Journal of Mines, Metals and Fuels, 72(3): 199-209; 2024. DOI: 10.18311/jmmf/2024/36590

Print ISSN : 0022-2755

Journal of Mines, Metals and Fuels

Contents available at: www.informaticsjournals.com/index.php/jmmf

Drilling of a Directional Exploration Well in Turkmenistan in the Waters of the Caspian Sea

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Abstract

The purpose of this study was to optimise directional drilling of exploration wells in the Caspian Sea area of Turkmenistan to improve efficiency and reduce environmental impact. The methods employed include the analytical method, classification method, functional method, statistical method, and synthesis method. The study analysed the experience of drilling a directional exploration well in the North Goturdepe field in South-West Turkmenistan with a bottom hole offset of more than 1000 m from the wellhead under anticentral intracavity pressure conditions. The findings of the study confirmed the effectiveness of the new methods to increase hydrocarbon production, reduce time costs, and mitigate the negative impact on the natural environment. This study emphasised not only the significance of modern technological solutions in the energy industry but also their substantial contribution to the sustainable development of the region and energy security.

Keywords: *Environmental Aspects, Economic Benefit, Energy Sector, Deposit, Reserves*

1.0 Introduction

The study of directional drilling of exploration wells in the Caspian Sea area of Turkmenistan forms an integral part of strategic planning in the energy sector. This study is critical in response to the ongoing changes in the energy industry and the need to ensure the sustainability of energy supplies. The development of innovative technologies and optimisation of drilling processes not only contribute to improving the efficiency of hydrocarbon production, but also help to reduce the adverse environmental impact. Understanding these processes not only provides economic benefits, but also plays a key role in ensuring the energy security of the region and the global energy market in an ever-changing energy paradigm[1]. This integrated approach not only enhances the technical readiness of energy projects in the region, but also promotes high standards of environmental sustainability, which is an essential element in modern energy management. Thus, the development of a sustainable and effective energy strategy for the Caspian region inherently links to the study of these processes.

The focus of this study is on the need for effective investigation and optimisation of directional drilling of exploration wells in the Caspian Sea area of Turkmenistan. Key aspects include a commitment to increasing hydrocarbon production as well as maintaining a balanced focus on environmental concerns. The challenge is to find innovative solutions that can not only increase extraction efficiency but also minimise the adverse impact on the marine environment. Considering the rapid changes in the energy industry, the purpose of this study was to find the best approaches to ensuring the sustainability and security of energy processes in this region.

A.G. Geldimyradov[2] emphasises the use of innovative methods of directional drilling to improve the efficiency of hydrocarbon production in the Caspian Sea. The study does not address the development of integrated management systems that could ensure oil and gas operations' long-term sustainability. B.R. Pulatov[3] emphasises the critical issue of developing sustainable directional drilling methods that factor in environmental aspects. The study lacks adequate attention to the environmental aspects and possible consequences of the impact of innovative techniques on the marine environment. B.M. Kholbaev and Sh.Sh. Muhammadiev[4] emphasise the significance of the application of analytical methods to assess the impact of drilling on the biodiversity of marine life. The study does not include aspects related to the use of classification methods for geological change adaptation and risk mitigation.

A.N. Zhakanov[5] notes the progressiveness of fusion methods in directional drilling processes, which contributes to the optimisation of hydrocarbon production. The researcher neglects to analyse the social and economic issues involved in using analytical methods to assess the impact of drilling on biodiversity. Y. Amanniyazov *et al*.,[6] emphasise the necessity of classification methods for effective control of directional drilling processes. The study does not address the long-term implications of synthetic approaches or their impact on marine ecosystems. Sh. Geldiev and B. Ovezmammedov[7] put forward a key question about the effectiveness of statistical methods in analysing the performance of directional drilling carried out within the framework of the analytical approach. The study does not explore issues regarding the social acceptability of statistical methods and their impact on public opinion.

The purpose of the research was to optimize the directional drilling of exploration wells in the Caspian Sea area of Turkmenistan to improve efficiency and reduce environmental impact. The study analyzed the experience of drilling a directional exploration well in the North Goturdepe field and found that the new methods increased hydrocarbon production, reduced time costs, and mitigated negative environmental impacts.

