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-THÈME-

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**NON CONVENTIONAL HORIZONTAL DRILLING WELLS MINIMUM  
STRESS DIRECTION (COMPARATIVE STUDY BETWEEN OMGZ801  
AND OMGZ60)**

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# DEDICATION

As I come to the end of my studies, it is my great pleasure to  
dedicate this modest work:

To my dearest mother, who always gives me hope in life and never  
stops praying for me.

To my dear father, for his encouragement, support, and sacrifice to  
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moment the most this achievement is as much yours as it is mine

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To all my friends.

To my lovely study partner Roufy.

To all those whom I love and respect.

**HIMEUR Nail**

# DEDICATION

I would like to dedicate this project to my beloved ones my family  
and my cat and my passed two cats

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tireless efforts have shaped the person I am today

I am forever grateful for your unwavering belief in me

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For my two babies who make me feel the true meaning of  
unconditional love

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To my study partner NAIL.

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Finally for the new light of my life.

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## **Abstract:**

Non-conventional drilling techniques have emerged as a vital solution for maximizing the productivity of non-conventional reservoirs. In particular, horizontal drilling in minimum stress has gained attention as a transformative approach with notable advantages. The importance of aligning the wellbore with the minimum stress direction to attain improved stability and optimized production. By emphasizing the significance of stress analysis in non-conventional drilling, this approach unlocks the full potential of non-conventional reservoirs. Overall, the transformative nature of horizontal drilling in minimum stress and its ability to enhance productivity in non-conventional drilling operations. This operation has been applied in several wells studied, such as in OMGZ 60, hoping for the development of low petrophysical characteristic zones in Hassi Messaoud.

**Keywords:** non-conventional drilling, horizontal drilling, minimum stress, petrophysical characteristic, wellbore stability

## **Résumé :**

Les techniques de forage non conventionnelles ont émergé comme une solution essentielle pour maximiser la productivité des réservoirs non conventionnels. En particulier, le forage horizontal en stress minimum a suscité l'attention en tant qu'approche transformative offrant des avantages notables. L'importance d'aligner le puits avec la direction de stress minimum pour obtenir une stabilité améliorée et une production optimisée est soulignée. En mettant l'accent sur l'importance de l'analyse du stress dans le forage non conventionnel, cette approche permet de libérer tout le potentiel des réservoirs non conventionnels. Dans l'ensemble, la nature transformative du forage horizontal en stress minimum et sa capacité à améliorer la productivité dans les opérations de forage non conventionnelles. Cette opération a été appliquée dans plusieurs puits étudiés, tels que dans OMGZ 60, dans l'espoir de développer des zones à faibles caractéristiques pétrophysiques à Hassi Messaoud.

**Les mots clés :** forage non conventionnelle, forage dirigé, contrainte minimal, caractéristique pétrophysique, stabilité du puits de forage.

## **الملخص:**

ظهرت تقنيات التنقيب غير التقليدية كحل جديد لزيادة إنتاجية الاحتياطي غير التقليدي لمكامن النفط والغاز. في هذا السياق، اكتسب التنقيب الأفقي في ظروف الإجهاد الأدنى اهتمامًا كنهج محول بمزايا ملحوظة. يُؤكد أهمية اتجاه البئر مع اتجاه الإجهاد الأدنى لتحقيق إنتاجية مُحسَّنة. من خلال التأكيد على أهمية تحليل الإجهاد في عمليات الحفر غير التقليدية. بصفة عامة، الحفر الأفقي في ظروف الإجهاد الأدنى يساهم في تعزيز الإنتاجية في عمليات التنقيب غير التقليدية. تم تطبيق هذه العملية في عدة آبار على أمل تطوير المناطق ذات سمات بتروفيزيائية منخفضة في حاسي مسعود مثل. OMGZ 60

**الكلمات المفتاحية:** تنقيب غير تقليدي، تنقيب أفقي، الإجهاد الأدنى، سمات بتروفيزيائية، استقرار تجويف البئر،

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## Nomenclature

symbol	Signification	unite
$\sigma_v$	vertical stress	[ Pa]
$\sigma_h$	horizontal minimum stress	[ Pa]
<b>TVD</b>	True vertical depth	[ m]
<b>A</b>	Azimuth	[ °]
<b>R</b>	rayon de courbure	[ m]
<b>ROP</b>	Rate of Penetration	[ m/h]
<b>WOB</b>	Weight on Bit	[ N]

## List of Abbreviation:

**MW:** Mud weight (densité)

**WBS:** Wellbore stability

**KOP:** Kick off point

**EOB:** End of build up

**BHA:** Bottom hole assembly

**UTM:** Universal transverse Mercator

**MWD:** Measurement while drilling

**LWD:** Logging while drilling

**PDM:** Positive displacement motor

**DC:** Drill collar

**HWDP:** Heavy weight drill pipe

**MEM:** Mechanical Earth Model

**EOB:** End of build up

# **GENERAL INTRODUCTION**

### **Introductions:**

In the realm of drilling operations, the quest for efficient and productive extraction of hydrocarbon resources has driven the industry to explore innovative techniques. Among these techniques, non-conventional horizontal drilling has emerged as a transformative approach, unlocking previously inaccessible reservoirs and revolutionizing the energy landscape. However, the success of these drilling endeavours hinges on a critical factor often overlooked: the understanding and utilization of the minimum stress direction.

Stress, in its various manifestations, plays a paramount role in drilling operations. The forces exerted upon the rock formation surrounding a wellbore significantly impact wellbore stability, drilling performance, and ultimately, the success of the project. The minimum stress direction, in particular, holds immense importance, serving as a guiding compass for optimal drilling trajectories and unlocking the full potential of non-conventional horizontal drilling.

In this thesis, we delve into the theoretical underpinnings of the minimum stress direction and its significance in non-conventional horizontal drilling wells. Our exploration begins with an understanding of stress in drilling operations, encompassing the different types of stress, their origins, and the interplay between stress and rock behaviour. We then venture into the realm of geomechanics, where stress analysis techniques enable us to discern the orientations and magnitudes of these forces acting within the rock formation.

As we uncover the implications of stress, we unravel the critical impact of the minimum stress direction on the trajectory of non-conventional horizontal drilling wells. By aligning the wellbore with the minimum stress direction, we unlock a myriad of benefits, including enhanced wellbore stability, reduced drilling problems, and optimized production performance. However, we also acknowledge the challenges that arise when drilling perpendicular or oblique to the minimum stress direction, and the measures that can be implemented to mitigate these obstacles.

Drilling in minimum stress and maximum stress conditions presents unique sets of considerations and potential risks. The minimum stress environment is characterized by a stress state where the least principal stress dominates, while the maximum stress environment refers to a scenario where the maximum principal stress governs.

By conducting a comparative analysis between two wells, namely OMGZ 801 drilled in a maximum stress environment and OMGZ 60 drilled in a minimum stress environment, we can gain valuable insights into the behaviour and performance of drilling operations under these contrasting stress regimes. This study aims to explore various aspects, including wellbore stability and integrity, rock deformation and failure mechanisms, fluid flow characteristics, and overall drilling performance. Furthermore, the study will examine how stress orientations, anisotropy, and rock properties influence drilling outcomes in both minimum and maximum stress environments. By conducting this comparative analysis, we aim to enhance our understanding of the implications of drilling in different stress conditions and inform the development of optimized drilling strategies for each scenario.

## **CHAPTER ONE:**

# **The Significance of Principal minimum Stress in Horizontal Drilling Wells**

### Introduction

In the field of oil and gas exploration and production, traditional vertical drilling techniques have been widely employed for many years. However, with the depletion of easily accessible conventional reserves and the increasing demand for energy, the industry has shifted towards non-conventional methods, such as horizontal drilling. Horizontal drilling involves drilling wells at an angle or horizontally through the rock formations, allowing for greater access to hydrocarbon reserves that were previously inaccessible.

One crucial factor in the success of non-conventional horizontal drilling wells is the understanding and consideration of the minimum stress direction. Stress directions within the Earth's crust play a significant role in determining the behaviour of rock formations during drilling and production operations. The minimum stress direction refers to the direction in which the rock formation is most susceptible to fracturing or failure under stress.

Identifying the minimum stress direction is crucial in horizontal drilling because it helps determine the optimal orientation and placement of the wellbore. By aligning the wellbore with the minimum stress direction, operators can enhance the effectiveness of the drilling process and maximize the productivity of the reservoir.

When the wellbore is drilled parallel to the minimum stress direction, it can result in several advantages. First, it facilitates hydraulic fracturing operations, commonly known as "fracking." Hydraulic fracturing involves injecting high-pressure fluid into the rock formation to create fractures and increase the permeability of the reservoir. By aligning the wellbore with the minimum stress direction, the created fractures tend to propagate preferentially along this direction, improving the connectivity between the wellbore and the reservoir, and enhancing the flow of hydrocarbons.

Moreover, drilling along the minimum stress direction helps minimize the risk of wellbore instability and formation damage. The rock formations are subjected to various mechanical forces during drilling, such as axial stress, hoop stress, and shear stress. When the wellbore is drilled perpendicular to the minimum stress direction, it can induce high levels of stress and strain on the formation, potentially leading to wellbore collapse, fracturing, or excessive fluid losses. By aligning the wellbore with the minimum stress direction, these risks can be significantly reduced, ensuring the stability and integrity of the well.

Additionally, the knowledge of the minimum stress direction is valuable for the placement of multilateral wells. Multilateral wells involve drilling multiple lateral branches from a single vertical wellbore, increasing the contact area with the reservoir and improving production. By aligning each lateral branch with the minimum stress direction, operators can optimize reservoir drainage and enhance well performance.

The minimum stress direction is crucial in non-conventional horizontal drilling wells. It helps optimize wellbore placement, enhance hydraulic fracturing, minimize formation damage, and improve overall well performance. Identifying the minimum stress direction is essential for maximizing hydrocarbon recovery and achieving success in non-conventional drilling operations

### **I.1. Non-conventional reservoirs and hydrocarbon recovery techniques:**

In the ever-evolving energy landscape, the quest for hydrocarbon resources has led to the exploration and development of unconventional reservoirs. Unlike conventional reservoirs that have high permeability and allow oil and gas to flow relatively easily, unconventional reservoirs pose unique challenges due to their low permeability. These reservoirs require unconventional techniques for hydrocarbon recovery, pushing the boundaries of engineering and technology in the oil and gas industry.

Unconventional reservoirs encompass a variety of formations, including shale gas, tight gas sands, and coalbed methane. These reservoirs are characterized by their complex geological structures, which trap hydrocarbons within tight rock formations. Extracting oil and gas from these reservoirs necessitates innovative and unconventional methods that go beyond traditional drilling and production techniques.

One of the most prominent examples of unconventional reservoirs is shale gas. Found within fine-grained sedimentary rocks such as shale, this type of gas requires hydraulic fracturing, commonly known as fracking, to unlock its potential. Fracking involves the injection of water, sand, and chemicals into the reservoir at high pressure, creating fractures in the rock and allowing the gas to flow. This technique has revolutionized the global energy landscape and has significantly increased natural gas production.

Tight gas sands are another type of unconventional reservoir, characterized by low permeability sandstone formations. Recovery from these reservoirs often involves a combination of hydraulic fracturing and horizontal drilling. These methods maximize contact between the reservoir and the wellbore, enabling the extraction of natural gas from previously inaccessible resources.

Coalbed methane (CBM) is yet another unconventional reservoir where natural gas is trapped within coal seams. The recovery of CBM involves the extraction of water from the coal seam, reducing the pressure and allowing the gas to desorb from the coal matrix. In some cases, hydraulic fracturing techniques are utilized to enhance the production of coalbed methane.

In addition to these specific reservoir types, unconventional hydrocarbon recovery techniques include various enhanced oil recovery (EOR) methods. These techniques aim to extract additional oil from both conventional and unconventional reservoirs. EOR techniques include steam-assisted gravity drainage (SAGD), carbon dioxide (CO<sub>2</sub>) injection, chemical EOR, and microbial EOR, among others. These methods involve the injection of steam, CO<sub>2</sub>, chemicals, or microorganisms into the reservoir to alter the fluid properties, improve displacement efficiency, and enhance oil recovery.

Unconventional reservoirs and the associated hydrocarbon recovery techniques continue to evolve with advancements in technology and ongoing research. These unconventional resources play a vital role in meeting global energy demands and diversifying energy portfolios. As the industry progresses, innovations and methods may emerge, further expanding the potential of unconventional reservoirs and contributing to the sustainable and efficient extraction of hydrocarbons.

### **I.2. Unconventional reservoirs:**

Unconventional reservoirs are hydrocarbon-bearing formations; these reservoirs contain enormous quantities of oil and natural gas but pose a technology challenge to both geoscientists and engineers to produce economically on a commercial scale. These reservoirs store large volumes and are widely distributed at different stratigraphic levels and basin types, offering long-term potential for energy supply. Most of these reservoirs are low permeability

and porosity that need enhancement with hydraulic fracture stimulation to maximize fluid drainage.[1].

There are several types of unconventional reservoirs, each with unique characteristics and challenges:

### I.2.1. Shale Reservoirs:

Shale reservoirs are unconventional formations with low permeability. They contain organic matter that turns into hydrocarbons like natural gas and oil over time. Extraction from shale involves hydraulic fracturing, creating fractures in the rock to enable hydrocarbon flow. Horizontal drilling maximizes contact with the reservoir. Shale's low porosity and environmental concerns require careful analysis and regulations. Shale reservoirs have revolutionized energy production but pose unique challenges and require advanced techniques for extraction [2].

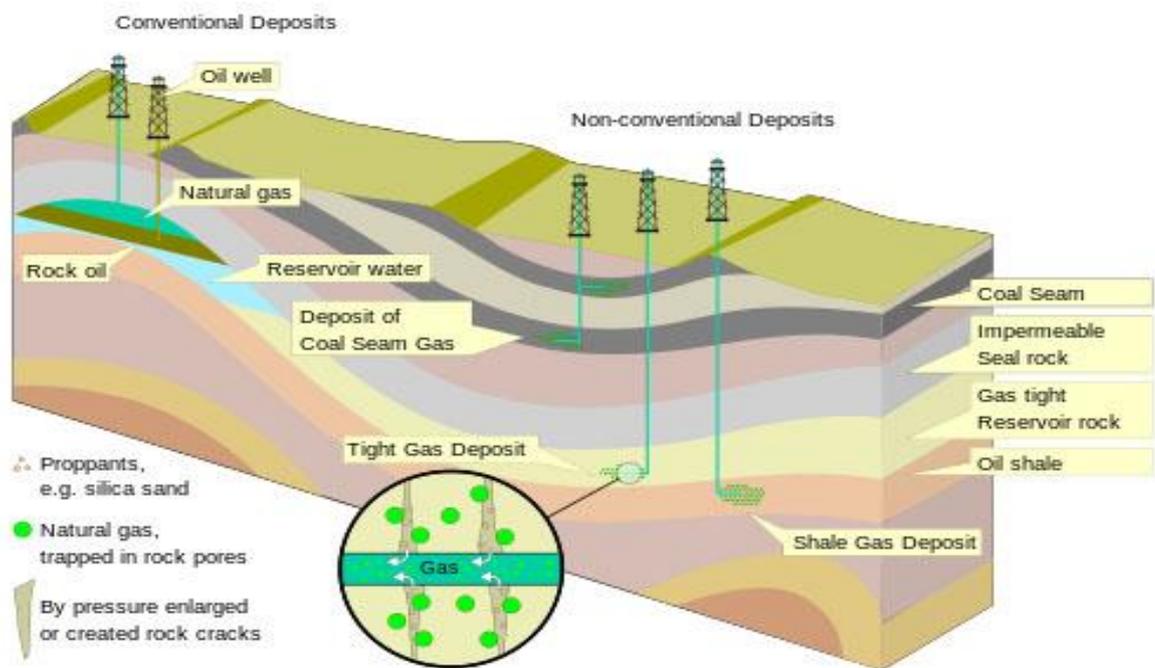


Figure I. 1: non-conventional reservoirs [3].

### I.2.2. Tight Gas Reservoirs:

Tight gas reservoirs are unconventional formations characterized by low permeability, presenting challenges for natural gas extraction. Hydraulic fracturing is a commonly employed technique, involving the injection of water, sand, and chemicals at high pressure to create fractures in the reservoir and increase permeability. Horizontal drilling is also utilized to maximize contact with the reservoir. Multi-stage fracturing allows for the creation of multiple fractures along the horizontal wellbore, enhancing gas flow. Effective water management is crucial due to significant water production alongside gas extraction. Ongoing technological advancements focus on improving fracturing fluids, proppants, and drilling techniques. Reservoir characterization plays a vital role in optimizing drilling and fracturing designs. Tight gas reservoirs hold substantial natural gas resources and their development contributes to meeting global energy demands while necessitating specialized techniques for efficient extraction [3].

### **I.2.3. Coal Bed Methane (CBM) Reservoirs:**

Coalbed Methane (CBM) reservoirs are unconventional reservoirs where natural gas is trapped within coal seams. These reservoirs require the extraction of adsorbed methane from the coal matrix. Production from CBM reservoirs involves dewatering the coal seam to reduce pressure and release the gas. Hydraulic fracturing may be utilized to enhance gas production by stimulating natural fractures and creating additional flow pathways within the coal. CBM typically has a higher methane content but can contain impurities. Reservoir heterogeneity and variations in coal properties influence production rates. Managing produced water, which is often saline, is a crucial aspect of CBM extraction. Environmental considerations, such as groundwater protection and methane emissions, are important factors in CBM operations. Ongoing research focuses on improving extraction efficiency and minimizing environmental impacts. CBM reservoirs contribute to diversifying natural gas resources and require specialized techniques for successful production. [4].

### **I.2.4. Tight Oil Reservoirs:**

Tight oil reservoirs, also known as unconventional oil reservoirs, are formations with low permeability that hold significant quantities of oil. Extracting oil from these reservoirs requires specific techniques due to the restricted flow caused by low permeability. Hydraulic fracturing is the primary method employed, involving high-pressure fluids that create

fractures in the rock, allowing the oil to flow more freely and be extracted. Horizontal drilling is commonly used to maximize contact with the reservoir, enhancing oil production and economic viability. Multi-stage fracturing further boosts oil recovery by creating multiple fractures along the horizontal wellbore. Thorough reservoir characterization is crucial for optimizing drilling and fracturing designs. Enhanced Oil Recovery (EOR) techniques may also be utilized to improve oil recovery. Environmental considerations, including water management and minimizing surface impacts, are essential for responsible operations. Tight oil reservoirs have played a significant role in expanding oil production and advancements in technology continue to improve production efficiency while addressing environmental concerns.

### **I.2.5. Heavy Oil and Oil Sands:**

Heavy oil and oil sands are unconventional resources characterized by high viscosity and density. Heavy oil has a low API gravity, indicating its density and reduced fluidity. Oil sands, also known as tar sands, contain a mixture of sand, water, clay, and bitumen. Extraction methods for heavy oil and oil sands include mining for surface deposits and in-situ techniques for deeper reserves. In-situ techniques involve thermal or chemical treatments to extract the bitumen. Upgrading processes are employed to improve the quality and viscosity of heavy oil and bitumen, making them suitable for conventional refining. Environmental considerations are vital, and efforts are made to mitigate the impacts of extraction, such as land disturbance and greenhouse gas emissions. Heavy oil and oil sands reserves are globally significant, with notable reserves found in Canada, Venezuela, and other regions. Advanced technologies and ongoing research are aimed at improving extraction efficiency, reducing environmental effects, and ensuring sustainable utilization of these resources. These resources play a crucial role in global oil production and meeting energy demands [4].

