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Introduction and Investigation into Oil Well Logging Operations (Review)

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ABSTRACT

Oil well logging, also known as wireline logging, is a method of collecting data from the well environment to determine subterranean physical properties and reservoir parameters. Measurements are collected against depth along the well's length, and many types of wire cabling tools depend on the physical property of interest. Well probes generally have a dynamic response to changes in rock layers and fluid composition. These probes or well logs are legal documents that record the history of a well during the drilling stages until its completion. Well probes record the physical properties of the well, which must then be interpreted in petrographic terms to obtain the characteristics of the rocks and fluids associated with the well. Many bases on which well probes depend on obtaining information, and preventing the rocks from responding to stimuli sent by special devices, whether those stimuli are electrical, radioactive, or acoustic. In addition, there are electrically controlled mechanical bases used to measure the diameter of the well, its flow, pressure, perforation, and taking samples. Wireline refers to the technique of using the cable to deliver special equipment to the bottom of the well to repair, evaluate, or equipment recovery. A simple wireline consists of a shiny metal wire (called a slickline) that is very durable for tensile and wear operations. It is (0.108" or 0.125") in diameter. The equipment is installed at the end of the wire. Still, sometimes a braided cable is used from many small steel wires (Braided line), which makes it stronger and heavier than the first type. The information obtained from the logs is considered to assess geological areas based on porosity, permeability, hydrocarbon fluids, and shale ratio. Well logging uses logs that are much cheaper than core operations and also cheaper than the information obtained from drilling mud. This review aims to pinpoint the most important logging processes used in oil wells, as well logs have an effective role in all stages of the oil industry.

Keywords: Oil well, Logging, Reservoir parameters, Drilling mud, Chart.

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مقدمة وتحقيق عن عمليات جس الابار النفطية (مراجعة)

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الخلاصة

تسجيل آبار النفط ، المعروف أيضًا باسم التسجيل السلكي ، هو طريقة لجمع البيانات من جوف البئر التي تسمح بتحديد الخصائص الفيزيائية الجوفية ومعلمات الخزان. يتم جمع القياسات مقابل العمق على طول البئر وهناك العديد من الأنواع المختلفة من أدوات الكابلات السلكية اعتمادًا على الخاصية المطلوب تحديدها وقياسها. بشكل عام ، تستجيب مجسات البئر للتغيرات في طبقات الصخور وتكوين السوائل. تحقيقات الآبار أو سجلات الآبار هي وثائق تسجل تاريخ البئر خلال مراحل الحفر حتى اكتمالها. تسجل مجسات البئر الخصائص الفيزيائية للبئر والتي يجب بعد ذلك تفسيرها بمصطلحات بتروغرافية للحصول على خصائص الصخور والسوائل المرتبطة بالبئر. تتعدد الأسس التي تعتمد عليها مجسات البئر في الحصول على المعلومات بحيث تتمكن الصخور من الاستجابة للمنبهات المرسلة بواسطة أجهزة خاصة ، سواء كانت تلك المحفزات كهربائية أو مشعة أو صوتية. بالإضافة إلى ذلك ، هناك قواعد ميكانيكية يتم التحكم فيها بواسطة طريقة كهربائية يمكن من خلالها قياس قطر البئر وتدفقه الى تقنية استخدام الكابل فى (Wireline) وضغطه وتثقيبه وأخذ العينات ، يشير دائما استخدام كلمة الواير لاين معدات عمليات .انزال معدات خاصه الى اسفل البئر بغرض القيام بعمليات متنوعه كالاصلاح أو التقيم أو استرجاع شديد التحمل لعمليات الشد (slickline)الواير لاين فى ابسط اشكالها تتكون من سلك معدنى لامع عادة يسمى والتآكل ويبلغ قطره (0.108انج او 0.125 انج) ويتم تثبيت المعدات فى نهاية السلك ولكن احياناً يستخدم كابل تعتبر .مما يجعله اقوى واثقل من النوع الاول (Braided line) مجدول من العديد من اسلاك الصلب الصغيره المعلومات التي تم الحصول عليها من السجلات أفضل طريقة لتقييم المناطق الجيولوجية على أساس المسامية والنفاذية والسوائل الهيدروكربونية ونسبة الصخر الزيتي ، بالإضافة إلى الميزات الأخرى. يعد تسجيل الآبار باستخدام المجسات أرخص بكثير من عمليات اخذ اللباب وادق أيضًا من المعلومات التي يتم الحصول عليها من طين الحفر. تهدف هذه المراجعة إلى إلقاء الضوء على أهم عمليات التسجيل المستخدمة في آبار النفط واسس تلك العمليات من اجل استخدامها للحصول على خواص الصخور المكمنيه وايجاد النسب الحجميه وخواص الموائع ومن ثم حساب الاحتياطي النفطي ، حيث أن عمليات جس الابارلها دور فعال في جميع مراحل صناعة النفط