2.0 Materials and Methods

The analytical method helped to gain a more profound understanding of the complex interrelationships and dynamics of the processes of directional drilling of exploration wells in the Caspian Sea area. This method allowed identifying the factors affecting drilling efficiency and conducting a systematic examination of the data, which substantially enriched the knowledge of physical and geological parameters affecting the success of hydrocarbon production operations. The key regularities and trends characterising the processes of directional drilling of exploration wells in the Caspian Sea area were identified using the statistical method. This method helped to examine large volumes of data obtained during well operation and identify statistically significant parameters affecting drilling efficiency. The resulting statistics on overall drilling efficiency and time costs have provided a fundamental basis for further refinement of the strategies and tactics used in drilling operations in this water area.

By applying the functional method, the main functional dependencies between various parameters and processes related to the directional drilling of exploration wells in the Caspian Sea area were identified. This method helped to identify the impact of various variables on overall drilling efficiency, identify optimal parameter values, and determine the key factors affecting the success of hydrocarbon recovery operations. The application the method of deduction made it possible to identify cause-and-effect relationships between various aspects of drilling, and to determine the basic principles and laws underlying efficient technologies. Thus, the application of the deduction method has enriched the understanding of the principles of operation and control of directional drilling processes.

The synthesis method provided a systematic integration of various components and variables to create effective strategies that combine technical efficiency and environmental considerations. The synthetic method enabled the integration of advanced technologies, considering the many variables affecting drilling processes. The innovations developed through the fusion method not only contribute to increased productivity but also reduce the negative impact on the marine environment. The resulting solutions constitute an integrated set of measures that include technical improvements, risk management and adherence to high standards of environmental sustainability.

The classification method helped in the systematisation of different types of geological formations and conditions affecting the processes of directional drilling of exploration wells in the Caspian Sea area. The application of this method highlighted the characteristics and features of different drilling zones, greatly facilitating the adaptation of drilling strategies to a variety of geological conditions. The classification method also contributed to the development of a system for determining the best drilling parameters depending on concrete geological characteristics[8].

3.0 Results

Oil and gas exploration and production activity has been steadily increasing globally in recent decades, with countries located near resource-rich regions playing a key role in this process. One of such countries is Turkmenistan, which occupies a strategic position on the shores of the Caspian Sea. Drilling directional exploration wells in the waters of this unique inland sea presents a complex engineering and environmental challenge but also offers the country great energy prospects[9].

One of the key aspects of drilling in the Caspian Sea is the use of directional well technology. This innovative technique allows drillers to extract hydrocarbons from different points in a subsea field, maximising efficiency and increasing production. Turkmenistan, with its rich reserves of natural resources, is committed to using advanced technologies to efficiently extract and maximise the potential of its deposits[10]. However, despite the prospects associated with drilling directional exploration wells in the Caspian Sea, there are also challenges. The environmental aspect takes centre stage, as even the most advanced technologies can pose a threat to the marine ecosystem. Discharges of drilling fluids, vapour emissions, and potential accidents can have serious consequences for the environment and the health of local communities[11]. Therefore, countries drilling in the Caspian Sea must strictly comply with international safety and environmental standards. The development and implementation of integrated control systems, continuous monitoring of environmental impacts, and active interaction with scientific research organisations form an integral part of sustainable development in this area[12]. One of the key tasks for the oil and gas industry in Turkmenistan is to increase hydrocarbon reserves. The President of Turkmenistan, Serdar Berdimuhamedov, emphasises the need to increase the production of hydrocarbon resources in the oil and gas sector, considering it an essential factor in ensuring the country's stability and economic independence. At the current stage of oil industry development, considering the improvement of drilling technologies and the development of new drilling equipment and chemical reagents, there are opportunities to use previously unknown methods and types in well construction[13].

