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**Study On Short Radius Sidetracking in Ohanet Field:Case Study
Of TJNE-5 Well**

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Abstract:

Short Radius Sidetracking is a drilling technique used to enhance hydrocarbon recovery from existing wells. It is employed to restore well productivity, bypass damaged sections, and access hydrocarbon zones that cannot be reached otherwise, while minimizing operational costs compared to drilling a new well. This study examines the implementation of Short Radius Sidetracking in the Ohanet Field through a case study of the TJNE-5 well. The study analyzes the planning, design, and execution of the sidetracking operation, including whipstock setting, well trajectory design, tool selection, and directional control. We pay attention to the problems we faced while drilling, such as the drill not being able to turn sharply the well not being stable and not being able to control the direction of the drill accurately. We also look at how well the drilling worked how efficient it was and the result to see if the sidetracking method we used was a good choice. What we found shows that Short Radius Sidetracking is a way to re-enter the part of the well where the oil is without spending too much time or money. This study shows that planning carefully using the drilling technology and watching what is happening in real-time are important for making sure that sidetracking operations work well in complicated oil and gas fields like Ohanet. Short Radius Sidetracking is a solution, for Short Radius Sidetracking operations. The Short Radius Sidetracking method used in the Ohanet Field is an example of how Short Radius Sidetracking can be used to improve well productivity.

Keywords: TJNE-5, Whipstock, Ohanet Field, Short Radius Sidetracking.

المخلص:

من التقنيات المتقدمة في الحفر الموجّه، (Short Radius Sidetracking) يُعتبر الحفر الجانبي قصير نصف القطر حيث يُستخدم لاستعادة إنتاجية الآبار، وتجاوز المناطق المتضررة، والوصول إلى المكامن الهيدروكربونية غير المستغلة بتكلفة أقل مقارنةً بحفر بئر جديدة. تركز هذه الدراسة على تطبيق تقنية الحفر الجانبي قصير نصف القطر في حقل أوهانت تتناول الدراسة مراحل التخطيط والتصميم والتنفيذ لعملية الحفر الجانبي، بما في TJNE-5 من خلال دراسة حالة البئر ، وتقنيات التحكم في المسار. كما تم (BHA) ، وتصميم المسار، واختيار جميع قاع البئر Whipstock ذلك تثبيت التركيز على التحديات الجيولوجية والتشغيلية التي تمت مواجهتها أثناء عملية الحفر، مثل محدودية نصف قطر الانحناء، واستقرار جدار البئر، ودقة التحكم الاتجاهي. إضافةً إلى ذلك، تم تقييم مؤشرات أداء الحفر والكفاءة التشغيلية والنتائج النهائية للبئر لتحديد فعالية تقنية الحفر المعتمدة. أظهرت النتائج أن تقنية الحفر الجانبي قصير نصف القطر وفّرت حلاً فعالاً واقتصادياً لإعادة الدخول إلى المكامن المستهدفة مع تقليل مدة الحفر والتكاليف التشغيلية. وتبرز هذه الدراسة أهمية التخطيط الجيد، واستخدام تقنيات الحفر الموجّه الحديثة، والمراقبة الآنية لتحقيق عمليات حفر جانبي ناجحة في الحقول النفطية المعقدة مثل حقل أوهانت.

الكلمات المفتاحية: الانحراف عن المسار ذي نصف القطر القصير، حقل أوهانت، وايبستوك، TJNE-5

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I have the great honor of dedicating this modest work:

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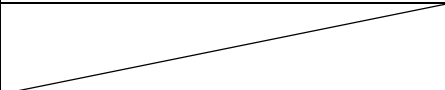
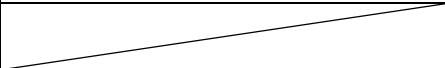
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Symbol	Description	Unit
Az_{True}	Azimuth True	°
$Az_{Magnetic}$	Azimuth Magnetic	°
$\Delta\alpha$	represents the change in inclination angle	°
ΔMD	the corresponding measured depth interval	m
PI	Productivity Index	m ³ /d/bar
Q	Production Flow Rate	m ³ /d
P_r	Static Reservoir Pressure	bar
P_{wf}	Flowing Bottom Hole Pressure	bar
DL	Dog Leg	[°/10 m],[°/30 m],or [°/100 ft]
A	Azimuth	°
I	Inclination	°
L	Length	m,ft
Ps	Thrust provided by the section.	
LW	Actual linear weight in air of an element of the section.	
Bf	Buoyancy Factor.	
Hv	Length of the vertical projection of the section.	m
z	Elevation	
d	Departure	
x	Longitude	m
y	Latitude	m
α	inclination	°

K	Correction Factor	
Abbreviation	Description	Unit
TJNE	Tadjentourt nord-est.	
TVD	True Vertical Depth.	m
MD	Mesured Depth.	m
RSS	Rotary Steerable Systems.	
UTM	Universal Transverse Mercator	
PDM	Positive Displacement Motor	
BHA	Bottom Hole Assembly	
LWD	Logging While Drilling	
<i>BUR</i>	Build Up Rate	°/30m
ROC	Radius of curvature	m
KOP	Kick of Point	
ROP	Rate Of Penetration	(m/h) or (ft/h)
EOR	Enhanced Oil Recovery	
DLS	Dog Leg Severity	(°/30m)
ERD	Extended Reach Drilling	
LR	Long Radius	m
GOR	Gas Oil Ratio	
MWD	Mesured While Drilling	
DC	Drill Collar	
RT	Rotary table	
KB	Kelly Bushing	
WHP	Well Head Pressure	Psi
DST	Drill Stem Test	

NOMENCLATURE

VS	Vertical Section	m
CBL	Cement Bond Log	
TD	True Depth	m
OBM	Oil Based Mud	
BOP	Blow Out Preventer	
CL	Course Length	m
NS	North-South displacement	m
EW	East-West displacement	m
Inc	Inclination	°
Az	Azimuth	°
PDM	Positive Displacement Motor	
TCI	Tungsten carbide inserts	
RSS	Rotary Steerable System	
UBHO	Universal Bottom Hole Orientation	

INTRODUCTION

INTRODUCTION:

The continuous growth of the oil and gas industry has driven the development of advanced drilling technologies capable of improving hydrocarbon recovery while reducing operational costs and surface constraints. Among these technologies, directional drilling has become one of the most important techniques in modern petroleum engineering. Unlike conventional vertical drilling, directional drilling makes it possible to intentionally deviate the well trajectory in order to reach subsurface targets located at different lateral distances and depths. This technology has evolved from a simple corrective operation into a highly sophisticated engineering discipline that relies on precise trajectory planning, real-time measurements, and advanced steering systems.

Today, directional drilling plays a major role in the development of oil and gas fields worldwide. It is widely used in offshore operations, inaccessible surface locations, horizontal and multilateral wells, relief wells, and especially in sidetracking operations. Among the different directional drilling applications, Short Radius Sidetracking has gained significant importance due to its ability to re-enter existing wells and create highly curved trajectories over short distances. This technique offers an effective solution for bypassing mechanical obstructions, reactivating abandoned wells, improving reservoir drainage, and accessing bypassed hydrocarbon zones without drilling new wells from the surface.

In mature oil and gas fields, where production decline and increasing development costs represent major challenges, short radius drilling provides considerable technical and economic advantages. By using the existing well infrastructure, operators can reduce drilling costs, minimize environmental impact, and optimize reservoir exploitation. In Algeria, and particularly in fields such as Ohanet Field and Hassi Messaoud, this technology has become an essential method for field rejuvenation and enhanced hydrocarbon recovery.

This thesis focuses on the study of Short Radius Sidetracking in the Ohanet Field through the case study of the TJNE-5 well. The objective of this work is to analyze the principles, techniques, tools, and operational procedures involved in the realization of a short radius sidetrack, while evaluating its technical feasibility and potential benefits for reservoir production optimization. Particular attention is given to trajectory control, directional drilling profiles, drilling tools, coordinate systems, and the operational stages required to successfully execute a short radius re-entry operation.

The thesis is organized into four main chapters.

The first chapter presents the fundamental concepts of directional drilling, including its historical development, objectives, applications, and the importance of short radius technology.

The second chapter discusses the fundamentals of directional drilling profiles, equipment, and tools used in trajectory control and navigation.

The third chapter focuses on trajectory calculation methods, directional surveys, dog-leg severity, and wellbore positioning techniques. Finally,

the fourth chapter presents the detailed case study of the TJNE-5 well in the Ohanet Field, including geological data, well conditions, operational chronology, trajectory design, and the implementation of the short radius sidetracking operation.

Through this study, the thesis aims to highlight the strategic importance of Short Radius Sidetracking as an efficient and economical solution for optimizing production in mature oil and gas fields, while demonstrating its practical application in the TJNE-5 well project.

CHAPTER I:

Generalities About Directional Drilling

I. Definition and General Concept:

I.1. Directional Drilling:

Directional Drilling is the science of deliberately deviating a wellbore on a planned trajectory to reach a specific target located at a specific lateral distance and depth from the surface. In modern petroleum engineering, it has evolved from a simple means of reaching a target to a sophisticated navigation process based on real-time data to maximize reservoir contact. Directional wells differ from traditional vertical wells in that their Measured Depth (MD) is much greater than their True Vertical Depth (TVD). (fig. I.1)

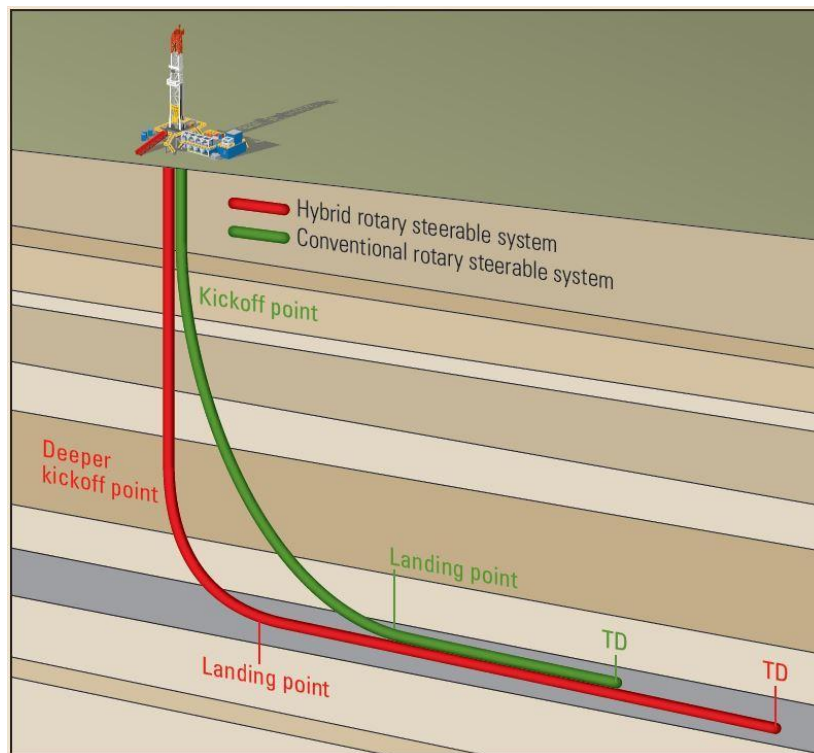


Fig I. 1 :Comparison between Vertical and Horizontal Well Trajectories.

I.2. Historical Evolution:

From Correction to Strategy From precision engineering to accidental discovery, directional drilling has a history of:

- **The 1920's (The Realization):** Drillers originally thought all wells were vertical. But in the early days surveyors found that many of the so-called 'vertical' wells were actually being unintentionally deviated due to the geology. This led to the development of techniques for "correcting" such deviations.
- **1930s (The First Intentional Step):** First planned directional well in Huntington Beach, California (USA). It was drilled from a location on shore to reach oil sands that were off shore, showing that drilling could be used to overcome geographical barriers.

• **The Modern Era (The Digital Revolution):** The 1960s saw the introduction of Mud Motors and the 1990s the introduction of Rotary Steerable Systems (RSS) that transformed directional drilling into a high-tech discipline. Today it allows for “geosteering” – using sensors to steer the drill bit through the most productive layers of the reservoir in real time.

I.3. Objectives of Directional Drilling:

The decision to drill directionally is driven by several critical engineering and economic objectives:

- **Accessibility of Remote Targets:** To reach reservoirs located under obstructed surface areas such as mountains, cities, or environmentally sensitive zones where a rig cannot be placed directly above the target..
- **Sidetracking :** This is a primary objective for your study. It involves deviating from an existing wellbore to bypass a mechanical obstruction (like a stuck pipe) or to exit a depleted zone to explore a new, more productive part of the reservoir.
- **Increase in Reservoir Contact:** By drilling horizontally or at a high angle through the “Pay Zone,” the wellbore is in contact with the oil-bearing rock for an extended distance, greatly increasing the production rate over a vertical intersection.
- **Salt Dome Drilling:** To prevent technical problems and risks associated with drilling through unstable salt formations, the well path is deviated to the flank of the dome where the oil is trapped.
- **Relief Well Drilling:** If a blowout occurs, a directional well is drilled to intersect the blowing well at depth to pump heavy fluids and regain control (kill the well).[1]

I.4. Applications of Directional Drilling:

I.4.1. Sidetracking and Remedial Operations:

In mature fields, sidetracking is a primary application. This is where a new wellbore is deviated from an existing one. This technique is used to bypass permanent mechanical obstructions such as unretrievable “fish” or lodged pipe. In advanced cases such as Short Radius Sidetracking, it allows operators to exit the original casing and re-target productive zones or bypassed oil within a very tight radius, maximizing the utility of the existing well infrastructure.[2]

I.4.2. Accessing Inaccessible Surface Locations:

• Directional drilling is used when the reservoir is located underneath surface areas where vertical drilling is not allowed. These barriers can be natural, such as rivers, lakes or steep mountains, or man-made, such as cities, factories or protected areas. The well can be steered to reach the target at depth by using a “kick-off” point from an accessible surface location.[1]

I.4.3. Offshore Multi-well Drilling from a Single Platform:

In offshore environments, the high cost of platform construction requires the drilling of several wells from one location. Directional drilling can allow a "cluster" of wells to be

drilled from a single platform. The top sections are “nudged” to have enough clearance and avoid collisions (Collision Avoidance) and the bottom sections are directed at different individual targets throughout the reservoir.[3]

I.4.4. Salt Dome Drilling:

Salt domes often serve as an effective barrier to the movement of hydrocarbons. Unfortunately, drilling vertically through these salt formations can be very risky from a technical perspective. The potential for washouts as well as problems with lost circulation and instability of boreholes can make penetrating a salt dome seem nearly impossible at times. However, engineers use directional drilling techniques to steer around a salt formation or to penetrate it at an optimum angle in order to reach any trapped hydrocarbons safely.

I.4.5. Relief Well Drilling for Well Control:

The placement of relief wells is one of many uses for directional drilling that help to improve safety in drilling operations. Relief wells are used when a blowout occurs and cannot be controlled from the surface. To control the blowout with a relief well, the relief well is drilled from a distance far enough away to keep the drilling rig out of harm's way, but close enough that it can intersect with the blowout wellbore at exactly the right depth, which provides the advantage of being able to inject "kill fluids" into the blowout wellbore to stop the flow of un-controlled hydrocarbons and restore pressure on the blowout.[4]

1.4.6. Horizontal and Multilateral Well Technology:

To maximise production, wells are generally drilled in a horizontal direction through the reservoir to increase the amount of "pay zone" exposure. In addition to this horizontal drilling method, multilateral applications can also be used to create multiple laterals off a mother-bore location. This drilling technique dramatically increases both the drainage area and recovery factor of the well while at the same time reducing the surface footprint and overall completion cost.[5].(fig I.2)

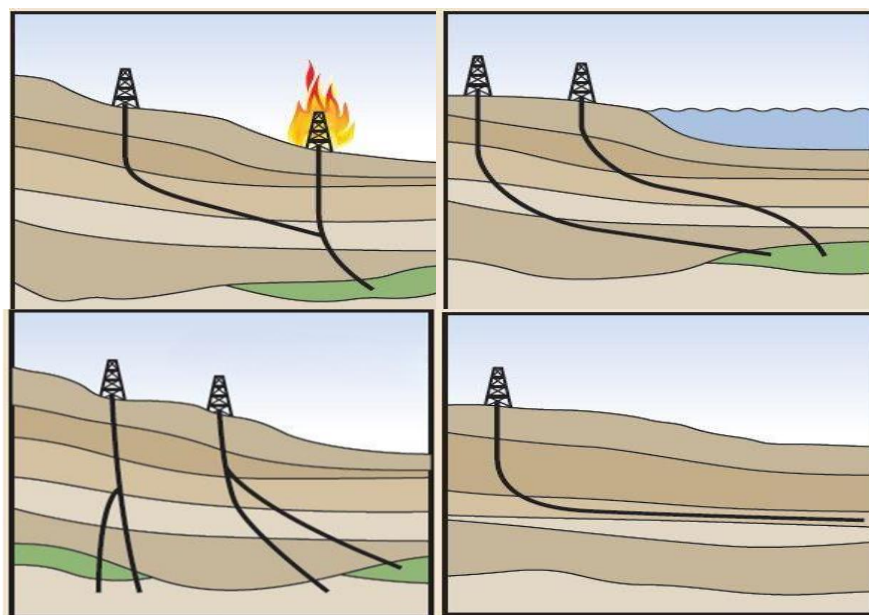


Fig I. 2:Main Engineering Applications of Directional Drilling.