### **I.2.6. Gas Hydrates:**

Gas hydrates are solid crystalline compounds formed by the trapping of gas molecules, primarily methane, within a lattice structure of water molecules. They occur under specific conditions of low temperature and high pressure, commonly found in deep-sea sediments and permafrost regions. Methane is the predominant gas component in hydrates, although other gases can also be present. Gas hydrates resemble ice and have high energy content, making

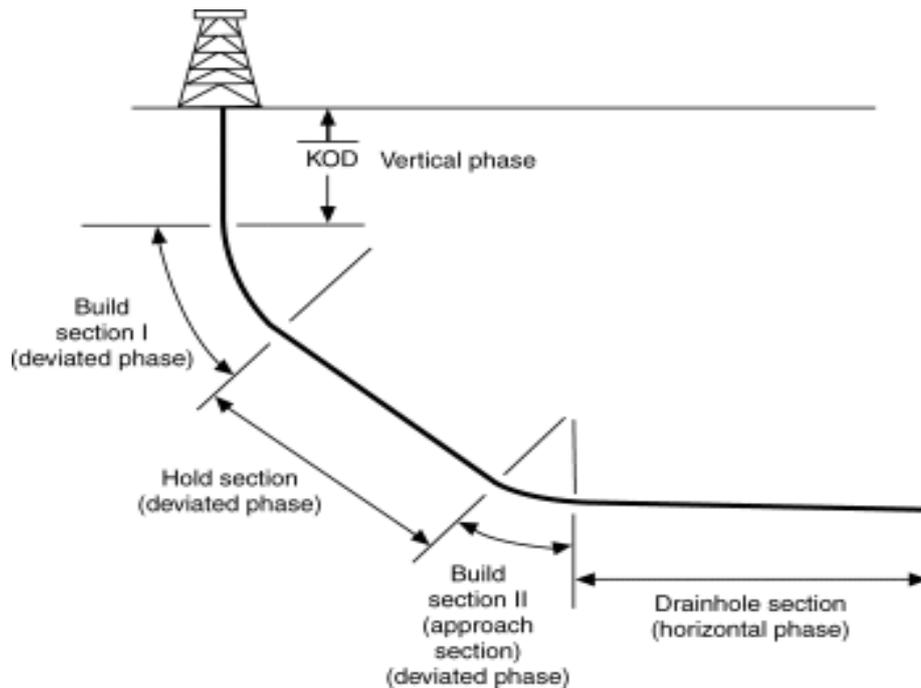
them a potential unconventional energy resource. However, extracting gas from hydrates is challenging due to technical and economic complexities, as well as concerns about potential environmental impacts and the release of methane, a potent greenhouse gas. Extensive research and exploration are underway to better understand gas hydrates, evaluate their resource potential, and develop safe and efficient extraction methods. Additionally, the environmental implications and climate change implications of gas hydrates are subjects of ongoing study and consideration [5].

### **I.3. Hydrocarbon recovery techniques for unconventional reservoirs:**

The development of unconventional reservoirs has significantly impacted the energy industry, unlocking vast reserves of oil and gas resources. Key techniques used in the recovery of hydrocarbons from unconventional reservoirs include hydraulic fracturing, horizontal drilling, multi-stage fracturing, advanced completion methods, reservoir characterization, and monitoring. These techniques have revolutionized the energy landscape, enabling the extraction of hydrocarbons from shale formations, tight oil and gas reservoirs, coalbed methane, and oil sands. Ongoing advancements in technology and understanding of these reservoirs continue to improve recovery rates and optimize production in unconventional plays, contributing to global energy supply.

#### **I.3.1. Horizontal Drilling:**

Horizontal drilling is a technique used in the oil and gas industry to maximize hydrocarbon recovery from reservoirs. Unlike traditional vertical drilling, horizontal drilling involves deviating the wellbore at an angle and drilling horizontally within the targeted reservoir zone. This technique allows for increased exposure to the productive formation, effectively accessing more hydrocarbons. By drilling horizontally, operators can intersect more fractures, natural fractures, or channels within the reservoir, enhancing the flow of hydrocarbons. Additionally, horizontal drilling enables the placement of multiple completion zones along the wellbore, increasing production potential. This technique has proven particularly effective in unconventional reservoirs, such as shale formations and tight oil or gas reservoirs, where the rock is less permeable. Horizontal drilling has significantly improved well performance, increasing overall recovery rates and optimizing hydrocarbon production from challenging reservoirs [6].



**Figure I. 2:** Horizontal drilling phases [6].

### **I.3.2. Managed Pressure Drilling:**

Managed Pressure Drilling (MPD) is an innovative technique employed in drilling operations to control and maintain the pressure within the wellbore. It allows for drilling through challenging formations, such as those with narrow drilling windows or high-pressure zones, with reduced risks of wellbore instability and fluid losses. MPD involves continuously monitoring the wellbore pressure and adjusting the drilling parameters in real-time to maintain the desired pressure regime. This technique enables precise control over the wellbore pressure, minimizing formation damage, improving drilling efficiency, and enhancing safety. By optimizing drilling operations and mitigating risks, Managed Pressure Drilling has proven to be a valuable tool in the exploration and production of hydrocarbon resources.

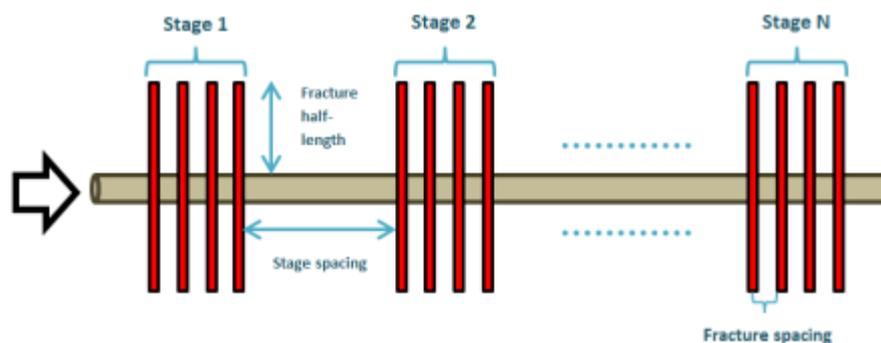
### **I.3.3. Hydraulic Fracturing:**

Hydraulic fracturing, commonly known as fracking, is a well stimulation technique used to extract hydrocarbons from deep underground reservoirs, particularly in unconventional formations like shale and tight gas. It involves the injection of a high-pressure fluid mixture, typically consisting of water, chemicals, and proppants, into the reservoir rock. The fluid

creates fractures in the rock, allowing trapped hydrocarbons to flow more freely and be extracted. Proppants, such as sand or ceramic particles, are used to hold the fractures open, enabling continued hydrocarbon flow. Hydraulic fracturing has revolutionized the energy industry, unlocking vast reserves of previously inaccessible hydrocarbons. It has significantly contributed to the increase in natural gas and oil production, reducing dependence on foreign energy sources. However, hydraulic fracturing remains a topic of debate due to concerns about potential environmental impacts, such as water contamination and induced seismicity. Striking a balance between energy extraction and environmental stewardship continues to be a focus for industry and regulatory efforts related to hydraulic fracturing.

### I.3.4. Multi-Stage Hydraulic Fracturing:

Multi-stage hydraulic fracturing is a technique widely used in the extraction of hydrocarbons from unconventional reservoirs, such as shale formations and tight oil or gas reservoirs. It involves the creation of multiple fractures along the horizontal wellbore through a series of controlled fracturing stages. Each stage consists of injecting a high-pressure fluid, typically water-based, along with proppants and additives, into the reservoir. The pressure causes the rock to crack, and the proppants, typically small grains of sand or ceramic material, prop open the fractures, allowing hydrocarbons to flow more efficiently to the wellbore. By creating multiple fractures and effectively stimulating the reservoir, multi-stage hydraulic fracturing significantly increases the contact area between the reservoir rock and the wellbore, enhancing the productivity and recovery rates of the hydrocarbons. This technique has revolutionized the development of unconventional resources and played a vital role in meeting global energy demands. [7].



**Figure I. 3:** Multiple fractures along a horizontal well. [7].

### **I.3.5. Reservoir Characterization and Modelling:**

Reservoir characterization and modelling are essential processes in understanding the properties and behaviour of subsurface reservoirs. These techniques involve analysing geological, geophysical, and petrophysical data to build a comprehensive model of the reservoir. Reservoir characterization involves studying rock properties, such as porosity, permeability, and lithology, as well as fluid properties and saturation levels. Geophysical techniques like seismic surveys and well logging help in mapping the subsurface structures and identifying potential reservoir zones. Petrophysical analysis provides insights into rock and fluid properties through laboratory measurements and data interpretation. Once the reservoir is characterized, reservoir modelling utilizes the collected data to construct a numerical model that represents the subsurface reservoir and simulates its behaviour. This model enables reservoir engineers to predict fluid flow patterns, estimate reserves, optimize well placement, and design efficient production strategies. Reservoir characterization and modelling are crucial for effective reservoir management, maximizing hydrocarbon recovery, and minimizing exploration and production risks.

### **I.3.6. Advanced Completion Techniques:**

Advanced completion techniques are instrumental in optimizing hydrocarbon production from reservoirs. These techniques go beyond traditional completion methods and include practices such as multi-stage fracturing, intelligent completions, and sand control mechanisms. Multi-stage fracturing enables the creation of multiple fractures along the wellbore, enhancing reservoir contact and hydrocarbon recovery. Intelligent completions utilize downhole monitoring and control systems to optimize production from different zones within the reservoir. Sand control mechanisms prevent sand and other solids from entering the wellbore, ensuring stable production. Advanced completion techniques play a crucial role in maximizing reservoir productivity and improving overall well performance.

### **I.3.7. Reservoir Stimulation:**

Reservoir stimulation is a vital technique used to enhance the production of hydrocarbons from subsurface reservoirs. It involves various methods aimed at improving the permeability and fluid flow within the reservoir, thereby increasing the recovery of oil and gas. One commonly used stimulation technique is hydraulic fracturing, where fluid is injected into the

reservoir at high pressure to create fractures in the rock formation, allowing hydrocarbons to flow more freely. Acidizing is another stimulation method, which involves the injection of acid into the reservoir to dissolve mineral deposits and enhance permeability. Other techniques include proppant placement, where solid materials are injected into the fractures to keep them open, and chemical treatments to alter fluid viscosity and improve flow characteristics. Reservoir stimulation plays a crucial role in optimizing production and maximizing the recovery of hydrocarbon resources from challenging reservoirs [8].

### **I.3.8. Reservoir Monitoring and Surveillance:**

Reservoir monitoring and surveillance are essential components of effective reservoir management. They involve the collection, analysis, and interpretation of various data sources to monitor the behaviour of hydrocarbon reservoirs. Data collected includes well data, production data, seismic data, pressure data, and fluid samples, providing insights into reservoir characteristics, fluid behaviour, production rates, pressure changes, and overall reservoir performance. Reservoir engineers analyse this data to assess reservoir performance, evaluate production rates, fluid flow behaviour, pressure trends, and identify potential issues or anomalies that may impact production or reservoir integrity. Techniques such as pressure transient analysis, production logging, seismic monitoring, reservoir simulation, and remote sensing are utilized. These monitoring and surveillance techniques enable proactive decision-making, optimization of production strategies, identification of reservoir changes, and risk mitigation. Continuous advancements in technology and data analysis techniques further enhance the capabilities of reservoir monitoring and surveillance, improving reservoir management practices and maximizing hydrocarbon recovery [8].

- ❖ Stress regimes in rock formations have a significant impact on the formation and development of unconventional reservoirs. Unconventional reservoirs, characterized by low permeability, require advanced extraction techniques such as hydraulic fracturing to recover hydrocarbons effectively. Understanding the stress regime is crucial for optimizing the design and efficiency of hydraulic fracturing operations. By analysing the stress distribution and orientation and ensuring the creation of an interconnected network of fractures that allows for efficient hydrocarbon flow towards the wellbore. Additionally, knowledge of the stress regime helps in assessing the geomechanical stability of the rock formation, mitigating risks associated with

induced seismicity, and preventing undesired outcomes such as rock failure or excessive deformation. Furthermore, stress regimes play a role in predicting and managing reservoir compaction and subsidence, which can occur as a result of fluid extraction and stress release. By incorporating stress regime analysis into reservoir characterization and engineering practices, operators can enhance the performance and productivity of unconventional reservoirs, ultimately maximizing hydrocarbon recovery.

### **I.4. Stress regimes in rock formations:**

Stress regimes in rock formations refer to the different types and orientations of stress that act on rocks within the Earth's crust. These stress regimes play a crucial role in shaping the behaviour and deformation of rocks, influencing the formation of geological structures and affecting the exploration and production of natural resources.

The Earth's crust is subject to various forces, including tectonic forces, gravitational forces, and the internal stresses within the rocks themselves. These forces result in three primary stress regimes: compressional, extensional, and shear.

In compressional stress regimes, rocks experience forces that push them together or compress them. This occurs in regions where tectonic plates collide or converge. The compressional stress leads to the folding of rocks, the formation of thrust faults, and the creation of mountain ranges.

Extensional stress regimes involve forces that pull rocks apart or extend them. This occurs in regions where tectonic plates move apart or diverge. The extensional stress leads to the thinning and stretching of rocks, the formation of normal faults, and the development of rift valleys.

The understanding of stress regimes is crucial in various geological and engineering applications. In terms of resource exploration, it helps identify areas where rocks may have undergone fracturing and faulting, potentially creating pathways for the migration and accumulation of hydrocarbons or mineral deposits. It also influences the behaviour of reservoir rocks and their response to drilling and extraction techniques.

### **I.4.1. Stress:**

Stress is a physical quantity that represents the internal forces acting within a material. It is a measure of the intensity of the internal resistance of a material to external forces or loads applied to it. When a material is subjected to external forces, it undergoes deformation, and stress is the force per unit area that develops within the material to counteract these external force [9].

Stress can be classified into different types based on the nature of the applied forces and the resulting deformation. The three main types of stress are:

#### **I.4.1.1. Principal vertical stress:**

Principal vertical stress is the component of stress acting perpendicular to the horizontal plane or parallel to the Earth's gravity. It is primarily caused by the weight of the overlying rocks and sediments and the pressure exerted by fluids (e.g., water, oil, gas) in the subsurface. The magnitude of vertical stress increases with depth due to the increasing weight of the overlying materials. It follows a linear relationship with depth in a homogeneous and isotropic medium. However, in real geological settings, the distribution of vertical stress is influenced by factors such as variations in rock density, lithology, and fluid pressure.

Principal vertical stress plays a crucial role in various geomechanical processes and phenomena. It influences rock strength, deformation, and failure, as well as the behaviour of fluids within the subsurface. Understanding the principal vertical stress is vital for assessing wellbore stability, designing foundations, evaluating slope stability, and analysing the response of underground structures. The principal vertical stress is commonly referred to as overburden pressure, as it represents the load imposed by the overlying rocks and sediments. Overburden pressure is an essential parameter in geotechnical and petroleum engineering, where it affects drilling operations, well design, and reservoir behaviour.

The principal vertical stress gradient refers to the rate of change of principal vertical stress with respect to depth. In most cases, the vertical stress gradient is relatively constant, assuming a hydrostatic pressure distribution in the fluids present in the subsurface. However, localized variations in fluid pressure or changes in lithology can lead to variations in the vertical stress gradient.

In porous formations, the principal vertical stress influences the pore pressure distribution and fluid flow. It determines the effective stress acting on the solid matrix, which governs the mechanical behaviour of the porous medium, including compaction, consolidation, and permeability changes.

Vertical stress can be estimated using empirical relationships, geological models, and analytical solutions based on rock density, overburden thickness, and fluid pressure. Direct measurement of vertical stress is challenging but can be achieved through in-situ stress testing techniques, such as hydraulic fracturing tests or stress monitoring using borehole instruments.[9].

### **I.4.1.2. Principal horizontal stress:**

Principal horizontal stress is a key parameter in geomechanics that plays a significant role in various subsurface engineering applications, including drilling and reservoir development. It refers to the stress acting horizontally within the Earth's subsurface and is characterized by two main components: the maximum stress ( $\sigma_1$ ) and the minimum stress ( $\sigma_3$ ). The maximum stress represents the largest magnitude of stress acting horizontally and governs the initiation and propagation of fractures and faults. On the other hand, the minimum stress represents the smallest magnitude of stress and determines the direction of least resistance within the rock formation. Understanding the horizontal stress regime, including the maximum and minimum stress directions, is crucial for optimizing drilling operations, ensuring wellbore stability, and designing efficient completions.

#### **I.4.1.2.1. Maximum principal horizontal stress:**

Maximum horizontal principal stress ( $s_H$ ) plays a crucial role in the field of wellbore stability and drilling optimization. Understanding the distribution and magnitude of principal horizontal stresses is essential for ensuring the structural integrity of a wellbore and avoiding drilling issues such as borehole instability, mud losses, and even wellbore collapse to estimate the maximum principal horizontal stress, the extended leak-off test (XLOT) combined with a fracture reopening test is commonly employed. The XLOT involves gradually increasing the wellbore pressure to induce a fracture in the formation. By monitoring the pressure required to initiate and propagate the fracture, engineers can deduce valuable information about the in-situ stress state, including the maximum principal horizontal stress.

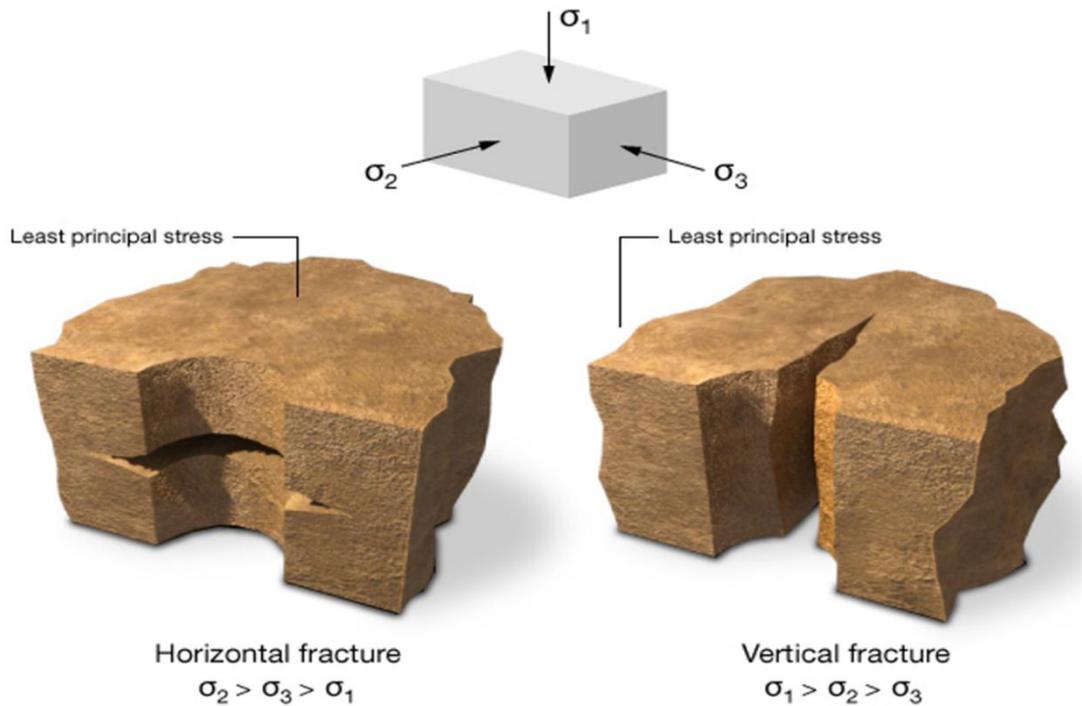
The fracture reopening test, based on the Kirsh solution for a circular hole under internal pressure, provides a means to quantify the stresses acting on the wellbore. The Kirsh solution describes the behaviour of a circular hole in an elastic and isotropic formation subjected to internal pressure. By measuring the pressure required to reopen a previously closed fracture, engineers can estimate the magnitude of the maximum principal horizontal stress.

It is worth noting that underground formations experience stress due to their confined nature. Overburden pressure from the weight of the overlying rock layers, as well as tectonic forces and the presence of natural fractures or faults, contribute to the overall stress state in the subsurface. Understanding these stresses and their orientations is crucial for successful wellbore drilling and completion operations.

### **I.4.1.2.2. Minimum principal Horizontal Stress:**

Minimum principal horizontal stress ( $s_h$ ) is one of the principle stresses that confined underground formations are subjected to. The other stresses are the principal vertical stress and the maximum principal horizontal stress. Hydraulic fracture propagates perpendicular to the minimum principle stress. Minimum horizontal stress is estimated using pyroclastic theory. It represents the smallest magnitude of stress acting in the horizontal plane within the subsurface.

The minimum principal horizontal stress is significant in various applications, including hydraulic fracturing, wellbore stability analysis, and reservoir engineering. In hydraulic fracturing operations, the orientation of  $s_h$  plays a crucial role in determining the direction of fracture propagation. Fractures tend to propagate perpendicular to  $s_h$  and parallel to the maximum horizontal stress ( $s_H$ ).  $s_H$  helps optimize fracture design and well placement for efficient hydrocarbon extraction [9].



**Figure I. 4:** Principal stress regime [10].

#### **I.4.2. Stress regimes:**

Stress regimes refer to the patterns or states of stress within geological formations. They are characterized by the magnitudes, orientations, and interrelationships of the principal stresses present in the subsurface. Understanding stress regimes is essential for various geomechanical applications, such as wellbore stability analysis, hydraulic fracturing design, and underground excavation planning. There are three primary stress regimes:

##### **I.4.2.1. Normal Stress Regime:**

In a conventional stress regime, the vertical stress ( $\sigma_v$ ) is the largest principal stress, reflecting the weight of overlying rocks and sediments. The maximum horizontal stress ( $\sigma_H$ ) is typically the second largest, caused by lateral forces acting on the formation, such as tectonic forces or stress transfer from nearby faults. The minimum horizontal stress ( $\sigma_h$ ) is the smallest and perpendicular to both the vertical and maximum horizontal stresses. The vertical stress is aligned with gravity, acting downward. The maximum horizontal stress is horizontal and parallel to the Earth's surface, while the minimum horizontal stress is perpendicular to the

maximum horizontal stress. Conventional stress regimes are often observed in sedimentary basins and regions with relatively low tectonic activity. The vertical stress dominates due to the weight of the overlying layers, while the horizontal stresses are influenced by regional tectonic forces [9].