Conventionally, all exploration wells have been drilled vertically, but there is now a rationale for changing this standard practice. The experience gained during the construction of the 147th horizontal directional well in the North Goturdepe field in cooperation with Schlumberger Company demonstrates the feasibility of exploratory drilling using horizontal directional wells in the shallow part of the Caspian Sea. Drilling such boreholes in different directions on existing artificial islands can substantially reduce the cost of geological investigations in the field, as noted in the study[14]. The first drilling of horizontal directional wells was successfully carried out in the Goturdepe Drilling Department of Turkmenistan. Specialists of the Goturdepe Drilling Department, together with Schlumberger Company drilled directional well No. 204 at the North Goturdepe field, offset from the vertical position at a depth of more than 1000 m. Own forces were used to drill to a depth of 3000 m, while the directional part of the string was drilled with Schlumberger specialists using special equipment.

The well successfully reached the target depth of 4850 m (drilled). The process of drilling this well to a depth of 3000 m follows the technical design and is analogous to the methods used in drilling other wells in the country. The drill starting point was set at a depth of 3000 m to achieve a zenith angle with an azimuthal angle of 270°. The target parameters include a design zenith angle of 45°, a maximum angle set intensity of 3.5° for every 30 m, and a bottom hole offset of 1046.58 m. Prior to drilling the directional section at a depth of 3000 m, the previous water-based drilling fluid was replaced with a hydrocarbon drilling fluid system called Versadril. Developed using specialised chemicals, this hydrocarbon formulation contains up to 80% hydrocarbons and 20% water. The main advantage of such solutions is their high resistance to water, which leads to the formation of thin and flexible crusts[15]. This preserves the natural reservoir properties of the productive part of the section, substantially reduces the mixing of clay substances in the solution and has other favourable characteristics.

The use of hydrocarbon slurries can cause difficulties in strengthening wells with cement slurries[16]. This problem occurs when cement slurries are mixed with hydrocarbon-based drilling fluids due to the coagulation process, which leads to an increase in the flowability and compaction of the mixture. To prevent such problems, the Nebitgazylmytaslama Institute has developed a special hydrocarbon-based buffer fluid that was successfully used in drilling the 204th well in North Goturdepe. During the drilling of this well, geological and technological tests were systematically carried out using the new Geotest-5 GTB station. The Geotest device automatically collects, processes, and visualises geological, geochemical, and technological data on the drilling process[17]. This tool monitors drilling parameters, assesses the overall situation, selects reservoirs in the section, and determines their saturation, preventing possible complications and accidents[18]. The station is a complex of three main modules: technological, gas logging, and geological[19]. The technology module is responsible for real-time control of the drilling process, ensuring efficient and accurate management of drilling operations[20]. The gas logging module records the total gas content and analyses the composition of the gas mixture, which plays a major role in assessing the safety and efficiency of the process[21]. The geological module performs prompt analysis of core, cuttings, drilling fluid, and reservoir fluids, providing valuable information for evaluating the geological characteristics and composition of borehole material[22].

Figure 1 presents a segment of a diagram depicting the process parameters during the curvature set period during drilling. Drilling to a depth of 3000 m was carried out using the following equipment: starting with a 295.3 mm-diameter screw downhole motor, model A800M 4553 XP-8.92 m, followed by a 269 mm-diameter, non-magnetic Integral Blade Stabiliser (IBS), followed by a 206 mm-diameter float sub and a 204 mm-diameter Drill Collar (DC) for 8.93 m. This was followed by a Telescope-825NF at 8.06 m, followed by another 203 mm DC at 37.15 m, a hydraulic jar at 10.07 m, another 203 mm DC at 9.19 m, a crossover, another crossover, and a 172 mm DC at 9.34 m. This entire complex was completed with drill pipe up to the wellhead. To maintain the set values of the zenith angle intensity during the angle acquisition, the following method was used: at a certain azimuth, drilling was performed at a depth of 4-5 m with the rotor closed for angle acquisition, then drilling was performed for another 4-5 m with rotor rotation and drill