II.Coordinate Systems and Directional Surveys:

II.1.Introduction:

The selection of a coordinate system is a vital step in directional drilling and varies from every country depending on local authorities and the oil company operating there. The use of these types of systems is paramount when converting angular measurements to a three-dimensional position,so that the drill bit can be accurately steered to the reservoir target.[6]

II.2. Universal Transverse Mercator (UTM) Projection:

The Universal Transverse Mercator (UTM) projection is a map projection that uses a transverse cylindrical surface positioned along a meridian to project the Earth's surface onto a plane. When the cylinder is unrolled, the resulting map represents the projected area; however, distortion increases with distance from the central meridian. To minimize this distortion, the system divides the Earth into 60 zones, each spanning 6 degrees of longitude [7] (Fig. I.3).

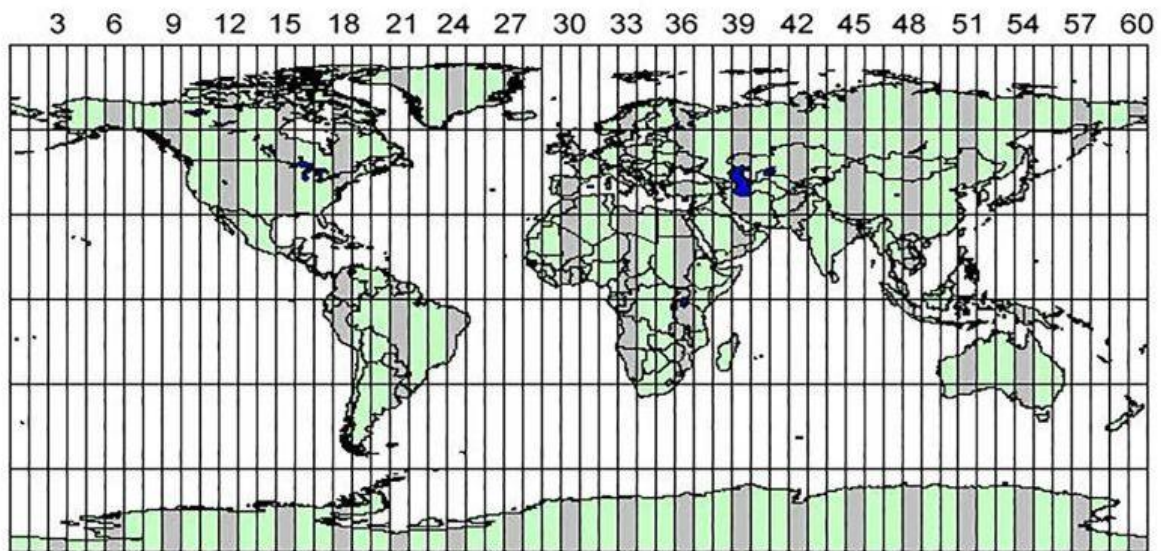


Fig I. 3:Universal Transverse Mercator (UTM) Projection System.

II.3.Lambert Projection:

The Lambert projection is a conical projection. The axis of the cone is identical to that of the axis of rotation of the Earth. The surface of the cone is tangent to the Earth along a "parallel of reference." This system fits small areas better and is defined at national level, so as to

reduce the deformations [6](Figure I.4)

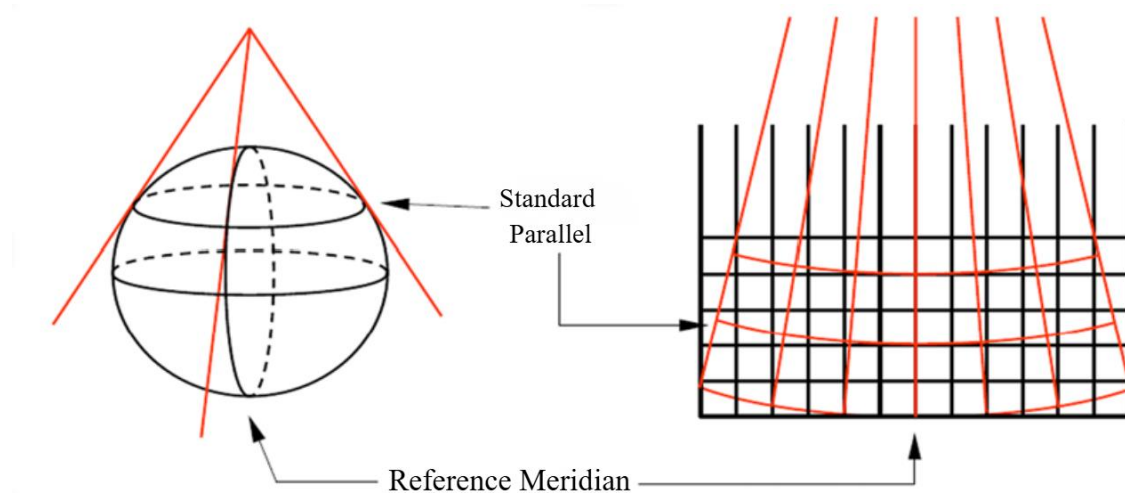


Fig I. 4: Principle of the Lambert Conformal Conic Projection System.

II.4. Horizontal Projection and Reference Norths:

In terms of directional drilling, there are three different north references that must be taken into account. They are:

- 1) True North (Geographic North): This is the stationary point at which the Earth's axis of rotation intersects the Earth's surface.
- 2) Magnetic North: This is the location obtained from a compass or magnetic sensor, and it is a moving point that shifts over time because of the magnetic field of the Earth.
- 3) Grid North (System North): This is the line of north defined by the vertical grid lines found on a map projection.[8].(Figure I.5)

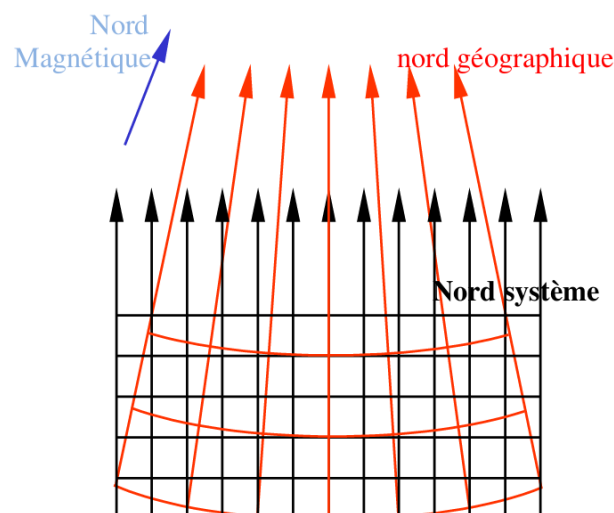


Fig I. 5 :Representation of Magnetic, Geographic, and Grid North.

II.5. Magnetic Declination:

Magnetic Declination. The angle between magnetic North and True North. Since nearly all survey instruments use a magnetic north as reference (magnetometer), any surveyed measurement will need to be corrected for local magnetic declination. A fixed point of reference is added or subtracted from this value depending on whether the declination is oriented East or West (Figure I.6), and stated as an angle to an orientation E or W respectively. To obtain the true azimuth the following equation can be used:

$$Az_{True} = Az_{Magnetic} \pm Declination \quad (I. 1)$$

Where positive(+) is for Eastern declination and (-) is for Western declination. This step is crucial in order to prevent a permanent angle error which will compound itself along the entire well depth, before any direction calculations are completed or wells plotted.[6] (Figure I.6)

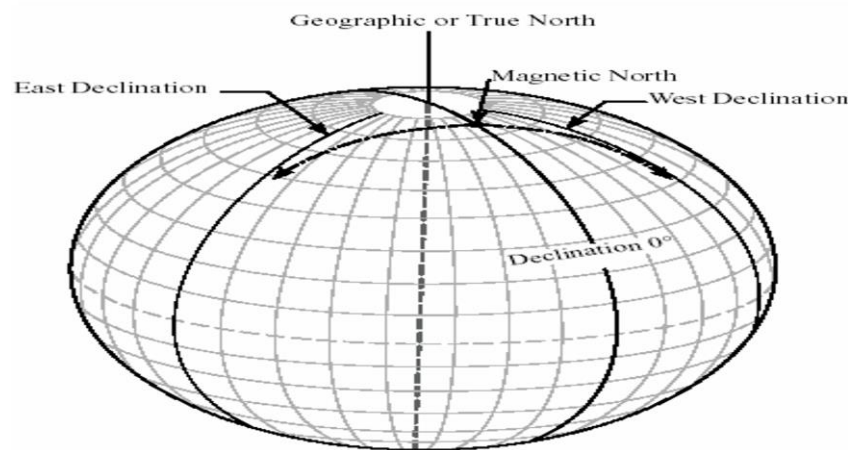


Fig I. 6:Magnetic Declination in Directional Surveying.

II.6. Convergence:

The difference in direction between True North and Grid North is called convergence, and its value changes depending on where the wellhead is located relative to the reference meridian used in the projection. All directional calculations will eventually need to be recorded either relative to True North or to Grid North in order to provide a consistent permanent record. The formula for the grid azimuth from True azimuth is:

$$Az_{Grid} = Az_{True} \pm Convergence \quad (I. 2)$$

When calculating the correct grid azimuth, if your location is East of the reference meridian, you'll use a positive sign (+); if you're West of it, you'll use a negative sign (-). In Algeria, many companies use both UTM and Lambert projections for their drilling operations, so you must make sure you apply both declination and convergence corrections correctly in order for the planned wellbore trajectory - especially during Short Radius operations where any

mistake in azimuth could cause the drill bit to miss hitting a very thin reservoir target - to be accurately executed in the field coordinate system (Figure I.7).[7]

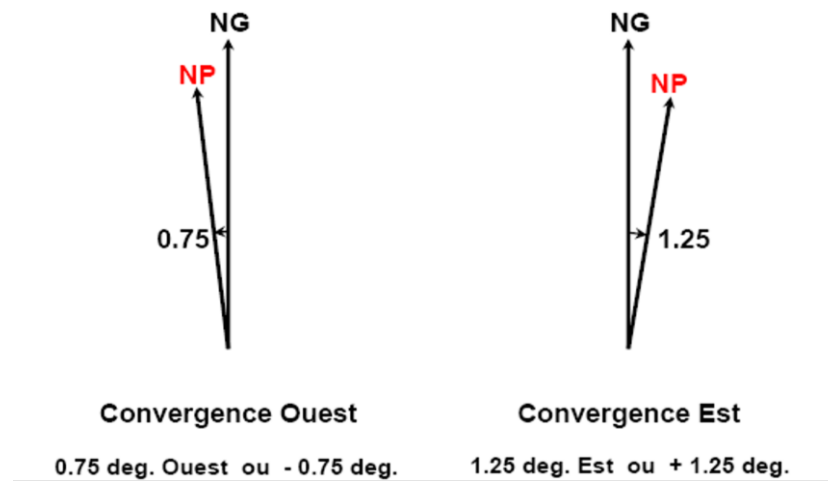


Fig I. 7:Convergence.

II.7. Azimuth Control:

Azimuth control is a process where the horizontal trajectory of the wellbore is constantly monitored. In the case of Short Radius Sidetracking it is important to maintain the azimuth because the rate of curvature is very steep and accurate knowledge of declination and convergence when drilling is required to ensure the bit cuts the target on the desired trajectory [9].

III.techniques and tools for trajectory control:

III.1. Kick-off Methods:

III.1.1 Downhole Motor Method:

For the start of any kick-off in current directional drilling technology, a PDM (Positive Displacement Motor) with a bent housing is the preferred tool. It makes the bit's rotation independent from the drillstring, allowing to perform a "sliding mode" and control the trajectory of the wellbore. For the Short Radius applications, there is need to use special short-body motors because of the high mechanical efforts applied to them. (Fig I.8)

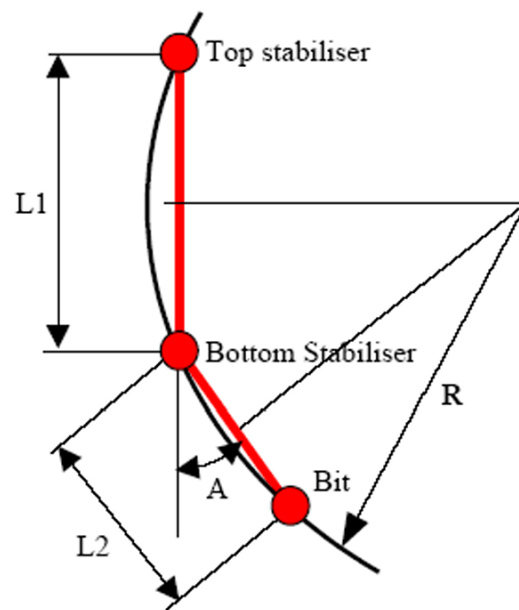


Fig I. 8:Downhole Positive Displacement Motor Used in Directional Drilling.

III.1.2 Jetting Method:

The jetting method is a technique used for deviating wells in unconsolidated(soft) formations where the wellbore is far more easily deflected than in hard formations. The bit used has one large jetting nozzle and two smaller alternate jetting/nozzle (plugged) configuration so that the high-pressure hydraulics created from the jetting action wash away the formations on one of the wall faces (see Figure I.09) to create a cavity behind the wellbore that allows the jetting action to force the bit to deflect in the direction desired.

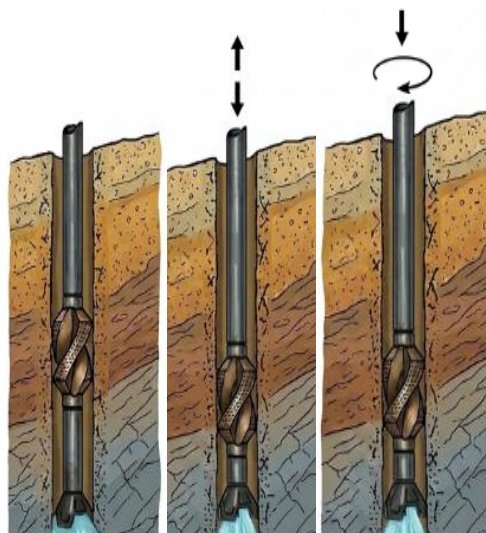


Fig I. 9:Jetting.

III.1.3. Mechanical Reflection Tools:

Physical deflection of the bit. Mechanical deflection is achieved by use of a whipstock, which is a steel wedge that is seated in the hole. Mechanical deflection can be necessary to sidetrack

off existing casing and will establish a solid ramp that the assembly is forced out of and onto the new trajectory.[10](Figure I.10)

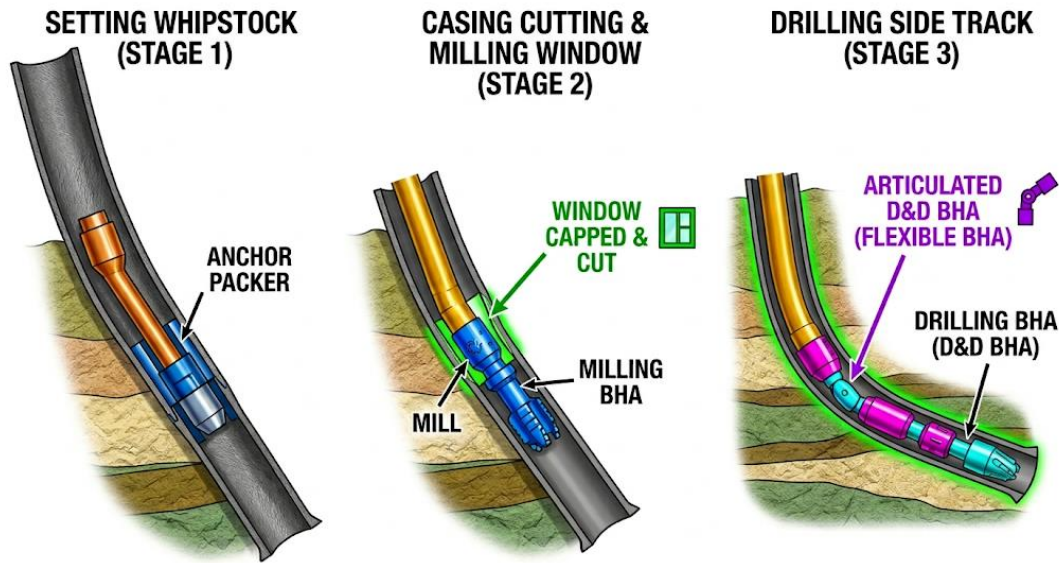


Fig I. 10:Reflection Tools.

III.2 Steering and Navigation Methods:

III.2.1. Conventional Directional Drilling:

This method relies on the "Fulcrum" or "Pendulum" effects by strategically placing stabilizers in the Bottom Hole Assembly (BHA). By adjusting the weight on bit and the BHA geometry, the assembly can be designed to build, hold, or drop the inclination angle.

III.2.2. Steerable Drilling (Navigation):

Navigation drilling utilizes a steerable motor that can operate in both rotary and sliding modes. This allows for continuous corrections of the trajectory without the need to pull the entire string to change the BHA, ensuring the well stays within the planned path. (Figure I.11).