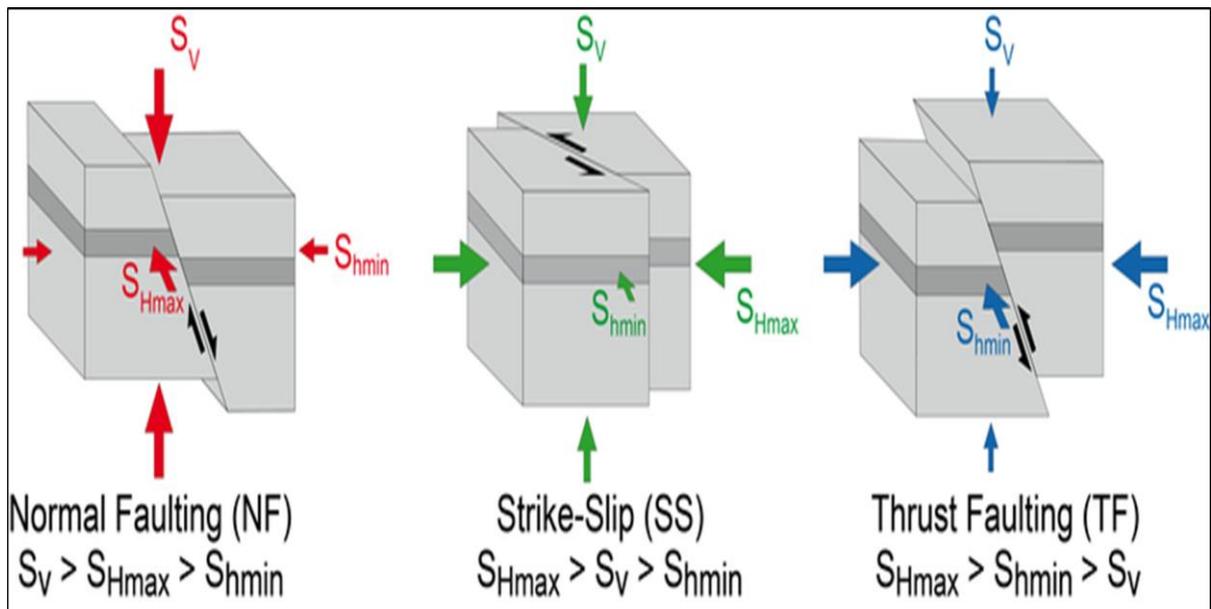
### **I.4.2.2. Strike-Slip Stress Regime:**

In a strike-slip stress regime, the maximum horizontal stress ( $\sigma_H$ ) is the largest principal stress, reflecting the shearing forces along fault planes. The vertical stress ( $\sigma_v$ ) is typically the second largest, while the minimum horizontal stress ( $\sigma_h$ ) is the smallest. The maximum horizontal stress is perpendicular to the fault or fracture planes, representing the direction of shearing forces. The vertical stress is still aligned with gravity, acting downward. Strike-slip stress regimes are commonly found in regions with active faulting, such as transform plate boundaries. The movement along the fault planes results in the dominance of the maximum horizontal stress.

### **I.4.2.3. Reverse/Thrust Stress Regime:**

In a reverse/thrust stress regime, the maximum horizontal stress ( $\sigma_H$ ) is the largest principal stress, reflecting the compressional forces causing rock layers to be pushed together. The minimum horizontal stress ( $\sigma_h$ ) is typically the second largest, while the vertical stress ( $\sigma_v$ ) is the smallest. The maximum horizontal stress is perpendicular to the compressional forces, acting horizontally and causing rock layers to be pushed together. The vertical stress is still aligned with gravity, acting downward.

Reverse/thrust stress regimes are prevalent in areas of crustal compression, such as convergent plate boundaries and fold-and-thrust belts. These stress regimes result from tectonic forces that compress and deform the rock layers [9].



**Figure I. 5:** stress regimes [10].

### **I.4.3. The Impact of Stress on Drilling Operations:**

Stress has significant relevance in drilling operations as it directly influences the stability of the wellbore, the efficiency of drilling, and the overall success of the project.

#### **I.4.3.1. Wellbore Stability:**

Wellbore stability is intricately linked to stress in drilling operations. The stress distribution within the rock formation surrounding the wellbore directly impacts its stability. The magnitude and orientation of stresses determine the potential for wellbore failure, including collapse, breakout, or shearing. The minimum stress direction is particularly significant, as aligning the wellbore with this direction helps minimize instability risks. Excessive stresses can induce failure mechanisms such as borehole breakout or collapse. Anisotropic rock behaviour, influenced by factors like bedding planes and fractures, must be considered, as it affects stability. Maintaining a balance between formation and mud pressures is crucial, requiring an understanding of the stress state to design proper mud weight. By integrating stress analysis techniques and continuous monitoring, drilling engineers can optimize practices and mitigate stability-related risks, ensuring safe and efficient drilling operations [6].

### **I.4.3.2. Drilling Problems:**

Drilling problems are challenges encountered during drilling operations, and stress plays a significant role in influencing their occurrence and severity. Excessive stresses can lead to borehole instability, such as collapse, breakout, or shear failure. High differential stresses cause borehole breakout, while tensile stresses result in borehole collapse. Stress-induced formation damage can impair permeability and reduce well productivity. Stress-related lost circulation occurs when drilling fluids escape into highly permeable or fractured zones. Wellbore tortuosity, caused by stress variations, can deviate the wellbore from its planned trajectory. Stuck pipe incidents can arise from stress-induced wellbore instability. Proper stress analysis and management are essential to mitigate drilling problems, maintain well control, and enhance drilling efficiency [11].

### **I.4.3.3. Hydraulic Fracturing:**

Hydraulic fracturing, or fracking, is a technique used to extract oil and gas from tight reservoirs by creating fractures in the rock formation. Stress plays a vital role in hydraulic fracturing as it determines the direction and extent of fracture propagation. Understanding the stress state helps optimize fracture design, control fracture complexity, and improve reservoir connectivity. Stress variations can result in complex fracture networks and affect fracture geometry and conductivity, impacting fluid flow within the reservoir. Managing stress and monitoring its changes during hydraulic fracturing operations are crucial for maximizing production and ensuring wellbore stability and integrity [7].

### **I.4.3.4. Casing Design:**

Casing design in well construction is essential for providing structural integrity and support to the wellbore. Stress considerations play a crucial role in casing design, ensuring the casing can withstand the mechanical loads and stresses during drilling, completion, and production. Factors such as load-bearing capacity, burst and collapse resistance, wellbore stability, cement bonding, and temperature effects are all influenced by the stress state. By analysing stress distribution, engineers can select appropriate casing dimensions, materials, and connection design to ensure wellbore integrity and prevent casing failure. Proper stress analysis is vital for optimizing casing design and ensuring safe and efficient well operations.

### **I.4.3.5. Risk Mitigation:**

Stress is highly relevant to risk mitigation in drilling and well construction. By understanding and managing stress-related risks, accidents, failures, and setbacks can be prevented. Key areas of risk mitigation include ensuring wellbore stability, maintaining casing and cementing integrity, mitigating formation damage, optimizing fracturing and reservoir connectivity, preventing equipment failure, and ensuring well control. Stress analysis helps identify potential risks, optimize design and operational practices, and minimize the likelihood of incidents. By considering stress-related risks and implementing appropriate mitigation strategies, drilling operations can be conducted safely and efficiently, protecting personnel, the environment, and minimizing costs. [11].

### **I.5. the process of stress analysis and its application in determining the minimum stress direction:**

The process of stress analysis involves studying the distribution and magnitude of stresses within a geological formation. It is a crucial step in geomechanics and plays a significant role in various applications, including determining the direction of the minimum stress ( $\sigma_h$ ) [12].

#### **I.5.1. Data Collection:**

In stress analysis, data collection involves gathering information about the geological formation and its properties. This includes wellbore data such as drilling records, well logs (gamma ray, resistivity, sonic, etc.), and core samples. Geophysical data, such as seismic surveys, can also provide valuable insights into the subsurface structure. The collected data helps in understanding the rock properties, stratigraphy, and structural features that influence the stress distribution.

#### **I.5.2. Stress Indicators:**

Stress indicators are geological features or phenomena that provide clues about the stress state within the formation. These indicators include borehole breakout, drilling-induced fractures, and natural fractures. Borehole breakout refers to the asymmetrical deformation of the wellbore wall due to the surrounding stress. It can be observed using wellbore imaging tools or by examining core samples. Drilling-induced fractures are fractures that occur during

the drilling process, and natural fractures are pre-existing fractures within the formation. These indicators help in understanding the orientation and magnitude of the principal stresses.

### **I.5.3. Interpretation Techniques:**

Various techniques are used to interpret the stress indicators and deduce the stress state. These techniques consider the geometry of the stress indicators, mechanical properties of the rock, and the theory of rock failure. One commonly used technique is the Mogi-Coulomb criterion, which relates the stress state to the observed failure patterns. The Andersonian faulting theory considers the orientations of fractures and their relationship with the principal stresses. Wellbore stability models, such as the elastoplastic or pyroclastic models, simulate the rock behaviour under stress and help interpret the stress indicators.

### **I.5.4. Determining the Minimum Stress Direction:**

Once the stress tensor is determined through stress inversion, the minimum stress direction ( $\sigma_h$ ) can be identified. In a typical stress regime, the minimum stress is perpendicular to the observed fracture planes or borehole breakouts. By analysing the orientations of these features and their relationship with the principal stresses, the direction of  $\sigma_h$  can be estimated. This information is crucial for various applications, including hydraulic fracturing, wellbore stability analysis, and reservoir engineering [12].

## **I.6. Data Gathering Methods for Stress Analysis:**

Several methods are used to gather data for stress analysis in geomechanics. These methods provide valuable information about the stress state within a geological formation. Here are some commonly used techniques:

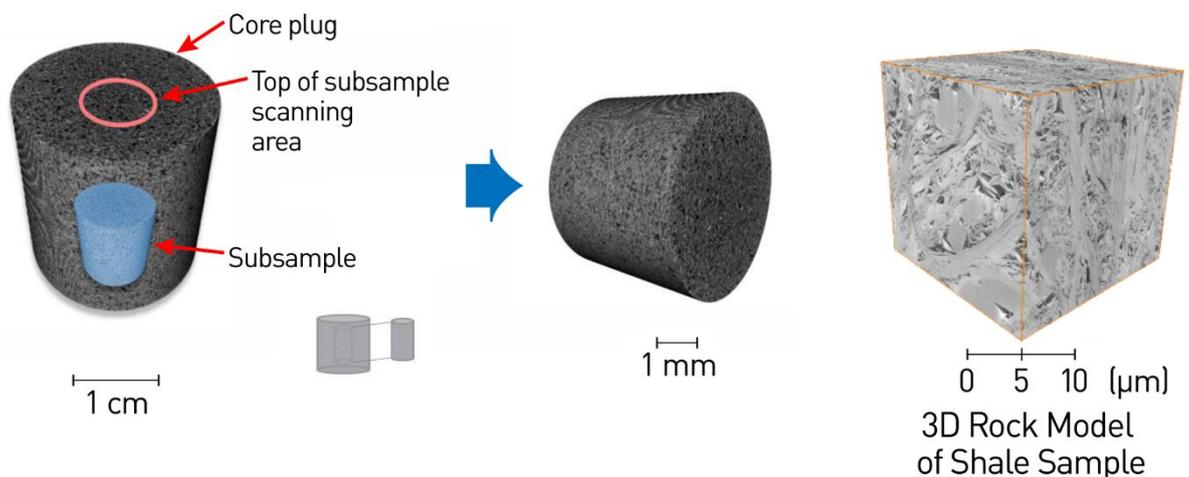
### **I.6.1. Borehole Imaging:**

Borehole imaging involves the use of specialized tools, such as borehole televiewers and acoustic scanners, to capture detailed images of the wellbore wall. These tools utilize cameras, acoustic or electrical sensors, and other measurement devices to provide high-resolution images of the borehole. The images reveal valuable information about the orientation and characteristics of fractures, borehole breakouts, and other features. Borehole

imaging aids in identifying the stress state by analysing the orientation and distribution of these features [12].

### I.6.2. Core Analysis:

Core analysis involves examining core samples extracted from the subsurface during drilling operations. These samples are analysed in the laboratory to identify and measure various properties, including rock fabric, microfractures, and mechanical properties. Rock fabric analysis helps determine the orientation and distribution of mineral grains, providing insights into the stress state. Microfracture analysis allows for the identification and characterization of natural fractures, which are influenced by the stress regime. Mechanical testing of core samples helps in understanding the rock's response to stress. [12].



**Figure I. 6:** Core analysis techniques to ease interpretation. [10].

### I.6.3. Well Logs:

Well logs provide measurements of various rock properties as a function of depth. Sonic logs, resistivity logs, and density logs are commonly used in stress analysis. Sonic logs measure the travel time of sound waves in the rock, which can be used to estimate the rock's mechanical properties and, indirectly, the stress state. Resistivity logs help identify zones with different fluid saturations, indicating variations in stress. Density logs provide information about the density and porosity of the rock, which can be related to the stress state.

**I.6.4. Seismic Surveys:**

Seismic surveys involve generating and recording seismic waves to create images of subsurface structures. Reflection seismic surveys are commonly used in stress analysis. They utilize seismic sources (such as explosives or vibrators) to generate waves that propagate through the subsurface. The reflected waves are then recorded by geophones or other receivers. By analysing seismic data, such as the orientation and alignment of reflectors or faults, geoscientists can infer the stress regime and identify areas of stress concentration. [12].

**CHPATER TWO:**

**Engineering Design for Horizontal Drilling  
Wells in Principal minimum Stress  
Direction**

### **Introduction:**

Engineering design and planning for non-conventional horizontal drilling wells with minimum stress direction involves the application of specialized techniques and considerations to optimize the drilling and completion of horizontal wells in unconventional reservoirs. These reservoirs typically consist of low-permeability formations, such as shale, tight gas, or coalbed methane, where traditional drilling methods may not yield economically viable production rates.

The primary objective of this engineering design and planning approach is to identify the minimum stress direction within the reservoir and orient the wellbore in a manner that maximizes reservoir contact and hydrocarbon recovery. By aligning the wellbore with the minimum stress direction, the risk of encountering drilling-induced fractures and associated formation damage is reduced, leading to improved well performance.

The process begins with a comprehensive analysis of the reservoir's geomechanical properties, which includes the characterization of rock strength, stress distribution, and in-situ stress magnitudes. This information is typically obtained from core samples, well logs, and data acquired from hydraulic fracturing operations in the area.

Based on the geomechanical analysis, engineers can identify the minimum principal stress direction, which represents the path of least resistance for hydraulic fractures to propagate. By aligning the horizontal wellbore with this direction, the fractures induced during the hydraulic fracturing process tend to grow preferentially within the reservoir, enhancing reservoir contact and increasing the effective drainage area.

To design and plan the drilling operation, engineers consider several factors, including well trajectory, wellbore placement, and completion design. Well trajectory planning involves determining the entry point, angle, and curvature of the wellbore to achieve the desired path aligned with the minimum stress direction. Various techniques, such as rotary steerable systems and advanced measurement-while-drilling tools, are employed to accurately steer the wellbore along the desired trajectory.

Wellbore placement involves selecting the lateral section within the reservoir that offers the most favourable geomechanical conditions for hydraulic fracturing and

hydrocarbon production. This requires analysing reservoir heterogeneities, such as natural fractures, fault zones, and variations in rock properties, to identify the optimal target zone.

Completion design focuses on the selection and optimization of hydraulic fracturing parameters, such as injection rates, proppant concentrations, and stage spacing. By carefully tailoring the stimulation design to the reservoir's geomechanical properties and the minimum stress direction, engineers can achieve more efficient fracture propagation and maximize reservoir contact.

Overall, engineering design and planning for non-conventional horizontal drilling wells with minimum stress direction combine geomechanical analysis, well trajectory planning, wellbore placement, and completion design to optimize the drilling and completion process. By aligning the wellbore with the minimum stress direction, engineers can enhance reservoir contact, improve well performance, and maximize hydrocarbon recovery in unconventional reservoirs.

### **II.1. Directional drilling techniques and their application in unconventional reservoirs:**

Directional drilling is an advanced technique used in the oil and gas industry to drill wells at non-vertical angles. Unlike traditional vertical drilling, which follows a straight path from the surface to the target reservoir, directional drilling involves intentionally deviating the wellbore to reach reservoirs located beneath the surface at a distance from the drilling location. This technique allows for increased access to oil and gas reserves that would otherwise be challenging or impossible to reach. By steering the wellbore along a predetermined path, engineers can optimize the extraction process, increase production rates, and minimize environmental impact.

Directional drilling techniques are used to reach specific targets within unconventional reservoirs. By intentionally deviating the wellbore, engineers can optimize reservoir contact, improve drilling efficiency, and enhance hydrocarbon recovery. Directional drilling techniques include build and hold, kick-off point selection, rotary steerable systems, measurement-while-drilling, geo-steering, extended reach drilling, whipstocks, and sidetracking. These techniques play a crucial role in successfully extracting hydrocarbons

from unconventional reservoirs by allowing for precise well placement and navigation through challenging geological formations [6].

### II.1.1. Build and Hold:

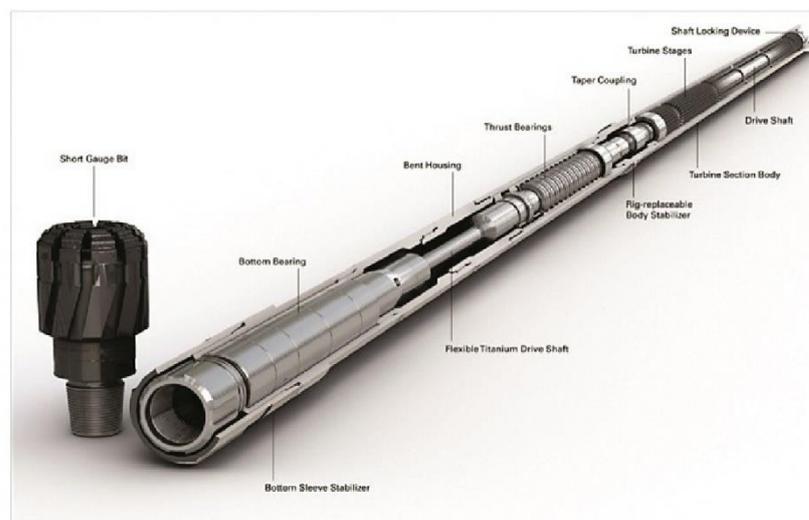
In this technique, the wellbore is gradually inclined (built) until the desired angle is achieved. Once the desired inclination is reached, the wellbore is held at a constant angle (hold). This technique is often employed when drilling through multiple target zones or when encountering unstable formations. It allows for controlled deviation while maintaining the desired trajectory.[13].

### II.1.2. Kick-off Point (KOP) Selection:

The KOP refers to the depth at which the wellbore deviates from the vertical plane. The selection of an optimal KOP is critical for positioning the wellbore in the most productive areas of the reservoir. Engineers consider factors such as reservoir characteristics, geological data, and well objectives to determine the appropriate KOP.

### II.1.3. Rotary Steerable Systems (RSS):

RSS technology enables continuous control of the wellbore trajectory while drilling. Unlike traditional methods that rely on sliding and rotating the drill pipe, RSS tools use downhole motors or adjustable bent housing assemblies to adjust the drilling direction. This allows for faster drilling rates, higher accuracy, and better steering control, making it suitable for navigating complex formations encountered in unconventional reservoirs.



