduction and is an integral part of the long-term field development strategy in this region, supporting the sustainable and strong growth of the oil industry (Wang *et alii*, 2017; Gooneratne *et alii*, 2020). The application of simultaneous separate operation technology opens up the possibility of producing from multiple productive horizons through a single well, using various methods ranging from production from the lower horizons by gushing to the use of a gas lift for production from the upper horizons characterized by low reservoir pressures (Deryaev, 2023).

Despite the positive results obtained in the first experience of SIMOPS technology, there are still technical difficulties that require refinement and improvement of this methodology to maximize its potential and overcome the technical challenges. This highlights the importance of further research and refinement of the technology to optimize its application in the oil industry. The introduction of SIMOPS has brought economic benefits by reducing the cost of drilling additional wells and introducing additional lifts, which in turn reduces payback periods and operating expenses. However, the decision to apply SIMOPS to a particular field or block requires in-depth economic analysis that considers the specifics of the horizon, reservoir and other factors. Reviewing methods of additional field exploration is also an important aspect. Consideration is being given to drilling advanced directional wellbores from existing wells directed below the Balkan Bay level to depths of 1000 to 1500 m. This approach can save resources and significantly optimize the drilling process (Sawaryn *et alii*, 2021; Ghosh, 2022).

In the long term, drilling directional wells and their development using the method of simultaneous separate operation act as the most reliable and economically feasible methods of hydrocarbon exploration and development. This is becoming a key solution to address the strategic objectives of active development of the oil and gas industry. The use of SIMOPS provides an opportunity to optimize field operation, reduce the cost of constructing new wells and increase overall hydrocarbon production, which is critical in the context of constant demand for energy resources.

DISCUSSIONS

The studies in the domain of petroleum production is of strategic importance to the energy industry and the economy (Isaksen, 2004; Medici *et alii*, 2018; Medici & West, 2023). These efforts are aimed at developing innovative approaches to hydrocarbon production, which is critical to ensuring energy security and meeting global demand for oil and gas. Field studies are also a key step in the search for optimal methods of resource extraction and utilization. They allow in-depth study of geological structures, formation of reservoirs, hydrodynamic processes, their interrelation, and impact on well performance. Such studies not only contribute to increasing production volumes, but are also important for improving methods and technologies aimed at reducing the negative impact on the environment and ensuring the safety of production processes. They are the basis for developing effective field management strategies and optimizing production processes in the oil industry.

The significance of our findings in the North Goturdepe field, especially regarding the heterogeneities within sandstone aquifers and their impact on hydrocarbon recovery, resonates with Medici & West's (2023) review on the Sherwood Sandstone aquifer. Similar to their discussion on the challenges posed by lithological and facies variability, our study underscores the intricate interplay between geological structures and the effectiveness of extraction technologies. The emphasis on novel modelling approaches, as suggested by Medici & West, aligns with our application of directional drilling and packer technologies to navigate the complex reservoir characteristics in Turkmenistan. Their advocacy for integrating new data and hydraulic testing advancements finds a practical application in our fieldwork, where such methodologies have been pivotal in overcoming the obstacles presented by the reservoir's heterogeneity. Moreover, the characterisation efforts by Medici, West & Mountney (2018) on the St Bees Sandstone Formation offer valuable parallels. Their findings on permeability variations and the impact of geological processes on aquifer properties provide a useful framework for understanding the fluid dynamics and reservoir conditions in the North Goturdepe field. The transition from high permeability in shallow zones to significantly reduced conductivity at greater depths mirrors our observations of fluctuating flow rates and the critical role of fault systems in facilitating hydrocarbon migration and entrapment. Isaksen's (2004) analysis of hydrocarbon systems in the central North Sea further enriches this discussion by offering a comparative geological and geochemical perspective. The HPHT conditions and the compositional histories of oil and gas within these reservoirs highlight the importance of understanding the thermal and pressure regimes that govern hydrocarbon maturation and migration. This comparative backdrop underscores the relevance of our work in Turkmenistan, where similar high-pressure and temperature conditions necessitate tailored drilling and evaluation strategies to maximize recovery and ensure the integrity of the reservoir.

One of the key areas of research in the oil industry is the development and application of the simultaneous separation method. This method is an innovative approach to producing hydrocarbons from several reservoirs of a single well using different technologies. SIMOPS application allows optimizing production processes by producing from different horizons of the well using different methods: gushing from the lower horizons and gas lift from the upper horizons, which increases the efficiency of well resources' utilization. This method is becoming an essential element in the strategy of increasing oil production and effective field management. SIMOPS application makes it possible to significantly increase production volumes at existing fields, reduce the cost of drilling additional wells, optimize operational processes and, in general, improve the efficiency of hydrocarbon production. However, to fully utilize the potential of SIMOPS method, it is necessary to constantly improve and further develop it. Technical problems arising in the process of its application require additional research and careful technological control. It is important to continue research aimed at improving the efficiency and safety of the SIMOPS method to maximize its potential in the modern oil industry.

According to the study by Bashir *et alii* (2021), the application of SIMOPS in hydrocarbon production can lead to a significant increase in the overall oil recovery of fields. As a result of SIMOPS application, the overall economic efficiency of the field can be increased and operating expenses per barrel of oil produced can be reduced. The paper noted that SIMOPS not only optimizes well operation processes, but also has a direct impact on the overall profitability of oil production in the industry. The study by the researchers, similar to the results of this study, also found a significant improvement in total oil recovery through the application of the simultaneous split operation method. This increase in total field recovery contributes to improved economic efficiency, which was also observed in our study. However, it is important to note that the mentioned results of the researchers focus on the overall oil recovery profitability of the industry, while this analysis has a closer look at the technical aspects of

SIMOPS and its impact on the optimization of well operation processes. Thus, both studies confirm that SIMOPS contributes to improving field performance and overall oil production efficiency.