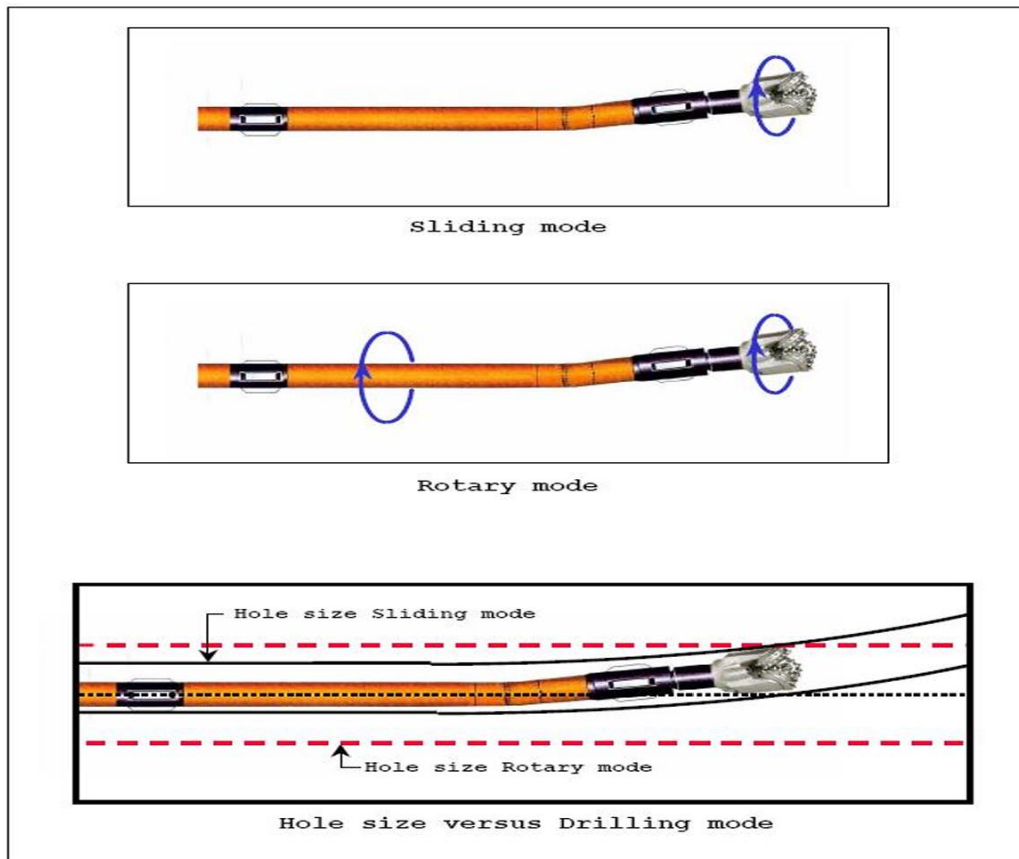


Fig I. 11: Directional drilling methods (Sliding and Rotary).

III.2.3. Geosteering:

Geosteering is the process of altering the actual direction of the well as it is drilled (LWD), in real-time and for geological purposes rather than for geometric targets. This guarantees that the entire horizontal distance of the well stays in the "pay zone" (target reservoir) in order to produce the most hydrocarbons.[11]

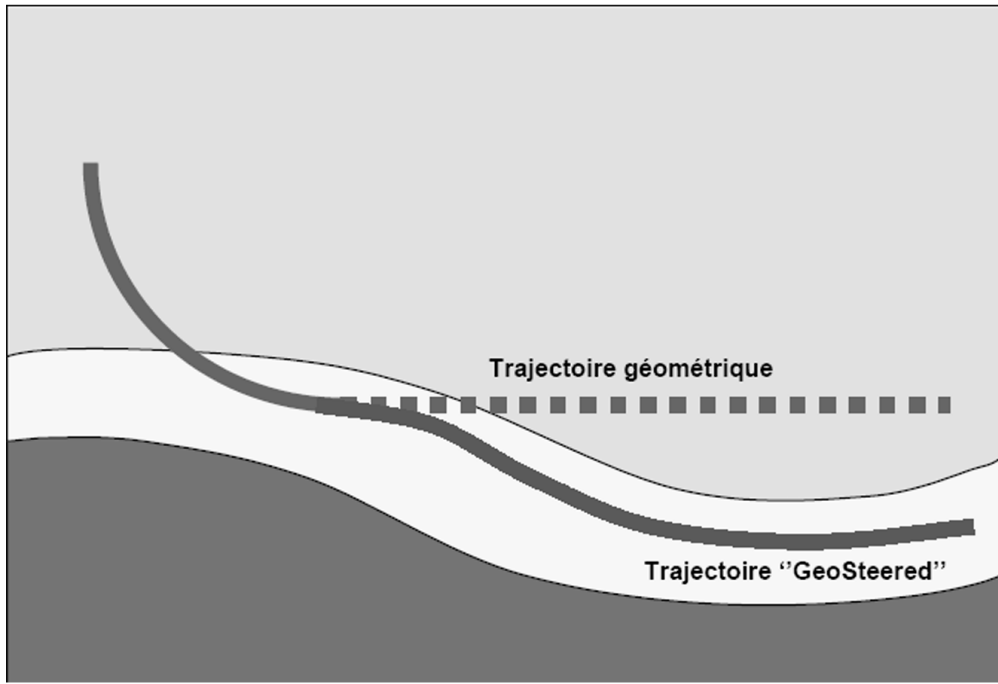


Fig I. 12:Geosteering and geometric drilling.

IV. Advantages and Disadvantages of Each Directional Well Type:

The choice of a directional well profile is an engineering decision controlled, by in the first instance, the build up rate (BUR) - a function describing the change in inclination of the wellbore per unit of measured depth, and it is given by:

$$BUR = \frac{\Delta\alpha}{\Delta MD} (^{\circ}/30m) \quad (1.3)$$

Where:

$\Delta\alpha$:represents the change in inclination angle (degrees).

ΔMD :is the corresponding measured depth interval (meters).

The geometric result of this value, the Radius of curvature (ROC) describing the "tightness" of the curve is directly given by:

$$ROC = \frac{180}{\pi \times BUR} \times 30(meters) \quad (1.4)$$

So a high BUR implies a tight ROC-characteristic of Short Radius wells, a low BUR produces a large ROC-characteristic of Long Radius wells. In addition to these geometric parameters the actual profile will also depend on the extent of the required horizontal length as well as other reservoir and surface factors. Each profile has a particular range of operational and technical trade offs that needs to be accounted for during the planning process. (Figure I.13)

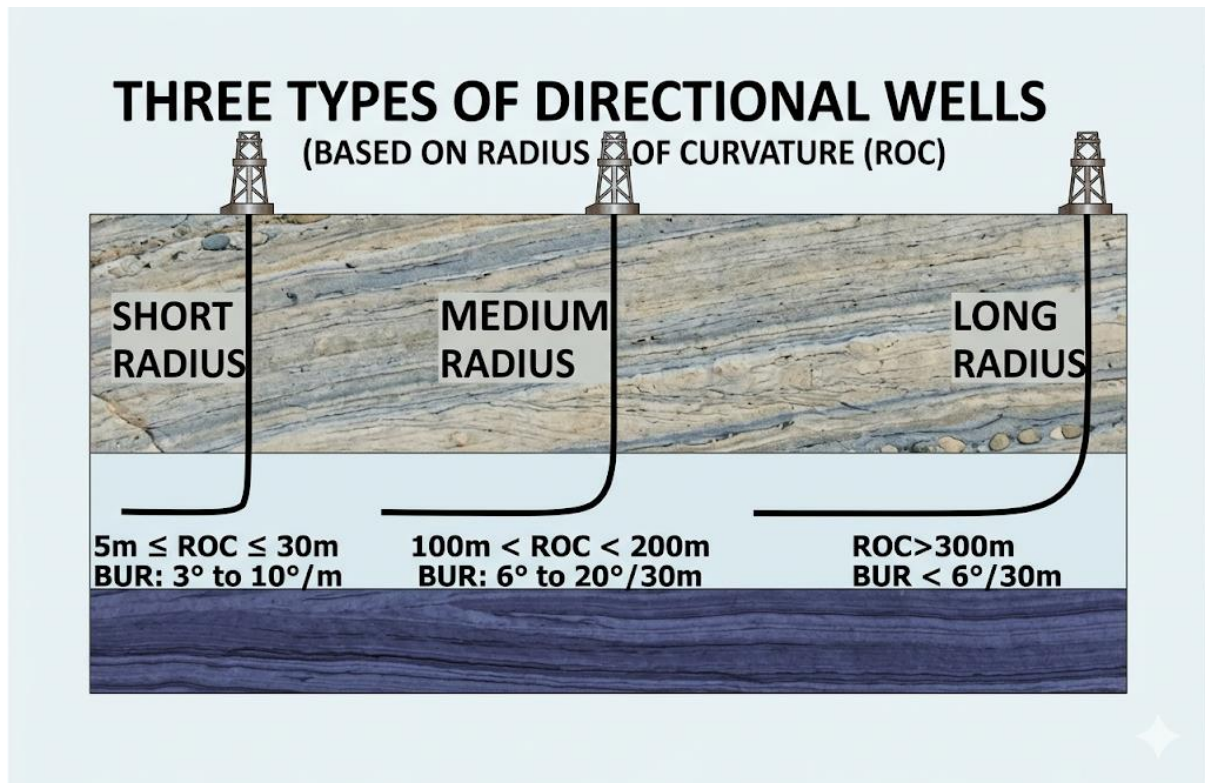


Fig I. 13:Directional Wells types.

IV.1 Wells with a Long Radius:

IV.1.1 Advantages:

The easiest to implement in terms of standards of operation are wells with a long radius because they do not require the use of any downhole motors in most cases (i.e. only normal rotary drilling equipment is used). Drill pipe and casing strings can be used without modification, and the daily expense associated with directional service is generally less than that of either medium or short radius operations, leading to long radius wells being the most economical direction when geological and geometrical parameters permit.

In addition to being able to drill longer horizontal holes than 1,500 metres, long radius wells provide operators with the ability to drill to targets that are at great lateral distances from the surface point of the well. Long radius wells are totally compatible with all types of conventional wireline logging suites, completion systems, stimulation methods, workover intervention and standard gas lift equipment, providing maximum flexibility during the life of the well.

IV.1.2 Disadvantages:

The greater depth to which measurements must be taken from a wellbore on a long radius trajectory will necessitate the use of a larger drilling rig and corresponding associated facilities such as a top-drive system, pumps with increased capacity, larger capacity mud storage and treatment tanks, etc., resulting in increased capital expenditure for these facilities. The longer trajectory to be drilled without casing or "open hole", can significantly increase the likelihood of the occurrence of stuck pipe problems, formations providing formation

fluids into the wellbore, and well bore wall collapses, necessitating additional and unplanned cased hole.

As the lateral separation between the Kick-Off Point and the target increases, it becomes increasingly difficult to land the wellbore at the target vertical depth, though this is less of an issue as accurate real-time MWD tools become more readily available. Long radius wells can only be drilled where the surface concession is very large because to gain 90 vertical the required lateral departure will be beyond the property line.[6]

IV.2 Medium Radius Wells:

IV.2.1 Advantages:

Landing accuracy in the target formation at the bottom of the wellbore on medium radius trajectories is greater than the equivalent on long radius trajectories, and as such this is the most popular deviation configuration in modern onshore operations. It is acceptable to use both standard-size MWD collar and retrievable slim-hole MWD (1" OD) tools as well as standard steerable motor assemblies. Coring at the target formation at up to 1500m horizontally can be attained using this trajectory. Conventional casing and completions are used, allowing full use of all conventional workover, stimulation, and production improvement technologies available throughout the life of the well.

IV.2.2 Disadvantages:

Due to the higher dog-legs within the wellbore it is not possible to transmit weight-on-bit through a long radius trajectory as efficiently, this can result in less than optimal ROP and directional control in the build section as the drilling components are under greater torsional strain, greater stress and therefore increased fatigue. The components used downhole must be sufficiently robust to handle the increased bending, torsional, and buckling forces.

For wellbores with diameters equal to and smaller than 6 inches, the options for MWD/LWD tools, casing, completions, wireline logs and workovers are highly limited for that well's entire life[11]

IV.3. Short radius wells:

IV.3.1. Advantages:

Short radius wells are the most precise in both vertical and horizontal positioning and are ideal for the exploitation of small concessions or very thin reservoir lenses where the true subsurface position of the reservoir is known with a high degree of certainty. Since most short radius work involves completing existing wellbores with a sidetrack, the initial completion cost is much less because existing infrastructure such as the wellhead and associated services, casing strings and civil and pipeline works are already available.

The kick off point is usually situated below the gas-oil contact, minimizing the potential for poor zonal isolation of reservoir fluids in contrast to medium and long radius wells. Moreover placing artificial lift below deeper, the bottom hole drawdown pressure decreases, therefore

well deliverability and lifetime are increased. It can also be effectively utilized to overcome gas and water conning and recover wells which have fish stuck in the existing wellbore.

IV.3.2. Disadvantages:

Short radius wells necessitate use of highly specialized bottom hole assemblies consisting of flexible and articulating motors, flexible components to the BHA and slim-hole MWD tools. These tools are inherently slower to manipulate on the rig floor, mechanically weaker than a normal API rated tool string and may not withstand the high bending loads within the curve section.

A low ROP and a much lower drill bit life mean that more frequent round trips will be needed to change the drill bit or reconfigure the BHA. These significantly add to non-productive time and hence the well cost. The maximum horizontal drain length is limited to 150m although can be up to 300m in the ideal case and does not allow for conventional coring or deferred wireline logging in the drain section. It only allows for open-hole completion methods and highly flexible completion strings, greatly restricting possible production and stimulation schemes.[12]

V. History and Importance of Short Radius Drilling:

V.1. Historical Background:

Short radius drilling began as a solution to the problem of revitalizing old oil fields and recovering hydrocarbons from places where it was too difficult or too expensive to drill straight down using traditional vertical drilling techniques. As horizontal drilling has become more mainstream since the mid-1980's and transitioned from an experimental process to a typical way of drilling for oil, it provided new opportunities for drilling horizontally instead of just vertically out of a single hole.[13]

Short radius drilling became popular in the early 1990's primarily because of advances in articulate downhole motors, flexible Measurement While Drilling (MWD) systems, and high-yield strength tubing that can withstand severe bending forces. As a result, operators could re-enter existing vertical wells and drill longer laterals with very small bend radii, enabling the recovery of reserves that had previously been uneconomic to exploit without drilling from a new surface location..[12]

V.2. Short Radius Drilling in Algeria — Historical Milestone:

The first short radius sidetracking in Algeria was performed in Hassi Messaoud in the mid-90s and represented the beginning of a paradigm shift regarding well reactivation and production optimization. This pioneering implementation of short radius technology allowed for the demonstration of technical success in the ultra-hard and abrasive Cambrian sandstone reservoir formations of Hassi Messaoud that had previously presented problems for standard drilling and stimulation technologies.

Following the success of this campaign, SONATRACH implemented a widespread short radius re-entry program across the field utilizing hundreds of vertical shut-in or under-

performing wells that were considered for short radius sidetracking, allowing them to unlock the potential of previously unrecoverable reserves for drastically reduced cost per barrel of incremental production. This program represented a transition away from a new well drilling philosophy towards a wellbore rehabilitation philosophy and demonstrated the economic advantages in utilizing existing infrastructure. The introduction of short radius wells at Hassi Messaoud and close interaction between SONATRACH engineers and service providers made possible further optimization of motor choice, bit design, and BHA configuration appropriate for the local geology that allowed for the reduction of total drilling cost of over 30% when compared to initial short radius programs run in the field.[14]

VI. Importance of Short Radius Drilling:

VI.1 Reservoir Contact and Production Enhancement:

Short radius drilling has great significance due to its capacity to tremendously enlarge the contact surface area between the wellbore and the reservoir to be produced. Short radius drilling reconfigures the well trajectory from a vertical well toward a near-horizontal well within the pay zone, hence enlarging the contact of reservoir rock along with wellbore. In doing so, the well productivity index increases and pressure draw down needed to maintain certain flow rate drops down.