**Figure II. 1:** Directional Control by Rotary Steerable. [14].

#### **II.1.4. Measurement-While-Drilling (MWD):**

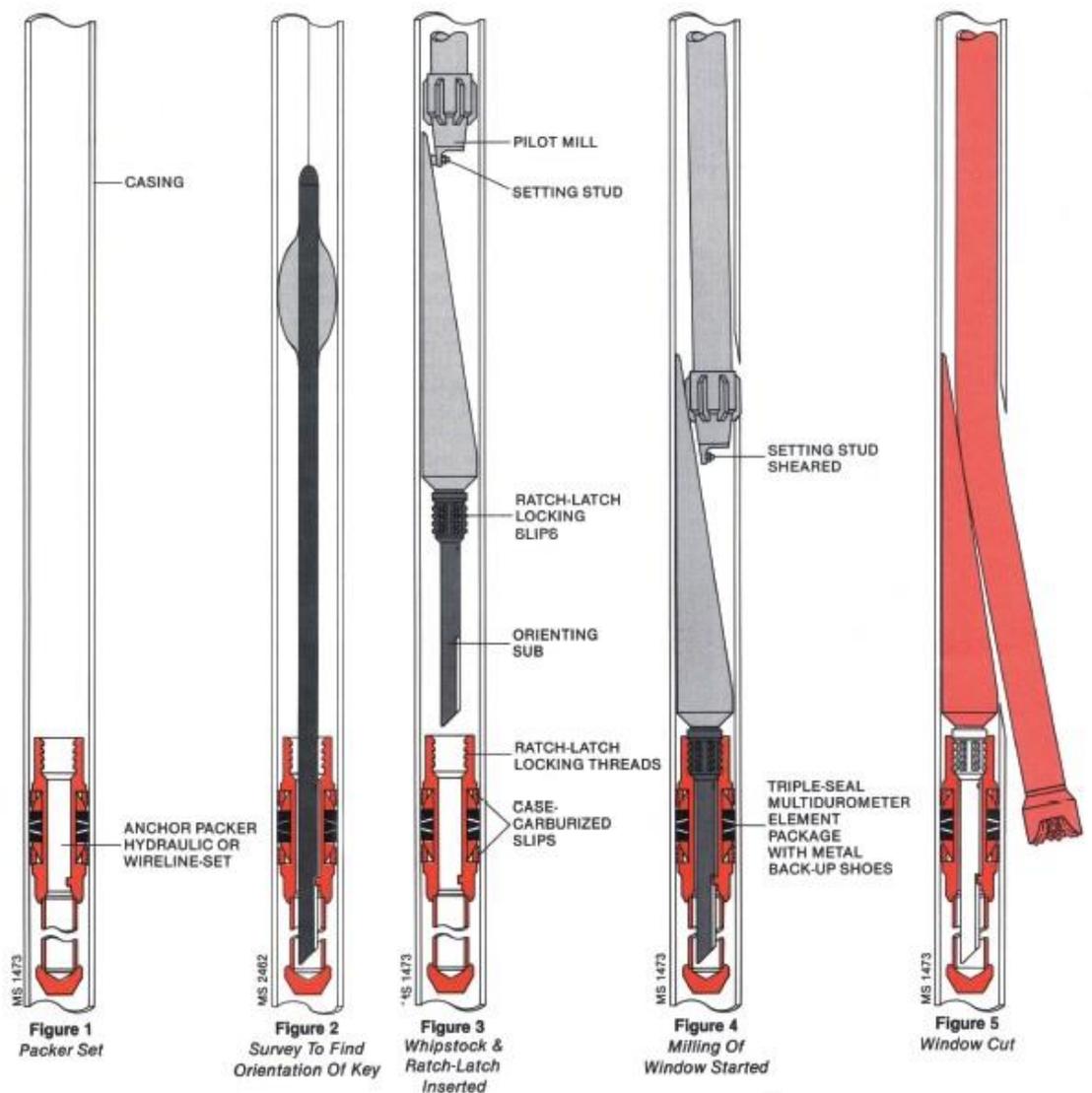
MWD tools provide real-time measurements of various parameters such as wellbore inclination, azimuth, and tool face orientation. These measurements are crucial for monitoring the wellbore trajectory and making necessary adjustments during drilling operations. MWD technology helps ensure accurate well placement, avoid drilling hazards, and maximize reservoir contact.

#### **II.1.5. Geo-Steering:**

Geo-steering involves using geological data acquired while drilling to guide the wellbore through the most productive areas of the reservoir. Measurements from gamma-ray logs, resistivity tools, and formation evaluation devices are used to interpret the geological formations encountered during drilling. By analysing this data, engineers can make real-time decisions on wellbore placement, optimizing hydrocarbon recovery by staying within the target zones.

#### **II.1.6. Whipstocks and Sidetracking:**

Whipstocks are mechanical devices used to create a window in the casing of a wellbore, allowing for a sidetrack to be drilled in a different direction. This technique is employed when there is a need to bypass obstacles, such as geological formations or damaged casing. Sidetracking enables the drilling of a new section from the existing wellbore, helping to reach previously unexplored or bypassed areas of the reservoir. [13].



**Figure II. 2:** Definition of sidetracking well. [15].

## **II.2. The Impact of Minimum Stress Direction on Well Trajectory:**

The minimum stress direction has a profound influence on the trajectory of wells, especially in non-conventional drilling applications. By understanding the minimum stress direction, it can optimize the placement, orientation, and path of the wellbore for improved performance. This knowledge enables operators to target the sweet spot, which is the most productive zone within the reservoir, by aligning the well trajectory parallel to the minimum stress direction. It also enhances fracture connectivity during hydraulic fracturing, ensures wellbore stability, and assists in steering and placement decisions. By considering the impact of minimum stress direction on well trajectory, operators can maximize hydrocarbon

recovery, optimize reservoir drainage, and increase the overall efficiency and profitability of drilling operations. [16].

### **II.2.1. Sweet Spot Targeting:**

In tight oil reservoirs or other unconventional formations, the minimum stress direction aids in identifying the sweet spot, which is the region with the highest hydrocarbon production potential. Aligning the well trajectory parallel to the minimum stress direction allows for better intersecting natural fractures and planes of weakness, optimizing the well's exposure to the most productive zones. This targeting of the sweet spot enhances reservoir drainage and maximizes production rates.

### **II.2.2. Fracture Connectivity:**

The minimum stress direction influences the connectivity of induced fractures during hydraulic fracturing operations. By aligning the fractures with the minimum stress direction, operators can create a network of interconnected fractures that enhance the flow of hydrocarbons through the reservoir. This improves the efficiency of well stimulation and increases the volume of the reservoir that can be effectively drained. [7].

### **II.2.3. Wellbore Stability:**

When drilling through complex and mechanically heterogeneous formations, the minimum stress direction is crucial for ensuring wellbore stability. By orienting the wellbore perpendicular to the minimum stress direction, operators can minimize the risk of wellbore collapse or instability. This alignment helps avoid encountering high-stress regions or weak planes that could compromise drilling operations or wellbore integrity. [11].

### **II.2.4. Steering and Placement:**

In directional drilling, the minimum stress direction assists in steering the wellbore along the desired trajectory. By considering the stress distribution, operators can adjust the drilling path to avoid obstacles, optimize well placement within the reservoir, and efficiently reach the target zones. This ensures that the well is positioned to intersect the maximum number of productive intervals and achieve the desired reservoir drainage. [16].

### **II.5.1. Directional Drilling Tools:**

Directional drilling tools are crucial for achieving the desired well trajectory in non-conventional horizontal drilling. These tools include downhole mud motors and rotary steerable systems (RSS). Mud motors convert hydraulic energy from drilling mud flow into mechanical energy to rotate the drill bit and control the wellbore's direction. RSS technology, on the other hand, allows for continuous steering of the drill bit while rotating, providing precise control over the well trajectory and reducing tortuosity. [6].

### **II.5.2. Measurement While Drilling (MWD) Systems:**

MWD systems play a vital role in providing real-time data during the drilling process. These systems utilize downhole sensors near the drill bit to measure parameters such as inclination, azimuth, drilling speed, and formation characteristics. The collected data is transmitted to the surface in real-time, allowing drilling engineers to monitor the drilling progress, verify the alignment with the planned trajectory, and make immediate adjustments as required. [19].

### **II.5.3. Drilling Fluids and Mud Systems:**

Drilling fluids, commonly referred to as mud, are essential for non-conventional horizontal drilling. These specialized fluids serve multiple purposes, including maintaining wellbore stability, controlling formation pressures, and lubricating the drill string. They also help carry the drill cuttings to the surface, cool the drill bit, and prevent formation damage. Various types of drilling fluids, such as water-based muds, oil-based muds, and synthetic-based muds, are used based on the specific drilling conditions and reservoir characteristics.

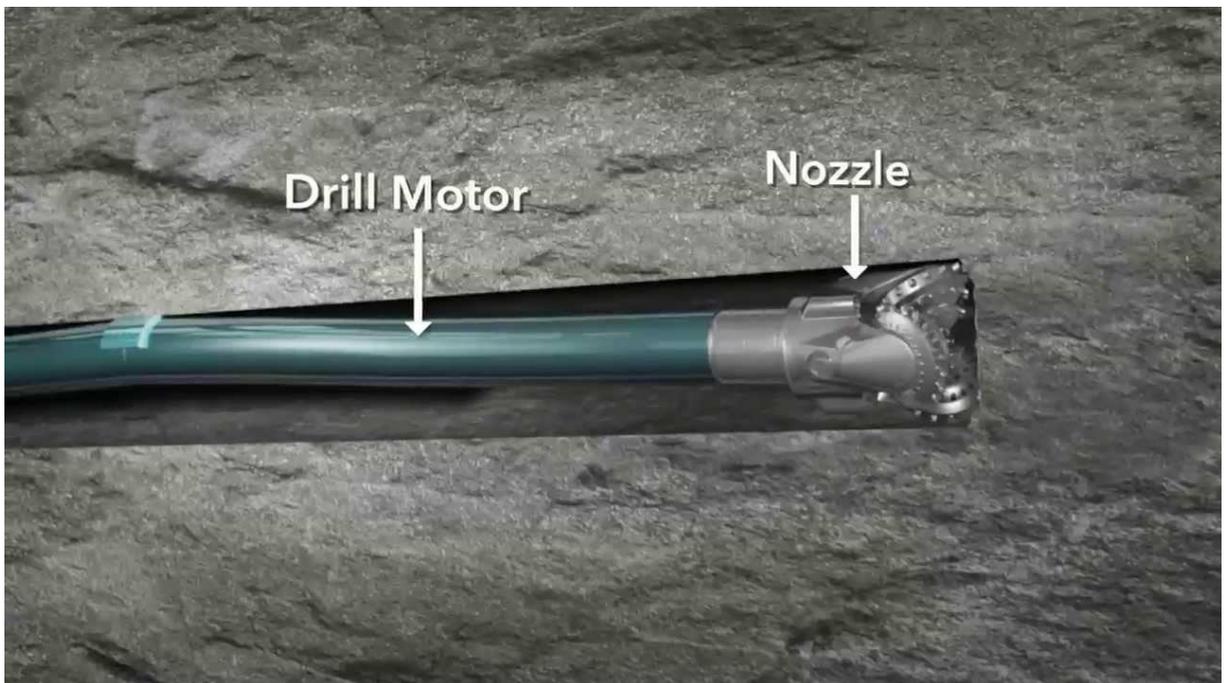
### **II.5.4. Casing and Completion Equipment:**

Non-conventional horizontal wells often require specialized casing and completion equipment to optimize production and reservoir connectivity. This includes techniques such as multistage hydraulic fracturing. In this method, the horizontal wellbore is divided into isolated sections using perforated casing, and each section is individually stimulated to

enhance hydrocarbon recovery. Completion equipment, such as packers, sliding sleeves, and fracture stimulation tools, is used to isolate and control fluid flow in the wellbore. [13].

### **II.5.5. Drill Bits:**

Drill bits are crucial components for efficient drilling in non-conventional horizontal wells. Various types of drill bits are used, including polycrystalline diamond compact (PDC) bits and roller cone bits. PDC bits are known for their durability and cutting efficiency in hard formations, while roller cone bits are more versatile and can handle varying formation conditions. The selection of the appropriate drill bit depends on the specific drilling parameters and the properties of the target formation.



**Figure II. 3:** Horizontal Directional Drilling Bit (HDD) [20].

### **II.5.6. Rig and Rig Equipment:**

Non-conventional horizontal drilling often requires robust drilling rigs capable of handling the extended reach and complex operations. Rig equipment, such as top drives, pipe handling systems, and power swivels, is used to efficiently handle the drill string and enable continuous drilling operations. Rig crews with specialized training and expertise are essential for the safe and effective operation of the drilling equipment.

**CHPATER THREE:**

**STUDY CAS**

III.5.STUDY CASE:

III.5.1.First case OMGZ-801:

III.5.1.1.Position:

The OMGZ-60 horizontal oil production well is located in the Upside Nord section of the Hassi Messaoud field,the well is part of the development of the Hassi Messaoud field through horizontal drilling.

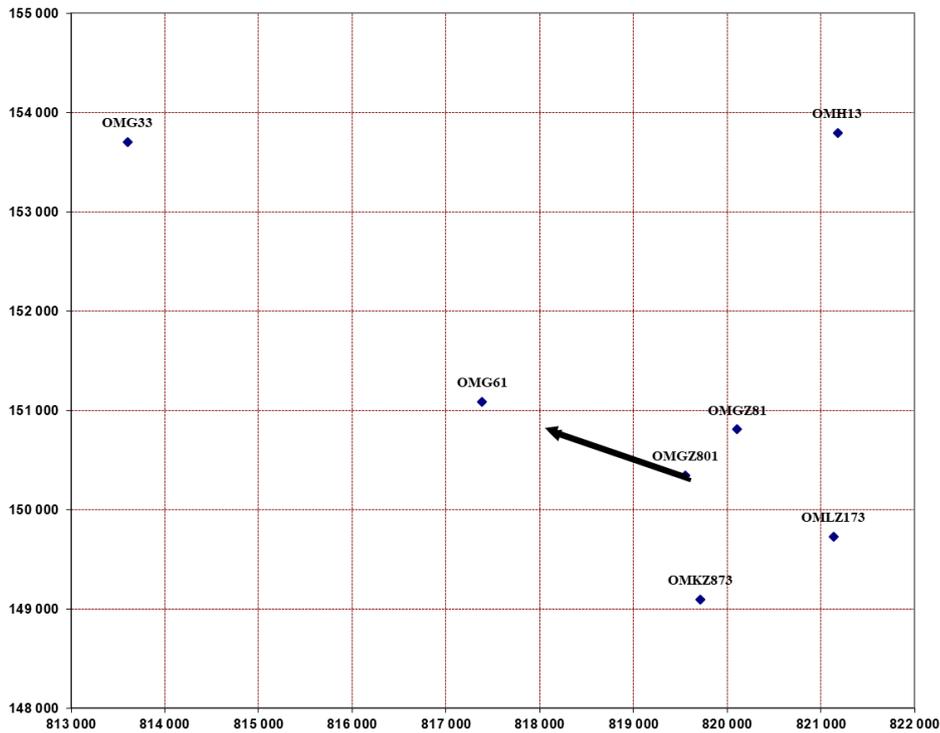


Figure III. 1: OMGZ-801 well position. [22].

Table III. 1: well situation

UTM	LSA	Altitudes
X= 791 069.012m E	X : 819,555.71m	Zsol : 150.06m
Y= 3 533 507.976m N	Y : 150,345.08m	Ztable : 160.00m

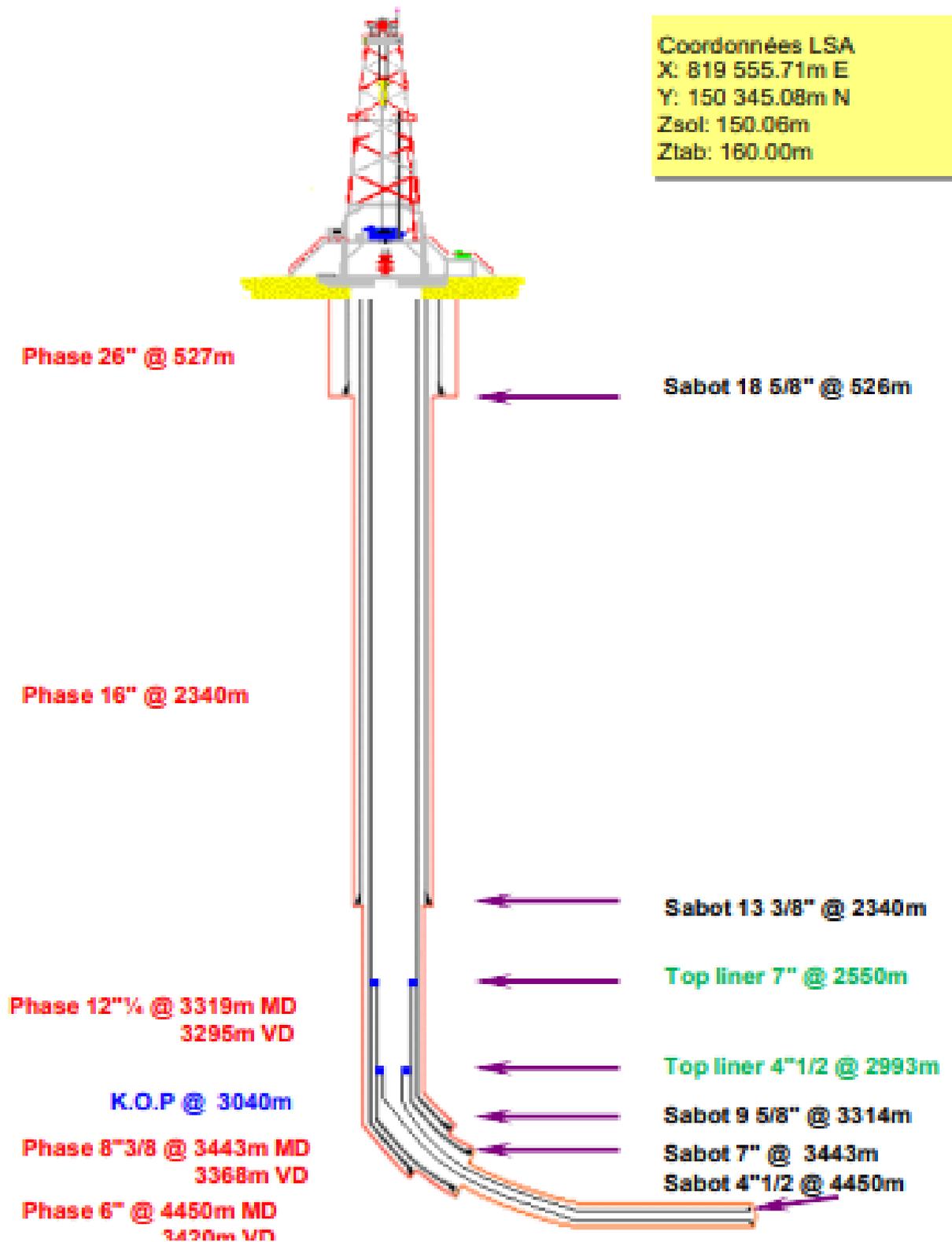


Figure III. 2: well profile [22].

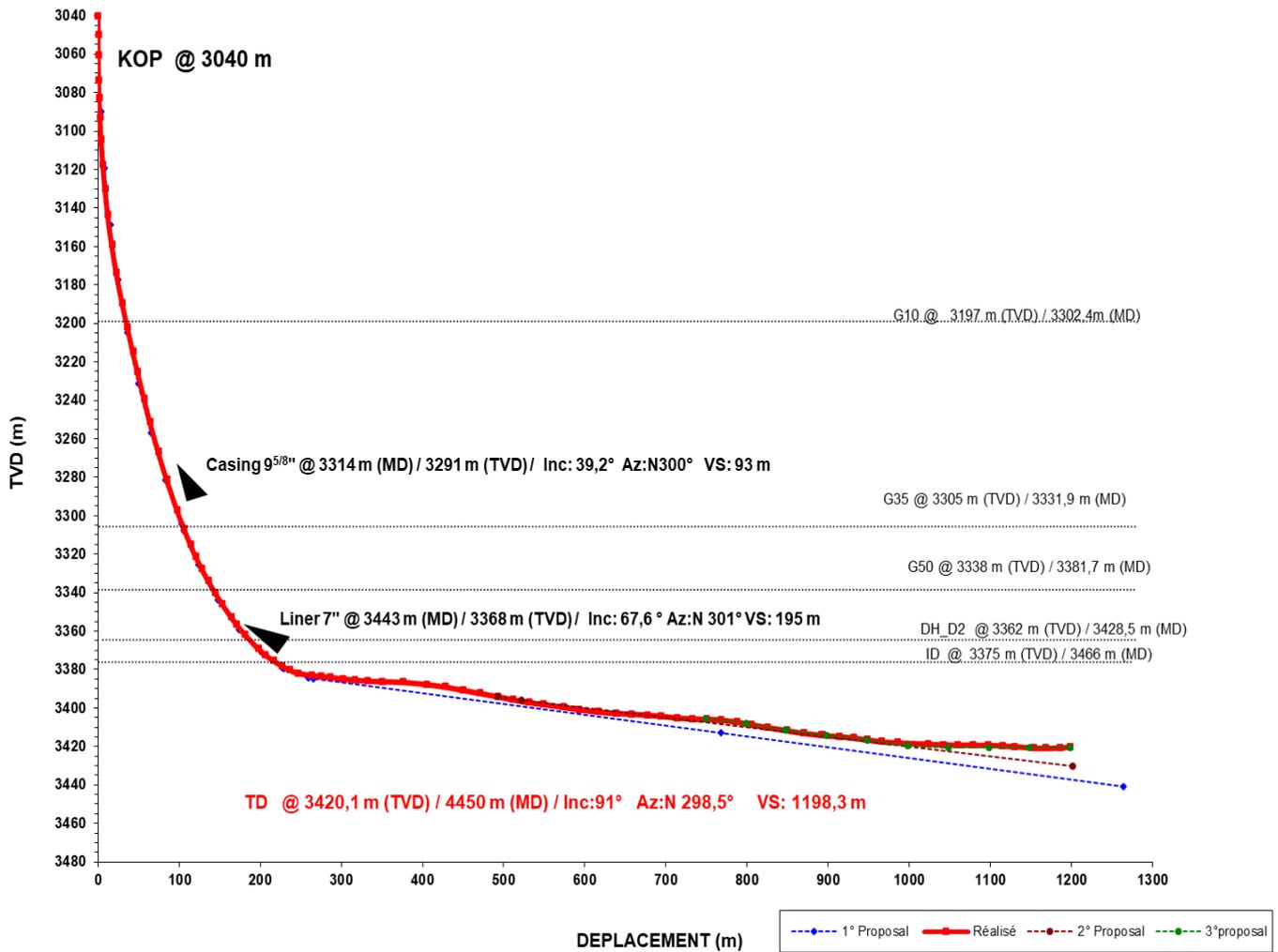


Figure III. 3: real profile [22].