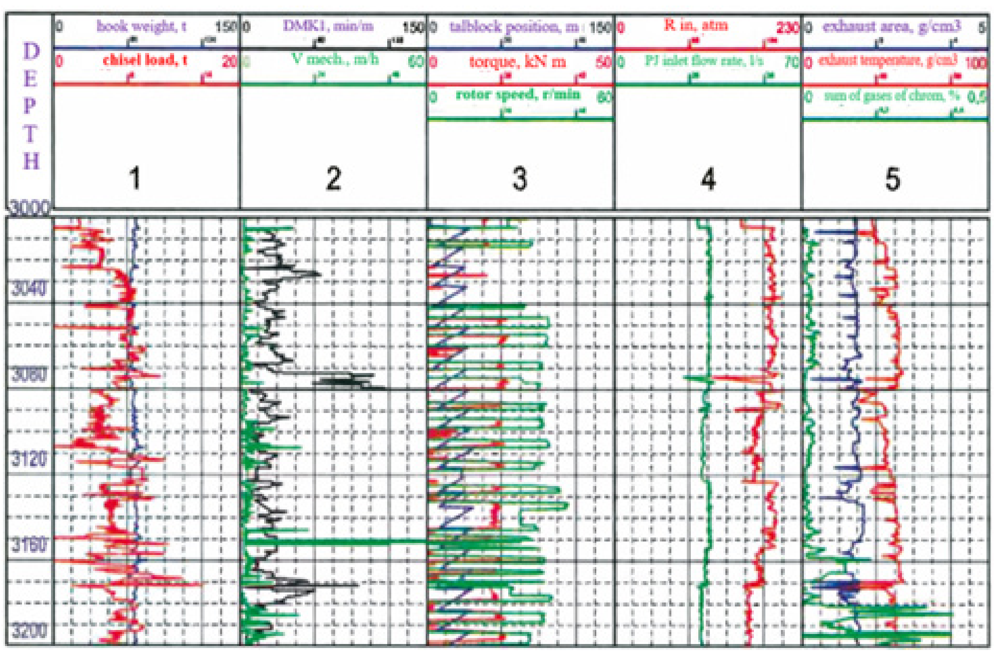

Figure 1. Parameters of the deepening process during the period of curvature formation.

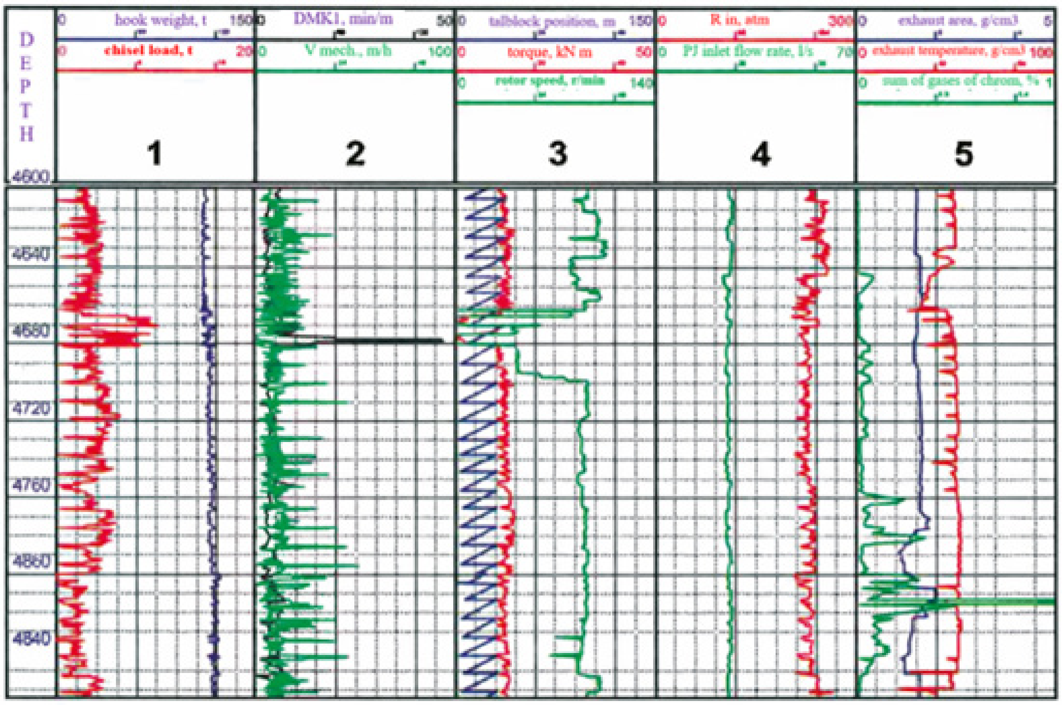

Figure 2. Parameters of the deepening process in a rectilinear section of inclination.

string bottom assembly to stabilise the zenith angle. This process is visualised in column 3 of Figure 1 by the curves showing the rotor speed and the position of the hoisting block.