The improvement of the well productivity index can be quantified as Production Flow Rate (q) divided by the pressure difference between the reservoir and the flowing bottomhole:

$$PI = \frac{Q}{P_r - P_{wf}} (m^3/d/bar) \quad (1.5)$$

Where:

- Q = production flow rate (m^3/d)
- P_r = static reservoir pressure (bar)
- P_{wf} = flowing bottomhole pressure (bar)

By increasing the length of the wellbore that is in contact with the reservoir, the Short Radius wells result in a smaller differential pressure ($P_r - P_{wf}$) necessary to achieve the same flow rate Q and thus higher PI. Field results from Hassi Messaoud illustrate consistent PI increases from 2 to 5 times higher than the initial vertical completion in the same well which is a confirmation that this method is a valuable technique to apply for the management of mature fields..[12] (figure:I.14)

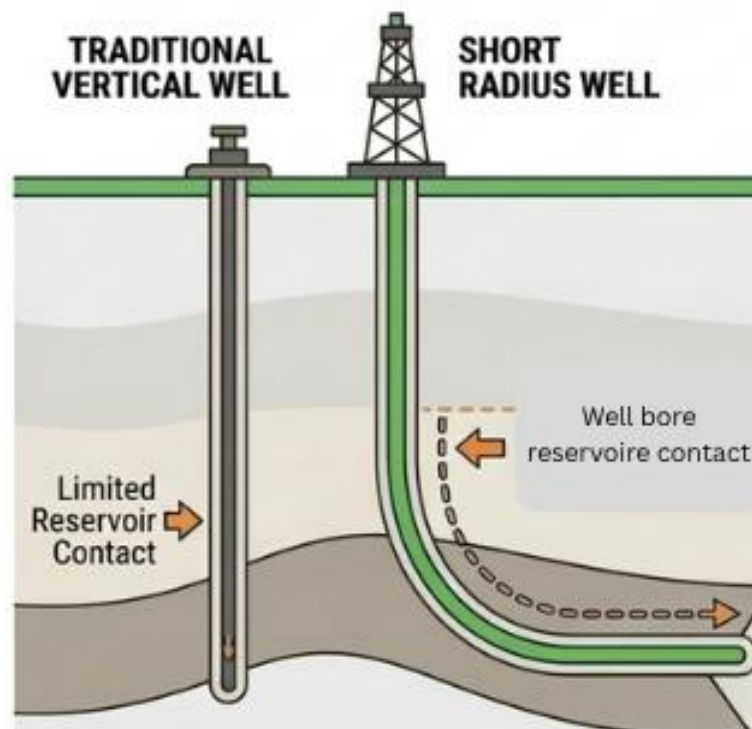


Fig I. 14:Short-Radius Horizontal Drilling and Reservoir Contact Optimization.

VI.2 Re-Entry and Field Rejuvenation:

Of all field revitalization techniques, short radius drilling has proven to be the most economical. Particularly in mature fields, a vast inventory of shut-in/abandoned vertical wells constitutes a valuable but undeveloped resource. Given that the wellbore infrastructure such as the wellhead, surface casing and production facility can be utilized for short radius drilling from a shut-in well, the marginal capital required to place the shut-in well back in production is a fraction of the capital required to drill a new well from surface..[13]

VI.3 Resolution of Production Problems:

In addition to providing new drainage area, the short radius lateral offers specific solutions to the following production impairment mechanisms: The horizontal aspect of the drain portion dramatically increases the critical flow rate where gas or water coning may become an issue, which extends the time during which the well produces under single-phase oil conditions. In wells where damage or depletion is in the vicinity of the vertical completion, short radius laterals can allow by-pass the problematic interval and encounter natural fracture networks at a more favorable angle thereby significantly enhancing production.

VI.4 Strategic Importance for Mature Fields:

As a wider field development concept, short radius drilling fits perfectly into the late life production plan for an aging oil field. As the rate of production from primary recovery slows

down, and pressure in the reservoir drops off, the opportunity to add significant drainage volumes without having to incur the capital expenditure required to develop new surface infrastructure through the use of existing well slots renders the approach technically and commercially attractive. Indeed at Hassi Messaoud, the relevance of the technique is reflected in the fact that a considerable amount of the current production comes from re-entry horizontal wells..[14]

VII. Strategic Applications of Short-Radius Technology:

Based on the advanced engineering principles of horizontal completion, Short-Radius (SR) drilling is utilized as a specialized solution for reservoir management where conventional geometric profiles fail to meet technical objectives. The primary applications are summarized as follows:

Exploitation of Attic Oil and Bypassed Zones

SR drilling can also access attic oil that will not be produced by vertical wells, because the kick-off point can be very near the structural high. (Figure I.16)

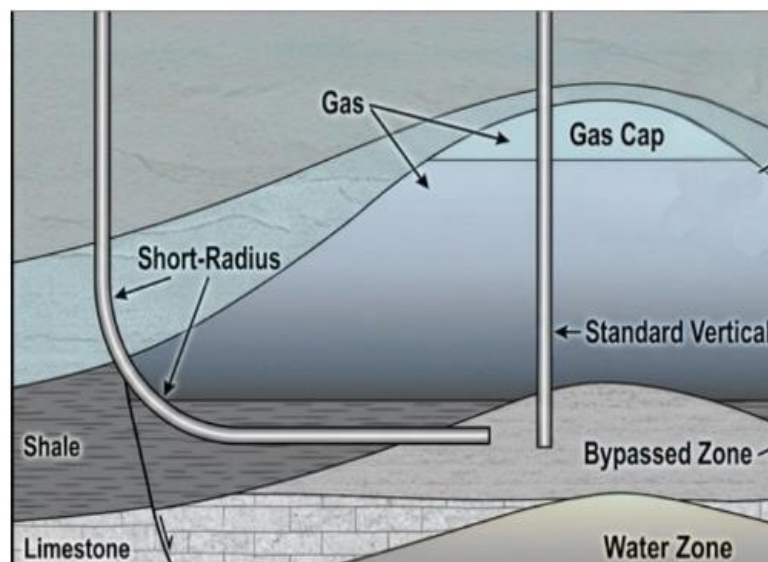


Figure I.16: Exploitation of Attic Oil and Bypassed Zones

Fracture Intersection in Tight Formations

For low-permeability reservoirs, as in fractured carbonated or tight sandstones, high SR wells build-up rate can enable multiple vertical natural fractures intersected within the confined drainage area, so that PI value increases exponentially. (Figure I.17)

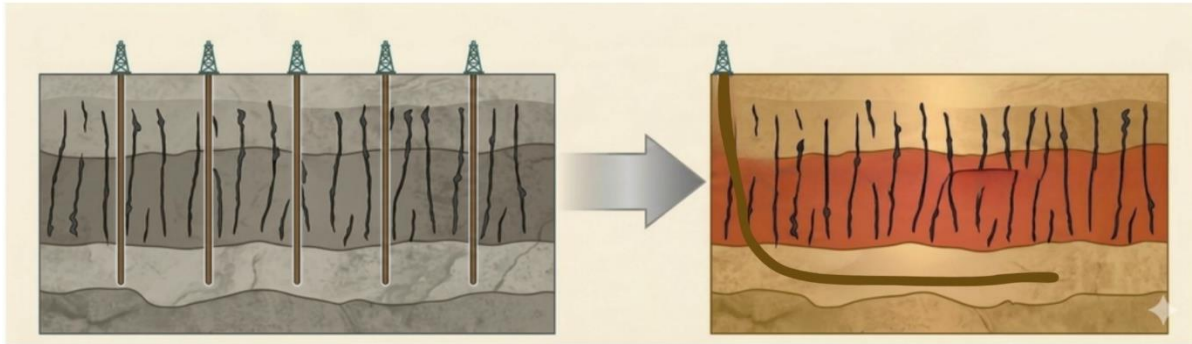


Figure I.17: Short-Radius Well Intersecting Vertical Natural Fractures.

Controlled Drainage in Thin Pay Zones

The Controlled Drainage ability of SR is maximized through the horizontal installation of SR into a vertical (TVD) well such that the length of the horizontal lateral lies entirely within the thin producing interval and, therefore, does not move out of the target formation.

Enhanced Oil Recovery (EOR) in Mature Fields

SR is also used as a cost-effective method for sidetracking existing wellbore (mechanically failed and depleted) with the use of the existing surface facilities and casing to access the reservoir at a lower cost than drilling a new hole [15].

Chapter II: Fundamentals of Directional Drilling: Profiles, Tools, and Equipment.

II-1. Introduction:

In the oil and gas industry, the ability to reach hydrocarbon reservoirs that are not located directly beneath the drilling site has become an essential requirement in modern well construction. Directional drilling is the technique by which a wellbore is intentionally deviated from the vertical to reach a predetermined target in the subsurface, offering significant advantages in terms of reservoir access, surface constraints, and field development efficiency.

Over the decades, directional drilling has evolved from a remedial technique into a highly planned and precisely executed engineering discipline. It is now widely applied in offshore platforms, where multiple wells are drilled from a single location, in horizontal and multilateral well configurations designed to maximize reservoir contact, and in complex geological settings where vertical drilling alone would be insufficient.

This chapter provides a comprehensive overview of the fundamental aspects of directional drilling. It begins by presenting the different wellbore trajectory profiles commonly used in the industry, each designed to suit specific geological, technical, or economic requirements. It then examines the key equipment and tools employed to plan, execute, and monitor directional drilling operations, including bottom hole assemblies, measurement while drilling systems, and steerable technologies.

A thorough understanding of these concepts is essential for any drilling engineer, as directional drilling continues to play a critical role in optimizing well placement and maximizing hydrocarbon recovery.

II-2. Different Directional Drilling Profiles:

The profile or shape of a well is the interval between the point located at the surface and the target(s). The conventional profiles are:

II-2-1. J-Shaped Wells:

This is the simplest and most common form of deviated well. It begins with a vertical section, followed by a build-up section, and ends with a straight section.

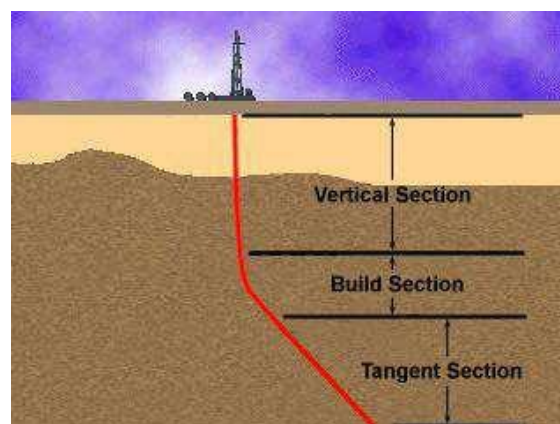


Fig II. 1:Profile of a J-Shaped Well.

II-2-2. S-Shaped Wells:

With a slightly more complex shape, these wells begin like a J-shaped well, but end with a drop in inclination, sometimes returning to the vertical position.

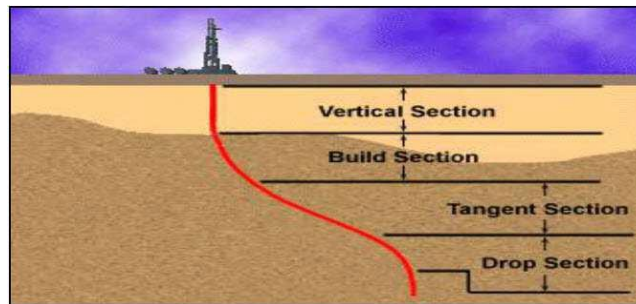


Fig II. 2:Profile of an S-Shaped Well.

II-2-3. Long-Reach Wells (Extended Reach Wells):

These are wells with a horizontal displacement of several kilometers, drilled at a high inclination and ending with a horizontal drain.[16]

II-2-4. Multilateral Wells:

This technique consists of drilling several lateral drains from a main wellbore, using a single wellhead.

II-2-5. Double Build-Up Wells:

Compared with S-shaped wells, these wells end with a second significant increase in inclination.

II.2.6. Slant Wells (Tilt or Slant Wells):

These are wells with an inclination starting from the surface, which may reach 45 degrees, and require a special drilling rig (tilt or slant rig). The use of this technique makes it possible to reach the horizontal section in shallow reservoirs.[16]

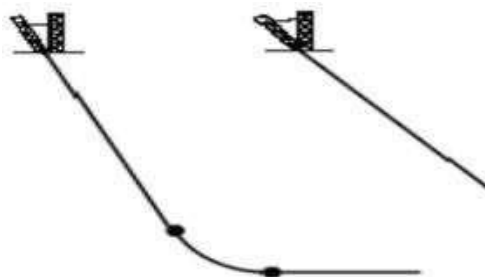


Fig II. 3:Profile of an Inclined Well.[19]

II-2-7. Horizontal Wells:

Horizontal drilling is a J-shaped directional well whose inclination is close to 90°. It is drilled within the reservoir in order to increase production according to the reservoir characteristics. [16]

II-3. Selection of the Horizontal Well Profile:

Well Curvature: Curvature depends on the gradient, inclination, and azimuth of the drilled trajectory. It is commonly defined by the term Dog Leg Severity (DLS) or Build-Up Rate (BUR) when the azimuth is constant. The selected trajectory profile depends on the well design. [20]

Another important aspect is selecting the most appropriate well profile for production purposes.

II-3-1. Long Radius:

Long Radius (LR) wells have a large radius of curvature: $ROC > 300$ m with $BUR < 6^\circ/30$ m. These profiles are particularly used for offshore wells and extended reach drilling (ERD) wells. [11]

II-3-2. Medium Radius:

These wells have a radius of curvature such that: $100 \text{ m} < ROC < 200$ m, with BUR ranging between 6° and $30^\circ/30$ m. These profiles, typically used for onshore drilling, were mainly developed in the United States to maximize horizontal drain length within relatively small lease areas. The drilling equipment used for medium-radius wells is limited by the clearance between the borehole and the drill string. Generally, modified versions of conventional long-radius equipment are used to withstand torsion and buckling. The maximum doglegs generated in sliding/orienting mode are approximately $16\text{--}20^\circ/30$ m.

II-3-3. Short Radius:

Short-radius wells have a radius of curvature: $5 \text{ m} \leq ROC \leq 20$ m, corresponding to a build-up rate between 3° and 10° per meter.[22]

Importance of Re-Entry in Ohanet:The main objectives of re-entry wells in Ohanet are:

- Solving water or gas breakthrough problems;
- Optimizing the number of development wells;
- Lowering abandonment pressure;
- Increasing total recovery;
- Draining zones with better petrophysical characteristics;
- Producing at a higher flow rate for the same ΔP (low drawdown).

Re-entry wells must satisfy the following conditions:

- Avoid the water zone;
- Avoid gas zones or the drainage radius of water or gas injection wells;
- Avoid dry zones;
- Avoid water zones for wells located on the flank of the structure or in water injection areas;
- Avoid gas zones for wells with high GOR.[17]

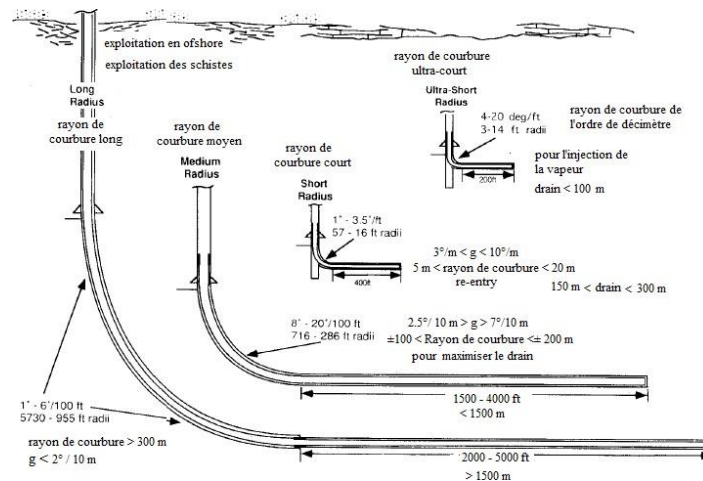


Fig II. 4:Profiles of Horizontal Drilling.[23]

II-3-4. Ultra-Short Radius:

This is the newest horizontal drilling method. It involves high-pressure jetting of a semi-horizontal drain, with a radius of curvature on the order of a few decimeters. These ultra-short radius wells are mainly used for steam injection.[20]

II-4. Directional Drilling Equipment:

II-4-1. Measurement Equipment:

II-4-1-1. Objectives of Measurements:

- Avoid bends and doglegs that generate friction, sticking, and drill string failure;
- Follow the planned theoretical trajectory as closely as possible in order to reach the target;
- Allow possible intervention or well killing in case of a blowout (relief well).[21]

II-4-1-2. Measurements :

Measurements concern inclination, azimuth, and drilled length. They are taken at specific intervals according to the drilling program and depend on the equipment used, whose precision is generally of the order of centimeters or decimeters. [21]

II-4-1-3. Types of Measurements and Their Sensors:

Measurements are performed to determine depth, inclination, and azimuth using sensors operating according to either gyroscopic or magnetic principles, including:

- Magnetic systems → detect the Earth's magnetic field using terrestrial gravity;
- Gyroscopic systems → based on inertia and referenced to true north.

Length: The drilled depth (tool displacement) can be determined by:

- Adding the lengths of drill pipes and drill collars (each known within ± 5 mm);
- Measuring the length of the wireline cable carrying the logging tool.

Inclination: Inclination can be measured using simple sensors such as inclinometers or accelerometers.

Inclinometer: A sensor used to measure deviation relative to the vertical line.

Accelerometer: A sensor fixed to a moving object or device that measures its linear acceleration. Examples of instruments using accelerometers include Steering tools and MWD (Measurement While Drilling) systems.

Azimuth: The geographical position of intermediate targets according to magnetic or geographic reference systems can be determined using: Magnetic needle; Magnetometer; Gyroscope (an angular position sensor that provides angular orientation). [9]

Inertial System: An inertial navigation unit designed to provide position, velocity, and acceleration data from a precise reference. [21]

Measurement While Drilling (MWD):

- Advanced measurement systems: highly sophisticated MWD systems capable of measuring inclination, gamma ray, tool face, azimuth, and resistivity using accelerometers and magnetometers, located in a sub positioned just behind the drill bit (geo-steerable systems);
- Rotary steerable systems.