الكلمات الرئيسية: بئر نفطي, جس الابار, خصائص المكامن, طين الحفر, مخطط

1. INTRODUCTION

Previously, when the drilling of a specific geological area was completed, it was necessary to know what this hole contains, what its characteristics are, and what are its features and contents, and to know and analyze this information, well drilling operations or the so-called oil well records were carried out **(Alhaleem et al., 2015).** Well logging operations have evolved at present to become an essential and important part of drilling conclusions in addition to the productive probing operations, which give us information about the productivity of the well and its distribution in the producing layer **(Assi, 2019**). Before dropping the casings into the well, well logging operations are carried out. Those mean operations in which electrical, electronic, and acoustic equipment and devices are lowered, recording the rock characteristics of the geological area and its fluids, as well as knowing the conditions of the well for the distance between the bottom of the well and the last casing. Some sensors are also used for casing the wells **(Assi et al., 2018).** Conrad and Marcel Schlumberger, who founded Schlumberger Ltd. in 1926, are considered the inventors of electrical well monitoring. Konrad Schlumberger developed an electrode, and it was a technique for prospecting deposits of mineral ores. The brothers adopted and adopted this technology for new applications that are used underground rather than just on the surface. On September 5, 1927, Schlumberger crew members lowered an electrical monitoring device down a well in Bachelbrunn, Alsace, France. And they created the first log of a well. In the modern sense, the first record was a resistance record that could be described as -3.5 meters in addition to the lateral record.

The wells palpation recording is used to obtain the properties of the reservoir rocks, i.e., to find the productive capacity of these rocks (porosity), find saturation, and also estimate the potential of the rocks to produce oil or gas (permeability). Porosity sensors require a constant value of the stony or slurry to be determined before the porosity (ϕ) of the range can be calculated **(Wyllie, et al., 1956).** From the geological point of view of the reservoir, determining the types of excavated rocks, their characteristics and levels, and determining the effective layers to compare the Correlation layers, as well as determining the depths, thickness, and degrees of curvature of the layers (Dip) **(Waxman and Smits, 1967).** The importance of well logs analysis lies in giving the necessary information about the condition of the well when it is being drilled for well completion operations or other operations **(Timur, 1968).** Using well palpation, different measurements are made according to the importance of hydrocarbon exploration, or measurements made to study production problems or cementing inside cased wells. Also, the formation coefficient symbolized by the letter (F), which is a variable used in the (Argy) equation for water saturation ($Sw^n = F*Rw/Rt$), changes according to the change in lithology. As a result, the water saturation changes as the formation modulus changes **(Bardon and Pied, 1969).** The resistivity values of drilling mud (Rm), mud leaching (Rmf), and mud cake (Rmc) and the temperature at which these values were measured are fixed on the probe tip. The value of the specific resistance of the formation water (Rw) is obtained by analyzing the water samples taken from the drill stem test from the water-producing well or the water resistance log, as well as determining the specific resistance of the formation water (Rw) from the Spontaneous potential log or It can be calculated in the water area (i.e., when it is (Sw=100%) by the method of apparent water resistivity (Rwa) **(Clavier, et al.,1984).** In quantitative sensor analysis, there are many reasons for knowing the lithology of a range, i.e., sandstone, limestone, or dolomite **(Worthington,1985).** The importance of the production log operations, which determines the productivity of wells, their distribution, pressure information, the nature of fluids and their movements behind the lining, and the acquisition of reservoir models for fluids without the need to kill the well **(Mahran, 1988)**. In well logging, there are many sensor types which are: Specific resistance sensors, Nuclear probes, Gamma-ray sensors, Density sensors, Porosity sensors, Acoustic sensors, Pulsed neutron lifetime sensors, Carbon oxygen sensors, and Geochemical Probes **(Vinegar, 1995).** **Table 1** represents a list of the different methods used to calculate the formation factor and shows how limpetites affect the formation factor. Formation temperature (Tf) is also an important factor in the analysis of sensors because the specific resistances of drilling mud (Rm), mud filtration (Rmf), and formation water (Rw) change with temperature **(Ostrof, 2000).**