Figure 2 shows a fragment of a straight-line drilling interval in the inclined part of the well. Technological parameters for deepening the well in the straight inclined interval were optimised using continuous rotor rotation

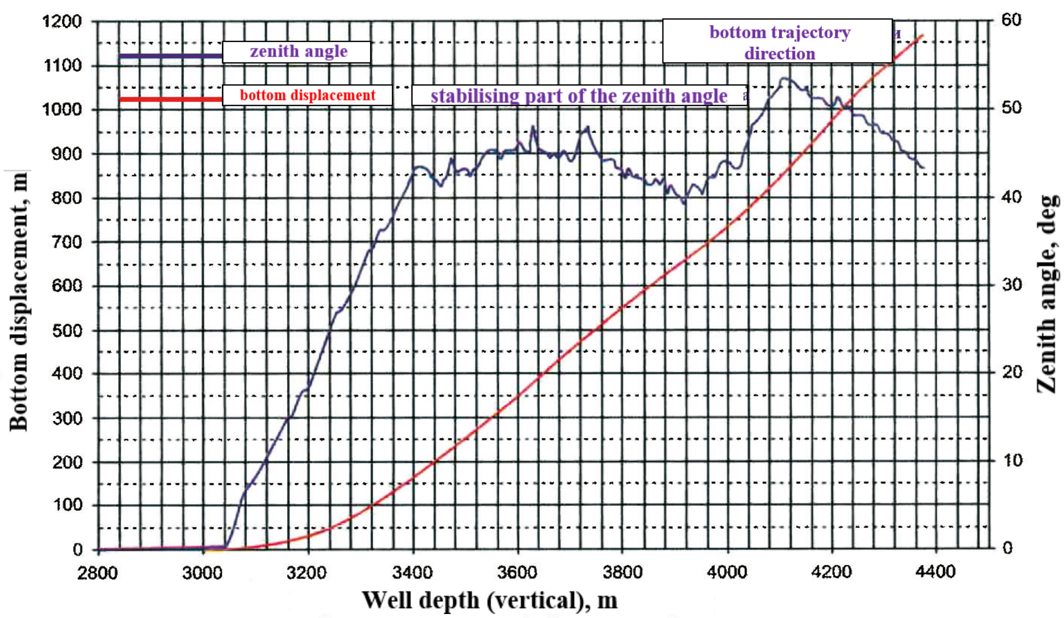

Figure 3. Change in inclination angle and bottom hole offset in well 204 in the North Goturdepe field.

and the corresponding drill string bottom configuration. Stability of the borehole trajectory was ensured by changing the position of calibrators in the drilling system and replacing PDC bits with roller cone bits (and vice versa) in the straight part of the well.

Having descended to a depth of 4450 m (along the borehole), a Ø (diameter) 244.5 mm casing string was successfully lowered into the well and secured. This process was carried out in two phases. Later, when the well reached the planned depth, it was decided to continue deepening it to investigate the productive strata of the NK3 horizon in greater detail. The well depth was increased to 4865 m, and a 139.7 mm production casing was installed (Figure 3).

During the drilling of well 204 in the North Goturdepe field, the maximum bottom hole deviation was 1167.48

Table 1. Study of oil from well 204 in the North Goturdepe field

Interval (along the wellbore) (m)		**4820-4830**	**4832-4844**
Horizon		**NK3**	
Amount of water (%)		47	30.5
Oil density (g/cm3)		0.8545	0.856
Oil solidification temperature (C)		+4	+4
Viscosity (Pa s)	20°C	11.4	11.5
	50°C	5	5.1
Conclusion		Liquid hydrocarbon fluid – light oil	