II-4-2. Equipment Used in Directional Drilling Operations:

During the drilling of a deviated well, both standard and specialized drilling equipment are used. Each component must be carefully selected according to several factors such as: the nature of the formations to be drilled; the physical and mechanical properties of the material; and the type of operation to be performed (straight drilling, vertical drilling, doglegs, etc.). [20]

II-4-2-1. Standard Equipment:

II.4.2.1.1. Drill Collars (DC):

Drill collars can help initiate, maintain, or eliminate deviation. This depends on selecting their optimum weight, dimensions (diameters), and materials (modulus of elasticity), since drill collar rigidity is related to the bending moment of inertia. There are several types of drill collars depending on their applications, such as:

- Slick drill collars (Slick DC);
- Spiral drill collars (Spiraled DC);
- Square drill collars (Squared DC).[21]

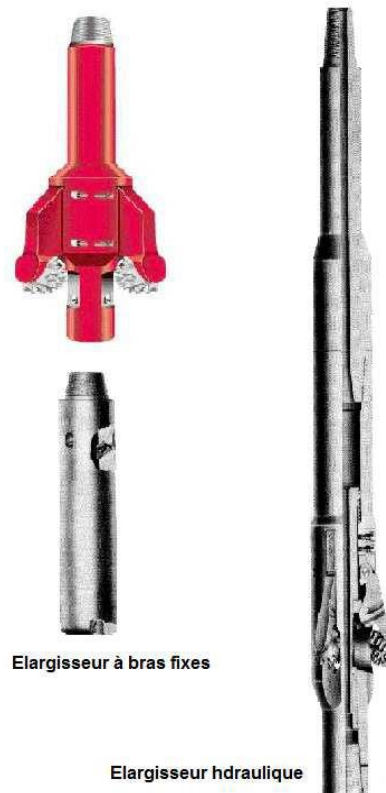


Fig II. 5:Types of Drill Collars.[20]

II.4.2.1.2. Hole Openers (Reamers):

Several reasons require first drilling a small-diameter hole before enlarging it,including:

- Safety: to detect or control a kick;
 - Evaluation: to perform quality logging;
 - In directional drilling: to ensure good control;
 - Possibility of program change: in case of risk of abandonment or need for a sidetrack.
- [21]

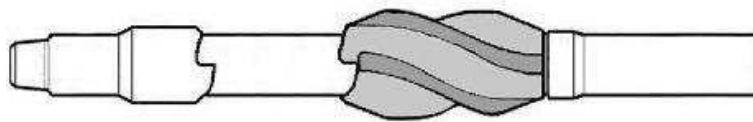


Fig II. 6:The Two Types of Hole Openers.[18]

II-4-2-1-3. Key-Seat Wipers:

A sleeve sliding over a mandrel equipped with aggressive blades around its circumference. It slides and rotates freely while running in hole or during drilling, and locks while pulling out on a lug. It is used to: maintain the diameter of a hole that tends to tighten; reduce doglegs; prevent or eliminate key seats.[21]

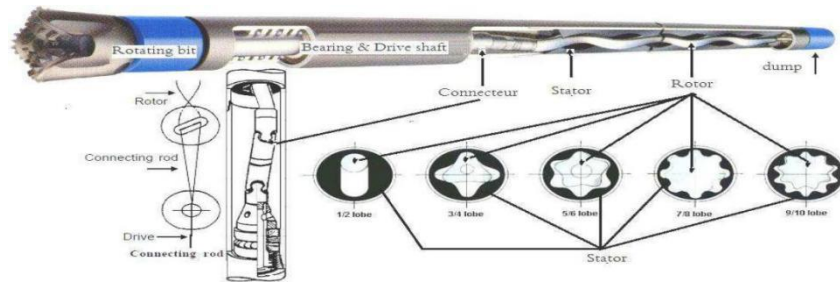


Fig II. 7:Key-Seat Wipers.[18]

II-4-2-2. Equipment Specific to Directional Drilling [23]:

II-4-2-2-1. Downhole Motors:

There are two types of downhole motors:

Positive Displacement Motors (PDM) — Hydraulic or Positive Displacement Motors:

Their main components are:

- The rotor: a helical stainless-steel component;
- The stator: an elastomer molded in the shape of an internal helix with one additional lobe compared to the rotor.

When drilling fluid is pumped through the motor, a pressure increase occurs, causing the rotor to rotate and allowing the fluid to pass into the adjacent cavity. The fluid then progresses from one cavity to another, generating continuous rotation of the rotor. The rotation speed is proportional to the flow rate through the motor.

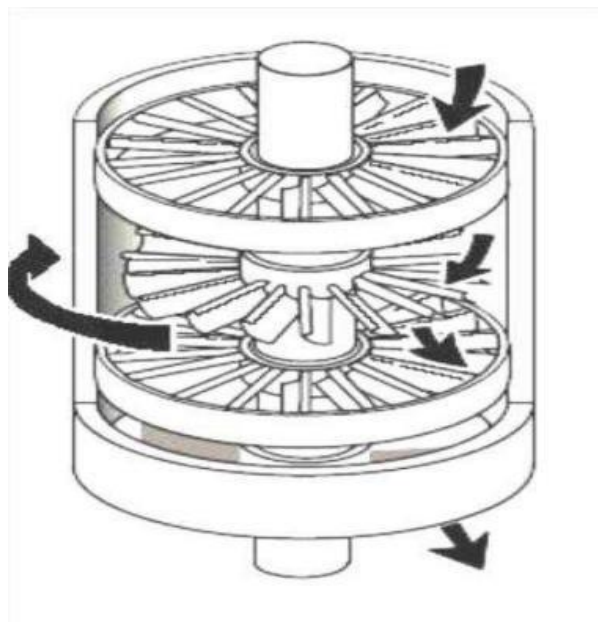


Fig II. 8:Geometry of a PDM.

Turbodrills: Turbodrills directly drive the drill bit. They are multi-stage axial-flow devices, where each stage consists of: a stator equipped with blades (vanes) that distribute the drilling mud; an identical rotor that converts the fluid flow into driving torque.

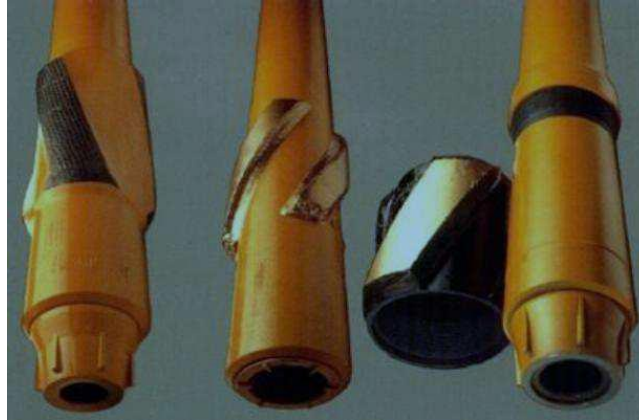


Fig II. 9:Turbodrill.[18]

II-4-2-2-2. Stabilizers:

Stabilizers are tools composed of blades mounted on tubular bodies having the same section as the drill collars. The blade diameter is equal to or smaller than that of the drill bit. These blades centralize the drill collars in the wellbore through several contact points. Stabilizers can be installed either:

- Directly above the drill bit → near-bit stabilizers;
- Higher in the BHA (Bottom Hole Assembly) → string stabilizers.

There are several types of stabilizers depending on blade design,such as:welded-blade stabilizers;integral-blade stabilizers;sleeve stabilizers; non-rotating sleeve stabilizers; variable-diameter stabilizers; clamp-on stabilizers.

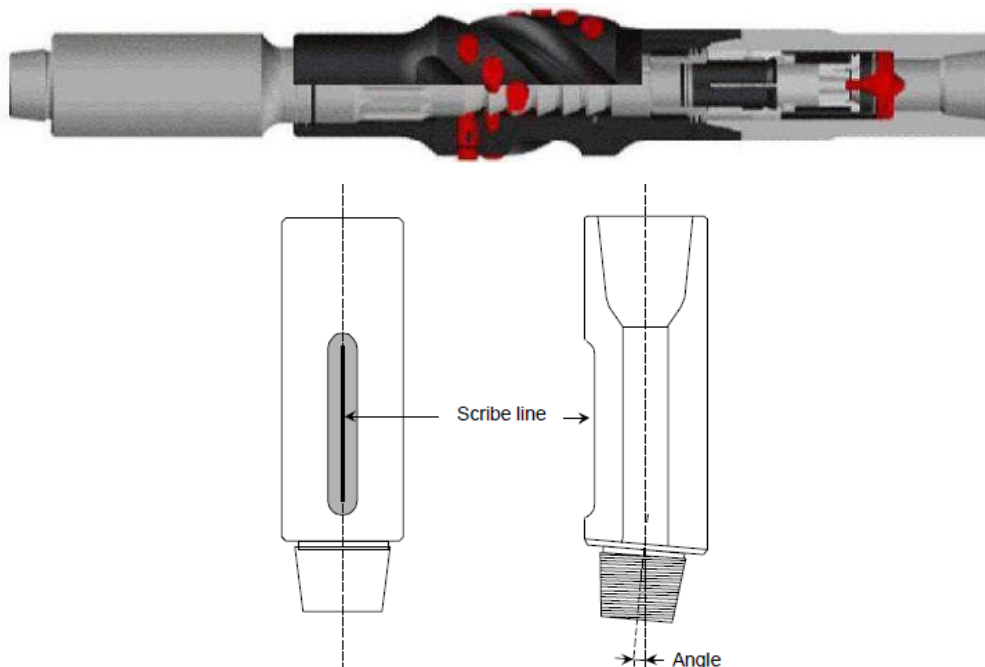


Fig II. 10:Integral-Blade,Welded-Blade,Sleeve-Type,and Variable-Diameter Stabilizers.[21]

II-4-2-2-3. Non-Magnetic Equipment:

For the proper use of magnetic measuring instruments, it is necessary to use so-called non-magnetic materials near the measurement sensors. These non-magnetic materials may include: aluminum; high-quality stainless steels; alloys such as Monel (70% nickel + 30% copper).

II-4-2-2-4. Subs:

Orientation Subs: Their lower end is designed to house measurement instruments and they are generally made of non-magnetic materials.[21]

Side Entry Subs: Used to house measurement instruments, such as the steering tool, through a sleeve system.

Bent Subs: Used to offset the downhole motor (including the drill bit) relative to the well axis. They are installed directly above the downhole motor and are manufactured either from standard steel or non-magnetic steel.

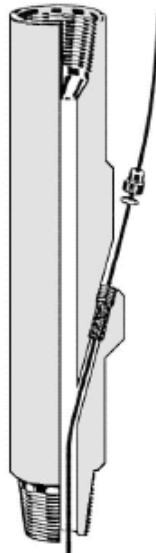


Fig II. 11:Connections.[20]

II-4-2-2-5. Deflection Tool (Whipstock):

A whipstock is a steel wedge whose inner surface is concave, on which the drilling tool rests. It is used to deflect the drilling assembly toward the wellbore wall and exit from the original well. There are permanent or retrievable whipstocks, orientable or non-orientable. They can be used in open hole operations to perform a sidetrack or start a lateral drain, or inside casing to open a window for re-entry operations.

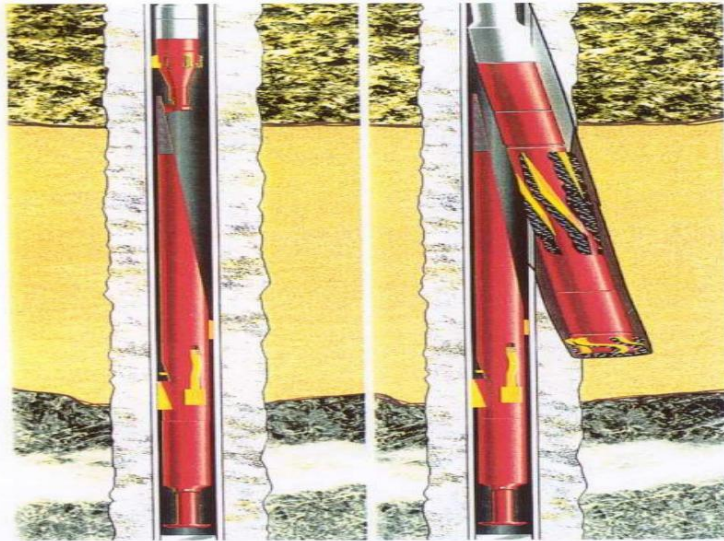


Fig II. 12:Deflection Tool (Whipstock).[18]

Chapter III:

Trajectory Control

III. Trajectory Control:

III-1. Introduction:

In order to reach the target and avoid missing it, a precise trajectory calculation must be carried out while selecting the simplest, most practical, and most suitable calculation method for the field. However, this alone is not sufficient to obtain good results; rigorous trajectory control is required to avoid missing the objective.

It can be summarized as follows: measure, calculate, represent, extrapolate, and decide. Currently, a large number of trajectory calculation methods have been developed to determine the position of the well in geometric space; all of them are derived from trigonometric considerations.

The establishment and determination of the trajectory of a deviated well, before and after its execution, is necessary for both technical and administrative reasons.

- Before execution → theoretical trajectory (planning).
- After execution → actual trajectory (execution).[28]

III-2. Calculation Principle:

The calculation is performed point by point, with the origin being a surface point. The method used consists of taking measurements at regular intervals and, using the obtained parameters, determining step by step and through calculation the position of the well. This position is considered the actual position of the well.

If necessary, errors resulting from measurement operations are taken into account in order to evaluate the "uncertainty domain" in which the well is actually located.

Actual profile → several stations according to the drilling program:

- Drilling rate (e.g., every 100 m);
- Geological formations encountered;
- Geometric position of the well at a given depth (any point along the trajectory / intermediate station).

Physically measurable parameters at a given depth (any point along the trajectory / intermediate station):

- $L \rightarrow$ depth [m]
- $I \rightarrow$ inclination [$^{\circ}$]
- $A \rightarrow$ azimuth [$^{\circ}$] [27]

III-2-1. Initial Conditions and Options: [29]

The determination of a number of initial parameters and options is necessary for trajectory calculation:

a) Reference Level: All depths are measured from this point, namely:

- Rotary table level (RT or KB for Kelly Bushing);

- Ground level;
- Sea level (or hydrostatic level).

b) Coordinate System: The choice of system varies from country to country and depends on both local authorities and the oil company. Commonly used systems are:

- UTM (Universal Transverse Mercator);
- Lambert system;
- Polar coordinates.

The coordinate system to be used must be defined in the drilling program, along with associated parameters: X, Y, Z coordinates of the wellhead; magnetic declination; convergence if necessary.

c) Calculation Method: The calculation method is defined by the drilling program.

d) Projection Azimuth: The projection azimuth required for vertical projection is usually chosen equal to the target direction. Several azimuths may be used in the case of three-dimensional wells.

e) Inclination: It is the angle between the vertical and the well axis. The measurement principle consists of detecting the deviation angle relative to the gravitational field using pendulums or accelerometers. [28]

III-2-2. Dog-Leg Calculation:

Dog-leg refers to the overall or three-dimensional change (curvature gradient) in direction, involving both inclination and azimuth simultaneously. There are two types of dog-legs:

- Desired dog-legs resulting from directional drilling procedures;
- Undesired dog-legs resulting from geological phenomena or drilling errors, which may have unwanted consequences on well construction.

In practice, dog-legs are:

- Normal or circular, corresponding to the average curvature of the well;
- Abnormal or abrupt, occurring during sudden changes in well direction.

Dog-leg calculation is empirical; it is based on assumptions and approximations. It is expressed in [$^{\circ}/10$ m], [$^{\circ}/30$ m], and [$^{\circ}/100$ ft]:

$$DL = \cos^{-1} [\cos I_1 \cos I_2 + \sin I_1 \sin I_2 \cos(A_2 - A_1)] [29] \quad (\text{III. 1})$$

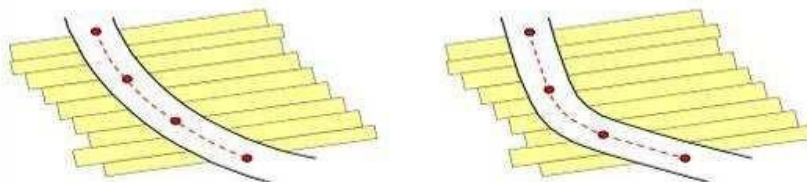


Fig III. 1: Dog-leg and Wellbore Curvature. [26]

Dog-Leg Severity (DLS):

$$DLS = DL / L \quad (\text{III. 2})$$

$$DLS = (DL \times 100) / L \quad (III. 3)$$

Where: A = azimuth; I = inclination; L = length.[25]

III-2-3. Toolface:

Toolface is the angle defined by the vertical plane passing through the axis of the motor located above the bent sub and the plane defined by the same axis and the axis of the motor section located below the bent sub. It is an angle that characterizes the direction of the drilling tool relative to the wellbore axis.