**III.5.1.2.Rig description :**

Nom : WOOL -SLAYER

Type : NATIONAL OIL WELL

Contractor : ENTP 202

- BOP

HYDRILL 13 5/8" : 5000psi.Fabricant : HYDRILL

- Treuil

Fabricant : 13 20 NATIONAL OIL WELLHP diamètre : 30".

Long : 56''. Diamètre Cable : 1 1/2''. WRAPS LINES : 36.

- Moufflage

Nombre de lignes : 12

- Table de rotation

Fabricant : NATIONAL OIL WELL

- Equipements de Surface

Stand pipe : 36.1m (ID=4").HOSE : 22.86m (ID=4").

SWIVEL : 2m (ID=4").CHOKE LINE : 10m (ID=4 1/16').

KILL LINE : 12m (ID=2/16").

- Pompes de Forage

Fabricant : LEW CO HW 16 12Type : TRIPLEX

- Geological monitoring of the well commenced on 03/12/2009 at a depth of 3812m during the drilling of the 6" phase.

### **III.5.1.3.Phase 6"**

Start of Phase: 11/21/2009 at 7:00 PM

End of Phase: 12/27/2009 at 12:00 AM

Interval: 3443m to 4450m

Duration: 36.21 days

During this phase, the drilling went through the Cambrian formations.

The drilling of Phase 6" started with the descent of XR+ tool No. 09, with a size of 3\*26/32", which drilled 1m from 3443m to 3444m, and then it was lifted to the surface.

Bit No. 10, K505BEPX type, with serial number JD0521 and TFA of 1.2 in<sup>2</sup>, continued drilling from 3444m to 3604m in 59.26 hours, with an average progress of 2.70m/h.

The same bit, No. 10RR, K505BEPX type, with serial number JD0521 and TFA of 1.2 in<sup>2</sup>, was lowered with a directional BHA to continue drilling in the reservoir from 3604m to 4100m, covering 496m in 167 hours, with an average progress of 2.97m/h. It was then lifted due to increased pressure. A mud loss of 40m<sup>3</sup> was recorded during the ascent.

Bit No. 11, HHD372G type, with serial number 7125076 and TFA of 0.66 in<sup>2</sup>, was lowered with a directional BHA to continue drilling. During the descent, the bit was positioned at 3560m, and before starting re-drilling, abnormal pressure was detected. Despite several attempts to stabilize, the pressure continued to increase. The bit was lifted to the shoe to attempt circulation, but the same result persisted, leading to the pumping of a plug, and then it was lifted to the surface.

The same bit, No. 11RR, was lowered again with a new directional BHA to continue drilling from 4100m to 4450m (TD), covering 350m in 92.27 hours, with an average progress of 3.79m/h, and then it was lifted to the surface.

A Wiper Trip was performed, bringing up the cuttings by cleaning the HW and the directional BHA.

The following electrical operations were carried out: (UBI-D, GPIT-F, OBMT-F, DSST-B, AIT-C, HNGS-BA, HILTH-FTB, ACTS-B, SAH-F) with the drill pipes up to the 3666m level, where the tools were placed. Logging tools were brought up, and the logging tool was lowered with circulation and rotation freely to the bottom

A second attempt to lower the logging tools was made, but without success, with the tool still positioned at the 3674m level.

A. Bitsettings:

Table III. 2: bit settings

N	Type	NS	Dia m (")	TFA (in2 ) Duse s (/32'' )	Interval (m)	ROP (m/h )	flow rate (l/mn)	RPM (t/mn )	SPP (psi)	WO P (t)
09	XR+	PJ6597		3*26	3443- 3444	-	-	-	-	-
10	K505BEP X	JD052 1		1.20	3444- 3604	2.7	900	34- 40	2900 - 3300	2-8
10R R	K505BEP X	JD052 1	6	1.20	3604- 4100	2.97	870-900	470- 520	2950 - 3180	4-15
11	HHD372 G	712507 6		0.66	Pressio n		proble ms			
11R R	HHD372 G	712507 6		0.66	4100- 4450	3.79	830-860	470- 520	3000 - 3200	4-10

**B.BHA Reports (Phase 6):**

**Table III. 3: BHA No. 01 (Drilling from 3604m to 4100m)**

Description	OD (")	ID (")	Length (m)	Accumulated (m)
Bit6"IMPREG	6		0.30	0.30
4-3/4"SperryDrilllobe2//3	43/4	2.8 2	8.90	9.20
DGWD SlimHole	43/4	2.6 1	10.24	19.44
NonMagPCM	417/2 0	2.8 1	2.18	21.62
Floatsub	43/5	2.2 5	0.79	22.41
PBL	413/2 0	2	2.47	24.88
114x31/2" DP(g)13,30#	413/2 0	2.7 6	1074.27	1099. 15
30x3 1/2"HWDP	31/2	3	278.10	1377. 25
43/4"DrillingJar	43/4	2.2 5	9.08	1386. 33
15x31/2"HWDP	31/2	2.0 63	139.78	1526. 11
63x3 1/2"DP(G) 13.30#	31/2	2.7 6	591.94	2118. 05
CrossOver Sub	43/4	2.2 5	1.16	2119. 21
			<b>Total</b>	<b>2119. 21</b>

Bit No.: 10RR Type: K505BEPX Serial No.: JD0521

Depth in (m): 3604 Depth out (m): 4100 TFA: 1.20 in<sup>2</sup>

**Table III. 4:** BHA No. 02 (Pressure issue).

Description	OD (")	ID (")	Length (m)	Accumulated (m)
Bit6"IMPREG	6		0.28	0.28
4-3/4"SperryDrilllobe2//3	43/4	2.82	8.88	9.16
SlimRLLH1	43/4	2.62	9.48	18.64
HOCSlimTM/HC	43/4	2.62	3.44	22.08
Floatsub	43/5	2.25	0.79	22.87
CirculatingSub	413/2 0	2.00	1.24	24.11
114x31/2" DP(g)13,30#	413/2 0	2.76	1074.27	1098. 38
30x3 1/2"HWDP	31/2	3.00	278.10	1376. 48
43/4"DrillingJar	43/4	2.25	9.08	1385. 56
15x31/2"HWDP	31/2	2.06	139.78	1525. 34
63x3 1/2"DP(G) 13.30#	31/2	2.76	591.94	2117. 28
CrossOver Sub	43/4	2.25	1.16	2118. 44
			<b>Total</b>	<b>2118. 44</b>

Tool No.: 11 Type: HHD372G Serial No.: 7125076

Depth in (m): 4100 Depth out (m): 4100

**Table III. 5:** BHA No. 03 (Drilling from 4100m to 4450m).

Description	OD (")	ID (")	Length (m)	Accumulated (m)
Bit6"IMPREG	6		0.28	0.28
4-3/4"SperryDrilllobe2//3	43/4	2.82	8.89	9.17
SlimRLLH1	43/4	2.62	9.48	18.65
HOCSlimTM/HC	43/4	2.62	3.44	22.09
Floatsub	43/5	2.25	0.79	22.88
CirculatingSub	413/2 0	2.00	1.22	24.10
114x31/2" DP(g)13,30#	413/2 0	2.76	1074.27	1098. 37
30x3 1/2"HWDP	31/2	3.00	278.10	1376. 47

## CHAPTER THREE: STUDY CASE

43/4"DrillingJar	43/4	2.25	9.08	1385.55
15x31/2"HWDP	31/2	2.06	139.78	1525.33
63x3 1/2"DP(G) 13.30#	31/2	2.76	591.94	2117.27
CrossOver Sub	43/4	2.25	1.16	2118.43
<b>Total</b>				<b>2118.43</b>

Bit No.: 11RR Type: HHD372G Serial No.: 7125076

Depth in (m): 4100 Depth out (m): 4450 TFA: 0.66 in<sup>2</sup>

**Table III. 6: BHA n° 04 (Scraper).**

Description	OD (")	ID (")	Length (m)	Accumulated (m)
BIT	6		0.28	0.28
SCRAPER		2.82	1.20	1.48
BITSUB	43/4	2.81	1.20	2.68
9x43/4"DC	43/4	2.25	83.10	85.78
JARS	43/4	2.25	9.08	94.86
3x43/4"DC	43/4	2.25	28.36	123.22
67STDS31/2"DP	31/2	2.76	1892.13	2015.35
XO	43/4	2.25	1.16	2016.51
<b>Total</b>				<b>2016.51</b>

### C. Mud Parameters:

Type: OBM Invermul

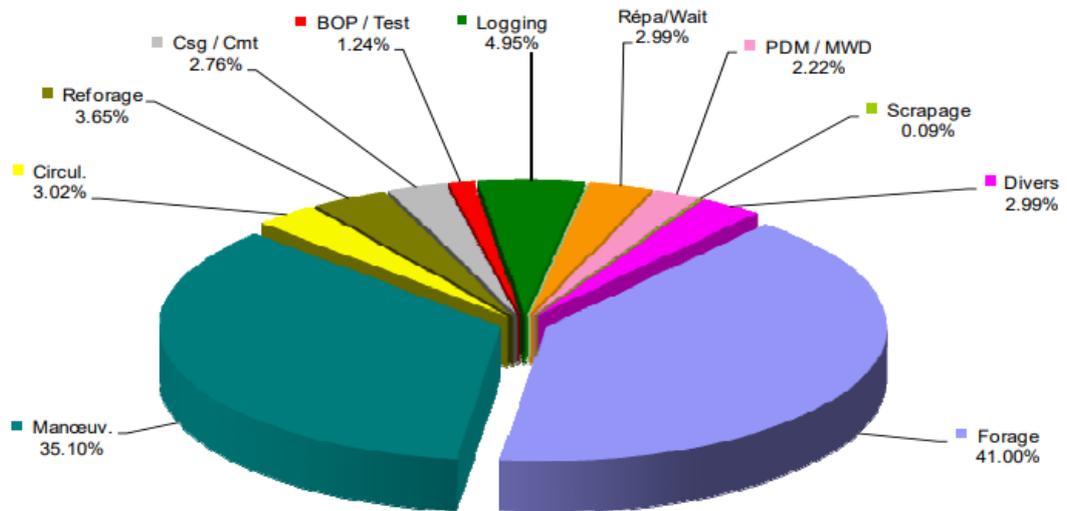
**Table III. 7: mud parameters.**

MW(SG)	PV (cp)	YP	FV (Sec)	Filtrate	H/E
1.42– 1.45	18-23	10-13	45-48	4.8	90/10– 95/5

Before running the 4 1/2" liner, scraping of the 7" liner was performed.

At the end of this phase, a 4 1/2" liner was run at a depth of 4450m and anchored at 2993m.

**D. Time Analysis**



**Figure III. 4:** Time Analysis. [22].

**III.5.2. Second case OMGZ-60:**

**III.5.2.1. Purpose of the drilling:**

The OMGZ-60 oil-producing horizontal well is located in the northern Upside part of the Hassi Messaoud field. It is the first pilot well to be drilled as part of the "Development of Low Petrophysical Characteristic Zones in Hassi Messaoud" project. The objective of this project is to exploit the compact zones through the use of unconventional technology, which involves drilling horizontal drains parallel to the direction of the minimum stress (Shmin), followed by hydraulic fracturing. The interpretation of the 3D seismic data has shown that at the R2ab drain level, this well is located in a high structural area, bordered by NE-SW fault networks. The effect of Hercynian erosion in the sector is significant, particularly at the D2 drain with a thickness of 22m. The OMGZ-60 well is situated in an area with a moderate well density, allowing for four control points.

**III.5.2.2. Well status:**

**Table III. 8:** The coordinates of the OMGZ-60 well platform.

UTM	Géographiques	Altitudes
X= 788 768,991m	Long.= 6° 03' 11.48197" E	Zsol : 169.929m
Y= 3 533 288,962m	Lat. = 31° 54' 04.50226" N	Ztab : 179.069m

**III.5.2.3.Description of the drilling rig:**

Item	Description
<b>Mast</b>	WOOL SLAYER
Type	Cantilver
Racking Capacity	240 std of 5"DP +06 std of 8"DC+06 std of 9 ½ DC

<b>Substructure</b>	WOOL SLAYER
Type	Cantilver
Clear Height	30 ft
Rated Setback Load Capacity	600.000 lb
Rated Rotary Load Capacity	1000.000 lb

<b>Drawworks</b>	OIL WELL
Model	OIL WELL E2000
Rating Horse power	2000 HP
Drilling Line Size	1"3/8
Motor	GE-752

<b>Generator</b>	Caterpillar 3512
Power	KVA: 1500 ;KW: 1050;VOLT: 347/600;AMP: 1443; RPM: 1200 t/m ; HZ: 60
<b>Backup generator</b>	Caterpillar 3406
Power	KVA: 320 - KW: 1050- VOLT: 460-AMP: 462- RPM: 1800 t/m -HZ: 60

<b>SCR</b>	IER
Type	1400 PLC

<b>Top Drive (w/soft torque)</b>	-
Capacity	500T
Type	8050 AC

## CHAPTER THREE: STUDY CASE

<b>Rotary Table</b>	National oil well
Rated Capacity	500 Tons
Type	C375
Opening	37 ½"

<b>Crown Block</b>	WOOLSLAYER
Type	/
Rated Capacity	583 Tons

Item	Description
<b>Travelling Block</b>	G-DENVER
Type	GD550
Capacity	500Tons

<b>Hook</b>	Bayron Jackson
Type	5500
Capacity	500Tons

<b>Swivel</b>	National
Type	P-500
Capacity	500Tons

<b>BOP Equipment</b>	ABB
Annular BOP	Cameron GK
Size / Rating	13 5/8"*10M
Double Ram BOP	Cameron U 13 5/8"*10M
Choke Manifold	Stew Steven D 4 1/16" 10M

<b>Mud Pumps</b>	National oil well
Rated Horse Power	1600 HP
Type	12 P160

<b>Mud Conditioning Equipment</b>	
Shakers	Derrick FLC 514 *3
Desilter / Mud Cleaner	Derrick FLC 514

<b>Fluid Storage</b>	
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## CHPATER THREE: STUDY CASE

Aspiration Tank	429.2 bbls
Decantatin Tank	424.1bbls
Reserve Tank	472.8 bbls*5
Trip Tank	46.6 bbls

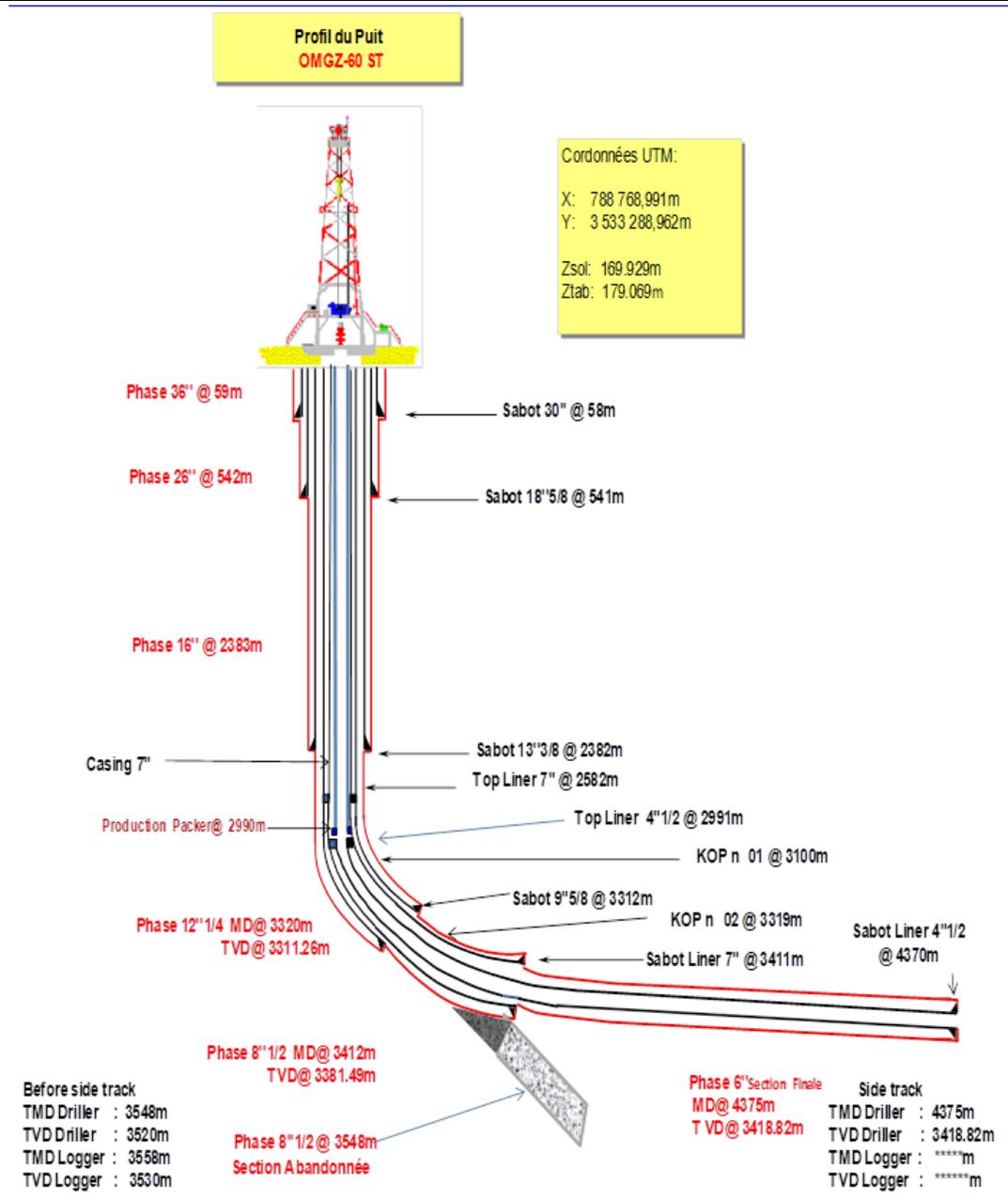


Figure III. 5: well profil [23].

### III.5.2.4.Phase Report:

#### A. Phase 8 1/2":

Phase Start: 06/12/2022 at 06:00 AM

Phase End: 10/01/2023 at 03:45 PM

Interval: 3320m to 3548m

Duration: 35.41 days

Liner 7": Shoe @ 3411m - TOL @ 2582m

This phase began with the deployment of a PDC bit, GT74DHE type, SN: 1338253, sized 6\*13/32 with a slick BHA. It reached the cement at 3288m after reaming the accessories of the 9 5/8" casing, namely the float collar and cement, from the depth of 3288m to 3309m (3 meters before the shoe). Subsequently, a bottom cleaning circulation was performed, and then the tool was freely lifted to the surface.

Bit No. 06, FTK83 type, SN: A287459, sized 8\*12/32, was run with a directional BHA from Schlumberger equipped with a Type: A675M4570XP (BH1.15) motor, 8-3/8" Sleeve, and SN: 2204 k=0.13 rev/liter. The mud displacement was performed from OBM with a density of 2.10sg to OBM with a density of 1.40sg. The cement reaming and guide from the depth of 3309m to 3312.5m were conducted, followed by reaming of the formation from 3312.5m to 3320m. The pilot hole drilling continued from 3320m to 3419m MD (3386.03m TVD), with an average rate of penetration of 3.00m/h. After a circulation and bottom cleaning of 1.5 hours, the bit was freely lifted to the surface.