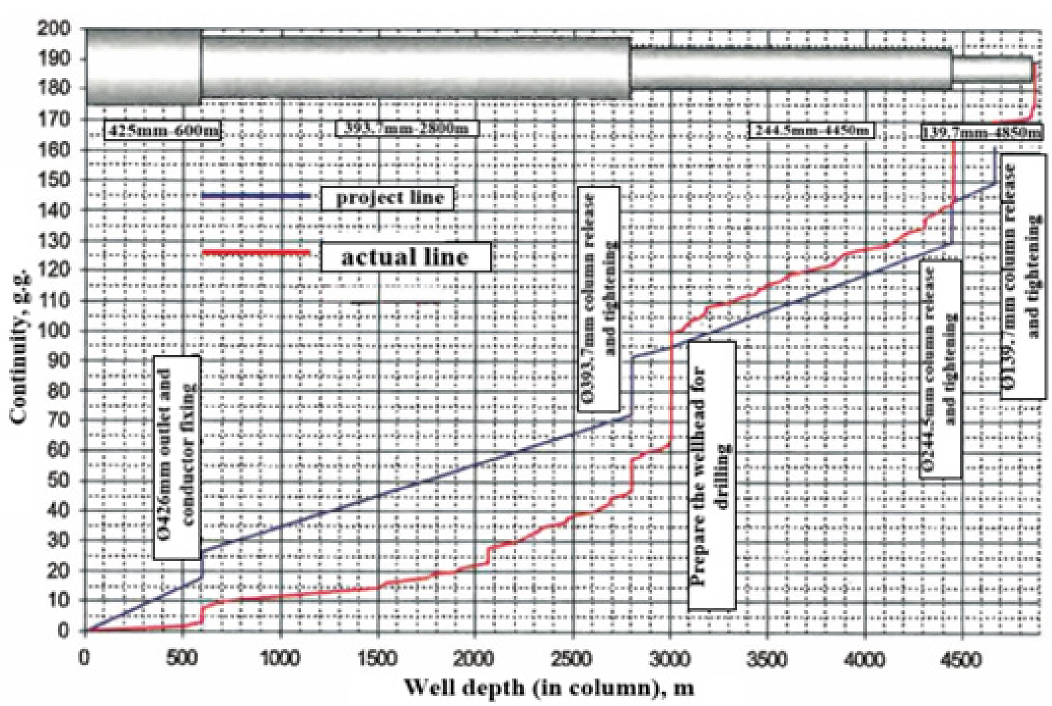

Figure 4. Diagram showing the chronology of the construction of well 204 North Goturdepe.

m at a magnetic azimuth of 266.15º, and the maximum zenith angle reached 53.46º at a depth of 4,440 m. The changes in the vertical profile of the well and zenith angle are visualised in Figure 3. Production from the first target (NK3) resulted in a maximum flow rate of 80 t/day. The results of analyses of this product performed in the geochemical laboratory of oil, gas, and rocks of the Nebitgazylmytaslama Institute are presented in Table 1.

The well construction schedule presented in Figure 4 highlights the prospects for increased drilling speeds for this type of well. One of the key factors affecting the efficiency and productivity of drilling is the reduction of the preparation time for drilling the deviated part of the well[23]. In the current context of the graph, the time taken to prepare for drilling the incline can be reduced. This is an essential observation because more efficient and faster preparation for slope drilling will reduce time delays and improve the overall performance of the drilling process. This aspect is of strategic importance, as increased drilling speed leads to faster hydrocarbon production, which improves economic efficiency and provides a faster return on investment. This outlook reflects the industry's commitment to continuous improvement in technology and processes to optimise production and increase its sustainability in the long term.

Commercial well productivity is defined as an average drilling rate reaching 817 m/month with a fully effective drilling time of 100%. The data on the distribution of time between the main operations is as follows: 27.3% of the time is spent on drilling, 17.2% on pulling and running operations, 18.06% on grouting processes, and 35% on auxiliary operations. These indicators are essential for assessing the overall efficiency of the drilling process and provide information on the time spent on each stage of the operation.

In conclusion, drilling directional exploration wells in the Caspian Sea is a challenging but promising path for a country seeking to maximise the use of its natural resources. It is necessary to strike a balance between economic benefit and responsible use of nature to ensure sustainable development and the preservation of the unique natural environment of this region.