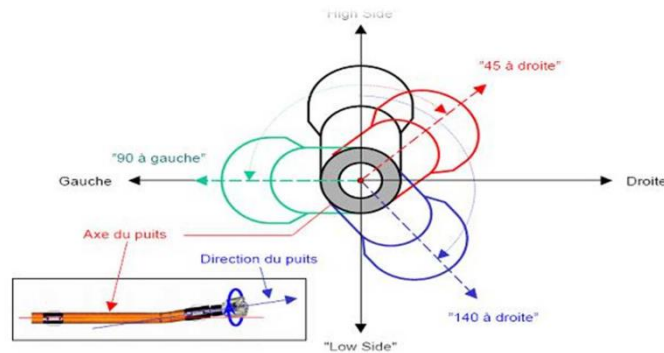


Figure III.2 : TOOL-FACE.[1]

Fig III. 2:Toolface. [24]

III-2-4. Maximum Available Weight at the Bit:

One of the essential functions of the drill string is to provide the force required for the advancement of the drilling tool. The maximum weight on bit that can be provided by a section of the drill string can be calculated using the following formula:

$$P_s = LW \cdot Bf \cdot Hv \quad (III. 4)$$

Where:

- P_s : thrust provided by the section
- LW : actual linear weight in air of an element of the section
- Bf : buoyancy factor
- Hv : length of the vertical projection of the section [25]

III-3. Calculation Methods: [29]

A large number of methods have been developed to determine the position of the well in geometric space. All of these methods are derived from trigonometric considerations:

III-3-1. Tangential Method :

Parameter	Description
Assimilation	Segment ab is assimilated to segment ab', parallel to the tangent at point b to the actual trajectory, where inclination α_2 and A_2 are measured at point b.
z (elevation)	$L \cos \alpha_2$
d (departure)	$L \sin \alpha_2$
x (longitude)	$D \sin A_2 = L \sin \alpha_2 \times \sin A_2$
y (latitude)	$D \cos A_2 = L \sin \alpha_2 \times \cos A_2$
Disadvantage	Lack of accuracy; calculated trajectory is far from the actual trajectory; in build-up sections: the calculated vertical depth is less than the real depth; the calculated departure is greater than the actual departure.
Advantage	Simple calculation.
Use	Abandoned (deviation between calculated and actual trajectory).

Table III. 1:Characteristics of the Tangential Method.

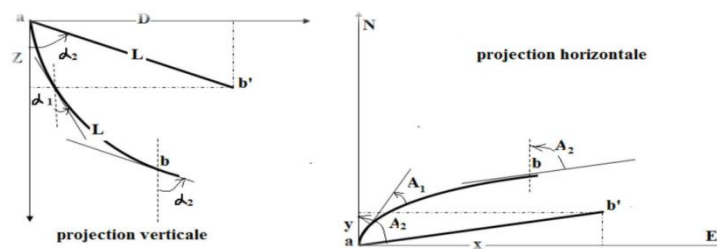


Fig III. 3:Tangential Method.

III-3-2. Average Angle Method:

Presented by J.E. Edison in 1957.

Parameter	Description
Assimilation	The drilled section is approximated as a straight-line segment of the same length, with $\alpha = (\alpha_1 + \alpha_2) / 2$ and $A = (A_1 + A_2) / 2$.
z (elevation)	$L \cos \alpha$
d (departure)	$L \sin \alpha$
x (longitude)	$L \sin \alpha \times \sin A$
y (latitude)	$L \sin \alpha \times \cos A$

Disadvantage	In build-up: calculated vertical depth is greater and departure is shorter than reality. In drop-off: the opposite occurs.
Advantage	Simple calculation.
Use	Does not require a computer.

Table III. 2:Characteristics of the Average Angle Method.

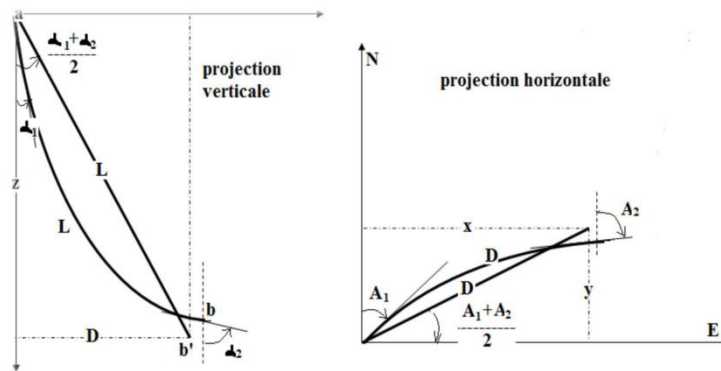


Fig III. 4: Average Angle Method.

III-3-3. Weighted Tangential Method (Balanced Tangential Method):

Presented by J.E. Walstrom in 1971.

Parameter	Description
Assimilation	The drilled section is approximated as two consecutive straight-line segments of equal length, where $L' = L / 2$, with α_1 and A_1 at point a, and α_2 and A_2 at point b.
z (elevation)	$L' (\cos \alpha_1 + \cos \alpha_2)$
d (departure)	$L' (\sin \alpha_1 + \sin \alpha_2)$
x (longitude)	$L' (\sin \alpha_1 \times \sin A_1 + \sin \alpha_2 \times \sin A_2)$
y (latitude)	$L' (\sin \alpha_1 \times \cos A_1 + \sin \alpha_2 \times \cos A_2)$
Disadvantage	In build-up: calculated vertical depth is greater and departure is shorter than reality. In drop-off: the opposite occurs.
Advantage	Good accuracy.
Use	Relatively difficult manual calculations.

Table III. 3:Characteristics of the Weighted Tangential Method.

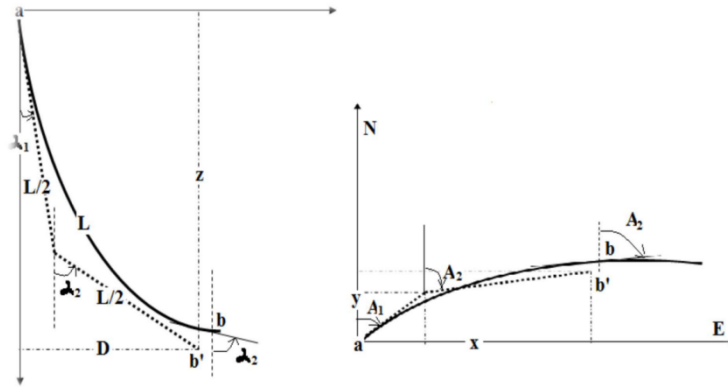


Fig III. 5:Weighted Tangential Method.

III-3-4. Radius of Curvature Method:

Presented by G.J. Wilson in 1968.

Parameter	Description
Assimilation	The drilled section is approximated as a curve lying on a cylindrical surface with a vertical axis. The vertical and horizontal projections of this curve are assumed to be circular arcs whose radii are calculated based on: inclination gradient $(\alpha_2 - \alpha_1) / L$; azimuth gradient $(A_2 - A_1) / L$.
z (elevation)	$[(180/\pi) \times (L / \alpha_2 - \alpha_1)] (\sin \alpha_2 - \sin \alpha_1)$
d (departure)	$[(180/\pi) \times (L / \alpha_2 - \alpha_1)] (\cos \alpha_1 - \cos \alpha_2)$
x (longitude)	$[(180/\pi) \times (D / A_2 - A_1)] (\cos A_1 - \cos A_2)$
y (latitude)	$[(180/\pi) \times (D / A_2 - A_1)] (\sin A_1 - \sin A_2)$
Advantage	Very high accuracy.
Use	Requires computer-based calculation.

Table III. 4:Characteristics of the Radius of Curvature Method.

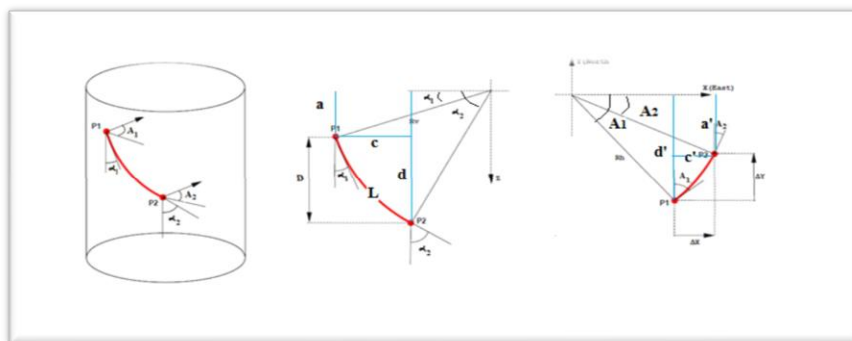


Fig III. 6:Radius of Curvature Method.

III-3-5. Minimum Curvature Method:

Presented by W.A. Zaremba in 1973.

Parameter	Description
Assimilation	Calculated from the tangents at points A and B, by introducing a correction coefficient. The resulting computation assumes that the AB trajectory is a circular arc. Point B' is determined using: $K = (\Delta L / DL) \times (180/\pi) \times \tan(DL/2)$. Dog-leg (DL) is given by: $DL = \cos^{-1}[\cos \alpha_1 \cos \alpha_2 + \sin \alpha_1 \sin \alpha_2 \cos(A_2 - A_1)]$
z (elevation)	$K (\cos \alpha_1 + \cos \alpha_2)$
d (departure)	$K (\sin \alpha_1 + \sin \alpha_2)$
x (longitude)	$K (\sin \alpha_1 \times \sin A_1 + \sin \alpha_2 \times \sin A_2)$
y (latitude)	$K (\sin \alpha_1 \times \cos A_1 + \sin \alpha_2 \times \cos A_2)$
Advantage	Very high accuracy.
Use	Requires computer-based calculation.

Table III. 5:Characteristics of the Minimum Curvature Method.

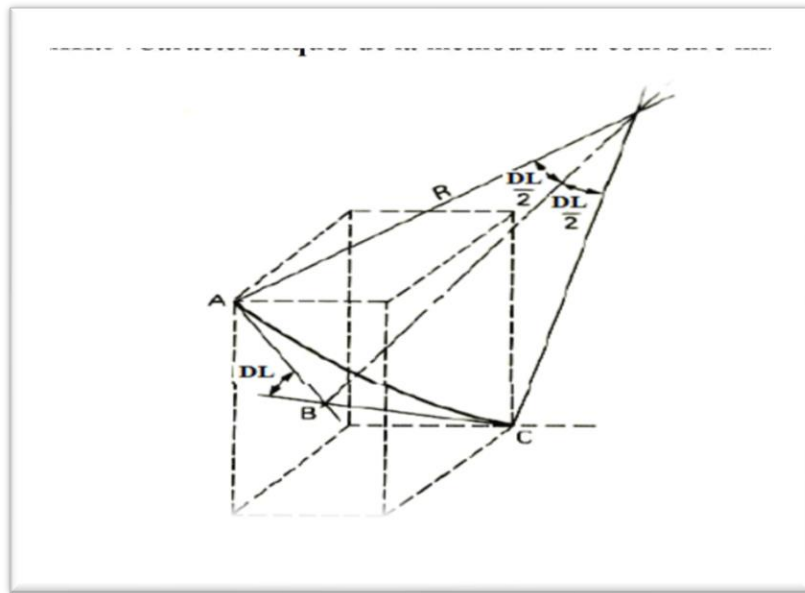


Fig III. 7:Minimum Curvature Method.

Where: A = azimuth; α = inclination; L = length; DL = dog-leg; K = correction factor: $K = (\Delta L / DL) \times (180/\pi) \times \tan(DL/2)$. [24]

III-4. Uncertainty:

The theoretical calculation of a deviated trajectory requires a confidence envelope that guides well construction, keeping it within acceptable limits so that it is properly located and can reach the reservoir within the specified target. This is called the uncertainty domain.[11]

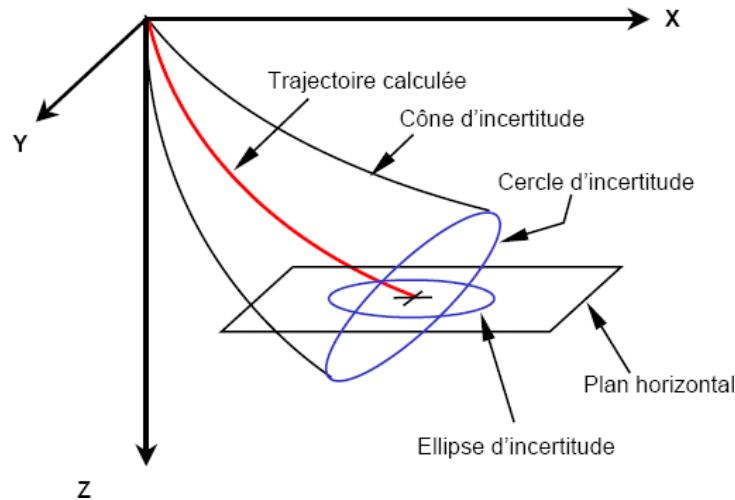


Fig III. 8:Uncertainty Domain.[25]

III-5. Sources of Errors:

- ▶ Errors due to measurement instruments;
- ▶ Errors due to the position of the measurement tool in the well;
- ▶ Errors due to local measurement conditions;
- ▶ Errors due to human factors;
- ▶ Errors due to calculation methods. [24]

III-6. Anti-Collision Study:

In order to avoid collisions between wells, their positions are compared in a horizontal plane by applying different calculations such as:

- ▶ Horizontal distance between wells;
- ▶ Uncertainty parameters depending on the type(s) of equipment used;
- ▶ Uncertainty ellipses or spheres;
- ▶ Compilation of different results. [24]

Chapter III:

Case Study TJNE-5 Well

IIII.1 Introduction:

The well TJNE-5 was drilled and completed as a gas producer in the Ordovician reservoir. It is part of an oil development drilling program targeting the F2 Devonian reservoir. It is located on Block 239c in the southwestern part of the Gara Tisset III research perimeter. Drilling reached a final depth of 3160 m in the Precambrian basement. Well TJNE-5 was never put into production. Following the non-feasibility of fracturing the Ordovician reservoir, it was decided to convert the well in Reservoir F2 by crossing the formation with a horizontal drain to access the potentially better-drained area.

IIII.1.1 Purpose of the recovery:Recovery of the well in Short Radius in Reservoir F2.

IIII.2 Situation of the well:

The TJNE-5 well is part of the Upper Devonian oil field F2, located in the Gara Tisset III perimeter, it is 6 km southeast of the well TJNE-1, and about 2 km southeast of the well TJNE-3 and 5 km southeast of the well TJNE-2 oil producers in Devonian F2. The coordinates of the well are as follows:

geographic coordinates	coordinates UTM (Fuseau 32/ Clarke 1880)	Altitudes
X : 09° 04'09.36758"E Y : 28°21'32.77312"N	X : 506 788.113 m Y : 3 136735.59 m	Zsol : 528.166m Z table : 535.666m

Table IIII. 1:Situation Of the Well TJNE-5.

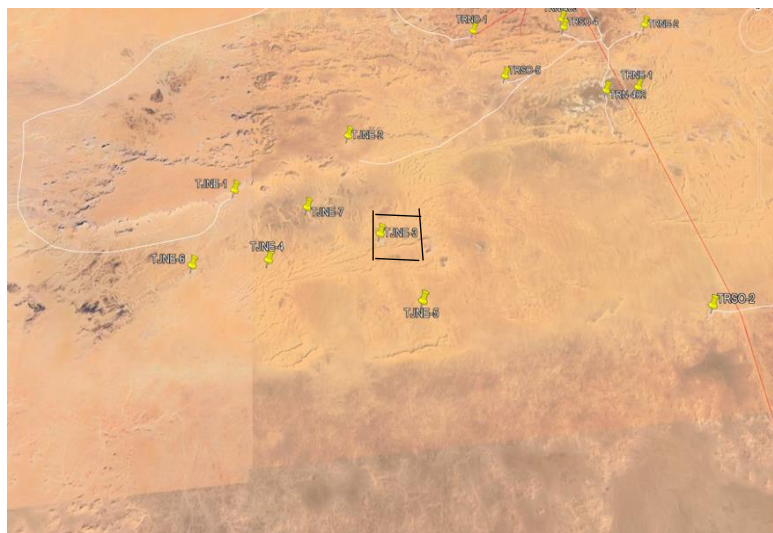


Fig IIII. 1:Geographical Position Of TJNE-5 Well in Ohanet Field.

Well condition:

IIII.2.1 General data of the TJNE-5 well:

Region	OHANET
Perimeter	Tadjentourt Nord -Est
Titulaire	SH/DP OHANET
Operator	ENAFOR
Sondage	TJNE-5 Vertical
Primary objective	Developpement Devonien F2
Drilling Rig	ENF-20
Start of drilling	12/09/2024
Survey End	24/12/2024
Drilling depth	3160 m

Table IIII. 2:General Technical Information of the TJNE-5 Well.

IIII.2.2 DRILLING OPERATIONS:

The TJNE-5 well was drilled in five (05) phases, crossing a series of deposits 3160 m thick.

	PHASE-1	PHASE-2	PHASE-3	PHASE-4	PHASE-5
Drilling	26"	16"	12 1/4"	8 1/2"	6"
Depth	256 m	665 m	2014 m	2816 m	3160 m

Table IIII. 3:Drilling Program and Hole Diameter Intervals.