The wear pattern was: 2 - 2 - CT - A - X - I - WT - PR.

The same directional BHA from Schlumberger, equipped with 02 Stabilizers and Bit No. 07 of type K503BPX, SN: JN8692, TFA=1.5, was run to continue drilling the pilot hole with a Type: A675M4570XP (BH0.0) motor, 8-3/8" Sleeve, and SN: 1118359 k=0.13 from 3419m to 3548m. The average rate of penetration was 1.61m/h. After a circulation and bottom cleaning of 2.25 hours, a short lifting operation was performed between the bottom and the 9 5/8" shoe, followed by a bottom's up circulation. The tool was then freely lifted to the surface

The wear pattern was: 1 - 2 - WT - A - X - I - NO - TD.

Subsequently, a hole check was performed using the same directional BHA from Schlumberger equipped with 02 Stabilizers and bit No. 07rr of type K503BPX, SN: JN8692, TFA=1.5. The washing down was conducted to the bottom at the depth of 3548m, followed by a circulation of 1.5 hours. The bit was then freely lifted to the surface.

➤ A BOP test was conducted as follows:

Annular 300/2500 psi.

Variable pipe rams Kill & Choke lines, Check v/v & 3 Master v/v 300/5000psi.

Blind rams operating.

Next, a second A hole check was performed using the same directional BHA from Schlumberger equipped with 02 Stabilizers and bit No. 07rr of type K503BPX, SN: JN8692, TFA=1.5. The washing down was conducted to the bottom at the depth of 3548m, followed by a circulation of 1.5 hours. The bit was then freely lifted to the surface.

An extension of bare rods was run down to the depth of 3547m to pump the first plug of the pilot hole.

A slick BHA was deployed with the 8 ½" GT74DHE tool, SN: 1338253, sized 6\*13/32, which reached the cement at 3276m. The cement reaming started from the depth of 3276m (ROP: 100m/hr) until the depth of 3295m. Due to the excessive hardness of the cement indicating rapid advancement in this interval, it was necessary to wait until the cement set, which occurred on 21/12/2022, requiring an additional 2 hours. After reattempting, the cement was reamed from the depth of 3295m to 3305m at a rate of 50m/hr, and from 3305m to 3400m at a rate of 30m/hr.

An extension of bare rods consisting of a 3 1/2" and 5 1/2" DP packer was run down to the depth of 3399m to pump the second plug of the pilot hole.

After the placement of the second cement plug within the interval (3057m-3400m) using a packer composed of bare rods (Refer to cementing report), the 8 ½" GT74DHE tool, SN: 1338253, sized 6\*13/32, was at the depth of 3000m to allow for cement setting. The cement was encountered at the depth of 3130m (expected at 3157m), and then the cement was reamed up to the depth of 3230m at an average rate of 50m/hr (see Daily Report). Cement setting time was allowed for several days until a hard cement was obtained after a total of 19.5 hours at the depth of 3314.5m. A cement hardness test was conducted by applying a load of 12T without circulation for 10 minutes, and then the tool was freely lifted to the surface.

Bit No. 08, a GX-MS18 tool, SN: 5307363, sized 8\*12/32, was run with a directional BHA from Schlumberger equipped with a Type A675M4570XP (BH2.12) Sleeve 8-3/8 motor under Serial No. 6412, with a K-factor of 0.13 rev/liter, to begin the deviation according to the new well plan. However, a loss of MWD signal was recorded at the depth of 3315m, leading to the decision to retrieve the tool for replacement.

The same bit, No. 08rr, a GX-MS18 tool, SN: 5307363, sized 8\*12/32, was then run with a directional BHA from Schlumberger, equipped with the same Type A675M4570XP (BH2.12) Sleeve 8-3/8 motor under Serial No. 6412 with a K-factor of 0.13 rev/liter. This was done to commence the deviation according to the new well plan from 3315m to 3319m. Cement-formation samples were collected to ensure the percentage of the formation (Clay - Shale "G30"). The drilling continued from the depth of 3319m to 3322m at an average rate of 0.20m/hr. The bit was then freely lifted for a BHA (tool + motor) change after reaching the objective and waiting for the formation to continue in the new plan.

The wear on the bit was: 1 - 1 - WT - A - E - I - NO - BHA.

Bit No. 09, a DSF811M tool, SN: A250370, sized 8\*12/32, was run with a directional BHA from Schlumberger, equipped with the same Type A675M4570XP Sleeve 8-3/8 motor, but with a change in BH 1.83° and a K-factor of 0.13 rev/liter. This was done to continue drilling the formation from 3322m to 3412m MD, equivalent to 3382m TVD, at an average rate of 1.24m/hr. After a circulation of 0.75 hours and bottom cleaning, a short upward movement between the bottom and the 9 5/8" shoe was followed by another circulation. The bit was then freely lifted to the surface after achieving its objective and completing the phase.

The wear on the bit was: 2 - 1 - WT - A - X - I - NO - TD.

➤ **Bit settings :**

**Table III. 9:** bit settings

N°	Type	N°S	Diam (")	Duses (/32")	Intervalle (m)	ROP (m/h)	Débit (l/mn)	RPM (t/mn)	SPP (psi)	WOB (t)
06	FTK83	A287459	8.5	8*12	3320-3419	3.00	1800-3430	240-320	2145-2830	3-8
07	K503BPX	JN8692		1.5	3419-3548	1.61	1730-2730	300-350	2730-3100	3-8
<b>SIDE TRACK @ 3319m</b>										
08	GX-MS18	5307363	8.5	8*12	3319-3322	0.20	1700	222	2500	0-2
09	DSF811M	A250370		8*12	3322-3412	1.24	1680-2000	218-289	2370-3050	2-10

➤ **BHA Reports**

ON°:06      Type: FTK83   SN°: A287459

In: 3320m      Out: 3419m      Duse :8\*12/32"

**Table III. 10:** BHA n° 08 (Cement reaming from 3309m to 3320m & Directional drilling from 3320m to 3419m)

Description	OD (")	ID (")	Length (m)	Cumulated (m)
PDC	8"1/2		0.25	0.25
A675M4570XP(BH1.15) Sleeve 8-3/8	6 3/4	5 1/2	8.65	8.90
8 1/4" Stabilizer	6 3/4	2 1/4	1.43	10.33
6 1/2"Non-Mag Pony	6 1/2	2 4/5	2.29	12.62
SlimPulse675-Bat.On top	6 3/4	3 7/8	10.45	23.07
Circulating,sub	6 4/9	2 4/5	1.23	24.30
27 HWDP 5"	5	3	249.08	273.38
D/JAR	6 1/2	2 3/4	8.78	282.16
8 HWDP 5"	5	3	74.62	356.78
Crossover	8	3	1.11	357.89
			<b>Total</b>	<b>357.89</b>

ON°:07      Type: K503BPX      SN°: JN8692

In: 3419m      Out: 3548m      TFA :1.50

**Table III. 11:** BHA n° 09 (Directional drilling from 3419m to 3548m).

Description	OD (")	ID (")	Length (m)	Cumulated (m)
PDC	8"1/2		0.31	0.31
A675M4570XP(BH1.15) Sleeve 8-3/8	6 3/4	5 1/2	8.65	8.96
8 1/4" Stabilizer	6 3/4	2 1/4	1.43	10.39
6 1/2"Non-Mag Pony	6 1/2	2 4/5	2.29	12.68
SlimPulse675-Bat.On top	6 3/4	3 7/8	10.45	23.13
8 1/4" Stabilizer	6 3/4	2 1/4	1.72	24.85
Circulating,sub	6 4/9	2 4/5	1.23	24.36
27 HWDP 5"	5	3	249.08	273.44
D/JAR	6 1/2	2 3/4	8.78	282.22
8 HWDP 5"	5	3	74.62	356.84
Crossover	8	3	1.11	357.95
			<b>Total</b>	<b>359.67</b>

## CHPATER THREE: STUDY CASE

ON°:08RR    Type: GX-MS18    SN°: 5307363  
 In: 3319m    Out: 3322m    Duse :3\*20/32"

**Table III. 12:** BHA n° 10 (Directional drilling from 3319m to 3322m).

Description	OD (")	ID (")	Length (m)	Cumulated (m)
PDC	8"1/2		0.26	0.26
A675M4570XP(BH2.12) Sleeve 8-3/8	6 3/4	5 1/2	7.68	7.94
SlimPulse675-Bat.On top	6 3/4	3 7/8	9.45	17.39
6 1/2"Non-Mag Pony	6 1/2	2 4/5	9.12	26.51
Circulating,sub	6 4/9	2 4/5	0.74	18.13
27 HWDP 5"	5	3	249.08	267.21
D/JAR	6 1/2	2 3/4	9.19	276.40
8 HWDP 5"	5	3	74.62	351.02
Crossover	8	3	1.11	352.13
			<b>Total</b>	<b>361.25</b>

ON°:09    Type: DSF811M    SN°: A250370  
 In: 3322m    Out: 3412m    Duse :8\*12/32"

**Table III. 13:** BHA n° 11 (Directional drilling from 3322m to 3412m).

Description	OD (")	ID (")	Length (m)	Cumulated (m)
PDC	8"1/2		0.31	0.31
A675M4570XP(BH1.82) Sleeve 8-3/8	6 3/4	5 1/2	8.63	8.94
6 1/2"Non-Mag Pony	6 4/7	3 7/8	3.03	11.97
SlimPulse675-Bat.On top	6 3/4	3 7/8	10.53	22.50
6 1/2"Non-Mag Pony	6 1/2	2 4/5	9.12	31.62
Circulating,sub	6 4/9	2 4/5	1.14	32.76
27 HWDP 5"	5	3	249.08	281.84
D/JAR	6 1/2	2 3/4	9.19	291.03
8 HWDP 5"	5	3	74.62	365.65
Crossover	8	3	1.11	366.76
			<b>Total</b>	<b>366.76</b>

### ➤ Mud Parameters:

Type: OBM

**Table III. 14:** mud parameters

MW (Sg)	FV (Sec)	PV (Cp)	YP	Filtrat	H/E
1.40	48-59	18-22	9-13	4-7.60	90/10-91/09
<b>SIDE TRACK @ 3319m</b>					
1.45	62-74	23-29	11-16	4-6.4	90/10-92/08

At the end of this phase, a 7" 32# P110 N.VAM BTC liner, consisting of 70 joints, was run down to the depth of 3411m and anchored at 2582m. It was then cemented without any issues (refer to Casing and Cementing report).

In preparation for the 6" phase of BOP tests, the following steps were carried out:

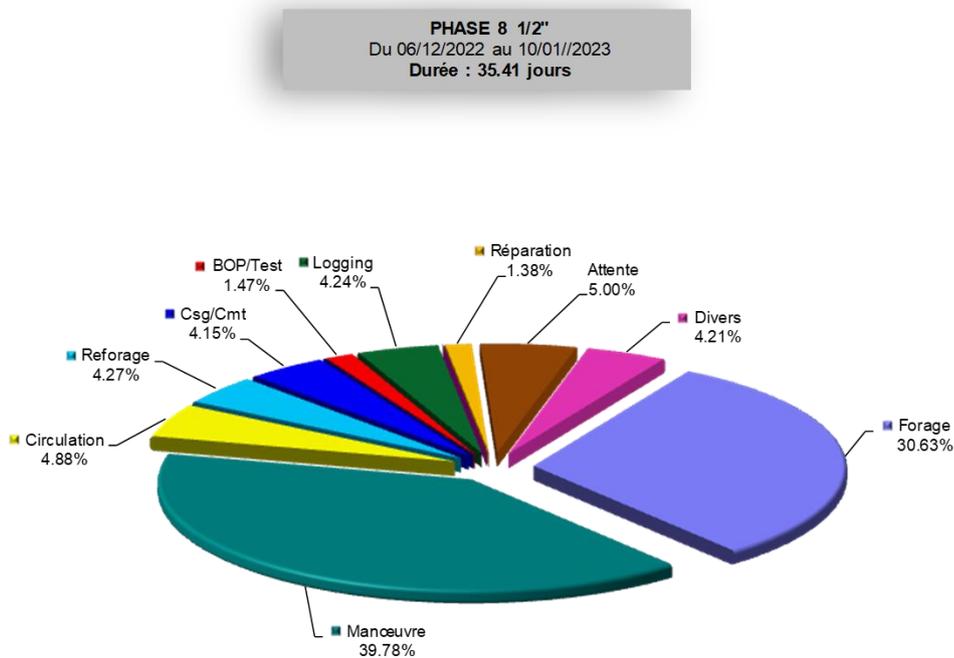
Annular test at 300/2500 psi.

Variable pipe rams, Kill & Choke lines, Check valve & 3 Master valves at 300/5000 psi.

Blind rams operating.

Afterward, stacking of 3.5" DP and HW was performed.

➤ **Time analysis :**



**Figure III. 6:** Time analysis [23].

### **B. Phase 6":**

Start of Phase: 10/01/2023 at 15:45

End of Phase: 23/04/2023 at 12:00

Interval: 3412m to 4375m

Duration: 102.84 days

Liner 4.5": Shoe @ 3470m - TOL (Total Depth of Liner) @ 2992m

CSG (Casing) 7" Supplementary Tie Back @ 2582m.

The phase began with the descent of the PDC tool, MM94 type, SN: 12947169, sized 332/32+312/32. It was lowered and used to drill the accessories of the 7" casing (landing collar + float collar) and perform cementing operations from 3374m to 3409m. After a 2-hour circulation for bottom cleaning, the bit was raised to the surface to carry out electrical operations (GR - CBL - VDL - CCL) on the 7" liner by Schlumberger company (refer to electrical operations report).

Next, the bit No. 10 IMP, type K505BPX with a TFA of 0.5 and serial number JV9850, along with an SLB A475M4560XP motor, was lowered to the depth of 3409m. Mud displacement from OBM with a density of 1.45sg to 1.34sg was carried out before resuming the cementing and shoe drilling of the 7" liner up to the depth of 3412m. Following that, the drilling of the 6" horizontal section was performed from 3412m to 3530m, taking 159.92 hours, with an average advancement of 0.74 m/h. After a 2.5-hour circulation, a short upward movement between the bottom and the 7" shoe, and a 1.5-hour circulation, the bit was freely raised to the surface for a motor change that reached its objective (refer to Deviation Report).

The wear pattern observed was: 3 - 3 - BT - A - X - I - WT - BHA.

A BOP (Blowout Preventer) test was conducted as follows:

Annular @ 300/2500psi - okay

Variable Rams + kill line & Choke line + 03 master valves + check valve 300/5000 psi - okay

Operating Blind rams - okay

The bit No. 11 IMP, type K505 BPX, SN: JV9830, TFA=0.5, was then lowered with a new DRU1-120RF motor. With a BH of 1.02deg under the serial number 6767, with a k value of 0.59 rev/liter, drilling of the horizontal section continued from 3530m to 3621m, with an

average advancement of 1.13 m/h. After a 2-hour circulation and bottom cleaning, the tool was freely raised to the surface for a motor change. The decision to pull out was made due to a pressure loss (No advancement &  $\Delta Pr$ : 0 psi).

The wear pattern observed was: 2 - 2 - WT - A - X - I - BT - DFM.

The bit No. 12, type K505 BPX, SN: JV8938, TFA=0.5, was lowered with a new DRU1-120RF motor. With a BH of 1.02deg under the serial number 7035 and a k value of 0.59 rev/liter, drilling of the horizontal section continued from 3621m to 3765m, with an average advancement of 1.12m/h. After a 2-hour circulation and bottom cleaning, the tool was freely raised to the surface. The decision to pull out was made due to a pressure loss (No advancement &  $\Delta Pr$ : 0 psi).

The wear pattern observed was: 2 - 1 - WT - A - X - I - NO - DFM.

A positive BOP test was conducted as follows:

- Recovery of 11" JMP wear bushing;
- Installation of 11" JMP tester plug;
- Annular test at 300/2500 psi;
- Variable pipe rams, Kill & Choke lines, Check valve & (03) Master valves test at 300/5000 psi;
- Operating Blind rams;
- Installation of 11" JMP wear bushing.

The bit No. 13, type K505 BPX, SN: JV9120, TFA=0.5, was then lowered with a new DRU1-120RF motor. With a BH of 1.02deg under the serial number 6764 and a k value of 0.59 rev/liter, drilling of the horizontal section continued from 3765m to 3950m, with an average advancement of 1.03m/h. After a 2.75-hour circulation and bottom cleaning, the bit was freely raised to the surface, as the circulation hours were completed (224.58 hrs).

The wear pattern observed was: 3 - 2 - WT - A - X - I - NO - BHA.

The bit No. 14, type K505BPX, SN: JV9856, TFA=0.5, was lowered with a DRU1-120RF motor. With a BH of 1.02deg under the serial number 6808 and a k value of 0.59 rev/liter, drilling of the horizontal section continued from 3950m to 4201m, with an average

advancement of 1.36 m/h. After a 3-hour circulation and bottom cleaning, the bit was freely raised to the surface, as the circulation hours were completed (237.57 hrs).

The wear pattern observed was: 2 - 2 - CT - A - X - I - NO - BHA.

The bit No. 15, type K505BPX, SN: JV9872, TFA=0.5, was lowered with a DRU1-120RF motor. With a BH of 1.02deg under the serial number 7035 and a k value of 0.59 rev/liter, drilling of the horizontal section continued from 4201m to 4375m (TD), with an average advancement of 1.40 m/h. After a 2.5-hour circulation and bottom cleaning, the bit was raised with circulation to the 7" liner shoe at 3411m for a short upward movement between the bottom and the 7" shoe, followed by a bottom's up circulation. The bit was then freely raised to the surface.

The wear pattern observed was: 2 - 2 - CT - A - X - I - NO - TD.

Note: During this phase, partial losses were recorded as indicated below (annex).

The bit No. 16, type K505BPX, SN: JV9847, TFA=0.5, was lowered with a DRU1-120RF motor. With a BH of 1.15deg, under the serial number A475M4560XP and a k value of 0.27 rev/liter, it was equipped with a BHA containing logging equipment (GR + Resistivity) to perform electrical operations by the company SPES (See Logging Report).

A positive BOP test was conducted as follows:

Recovery of 11" JMP wear bushing.

- Set 11" JMP tester plug;
- Annular 300/2500 psi;
- Variable pipe rams, Kill & Choke lines, Check valve & (03) Master valves 300/5000 psi;
- Operating Blind rams;
- Install 11" JMP wear bushing.

The bit No. 16rr, type K505BPX, SN: JV9847, TFA=0.5, was re-lowered with the same DRU1-120RF motor. With a BH of 1.15deg, under serial number A475M4560XP and a k value of 0.27 rev/liter, it was equipped with a BHA containing logging equipment (GR + Sonic) to perform electrical operations by the company SPES).

A BHA of logging equipment (GR - Caliper - Imagery) was lowered on TLC with drill pipes to the depth of 4158m. After filling the inner pipe, the bit got stuck -11T both upwards and downwards. Multiple attempts were made to free the tool using circulation (Q=950lpm; P=2300psi), pulling +70T, and pushing -25T, but without success.

The bit remained under tension with a pull force between 2-7T, but a pressure drop from 1880psi to 1110psi was observed. After this incident, the SLB logging team managed to recover 860m of cable (the distance between the surface and the side entry sub-part of the cable in the annular space).

It was decided to perform an electrical back-off, and after retrieving the tool, 80 lengths of 5.5" DP (Length=2298.54m) + XO=0.18m + Side Entry Sub (0.6m) + XO=0.38m + 16 joints of 3.5" DP (152.55m) + x-over=1.04m) were recovered, leaving 1684.02m of 3.5" DP + 25.47m of logging tools + the logging cable in the well. The top of the fish was at approximately +/- 2453m.

The retrieval operations were carried out in the following order:

### **1st operation:**

A retrieval BHA with a wireline cable containing a special tool -ROPE SPEAR- was lowered to the top of the wireline cable at the depth of 1625m, confirmed with a pull force of 4T. The retrieval operation was successful, confirmed with a pull force between +8T and +15T during the ascent, recovering the entire wireline cable (3275m) + latching bar.

### **2nd operation:**

First, a BOP test was conducted as follows:

Annular @ 300/5000 psi.

Variable pipe rams, Kill & Choke lines, Check valve & 3 Master valves @ 300/5000 psi.

Operational blind rams.

A screwing BHA was lowered to the top of the fish at 2454m, and successful attempts were made to screw the 3.5" DP with the fish. Circulation was restored with a 100% return.

After 1.5 hours, attempts were made to work the tool to release it downwards with a drag force of -20T and upwards with a pull force of +65T, but without success.

Subsequently, attempts were made to hammer the tool downwards and upwards, also without success.