The work of Ding *et alii* (2020) confirms that the SIMOPS method can improve production management, especially when dealing with reservoirs characterized by non-uniform pressure and different physical properties. This method allows oil to be recovered from different horizons in a tailored manner, resulting in improved overall oil recovery and field production efficiency. In addition, the SIMOPS approach reduces the risks associated with water intrusion into the well and allows for effective control of development processes. The results, presented in the study by the researchers, characterize the simultaneous separate operation method as effective when working with heterogeneous reservoirs and in conditions of different pressures. However, it should be considered that sometimes, when using the method of simultaneous separate operation, there may be difficulties in adapting to the dynamics of changes in the reservoirs. Because reservoir conditions can change over time and in different parts of the wells, SIMOPS may not always be flexible to such changes. It may also not always be possible to anticipate all changes in geological formations. Even with the advantages of SIMOPS, its effectiveness may depend on the accuracy of predicting geological characteristics and formation behaviour over time (Ripetskyi et alii, 2023).

Epelle & Gerogiorgis (2019) note that the use of the method of simultaneous separate exploitation provides an opportunity to optimize processes and improve the overall efficiency of hydrocarbon production. It is emphasized that this method contributes to a more rational use of resources, reduces operating expenses and improves the overall economic benefits of production in the fields. It also contributes to better control of production processes, which plays an important role in reducing risks and ensuring the stability of well operations. A study by the researchers confirms that the simultaneous separation method does contribute to optimizing production processes and improving the overall efficiency of hydrocarbon production in the fields. These findings correlate with the overall results of our study, which also emphasize the advantages of the method in increasing efficiency and reducing production costs. However, before SIMOPS can be widely implemented, its scalability across different field types and regions needs to be evaluated. This will ensure its applicability in various geological conditions.

In turn, Gao (2022) emphasizes that the use of innovative technologies in drilling and well development significantly increases the efficiency of hydrocarbon production. It is noted that the development of new methods of geological and technical support allows increasing the productivity of wells, reduce the costs of their operation and ensure the optimal use of oil fields. In addition, the integration of the latest technologies into the production process contributes to improving the safety and efficiency of oil and gas production. Innovative technologies in hydrocarbon production play a key role in improving the efficiency, safety, and sustainability of the oil industry. However, their successful implementation requires a comprehensive approach and constant adaptation to the specifics of each field. It should also be borne in mind that the introduction of innovative technologies requires significant investment in research and development. Not always new methods can be easily implemented due to the high costs of technological upgrades and personnel training. Another important aspect is the adaptation and improvement of technologies to various geological conditions, which may require additional effort and time.

As noted by Lei *et alii* (2021), rational use of technologies and exploration methods can significantly optimize oil and gas production processes. It is emphasized that an integrated approach to field development, based on the integration of new drilling and control methods, helps to increase efficiency, reduce costs and minimize negative environmental impact. This includes not only technical innovations but also improved well management and operation strategies, which contribute to more efficient resource utilization and risk reduction in field operations. The results presented by the researchers are further evidence of the importance of an integrated approach in oil and gas production. They highlight important aspects of optimizing field processes through the use of new drilling and control methods. By comparing both works, it can be highlighted that the use of innovative drilling methods and technologies in combination with effective control strategies represents the most promising direction for increasing the overall efficiency of oil and gas production. Both approaches emphasize the importance of integrated approach and management, which demonstrates the promise of such strategies in the development of the oil industry.

In general, research in the field of oil and gas production plays a crucial role in the development of innovative methods and technologies aimed at increasing the efficiency of field development. It is especially important to consider innovative methods in both the technical and strategic plans of production management, which allows not only to increase overall productivity, but also to minimize the risks associated with the exploitation of fields. These studies act as an important catalyst for the development of the industry, providing more efficient use of resources, reducing costs and creating innovative approaches to hydrocarbon production in today's energy market.

CONCLUSIONS

The final results of the study demonstrated that the introduction of advanced technology and equipment into the drilling and well development process had a tangible impact on hydrocarbon production. The application of the simultaneous separation method resulted in improved efficiency, not only in terms of reduced well construction time, but also in increased oil and gas production. This approach made it possible to produce from different horizons through a single well using various techniques, including flowback and gas lift, which proved key to increasing overall production. However, for all its positive aspects, the SIMOPS method has encountered technical challenges that require careful analysis and further research to optimize and improve its performance. This highlights the need for a more in-depth analysis of the specifics of each field when deciding on its application, considering factors such as geological conditions and economic feasibility.

One potential way to optimize the production process is to use advance exploration directional wellbores from existing wells. This could save the cost of drilling new wells during reservoir exploration, which would be the key to efficient hydrocarbon production. Thus, despite the technical challenges, the SIMOPS method remains important for the strategic development of the oil and gas industry, ensuring sustainable growth and increased energy production in the long term. Key areas for further research in this area include an in-depth examination of the technical aspects of the SIMOPS method to optimize its application in specific fields. This includes further analysing and improving production control methods, investigating new technologies for drilling directional wells, and developing innovative exploration methods for optimal selection of drilling locations. The realization of such research represents a strategic investment in the future of the energy industry, ensuring optimal resource utilization while maintaining environmental sustainability.

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