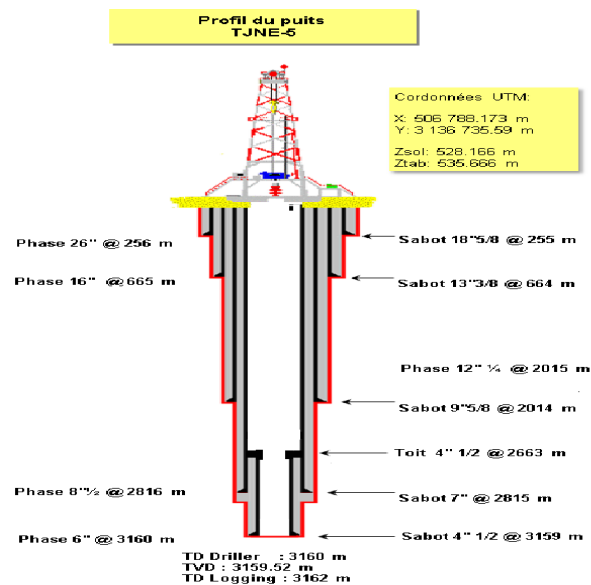


Fig IIII. 2:Well architecture TJNE-5.

IIII.3 Evaluation of cementation:

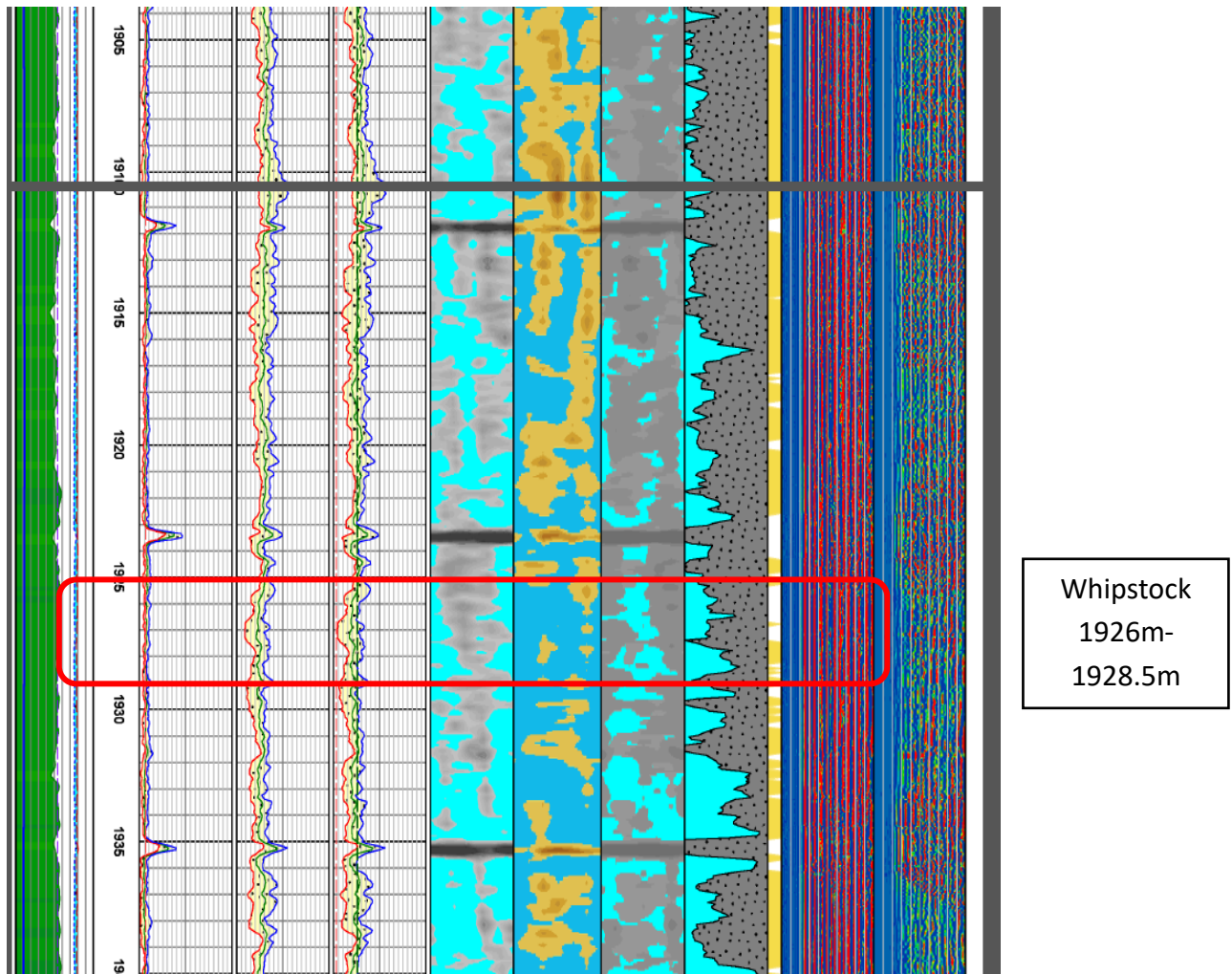


Fig IIII. 3:Log Intex 7" of well TJNE-5.

log Intex of the Csg 9"5/8 shows good cementing in the 1926m-1928.5m section (Whipstock Windows).

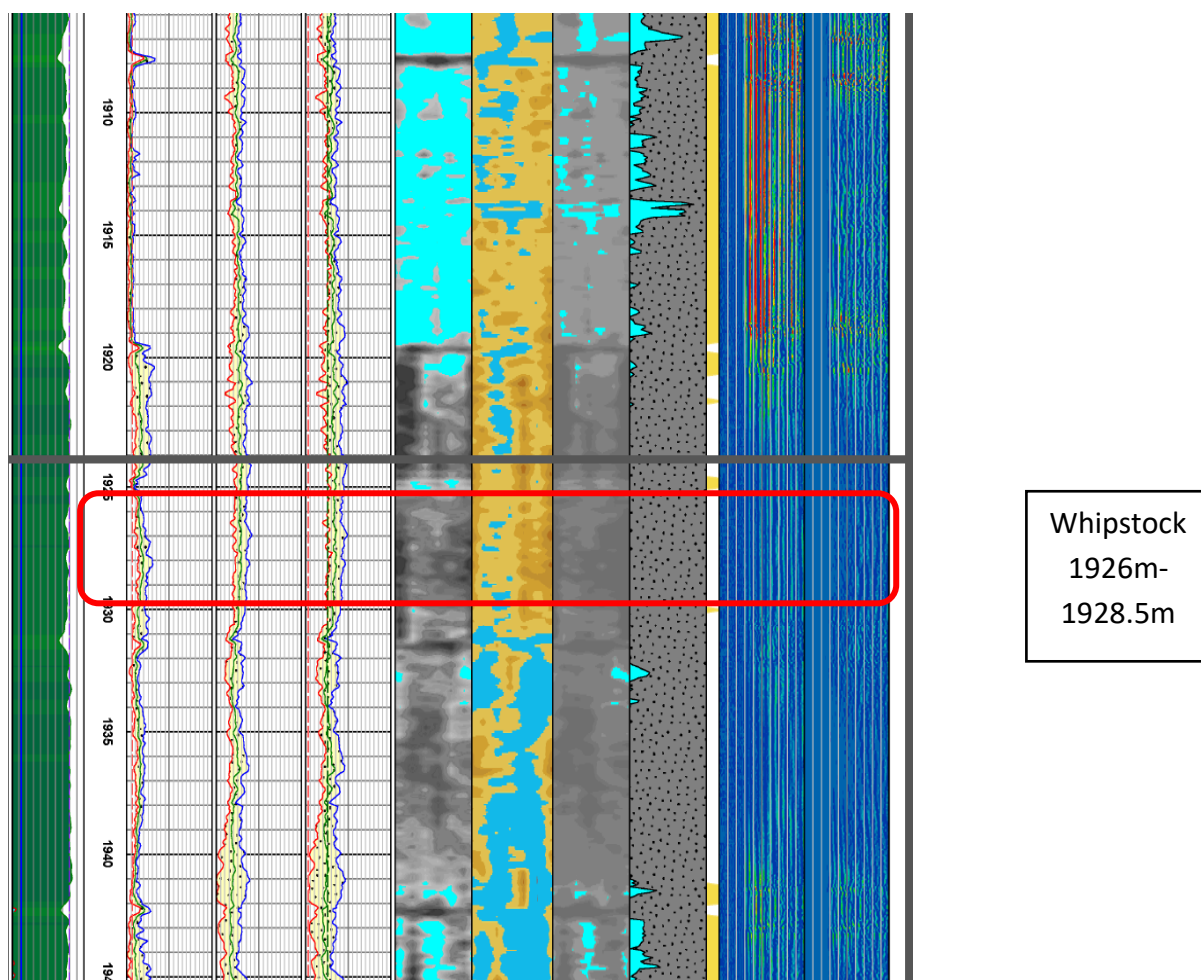


Fig III. 4:Log Intex 9"5/8 from well TJNE-5.

IIII.4 Geological and petrophysical data of Reservoir F2:

The Upper Devonian F2 of the Northeast Tadjentourt deposit is formed by a clay-sandstone complex, composed of gray-white, white, very fine to fine, silico-clay, moderately hard to friable and gray-black clay, indurate and silty. The porous sandstone banks have a variable thickness of 0.5 to more or less 5m in this structure, their porosity reaches values of 20%.

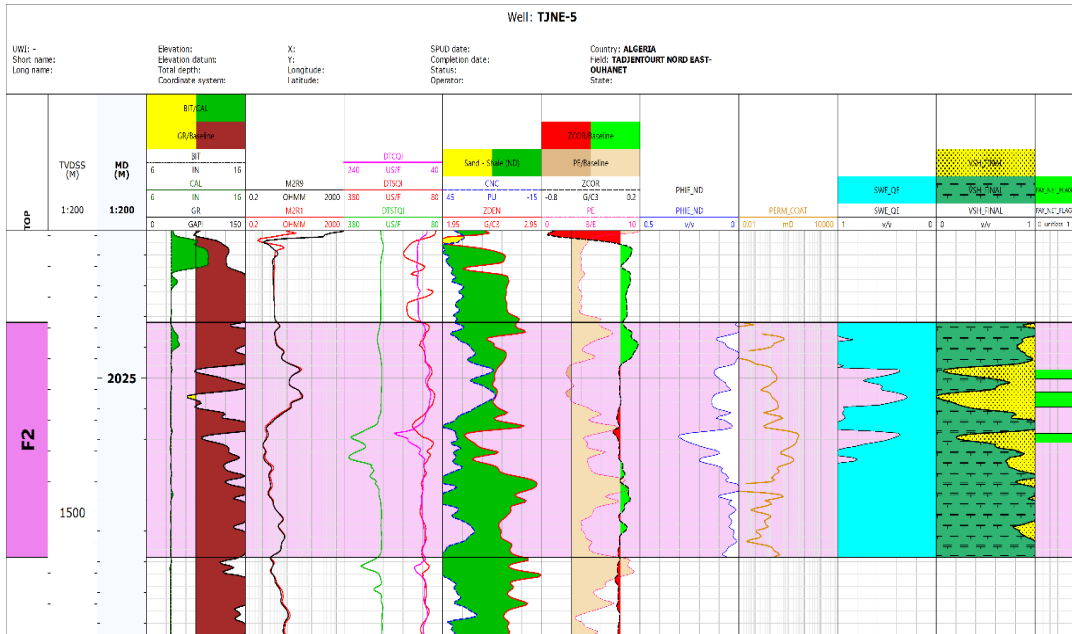


Fig III. 5: Momentum of the F2 reservoir of well TJNE-5.

The petro-physical characteristics:

Well	Zones	Flag Name	Top	Bottom	Gross (M)	Net (M)	Av_Shale Volume (v/v)	Av_Porosity (v/v)	Av_Water Saturation (v/v)	Av_Permability (mD)
TJNE-5	F2	ROCK	2020	2040	19	3.66	16.30%	18.50%	50.20%	13.1
		RES			19	3.66	16.30%	18.50%	50.20%	13.1
		PAY			19	2.74	13.10%	18.40%	41.40%	12.8

Table III. 4:Petrophysical Properties for the F2 Reservoir Zone in TJNE-5 Well.

The petrophysical characteristics of reservoir F2:

- * Volume of useful clay:13%.
- * Useful effective porosity:18%.
- * water saturation:41%.
- * useful thickness:2.7m.
- * average permeability:13 md.

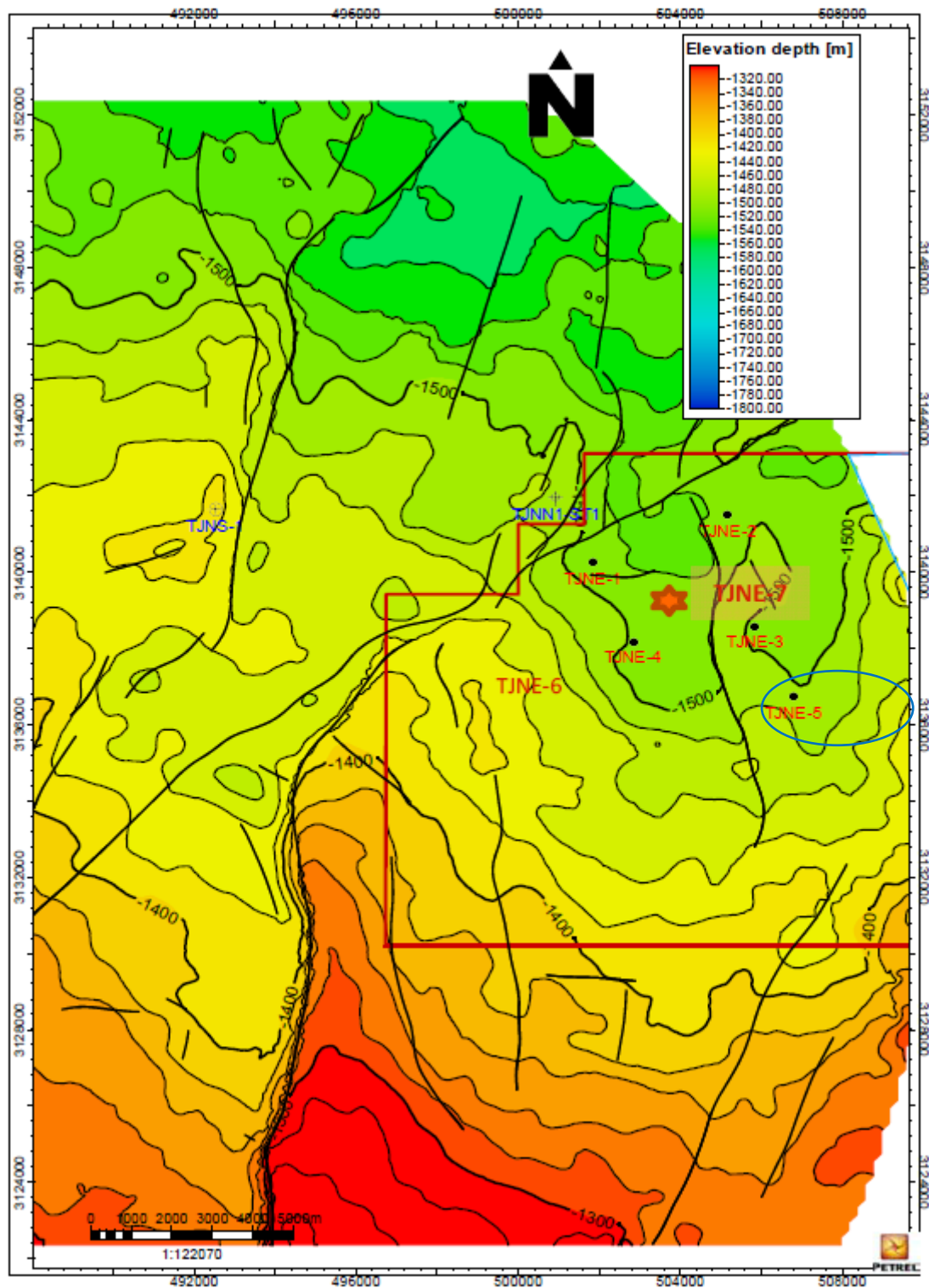


Fig IIII. 6:Isobath map at the Devonian F2 roof of the TJNE-5 well.

IIII.5 Stratigraphic sheet of the TJNE-5 Reservoir:

Ere	Etage	Formation		Tops (m) géologiques		
				Previs	Réels	Elec
MESOZOIQUE	CRETACE	Serie d'In Akamil		9	-	-
		Taouratine superieur		68	46	-
		Taouratine inferieur		316	282	-
		Zarzaitine sup et moy		354	330	-
		Zarzaitine inf		524	507	510
	CARBONIFERE	Tiguentourine		656	648	637
		Namurien - Westphalien	Westphalien -F	781	779	776
			Westphalien-Namurien-E	943	929	927
		Viséen	Namurien-D	1171	1163	1163
			Viséen -C	1418	1407	1409
			Viséen -B	1608	1600	1596
		Tournaisien - A		1902	1897	1906
		DEVONIEN	Réservoir F2		2034	2021
	Série Argileuse supérieure		2052	2039	2040	
	Réservoir F 4		2268	2267	2268	
	Série Argileuse inferieur		2306	2287	2293	
	F2		C3	2324	2305	2314
			C2	2346	2313	2349
			C1	2364	2347	2361
			Unité B	2375	2357	2374
			Unité A	2392	2372	2392
			Unité M2	2427	2392	2420
			Unité M	2482	2449	2481
			Silurien Argileux	2527	2496	2516
	ORDOVICIEN		Unité IV-3		2867	2885
		Unité III-3		2952	2984	2980
		Unité III-1		2992	3024	3009
Unité II		3037	3070	3072		
	SOCLE		3122	3127	3090	
	Profondeur TOTALE		3162	3160	3162	

Fig IIII. 7:Stratigraphic Sheet Of TJNE-5 Reservoir.