4.0 Discussion

Drilling directional exploration wells in the Caspian Sea area of Turkmenistan is a topic around which both prospects and challenges are centred. This process is of significant strategic importance to Turkmenistan as it seeks to maximise its hydrocarbon production potential. Turkmenistan has considerable oil and gas reserves in the Caspian Sea. Directional drilling provides a unique opportunity to efficiently extract these resources. This technology allows hydrocarbons to be extracted from different points in the fields, thereby increasing overall production and improving the country's energy security[24]. The use of directional exploration wells requires advanced technology and engineering solutions. The introduction of modern drilling and geological exploration techniques can considerably improve the efficiency and accuracy of production[25]. Such innovations contribute not only to increasing production volumes but also to reducing the environmental impact on the environment.

Serious attention should be paid to the environmental and social aspects of drilling in the Caspian Sea. Discharges and emissions can have negative impacts on the marine ecosystem as well as the health of local communities[26]. Strict adherence to international standards, the development and implementation of environmentally friendly technologies, and community engagement are therefore key elements of a sustainable approach to hydrocarbon exploration and production. The success of drilling in the Caspian Sea also depends on geopolitical factors. Turkmenistan should engage in dialogue and cooperation with neighbouring countries that have interests in the region. Effective resource management and resolution of boundary issues contribute to stability and increased investment in the energy sector. Generally, drilling directional exploration wells in the Caspian Sea area of Turkmenistan is a complex task that requires an integrated approach, a balance of interests, and consideration of environmental and social factors. The implementation of projects considering these aspects may become a key element of the sustainable development of the energy sector in the country.

According to the findings of T. Eren and V.S. Suicmez[27], positioning calculations for directional drilling play a key role in ensuring the accuracy and efficiency of this technological process. The primary purpose of these calculations is to accurately determine the coordinates of the well at various depths, allowing engineers and drillers to effectively manipulate the direction and angle of drilling to achieve desired objectives. In directional drilling, tools such as measuring gyroscopes and accelerometers are used to determine the position and angle of the borehole relative to the vertical. This data is then subjected to complex mathematical calculations involving trigonometry and geometry to determine the exact coordinates of the well at each stage of drilling. Accurate positioning calculations not only ensure increased hydrocarbon production, but also reduce the risk of potential problems such as cross-drilling of neighbouring wells or deviation from the target formation. This is especially important in complex geological structures or when working in marine environments. These findings are consistent with the arguments presented in the previous section. Positioning calculations in directional drilling represent an integral part of the technology to guarantee the accuracy and efficiency of the process. Modern methods and technologies in this field help optimise hydrocarbon production and ensure sustainability in field exploration and development.

According to the definition proposed by P. Fang *et al*.,[28] the study of key technologies for intelligent directional drilling equipment represents a vital aspect of the development of the oil and gas industry. These technologies aim to improve drilling processes, increase accuracy and efficiency, and reduce the risks associated with hydrocarbon production. A key element is the use of advanced navigation and control systems, including integrated gyroscopes, accelerometers, and geomagnetic sensors. Intelligent equipment allows real-time monitoring of drilling parameters such as inclination angle, direction, and well depth. Artificial intelligence-based data processing algorithms can predict and warn against potential problems, substantially improving drilling safety and productivity. The application of artificial intelligence technologies also includes the automation of decision-making processes based on collected data. This allows operators to react quickly to changing conditions and adjust drilling parameters in real time, optimising production performance. Such systems also help to reduce human impact on the drilling process, which reduces the risk of accidents and errors. Notably, research into these technologies is aimed at creating sustainable, intelligent drilling systems capable of adapting to different geological conditions. These innovations open new perspectives in hydrocarbon exploration and production, improving efficiency and reducing the environmental impact on the natural environment.

H. Li *et al*.,[29] found that the modified Boltzmann differential annealing evolution algorithm is an innovative approach to the problem of inverting directional resistivity logging measurements during drilling. Log data inversion is a key tool in geophysical exploration, providing information on rock, borehole, and environmental properties. The differential evolution algorithm combined with the Boltzmann annealing method provides an efficient optimisation method, allowing researchers to find optimal resistivity values for rocks in real time. The modification of the algorithm is designed to improve its convergence and robustness under difficult drilling conditions, making it particularly useful in the field of oil and gas exploration. We can agree with this opinion that applying the algorithm to directional logging data allows a more accurate reconstruction of the resistivity of rocks at different depths of the borehole. This is essential for determining rock composition, identifying industrially significant zones, and optimising hydrocarbon extraction processes. These innovative inversion techniques substantially improve the accuracy and informativeness of real-time data obtained during the drilling process.