A displacement from mud with a density of 1.34sg to mud with a density of 1.00sg was performed in an attempt to release the tool by utilizing the pressure differential. Hammering the tool downwards and upwards was attempted again to regain rotation but without success.

Returning to the initial mud by displacing mud with a density of 1.34sg with mud of 1.00sg and hammering downwards and upwards to regain rotation, but without success. Working the tool to release it with a maximum overpull of 65T and drag force of -20T was also unsuccessful.

\* Q=800 lpm; SPP=1550 psi.

### **3rd operation:**

A displacement from mud with a density of 1.34sg to mud with a density of 0.90sg was performed in an attempt to release the tool using the pressure differential and hammering downwards and upwards to regain rotation, but without success. It was decided to pump a 9m<sup>3</sup> acid plug and circulate it at a low rate to allow the acid to remove the cake around the tool joints of the drill pipe. After working the tool with an overpull of 60T and drag force of -7T multiple times, rotation was regained, and the tool was successfully released.

Next, the fish was pulled out of the well with circulation until reaching the 7" liner shoe at 3411m to return to the initial mud by displacing mud with a density of 0.9sg with mud of 1.34sg.

The retrieval BHA was pulled out, successfully recovering the entire fish (1684m of 3.5" DP + 25.47m of logging tools).

A positive BOP test was performed as follows:

Recovery of 11" JMP wear bushing.

- \* Set 11" JMP tester plug.
- \* Annular 300/2500 psi.
- \* Variable pipe rams, Kill & Choke lines, Check valve & (03) Master valves 300/5000 psi.
- \* Operating Blind rams.
- \* Install 11" JMP wear bushing.

A directional BHA equipped with bit No. 16RR2, type K505BPX, SN: JV9847, TFA=0.5, was lowered with the same DRU1-120RF motor. With a BH of 1.15deg, under serial number A475M4560XP and k value of 0.27 rev/liter, it was used for a hole check, descending without drag from the 7" liner shoe at 3411m to 4120m. The descent continued with circulation and rotation to the bottom at 4375m, where circulation was performed until the mud was homogenized (din=dout=1.34sg). Then, the directional BHA was freely pulled back to the surface.

A slick BHA was assembled with the previous 6" tool and a bit-sub to perform a motorless well check to the bottom. Circulation was performed until the mud was homogenized, and then the BHA was freely pulled back to the surface.

➤ **Bit settings:**

**Table III. 15:** tool settings.

N°	Type	N°S	D (")	TFA	Intervalle (m)	ROP (m/h)	Débit (l/mn)	RPM (t/mn)	SPP (psi)	WOB (t)
10	K505BPX	JV9850	6	0.5	3412-3530	0.74	691-922	201-273	1867-2843	2-7
11		JV9830			3530-3621	1.13	777-908	485-566	2277-2758	2-8
12		JV9838			3621-3765	1.12	790-855	485-535	2385-2655	1-11
13		JV9120			3765-3950	1.03	800-850	480-530	2460-2650	1-12
14		JV9856			3950-4201	1.36	770-850	455-536	2596-3330	1-14
15		JV9872			4201-4375	1.4	745-851	447-536	2643-3351	1-16

➤ **Mud Parameters:**

Type: OBM

**Table III. 16:** mud parameters.

MW (Sg)	FV (Sec)	PV (Cp)	YP	Filtrat	H/E
1.34	65-76	18-29	11-21	4.7-6	92/08-96/04

At the end of this phase, a 4-1/2" P110 15.1# Vam-TOP Tubing Liner, consisting of 136 joints, was run in the hole using 3-1/2" and 5-1/2" tongs until reaching a depth of 4370m. It was anchored at 2992m and cemented without any issues (see Casing and Cementing report), followed by retrieving the running tool to the surface.

A 6" bit of type MM94, SN: 12947169, open, was used to confirm the top of the 4-1/2" Top Liner at a depth of 2991m. It was followed by a 2-hour circulation and freely pulling it to the surface. A string consisting of 24 joints of 2-7/8" tubing (230m) and 153 joints of 3-1/2" DP, complemented with 5-1/2" tongs, was run to a depth of 2990m to set an isolating cement plug (see Casing and Cementing report).

The same 6" bit of type MM94, SN: 12947169, open, was used to confirm the hardness of the isolating plug, which was topped at 2711m. It was then reamed to a depth of 2800m, followed by a 6-hour circulation and freely pulling it to the surface.

A BHA consisting of a 7" Polish Mill with SN: 80270700001 was used to dress the top of the 7" liner at a depth of 2582m. It was followed by a 2-hour circulation (trace of metal debris at the surface) and then pulled back to the surface.

An additional 7" TIE BACK (ANTON) Tubing with 1 joint and ANTON Float Collar, and 1 joint of 7" liner 32# P110 (220 joints), was run and cemented without any issues (see Casing and Cementing report).

A BOP test was performed as follows:

\* Annular 300/2500 psi.

\* Variable pipe rams, Kill & Choke lines, Check valve & 3 Master valves 300/5000 psi.

\* Operating Blind rams.

The same 6" bit of type MM94, SN: 12947169, open, was used to ream the accessory of the 7" tubing. It was topped at the landing collar at 2577m and reamed to a depth of 2600m. It was followed by a 1-hour circulation and a 15-minute Tie Back test with 2500 psi (successful). The reaming of cement continued to a depth of 2860m, followed by a washdown to the top of the 4-1/2" Top Liner at a depth of 2991m. A 2-hour circulation was performed, and it was freely pulled back to the surface with the cleaning of the 5-1/2" tongs.

### **F/ Completion**

Start of Phase: 23/04/2023 at 12:00 PM

End of Phase: 13/05/2023 at 12:00 AM

Duration: 20.50 days

This phase began with the descent of a 3-7/16" Junk Mill, N/S GEA0399, with a 2-3/8" DP (165 joints) for confirmation of the landing collar depth at 4338m. This was followed by a 4.5-hour circulation before pulling it to the surface.

The same 3-7/16" Junk Mill, N/S GEA0399, was then used with a 4-1/2" scrapper, SN: A01207, for two passes of scraping in the interval from 3000m to 4335m. This was followed by a 5.25-hour circulation before pulling it to the surface.

Next, the same 3-7/16" Junk Mill, N/S GEA0399, was used with 2-3/8" DP (165 joints) and 3-1/2" tongs for a displacement operation to displace the mud (density: 1.34 sg) with water (density: 1.00 sg) as per the Logging operator's request. It was then pulled to the surface.

As part of the CBL-VDL Logging, Schlumberger proposed a technique to incorporate the cable and logging tools below the coiled tubing to reach the 6" drain where the well is tubed and cemented.

A 4-1/2" polish mill, SN: ASSY 11723691 (667837), was descended with 3.5" rods to dress the top of the liner at 2992m to 2994m. This was followed by a 1.5-hour circulation before pulling it to the surface (excess 3.5" rods were washed out).

A drill pipe string equipped with a 7" scraper was descended to clean the interval from 2890m to 2990m. After a 1.25-hour circulation and cleaning, the scraper was pulled to the surface (excess 3.5" rods were washed out).

A drill collar of 4-3/4" and drill pipes of 3-1/2", equipped with a 7" RBP, were descended to install the 7" RBP in the 7" casing at the depth of 500m. The setting tool was then pulled to the surface.

Work on the BOP was initiated, including cutting and straightening the 7" casing to install the 4-1/2" tubing head (THS 11"5K x 7"1/16 5K x ADP TO 13"5/8 10K). The tubing head was tested at 5000psi, and once the test was successful, the BOP was installed and the tubing head was tested at 500psi and 5000psi.

Next, a control line was run down to the depth of 654m, and the retrieval was done by washing out the entire string consisting of 57 joints of 3.5" drill pipe and 15 joints of 4-3/4" drill collar.

A production string composed of 325 joints of 4-1/2" tubing (13.5# P110 N.VAM) was run down to the depth of 2990m. After adjusting the string and testing the tie back seal at 400psi (which passed), a displacement operation was performed to replace the fresh water with brine of density 1.50sg.

Schlumberger arrived on site to perform slickline operations to calibrate and anchor the 7" hydraulic packer using the Halliburton unit, applying a pressure of 7500psi at 2981m and conducting a pull/slick-off test of 10/10 tons.

Slickline operations were carried out by Schlumberger as follows: running a 92mm drift to confirm that the production string is free.

Finally, the wellhead assembly was installed and tested, along with all the valves at 5000psi, to ensure well safety.

### ➤ **BHA Reports**

ON°:10      Type: K505BPX      SN°: JV9850

In: 3412m      Out:3530m      TFA : 0.5in<sup>2</sup>

**Table III. 17:** BHA n° 12 (Cement reaming from 3374m to 3412m & Directional drilling from 3412m to 3530m).

Description	OD (")	ID (")	Length (m)	Cumulated (m)
BIT IMP	6"		0.22	0.22
A475M4560XP BH 1.02deg Low pressure bearing.	4 3/4	3 3/4	7.22	7.44
UBHO	4 5/6	2 1/4	1.07	8.51
SlimPulse 475 - Bat. On bottom	4 3/4	3 1/4	9.83	18.34
4 3/4" Flex NMDC	3 1/2	2 1/4	9.50	27.84
4 3/4" Circulating Sub	4 3/4	2 1/4	0.75	28.59
15 DP 3.5"	3 1/2	2 3/4	143.68	172.27
33 HWDP 3.5"	3 1/2	2 1/16	308.40	480.67
D/JAR	4 3/4	2 1/16	5.28	485.95
8 HWDP 5"	3 1/2	2 1/16	73.84	559.79
51 DP 3.5"	3 1/2	2 3/4	487.42	1047.21
Crossover	5	4 7/9	1.04	1048.25
			<b>Total</b>	<b>1048.25</b>

ON°:11      Type: K505BPX      SN°: JV9830  
 In: 3530m      Out:3621m      TFA : 0.5in<sup>2</sup>

**Table III. 18:** BHA n° 13 (Directional drilling from 3530m to 3621m).

Description	OD (")	ID (")	Length (m)	Cumulated (m)
BIT IMP	6"		0.22	0.22
DRU1-120RF. BH 1.02deg.	4 3/4	3 3/4	7.32	7.54
Float sub/Float Valve	4 5/6	2 1/4	0.78	8.32
SlimPulse 475 - Bat. On bottom	4 3/4	3 1/4	10.32	18.64
4 3/4" Flex NMDC	3 1/2	2 1/4	8.40	27.04
4 3/4" Circulating Sub	4 3/4	2 1/4	0.75	27.79
36 DP 3.5"	3 1/2	2 3/4	344.81	372.60
36 HWDP 3.5"	3 1/2	2 1/16	336.52	709.12
D/JAR	4 3/4	2 1/16	5.28	714.40
8 HWDP 5"	3 1/2	2 1/16	73.84	788.24
51 DP 3.5"	3 1/2	2 3/4	430.55	1218.79
Crossover	5	4 7/9	1.04	1219.83
			<b>Total</b>	<b>1219.83</b>

ON°:12      Type: K505BPX      SN°: JV9838  
 In: 3621m      Out: 3765m      TFA : 0.5in<sup>2</sup>

**Table III. 19:** BHA n° 14 (Directional drilling from 3621m to 3765m).

Description	OD (")	ID (")	Length (m)	Cumulated (m)
BIT IMP	6		0.22	0.22
DRU1-120RF. BH 1.02deg.	4 3/4	3 3/4	7.32	7.54
Float sub/FloatValve	4 5/6	2 1/4	0.78	8.32
SlimPulse 475 - Bat. On bottom	4 3/4	3 1/4	10.32	18.64
4 3/4" Flex NMDC	3 1/2	2 1/4	8.40	27.04
4 3/4" Circulating Sub	4 3/4	2 1/4	0.77	27.81
48 DP 3.5"	3 1/2	2 3/4	459.47	487.28
36 HWDP 3.5"	3 1/2	2 1/16	336.52	823.80
D/JAR	4 3/4	2 1/16	9.05	832.85
8 HWDP 5"	3 1/2	2 1/16	73.84	906.69
45 DP 3.5"	3 1/2	2 3/4	430.90	1337.59
Crossover	5	4 7/9	1.04	1338.63
			<b>Total</b>	<b>1338.63</b>

ON°:13      Type: K505BPX      SN°: JV9120  
 In: 3765m      Out: 3950m      TFA : 0.5in<sup>2</sup>

**Table III. 20:** BHA n° 15 (Directional drilling from 3765m to 3950m).

Description	OD (")	ID (")	Length (m)	Cumulated (m)
BIT IMP	6		0.22	0.22
DRU1-120RF. BH 1.02deg.	4 3/4	3 3/4	7.32	7.54
Float sub/FloatValve	4 5/6	2 1/4	0.78	8.32
SlimPulse 475 - Bat. On bottom	4 3/4	3 1/4	10.32	18.64
4 3/4" Flex NMDC	3 1/2	2 1/4	8.40	27.04
4 3/4" Circulating Sub	4 3/4	2 1/4	0.77	27.81
63 DP 3.5"	3 1/2	2 3/4	603.20	631.01
36 HWDP 3.5"	3 1/2	2 1/16	336.52	967.53
D/JAR	4 3/4	2 1/16	9.05	976.58
8 HWDP 5"	3 1/2	2 1/16	73.84	1050.42
45 DP 3.5"	3 1/2	2 3/4	430.90	1481.32
Crossover	5	4 7/9	1.04	1482.36
			<b>Total</b>	<b>1482.36</b>

ON°:14      Type: K505BPX      SN°: JV9856  
 In: 3950m      Out: 4201m      TFA : 0.5in<sup>2</sup>

**Table III. 21:** BHA n° 16 (Directional drilling from 3950m to 4201m).

Description	OD (")	ID (")	Length (m)	Cumulated (m)
BIT IMP	6		0.22	0.22
DRU1-120RF. BH 1.02deg.	4 3/4	3 3/4	7.32	7.54
Float sub/FloatValve	4 5/6	2 1/4	0.78	8.32
SlimPulse 475 - Bat. On bottom	4 3/4	3 1/4	10.30	18.62
4 3/4" Flex NMDC	3 1/2	2 1/4	9.05	27.67
4 3/4" Circulating Sub	4 3/4	2 1/4	0.78	28.45
84 DP 3.5"	3 1/2	2 3/4	803.42	831.87
42 HWDP 3.5"	3 1/2	2 1/16	392.78	1224.65
D/JAR	4 3/4	2 1/16	9.27	1233.92
8 HWDP 5"	3 1/2	2 1/16	73.84	1307.76
45 DP 3.5"	3 1/2	2 3/4	430.90	1738.66
Crossover	5	4 7/9	1.04	1739.70
			<b>Total</b>	<b>1739.70</b>

ON°:15      Type: K505BPX      SN°: JV9872

In: 4201m      Out: 4375m      TFA : 0.5in<sup>2</sup>

**Table III. 22:** BHA n° 17 (Directional drilling from 4201m to 4375m).

Description	OD (")	ID (")	Length (m)	Cumulated (m)
BIT IMP	6		0.22	0.22
DRU1-120RF. BH 1.02deg.	4 3/4	3 3/4	7.32	7.54
Float sub/FloatValve	4 5/6	2 1/4	0.78	8.32
SlimPulse 475 - Bat. On bottom	4 3/4	3 1/4	10.30	18.62
4 3/4" Flex NMDC	3 1/2	2 1/4	9.05	27.67
4 3/4" Circulating Sub	4 3/4	2 1/4	0.78	28.45
105 DP 3.5"	3 1/2	2 3/4	1005.13	1033.58
48 HWDP 3.5"	3 1/2	2 1/16	444.84	1478.42
D/JAR	4 3/4	2 1/16	9.87	1488.29
8 HWDP 5"	3 1/2	2 1/16	74.41	1562.70
33 DP 3.5"	3 1/2	2 3/4	315.58	1878.28
Crossover	5	4 7/9	1.04	1879.32
			<b>Total</b>	<b>1879.32</b>

➤ TAIMIN ANALYSIS

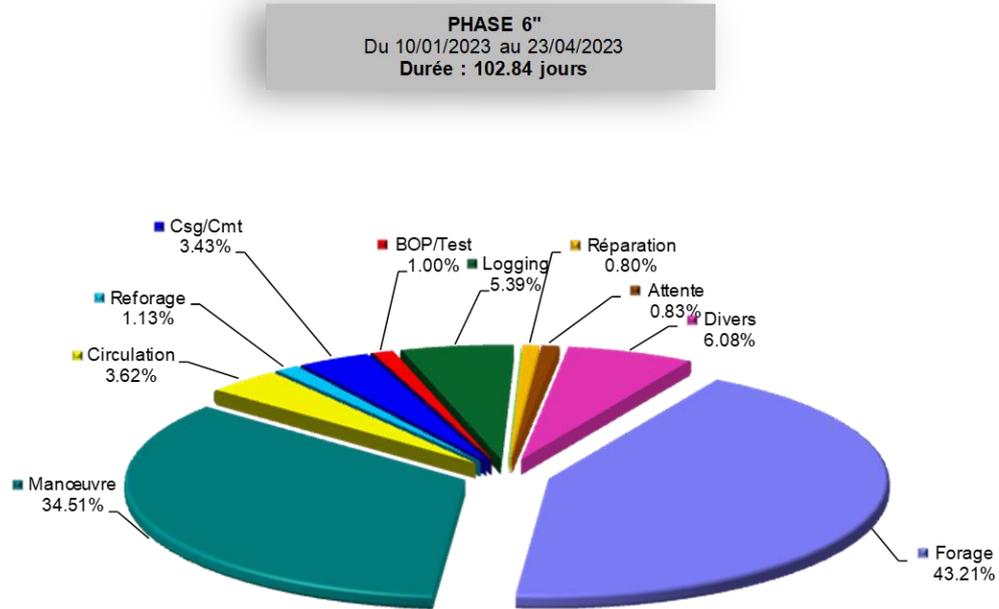


Figure III. 7: time analysis. [23].

III.6.The comparison:

Table III. 23: OMGZ -801 and OMGZ-60 data comparison.

	OMGZ-60	OMGZ-801
<b>Azimuth °</b>	40	300
<b>Mud weight</b>	1.34	1.45
<b>BHA</b>	10	4
<b>ROP</b>	2.5	3.79
<b>BIT</b>	10	5
<b>WOB</b>	1-4	1-15

### **Interpretation:**

#### **1. Stress Direction and Azimuth:**

- OMGZ-801: With an azimuth of 300°, OMGZ-801 was drilled in the maximum stress direction. Drilling in this direction can provide more favorable conditions for wellbore stability and drilling performance.

- OMGZ-60: With an azimuth of 40°, OMGZ-60 was drilled in the minimum stress direction. Drilling in this direction can present challenges, requiring careful considerations for wellbore stability.

#### **2. Mud Weight:**

- OMGZ-801: The mud weight used in OMGZ-801 was 1.45. Mud weight is an important parameter for maintaining wellbore stability and controlling pressure while drilling.

- OMGZ-60: The mud weight used in OMGZ-60 was 1.34, slightly lower than that of OMGZ-801. Adjusting the mud weight is crucial to ensure wellbore stability in the minimum stress direction.

#### **3. BHA (Bottom Hole Assembly):**

- OMGZ-801: BHA 4 was used in OMGZ-801. The specific components and configuration of BHA 4 would depend on the drilling requirements and objectives in the maximum stress direction.

- OMGZ-60: BHA 10 was used in OMGZ-60. Similar to BHA 4, BHA 10 would have been designed to meet the specific drilling needs in the minimum stress direction.

#### **4. ROP (Rate of Penetration):**

- OMGZ-801: The ROP in OMGZ-801 was 3.79. ROP refers to the speed at which the drill bit penetrates the formation. A higher ROP indicates faster drilling progress.

- OMGZ-60: The ROP in OMGZ-60 was 2.5, slightly lower than that of OMGZ-801. The drilling progress in the minimum stress direction was relatively slower.

**5. Bit:**

- OMGZ-801: OMGZ-801 used Bit 5 during drilling operations. The specific type and size of the bit would depend on the formation characteristics and drilling requirements in the maximum stress direction.

- OMGZ-60: OMGZ-60 used Bit 10 during drilling operations. Similar to OMGZ-801, the selection of Bit 10 would have been based on the formation and drilling objectives in the minimum stress direction.

**6. WOB (Weight on Bit):**

- OMGZ-801: The weight on bit (WOB) range in OMGZ-801 was 1 to 15. WOB refers to the downward force applied to the bit during drilling. Adjusting the WOB helps optimize drilling performance and maintain wellbore stability.

- OMGZ-60: The WOB range in OMGZ-60 was 1 to 4. The lower range of WOB indicates a lighter weight applied to the bit during drilling operations in the minimum stress direction.