IIII.6 TESTS DES FORMATIONS:

The test on the F2 tank during drilling:

Opening of the well on a torch with a 16/64 choke,parameters were recorded during the test an unstable pressure is WHP=100 psi,and an estimated oil flow Q:15m3/d.

IIII.7 RESERVOIR PRESSURES:

TJNE-5 Well F2 Reservoir Formation Pressure:

Reservoir	Reservoir pressure (DST)	Temperature
F2 Reservoir	2670 psi	84.7 °C

Table IIII. 5:DST Results for the F2 Reservoir.

The formation pressures of reservoir F2 from neighboring wells (source DST):

Reservoir F2	Wells	TJNE-1	TJNE-2	TJNE-3	TJNE-4	TJNE-6	TJNE-7
	Reservoir Pressure	2894 Psi	2833 Psi	2843 Psi	2681 Psi	2672 psi	2550 psi
	Temperature	84.9 C°	85 C°	81 C°	84 C°	80°C	83°C

Table IIII. 6:Reservoir Pressure and Thermal Characteristics of F2 Formation Wells.

IIII.8 Realization of the short radius phase 6":

The main operations to be carried out for the drilling of the 6" deviation are summarized as follows:

- Installation of a cement plug

- Recording a Gamma Whip with CCL to align with the reference Log GR/CCL.
- Installation of a seat cement plug.
- Drilling and adjustment of the cement plug according to the length of the Whipstock at 1926.5m.
- Test cement plug in compression and pressure.
- Install and adjust the Whipstock 7"X 9"5/8 according to the 1926.5m size.
- Operation W-L (GYRO to adjust azimuth N 300°).
- Anchoring of the Cased Whipstock 7"X 9"5/8 at the 1926.5 m mark.
 - **Creation of a window in the 7"X 9"5/8 diameter 6" casing**
- Milling and creation of a window in the 7"X 9"5/8 casing from 1926.5m at 1930m.
- Milling and drilling to make a 6"diameter hole with a length of 2.5 m in the 1932.5m formation.
- Cleaning and Circulation with Hi-Vis Pill to remove all scrap metal from the surface.
- Make sure the hole is properly cleaned before the "Directional BHA" descent.
 - **Drilling of a horizontal drain in the Devonian (F2)**
- Geological monitoring is mandatory throughout the section (from Kop to TD), confirming with GR reference and GR MWD the distance and actual coast of the top reservoir before penetration into the reservoir in order to provide for a correction of the trajectory in case of an offset Subsequently, there was also the appearance of the sandstones on the first bench of the F2.
- **Build section:** Drilling in deviation from 1932.5m to 2077m MD in the azimuth of N300°.
- **Hold Drain section 01:** Horizontal drilling from 2077 to 2220 MD to cross the first sandstone bank (2024-2025) in TVD.
- **Drop section:** Horizontal drilling with a change in inclination from 2220.69m to 2259.11 MD to quickly cross the Clayey bank (2025-2026) in TVD.
- **Hold Drain section 02:** following Horizontal drilling to cross the second sandstone bank (2026-2028) in TVD from 2259.11 m to 2460m in MD.
- (The total distance VS of the drain can be modified according to the hole conditions and the drilling progress).
- Perform a DST on barefoot due to 1932m at 2460m.
 - **Cementing of the liner and well equipment according to the DST results.**

- If the DST results are positive, the descent of the liner 4"1/2 X 2"7/8, and cementing will take place in two possible scenarios:
- **Scenario 01 Liner 4"1/2 and Crépiné 2"7/8:**
- Descent of a liner 4"1/2 I to the top tank F2, (Float shoe 4"1/2 above the top tank F2, and top liner about 150m inside the Csg 7"), and proceed with the cementing of the first section..
- Reforage of cement inside the liner, control and evaluation of cement quality (CBL).
- Run In Hole a 2"7/8 liner and inking the head inside the 4"1/2 liner into the vertical part of the 4"1/2 liner.
- **Scenario 02 Liner 4"1/2 Mixte:**
- Descent of a Mixte liner 4"1/2 (creped and full), with the creped part: from the TD to the top tank, and the full part of the top tank about 150m inside the Csg 7".
- Proceed with the cementing of the first section (full liner), isolating the part that has been cracked by the special equipment dedicated to this operation.
- Redrilling cement inside the liner, controlling and evaluating cement quality (CBL).

Well profile data					
Stations	MD (m)	TVD (m)	Inc. (°)	Az (°)	VS (m)
KOP (Top WSK)	1926	1926	0	N 300	0
Whipstock exit	1928.5	1928.5	2	N 300	0.04
Rathole	1932.5	1932.5	2	N 300	0.148
Build section	2077m	2024	89°	N 300	
Hold drain section 01	2220 m	2025	87 °	N 300	
Drop section	2259m	2026	89 °		
Hold drain section 02	2460	2028	87°	N 300	
TD	2460	2028	89°	N 300	473

Table IIII. 7:Trajectory of the Short Radius.

Fig III. 8:Well Data Sheet.

1. Rig Up Drilling Rig.
2. Water storage and production of OBM($D = 1.05$; $V = 55$).

NB : These characteristics must be reconsidered in every situation.

3. Circulation and neutralization, and observation of the open well.
 - Ensure the well is fully neutralized.
 - The KillMud parameters will have to be changed according to the well conditions.
4. If the well is stable, dismantling the wellhead.
5. Mounting BOPs, blocking and test accessories:
 - Draw down test of the Koomey unit.
 - Hydril closure at 2500 psi.
 - Fermeture sur tiges + manifold duse à 5000 psi.
 - Make sure to close manually.

6. Screwing the operating tube, olive clearance, and tension packing at +5T, and test for loosening the hydrostatic packer PFH + Anchor seal, if positive; circulation, sludge homogenization, and bottom cap discharge.
 - In the event of a negative situation, maintain the drill string at + 5T and proceed to point (7).
 - If positive, proceed with the operations starting from point (8).
 7. Electrical cutting of the tubing at the last 2"7/8 tubing joint above the permanent packer and raising the tubing column 2"7/8.
 8. Circulation, Mud homogenization, and bottom cap discharge.
 9. Back up, bottom equipment.
 10. Milling and permanent Packer recovery.
 11. Circulation and evacuation bottom plug.
 12. Scraping column 7" in 03 passes.
 13. Leak test of the 7" casing in one stage at 2000 psi and squeeze window, if applicable.
 14. Cementing operation:
 - Replacement of liner 4"1/2 with a bottom cement plug up to 50 m above the top liner.
 - Install a second cement plug from 2,400m to 1,926.5m (to cover the Devonian).
 - Place BP at the 1926.5 m.
 15. Test Annular 9"5/8 x 7" in 500 psi.
 16. Circulation and bottom-cleaning of the well.
 17. Scraping column 7" in 03 passes.
 18. Realization of the short radius phase 6".
- A- **Re-entry phase (Weatherford):** The operation will take place in three (03) steps:
- Etape 1 :** Set of whipstock @ 1926.5 m and Milling of 7" Casing.

Etape 2 :

Replacement of
Junk Mill and
milling of 9"5/8
Casing.

Etape 3 :

Remplacement of
the Junk mill and
drilling of the rat
hole from 1926.5
m to 1932.5m.



Top Casing Collar	1923.5m
Top of Window	1928.3m
Bottom of Window	1931.1m
Bottom of Rathole	1934.3m
RIH Depth	1934.3m
Bridge Plug	1932.5m
Bottom Casing Collar	1932m

Fig IIII. 9:Replacement Whipstock.

**Drilling of Build up and horizontal
section (Halliburton):**

- Build section : Drilling in deviation from 1932.5m to 2077m MD in the azimuth of N300°. (BHA:6" (5 7/8") TCI drill bit made up with TerraForce PDM (Standard bearing, bend set at 2.38°), in conjunction with MWD and UBHO for Gyro orientation if required./ 6" (5 7/8") PDC drill bit made up with TerraForce PDM (Standard bearing, bend set at 1.83° to 1.5°),in conjunction with MWD tool).
- Hold Drain section 01: Horizontal drilling from 2077 to 2220 MD to cross the first sandstone bank (2024-2025) in TVD(6" (5 7/8") PDC Bit made up with RSS Geo-pilot Dirigo 5200 (or terraforce PDM with bend setting 1.5°),in conjunction with MLWD tools.).
- Drop section followed by Horizontal Drilling with a change in inclination from 2220.69 m to 2259.11 MD to quickly cross the Clay bank (2025-2026) in TVD.
- Hold Drain section 02:following Horizontal drilling to cross the second sandstone bank (2026-2028) in TVD from 2259.11 m to 2460m in MD.

MD (m)	CL (m)	Inc (°)	Azi (°)	TVD (m)	NS (m)	EW (m)	V.Sec (m)	Dogleg (°/30m)
1926.000		0.000	0.000	1926.000	0.000	0.000	0.000	0.000
1928.500	2.500	2.000	300.000	1928.499	0.022	-0.038	0.044	24.000
1931.500	3.000	2.000	300.000	1931.498	0.074	-0.128	0.148	0.000
1942.000	10.500	2.000	300.000	1941.991	0.257	-0.446	0.515	0.000
2063.114	121.114	84.000	300.000	2023.200	38.122	-66.028	76.243	20.311
2077.451	14.337	89.600	300.000	2024.000	45.276	-78.420	90.552	11.718
2220.691	143.241	89.600	300.000	2025.000	116.895	-202.467	233.789	0.000
2240.452	19.760	87.500	300.000	2025.500	126.771	-219.574	253.542	3.188
2259.118	18.666	89.430	300.000	2026.000	136.100	-235.733	272.201	3.102
2460.159	201.041	89.430	300.000	2028.000	236.616	-409.831	473.232	0.000

Table IIII. 8:Survey of the KOP's short radius at TD.

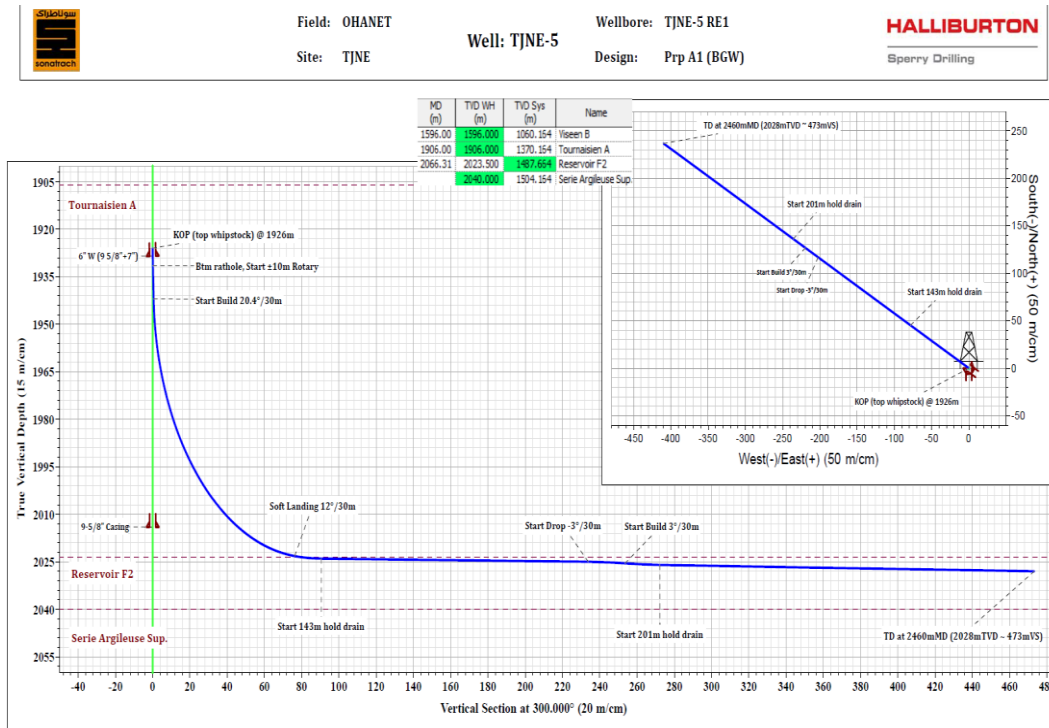


Fig IIII. 10:Trajectory of the short radius from KOP to TD.

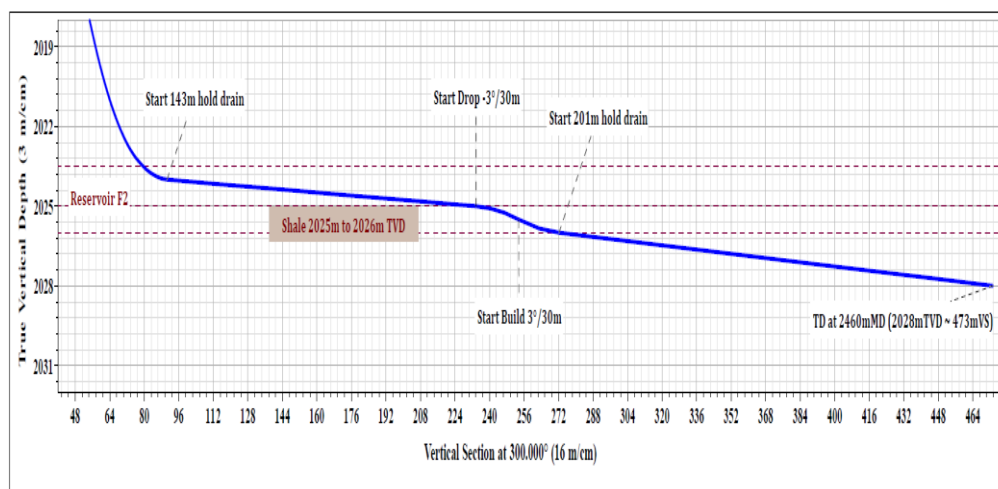


Fig IIII. 11:Zoom in the trajectory of the short radius from KOP to TD.

19. DST on barefoot due to 1932m at 2460m.
20. Cementing of the well liner and equipment according to the DST results.
21. Descent completion 2"7/8.
22. Operation Wire Line:
 - Control tubing 2" 7/8 With gauge cutter 59.6 mm et seat Landing Nipple X – 2"7/8.
 - Control tubing 2" 7/8 With gauge cutter 58 mm et seat Landing Nipple XN – 2"7/8.
 - Installation and anchoring plug XX in Landing Nipple X – 2"7/8.
23. Leak test of the tubing 2"7/8 à 2500 Psi.
24. Operation Wire Line:
25. Fishing plug XX Lnading Nipple X 2"7/8.
26. BOP disassembly, wellhead assembly and blocking.
27. Pumping and Mud Replacement on a oil.
28. Operation Wire Line:
29. Posing Testing Tools or plug XN in Landing Nipple XN– 2"7/8.
30. Test Of The Tubing + Bottom Equipment On 2500 Psi et anchoring the hydrostatic packer.
31. Hydrostatic packer anchorage test.
32. Operation Wire Line:
33. Fishing Testing Tools or plug XN.
34. Cellar cleaning and around the well.
35. TOP D.T.M.[30]

Conclusion

Conclusion:

The main objective of this study was to evaluate the technical re-engineering and optimization of the TJNE-5 well, located in the Ohanet region within the Gara Tisselit III perimeter. Initially drilled to a total depth of 3,160 m as a vertical gas producer in the Ordovician reservoir, the well was never put into active production due to the mechanical non-feasibility of hydraulic fracturing within that specific formation. To salvage the asset and maximize the recovery

of the Upper Devonian oil field, a strategic decision was executed to convert and sidetrack the well using a Short Radius horizontal drilling technique.

The synthesis of the geological, petrophysical, and operational data analyzed throughout this work leads to the following key conclusions:

- **Reservoir Potential:** Evaluation of the clay-sandstone complex confirmed viable petrophysical characteristics at the interval of 2,020 m – 2,040 m, featuring a useful effective thickness of 2.7 m, a volume of useful clay of 13%, an average porosity of 18.4%, and an average permeability of 12.8 mD.
- **Pressure and Hydrocarbon Indicators:** Formation testing (DST) during drilling yielded a reservoir pressure of 2,670 psi at 84.7 °C, confirming active continuity with neighboring Devonian.

producers (TJNE-1, TJNE-2, and TJNE-3). The initial open-hole torch test with a 16/64" choke produced an estimated oil flow of , proving commercial oil presence.

- **Operational Execution:** Structural integrity for the sidetrack was secured via verified casing cementation quality between 1,926 m and 1,928.5 m. The structural framework successfully accommodated the anchoring of a 7" x 9-5/8" casing Whipstock at 1,926.5 m, oriented via gyroscopic survey to an azimuth of N300°.
- **Trajectory Control:** A multi-stage 6" horizontal drain successfully built inclination from the KOP at 1,926 m up to 89° at 2,077 m MD (2,024 m TVD). The multi-segment trajectory (Build, Hold 01, Drop, and Hold 02 sections) allowed precise steering across variable lithologies, targeting the first sandstone bank, safely bypassing the interbedded clayey barrier, and maximizing contact with the secondary sandstone reservoir bank up to a total measured depth of 2,460 m.

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