D. Cao *et al*.[30] showed that the development and application of deep learning models in real time represent considerable progress in the field of improving the efficiency of directional drilling. This innovative technology is based on the use of neural networks to analyse the data collected during the drilling process and make decisions based on this analysis. Deep learning enables the creation of sophisticated models capable of automatically extracting high-level features from multidimensional data, such as drilling parameters and geological characteristics. These models can predict changes in well geology and prevent potential problems in real time. The application of real-time deep learning models in directional drilling enables more accurate control and correction of drilling direction and angle. This results in increased productivity, shorter drilling times, and reduced risks of possible failure. These findings support the above-mentioned study, as the development and application of real-time deep learning models in directional drilling offers the oil and gas industry the prospect of improving processes, reducing costs, and increasing overall efficiency.

According to B.E. Harris *et al.*,[31] a numerical study of the use of directional wells for geothermal energy extraction from abandoned oil and gas wells is a promising area that combines high efficiency and sustainability in the field of renewable energy. Abandoned oil and gas wells provide unique infrastructure that can be used to extract geothermal energy, bringing a second life to these sources. Numerical modelling allows estimating the geothermal energy potential at different depths of abandoned wells, considering the geothermal gradient. The use of directional wells further enriches this process by allowing for more efficient extraction of thermal energy from rock formations[32]. This approach not only enables the reuse of obsolete infrastructure but also promotes a sustainable and environmentally friendly method of energy extraction. Energy extracted from geothermal sources can serve both to support local energy systems and to reduce dependence on conventional energy sources. Analysing the findings obtained, such studies are significant because they help determine the best technologies and geological parameters for the use of abandoned wells for geothermal energy production. This area can help diversify the energy mix, improve its sustainability, and reduce negative environmental impacts[33].

A. Ihnatov *et al.*,[34] found that the development of rational layouts at the bottom of well-directional drilling represents a crucial area in drilling engineering, aimed at optimising processes and improving the efficiency of hydrocarbon production. This task requires an integrated approach, including geological studies, consideration of well requirements, and application of advanced engineering solutions. Rational directional drill string bottom assemblies include optimised bits and rotors designed to meet particular drilling conditions. Innovative geometries and materials can improve wear resistance, extend equipment life, and reduce maintenance costs. An efficient bottom hole layout also facilitates more precise control of drilling direction, which is critical to achieving targets in challenging geological conditions[35]. The integration of advanced technology into the automation of drilling and borehole control processes provides the ability to respond to changes in real time, improving accuracy and predictability.

Thus, the development of rational directional drill string bottom assemblies not only contributes to process optimisation but also improves productivity, reduces risks, and promotes sustainable development in the oil and gas industry.

5.0 Conclusions

The study aimed to optimize the directional drilling of exploration wells in Turkmenistan's Caspian Sea area to improve efficiency and reduce environmental impact. The use of advanced drilling technologies, including directional well drilling, has allowed for more efficient hydrocarbon extraction in the Caspian Sea region. However, drilling operations in the Caspian Sea also pose significant environmental risks that must be carefully managed. The study highlighted the importance of integrated management systems that combine technical efficiency and environmental considerations. Key innovations include hydrocarbon-based drilling fluids, automated data monitoring systems, and optimised bottom-hole assemblies. Advanced positioning calculations, intelligent drilling equipment, and real-time data analysis using deep learning can further improve the accuracy, efficiency, and sustainability of directional drilling operations. Repurposing abandoned oil and gas wells for geothermal energy extraction is a promising avenue for improving the overall environmental sustainability of energy production in the region.

The findings emphasise the need for a holistic approach to drilling in the Caspian Sea that balances economic, technological, and environmental priorities. Future research should continue to explore innovative drilling technologies, automation, and integration with renewable energy sources to promote the long-term sustainability of hydrocarbon production in this sensitive marine environment.

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