In summary, based on the corrected information, OMGZ-801 was drilled in the maximum stress direction with a higher mud weight, BHA 4, higher ROP, Bit 5, and a wider range of WOB (1-15). On the other hand, OMGZ-60 was drilled in the minimum stress direction with a lower mud weight, BHA 10, lower ROP, Bit 10, and a narrower range of WOB (1-4). These differences highlight the varying drilling conditions and considerations between the two wells, emphasizing the importance of tailoring drilling parameters to the stress direction for optimized drilling performance and wellbore stability.

**Table III. 24:** OMGZ -801 and OMGZ-60 data comparison.

	<b>TIME (DAYS)</b>	<b>COU (KDA)</b>
<b>OMGZ-60</b>	138.25	446218
<b>OMGZ-801</b>	36.5	74363

### **Interpretation:**

#### **1. Time (Days):**

- OMGZ-801: The drilling operation for OMGZ-801 was completed in 36.5 days, which indicates a relatively shorter drilling duration. This can be attributed to drilling in the maximum stress direction, which may have presented more favorable drilling conditions and fewer challenges.

- OMGZ-60: The drilling operation for OMGZ-60 took 138.25 days to complete, indicating a longer drilling duration. This can be attributed to drilling in the minimum stress direction, which typically presents more challenging drilling conditions and may have required additional time to overcome obstacles.

#### **2. Cost (KDA):**

- OMGZ-801: The total cost for drilling OMGZ-801 was 74,363 KDA, which is relatively lower compared to OMGZ-60. The lower cost can be attributed to the shorter drilling duration and potentially fewer expenses incurred during the drilling operation.

- OMGZ-60: The total cost for drilling OMGZ-60 amounted to 446,218 KDA, which is higher compared to OMGZ-801. The higher cost can be attributed to the longer drilling duration and the associated expenses such as rig operations, equipment rental, personnel, and other drilling services required over the extended period.

In summary, based on the updated information, OMGZ-60, drilled in the minimum stress direction, experienced a longer drilling duration and incurred a higher cost compared to OMGZ-801, which was drilled in the maximum stress direction. This contradicts the expectation that drilling in the minimum stress direction would generally result in more favorable drilling conditions and shorter durations. The specific circumstances of each drilling operation may have influenced the outcomes, leading to the observed differences in time and cost.

# CONCLUSION

### **General conclusion:**

After conducting a thorough comparison between wells OMGZ801 and OMGZ60, we can conclude that drilling in the direction of maximum stress is comparatively easier than drilling in the direction of minimum stress. This is primarily due to several factors associated with drilling in the direction of minimum stress.

Firstly, drilling in the direction of minimum stress necessitates a comprehensive geomechanical analysis to accurately determine the equivalent mud window for maintaining stability in the wellbore. This involves carefully managing the mud properties to ensure the wellbore walls remain intact and avoid any potential instability issues.

Secondly, drilling in the direction of minimum stress requires constant monitoring and adjustment of drilling parameters to prevent the well from becoming stuck or experiencing differential pressure-induced complications. This continuous movement of the wellbore increases the complexity and time required for drilling operations, leading to higher costs.

Furthermore, the limitations associated with drilling in the direction of minimum stress impact logging operations. The constrained wellbore conditions make it challenging to conduct logging activities, limiting the ability to gather crucial data about the subsurface formations. Consequently, it becomes more difficult to accurately identify the optimal location for well perforations within the weaker zones.

However, it is important to note that despite the challenges, drilling in the direction of minimum stress can have significant advantages in terms of reservoir productivity. Following fracturing operations, the reservoir exhibits enhanced productivity, allowing for sustained high flow rates over an extended period.

In summary, while drilling in the direction of minimum stress presents challenges such as the need for comprehensive geomechanical studies, increased drilling complexity, higher costs, and limited logging capabilities, the potential benefits in terms of long-term reservoir productivity make it a viable strategy in the production phase of the well.

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**Annexes:**

**1.First case OMGZ-801:**  
**Deviation Measurements Phase 6''**

N°	MD (m)	Inclinaison (deg)	Azimut (deg)	TVD (m)	NS (m)	EW (m)	Vert Sct(m)
1	3427.70	63.670	299.70	3361.6	89.2	-157.5	181.0
2	3445.40	68.210	300.75	3368.8	97.3	-171.4	197.1
3	3455.20	71.550	300.60	3372.2	102.0	-179.4	206.3
4	3466.10	74.310	301.14	3375.4	107.3	-188.3	216.7
5	3476.70	76.510	301.22	3378.1	112.6	-197.1	227.0
6	3486.60	79.080	301.72	3380.2	117.7	-205.3	236.7
7	3496.60	83.110	301.80	3381.7	122.9	-213.7	246.5
8	3513.10	88.770	302.80	3382.9	131.7	-227.6	263.0
9	3524.70	86.970	302.16	3383.3	137.9	-237.4	274.6
10	3536.20	87.050	300.88	3383.9	143.9	-247.2	286.0
11	3552.20	87.290	301.42	3384.7	152.2	-260.9	302.0
12	3567.10	88.120	302.35	3385.3	160.0	-273.5	316.9
13	3582.10	88.150	302.31	3385.8	168.1	-286.2	331.9
14	3600.00	89.720	301.52	3386.1	177.5	-301.4	349.8
15	3626.10	88.520	300.29	3386.5	190.9	-323.8	375.9
16	3655.40	87.230	298.72	3387.6	205.3	-349.2	405.1
17	3678.00	86.200	297.35	3388.9	215.9	-369.2	427.7
18	3700.40	85.030	299.15	3390.6	226.5	-388.8	450.0
19	3721.00	85.920	297.17	3392.2	236.4	-406.9	470.5
20	3742.90	85.530	298.23	3393.9	246.7	-426.1	492.4
21	3761.81	84.90	298.25	3395.5	255.6	-442.7	511.2
22	3781.60	86.270	299.25	3397.0	265.1	-460.0	530.9
23	3800.00	87.290	300.03	3398.0	274.2	-476.0	549.3
24	3825.00	86.120	299.24	3399.5	286.5	-497.7	574.2
15	3843.60	86.70	299.77	3400.6	295.7	-513.8	592.8
16	3868.00	87.47	300.90	3401.9	308.0	-534.8	617.2
17	3889.20	88.46	301.75	3402.6	319.0	-552.9	638.4
18	3908.80	89.35	303.07	3403.0	329.5	-569.5	657.9
19	3927.90	87.81	301.77	3403.5	339.7	-585.6	677.0
20	3945.10	87.78	301.02	3404.1	348.7	-600.3	694.2
21	3964.40	87.47	299.88	3404.9	358.4	-616.9	713.5
22	3983.30	89.14	299.99	3405.5	367.9	-633.3	732.4
23	4000.70	89.66	299.34	3405.7	376.5	-648.4	749.8
24	4019.10	87.50	298.18	3406.1	385.3	-664.5	768.2
25	4039.20	86.17	296.48	3407.2	394.6	-682.3	788.2
26	4056.60	85.33	295.75	3408.5	402.2	-697.9	805.5
27	4076.20	86.02	296.30	3409.9	410.8	-715.5	825.0
28	4100.80	86.17	299.99	3411.6	422.3	-737.1	849.5
29	4121.70	86.22	302.25	3413.0	433.1	-755.0	870.4
30	4143.60	88.52	303.47	3414.0	445.0	-773.4	892.2
31	4162.50	87.65	302.53	3414.6	455.3	-789.2	911.1
32	4182.10	87.59	301.74	3415.4	465.7	-805.8	930.7
33	4199.40	85.98	300.89	3416.4	947.9	-820.5	947.9

N°	MD (m)	Inclinaison (deg)	Azimut (deg)	TVD (m)	NS (m)	EW (m)	Vert Sct(m)
34	4216.70	87.46	303.09	3417.4	483.8	-835.2	965.2
35	4236.40	89.63	301.60	3417.9	494.4	-851.8	984.9
36	4255.20	88.82	300.38	3418.2	504.0	-867.9	1003.7
37	4274.90	88.83	300.59	3418.6	514.0	-884.9	1023.4
38	4293.40	89.20	301.19	3418.9	523.5	-900.8	1041.9
39	4311.10	89.63	299.87	3419.1	532.5	-916.0	1059.6
40	4330.10	90.19	299.59	3419.1	541.9	-932.5	1078.6
41	4349.40	89.20	298.31	3419.2	551.3	-949.4	1097.8
42	4366.90	88.76	297.35	3419.5	559.4	-964.9	1115.3
43	4381.20	88.27	298.29	3419.9	566.1	-977.5	1129.6
44	4405.30	88.08	297.16	3420.6	577.2	-998.6	1153.4
45	4420.10	90.87	296.99	3420.80	584.1	-1012.0	1168.5
46	4438.70	91.86	297.88	3420.30	592.6	-1028.5	1187.0
47	4450.00	91.00	298.50	3420.10	598.0	-1038.5	1198.3

### Mud Reports

Date	Prof. (m)	MW (sg)	FV (cp)	PV (cp)	YP	GEL 0/10	Filtrat	Huile (%)	Eau (%)	Solides (%)	H/E
21/11/2009	3443	1.30	45	19	10	9/13	4.0	75	8	20	94/6
22/11/2009	3443	1.45	46	20	10	9/12	4.0	72	8	20	90/10
23/11/2009	3444	1.45	45	20	10	9/11	4.0	72	8	20	90/10
24/11/2009	3444	1.45	45	20	10	9/11	4.0	72	8	20	90/10
25/11/2009	3445	1.45	46	25	12	8/12	4.8	73	6	21	92/8
26/11/2009	3507	1.45	46	26	12	9/13	4.8	73	5	22	93/7
27/11/2009	3570	1.45	45	25	13	9/12	4.8	72	5	22	93/7
28/11/2009	3604	1.45	44	21	11	8/12	4.8	72	4	24	95/5
29/11/2009	3604	1.45	44	21	11	8/12	4.8	72	4	24	95/5
30/11/2009	3662	1.45	46	22	12	9/13	4.8	73	5	22	94/6
01/12/2009	3738	1.45	44	18	12	9/13	4.8	73	5	22	94/6
02/12/2009	3794	1.45	45	19	13	9/13	4.8	73	5	22	94/6
03/12/2009	3860	1.45	45	20	13	9/14	4.8	73	5	22	94/6
04/12/2009	3927	1.45	46	21	13	9/14	4.8	73	5	22	94/6
05/12/2009	3988	1.45	47	22	13	10/15	4.8	73	4	23	95/5
06/12/2009	4048	1.45	47	22	13	9/14	4.8	73	4	23	95/5
07/12/2009	4100	1.45	47	23	13	9/14	4.8	73	4	23	95/5
08/12/2009	4100	1.45	47	23	13	9/14	4.8	73	4	23	95/5
09/12/2009	4100	1.45	47	23	13	9/14	4.8	73	4	23	95/5
10/12/2009	4100	1.45	47	23	13	9/14	4.8	73	4	23	95/5
11/12/2009	4111	1.43	44	19	12	9/14	4.8	73	4	23	95/5
12/12/2009	4165	1.42	45	20	12	9/13	4.8	73	4	23	95/5

13/12/2009	4271	1.42	45	20	12	9/13	4.8	73	4	23	95/5
14/12/2009	4358	1.42	47	22	13	9/13	4.8	73	4	23	95/5
15/12/2009	4426	1.42	48	23	13	9/14	4.8	73	4	23	95/5
16/12/2009	4450	1.42	48	23	13	9/14	4.8	73	4	23	95/5
17/12/2009	4450	1.42	48	23	13	9/14	4.8	73	4	23	95/5
18/12/2009	4450	1.42	48	23	13	9/14	4.8	73	4	23	95/5
19/12/2009	4450	1.42	48	23	13	9/14	4.8	73	4	23	95/5

Date	Prof. (m)	MW (sg)	FV (cp)	PV (cp)	YP	GEL 0/10	Filtrat	Huile (%)	Eau (%)	Solides (%)	H/E
20/12/2009	4450	1.42	48	23	14	9/14	4.8	73	4	23	95/5
21/12/2009	4450	1.42	48	23	14	9/14	4.8	74	4	22	95/5
22/12/2009	4450	1.42	48	23	14	9/14	4.8	74	4	22	95/5
23/12/2009	4450	1.42	48	23	14	9/14	4.8	74	4	22	95/5
24/12/2009	4450	1.42	48	23	14	9/14	4.8	74	4	22	95/5
25/12/2009	4450	1.42	48	23	14	9/14	4.8	74	4	22	95/5
26/12/2009	4450	1.42	48	23	14	9/14	4.8	74	4	22	95/5
27/12/2009	4450	1.42	48	23	14	9/14	4.8	74	4	22	95/5

### Fiche stratigraphique du puits :

Ere	Système	Formation		Tops(m)			Epais. MD
				Géologiques			
				Prévis. TVD	Réels		
MD	TVD						
CENO-ZOÏQUE	Néogène	Mio-Pliocène		00	-	-	-
	Paléogène	Eocène		268	-	-	-
P O N O :	Crétacé	Sénonien	Carbonaté	338	-	-	-
			Anhydritique	486	-	-	-
			Salifère	708	-	-	-
		Turonien		877	-	-	-
		Cénomanién		963	-	-	-
		Albien		1094	-	-	-
		Aptien		1453	-	-	-
		Barrémien		1479	-	-	-
	Néocomien		1730	-	-	-	
	Jurassique	Malm		1915	-	-	-
		Dogger	Argileux	2140	-	-	-
Lagunaire			2247	-	-	-	
Lias		Dolomitique1	2463	-	-	-	
		Salifère1	2547	-	-	-	
	Dolomitique2	2624	-	-	-		

			Salifère2	2681	-	-	-		
			Dolomitique3	2742	-	-	-		
			Salifère	TS1	2774	-	-	-	
				TS2	2829	-	-	-	
				TS3	3007	-	-	-	
			KOP@ 3040m						
			Trias	Argileux	G10	3207	-	-	-
					Argilogr éseux	G35	3328	-	-
				G50		3355	-	-	-
				Andésite		-	-	-	-
PALEO- ZOÏQUE	Cambrien	Ri	-	-	-	-			
		DH-D2	3376	3812					
		ID	3378						
		D1	3408						
		R2	3442	-	-	-			
		TD	3441	4450	3420	-			

## 2.Second case OMGZ-60:

### Phase 8 ½"

During this phase, the drilling crossed the following stages

Etage	Intervalle (m)	
	MD	TVD
Trias argileux (G30) complément	3309 - 3329	3301.46 - 3319.71
Trias argileux (G35)	3329 - 3344	3319.71 - 3333.20
Trias Grés Sup (G50)	3344 - 3394.75	3333.20 - 3379
Cambrien Réservoir RA DH/D3	3394.75 - 3405	3379 - 3388.50
Cambrien Réservoir RA D2	3405 - 3427	3388.50 - 3408
Cambrien Réservoir RA ID	3427 - 3461	3408 - 3438
Cambrien Réservoir RA D1	3461 - 3488	3438 - 3464
Cambrien Réservoir RA Zpsg	3488 - 3495.35	3464 - 3471
Cambrien Réservoir R2 ab	3495.35 - 3534	3471 - 3507
Cambrien Réservoir R2 c	3534 - 3548	3507 - 3520
<b>Side Track @ 3319m</b>		
Trias argileux (G30) complément	3319-3330	3310.23-3319.86
Trias argileux (G35)	3330-3345	3319.86-3332.36
Trias Grés Sup (G50)	3345-3406	3332.36-3378.07
Cambrien Réservoir RA DH/D3	3406-3412	3378.07-3382.09

The objective of drilling the OMGZ-60 Pilot Hole, based on the comprehensive logging, is to:

- Determine the different reservoir drains.
- Conduct geological, petrophysical, and geomechanical studies.
- Record electrical operations for the optimal target, the "Cambrian Ra Inter Drain."

By achieving these objectives, the drilling operation aims to gather essential information about the reservoirs, their geological characteristics, petrophysical

properties, and geomechanical behavior. This data is crucial for understanding the reservoir's potential, optimizing production strategies, and ensuring effective reservoir management. Additionally, the recording of electrical operations helps in accurately identifying and targeting the desired zone within the Cambrian Ra Inter Drain, maximizing the chances of successful production.

Mud type: OBM

Date	Prof. (m)	MW (sg)	FV (sec)	PV (cp)	YP	GEL 0/10	Filtrat	Huile (%)	Eau (%)	Solides (%)	H/E
08/12/2022	3351	1.40	48	18	9	7/9	4.8	72	8	20	90/10
09/12/2022	3411	1.40	48	18	10	8/10	7	72	8	20	90/10
10/12/2022	3419	1.40	49	18	10	7/10	7	72	8	20	90/10
11/12/2022	3427	1.40	51	19	10	7/10	7.20	72	8	20	90/10
12/12/2022	3452	1.40	52	20	10	7/9	7.60	73	7	20	91/09
13/12/2022	3485	1.40	53	21	10	7/10	7.60	73	7	20	91/09
14/12/2022	3517	1.40	54	21	10	8/11	6.80	73	7	20	91/09
15/12/2022	3548	1.40	56	21	12	8/11	4	73	7	20	91/9
16/12/2022	3548	1.40	56	21	12	8/11	4	73	7	20	91/09
17/12/2022	3548	1.40	56	21	12	7/10	4	73	7	20	91/09
18/12/2022	3548	1.40	56	21	12	7/10	4	73	7	20	91/09
19/12/2022	3548	1.40	56	21	12	7/10	4	73	7	20	91/09
20/12/2022	3548	1.40	57	21	12	7/11	4	73	7	20	91/09
21/12/2022	3548	1.40	56	21	12	7/10	4	73	7	20	91/09
22/012/2022	3548	1.40	59	22	13	8/11	4	73	7	20	91/09
23/012/2022	3548	1.40	59	22	13	8/11	4	73	7	20	91/09
24/012/2022	3548	1.40	59	22	13	8/11	4	73	7	20	91/09
25/012/2022	3548	1.40	59	22	13	8/11	4	73	7	20	91/09
26/012/2022	3548	1.40	59	22	13	8/11	4	73	7	20	91/09
Date	Prof. (m)	MW (sg)	FV (sec)	PV (cp)	YP	GEL 0/10	Filtrat	Huile (%)	Eau (%)	Solides (%)	H/E
27/012/2022	3548	1.40	59	22	13	8/11	4	73	7	20	91/09
28/012/2022	3548	1.40	59	22	13	8/11	4	73	7	20	91/09
29/012/2022	3548	1.40	59	22	13	8/11	4	73	7	20	91/09

### Phase 6":

During this phase, drilling has penetrated the following layers.

Etage	Intervalle (m)	
	MD	TVD
Cambrien Réservoir Ra DH/D3	3412-3422.32	3382.09-3388
Cambrien Réservoir Ra D2	3422.32-3481.61	3388-3411
Cambrien Réservoir Ra ID	3481.61-4375	3411-3418.82

Mude type : OBM

Date	Prof. (m)	MW (sg)	FV (sec)	PV (cp)	YP	GEL 0/10	Filtrat	Huile (%)	Eau (%)	Solides (%)	H/E
11/01/2023	3412	1.45	74	29	11	10/11	4	72	6	22	92/08
12/01/2023	3412	1.45	74	29	11	10/11	4	72	6	22	92/08
13/01/2023	3412	1.45	74	29	11	10/11	4	72	6	22	92/08
14/01/2023	3422	1.34	65	18	10	12/16	4.8	74	7	19	91/09
15/01/2023	3430	1.34	65	18	10	12/16	4.8	74	7	19	91/09
16/01/2023	3442	1.34	67	21	13	14/20	4.8	74	7	19	91/09
17/01/2023	3459	1.34	67	20	13	13/18	7.20	74	7	19	91/09
18/01/2023	3474	1.34	65	19	12	12/16	7.60	75	6	19	93/07

19/01/2023	3494	1.34	65	19	12	12/16	8	75	6	19	93/07
20/01/2023	3512	1.34	65	20	13	13/17	10	75	6	19	93/07
21/01/2023	3524	1.34	67	21	14	15/19	5.20	75	6	19	93/07
22/01/2023	3530	1.34	67	21	14	15/19	5.20	75	6	19	93/07
23/01/2023	3530	1.34	67	21	14	15/19	5.20	75	6	19	93/07
24/01/2023	3542	1.34	67	21	14	15/19	5.20	75	6	19	93/07
25/01/2023	3569	1.34	68	21	15	16/21	6.8	75	5	20	94/06
26/01/2023	3592	1.34	68	21	15	16/21	6.8	75	5	20	94/06
27/01/2023	3614	1.34	68	22	15	16/21	6.8	75	5	20	94/06
28/01/2023	3621	1.34	68	22	15	16/21	6.8	75	5	20	94/06
29/01/2023	3624	1.34	68	22	15	16/21	6.8	75	5	20	94/06
30/01/2023	3650	1.34	68	22	15	16/21	6.8	75	5	20	94/06
31/01/2023	3675	1.34	68	24	14	16/21	8	75	5	20	94/06
01/02/2023	3695	1.34	69	24	15	16/21	6.4	75	5	20	94/06