The formation temperature is determined by the following:
-composition depth
- bottom hole temperature (BHT)
-Total bore depth (TD)
-surface temperature, it is possible to determine a reasonable value for the formation temperature using these data and assuming a linear geothermal gradient. **Table 1** shows the equation that is used to calculate the formation factor **(Bigelow, 2002).**

Well analyses are also important in evaluating the producing layers by determining their porosity and fluid content, the level of oil, water, and oil and gas contact, and the length of the oil column **(Torres, 2004). Fig. 1** is divided into three concentric regions: the middle annular region refers to the subterranean features to be evaluated, the inner region refers to the specialized recording tools mentioned below, and the outer region refers to the recording tools mentioned above. The corresponding inner and outer regions show how different tools complement each other in investigating certain properties beneath the surface. Oil well logging, also known as wireline logging, is a method of collecting data from a well's environment to learn about subterranean physical properties and gather as much information about a reservoir as possible. Measurements are collected against depth along the well **(Oil Well Glossary, 2020).** Also, Measurement While Drilling (MWD) is currently considered one of the most important auxiliary operations during the drilling of directed wells, as it contributes significantly to reducing drilling time and increasing the accuracy of directing wells by giving real-time data on down-well variables without the need to stop the drilling process. Based on the great diversity of measurements and palpation of wells, certain things must be taken into account, including whether the well is open or lined and the type of well in which the measurements will be carried out (excavation, exploratory, production), in addition to that of lithology (carbonate rocks, sandy, mixed). The engineering position of the well, the diameters of the boreholes, the casing pipes, the drilling means used, and the type of target tank is it (porous, cracked, cavitated, or mixed) all to achieve the main objectives of the measurements. Among the important things that must be considered when developing a program for palpation measurements of a well are the ergonomic conditions and the physical capabilities of each measuring device, in addition to the petrophysical and storage specifications for the fields whose specifications will be measured. What is valid in one layer may not be valid for use in another layer **(Douglas, 2021).** Well probing is used not only for oil wells but also for water wells. Researchers also use well palpation logging to conduct geothermal, geotechnical, and environmental studies. Well logs tell researchers the depth of specific formations and the types of formations that are underground. Well probes are used during drilling to determine the suitability of a well and to record any events, such as any problems occurring, along with the type of formations being drilled through. This information is then used to determine whether formations are desirable or undesirable depending on the type of well. Well sensors also tell workers if an oil well contains enough oil or gas. They also tell workers if the oil from the well needs additional processing before it can be used commercially **(Helby, et al.,1987).** Well sensors generally respond to changes in rock layers and fluid composition. This review aims to shed light on the well probes used in oil fields, their types, the purpose of using each, and the relationship between the types of probes used.

Table 1. The used Coefficients and exponents in calculating the formation factor (F).

Coefficients and exponents used in calculating the formation factor (F)	
General equation	$F = a/\phi^m$
limestone, dolomite	$F = 1/\phi^2$
hard sandstone	$F = 0.81/\phi^2$
Fuggy sandstone	$F = 0.62/\phi^{2.15}$
For sand in general	$F = 1.45/\phi^{1.54}$
shale sand	$F = 1.65/\phi^{1.33}$
limestone	$F = 1.45/\phi^{1.20}$
Carbonate (calcite)	$F = 0.85/\phi^{2.14}$

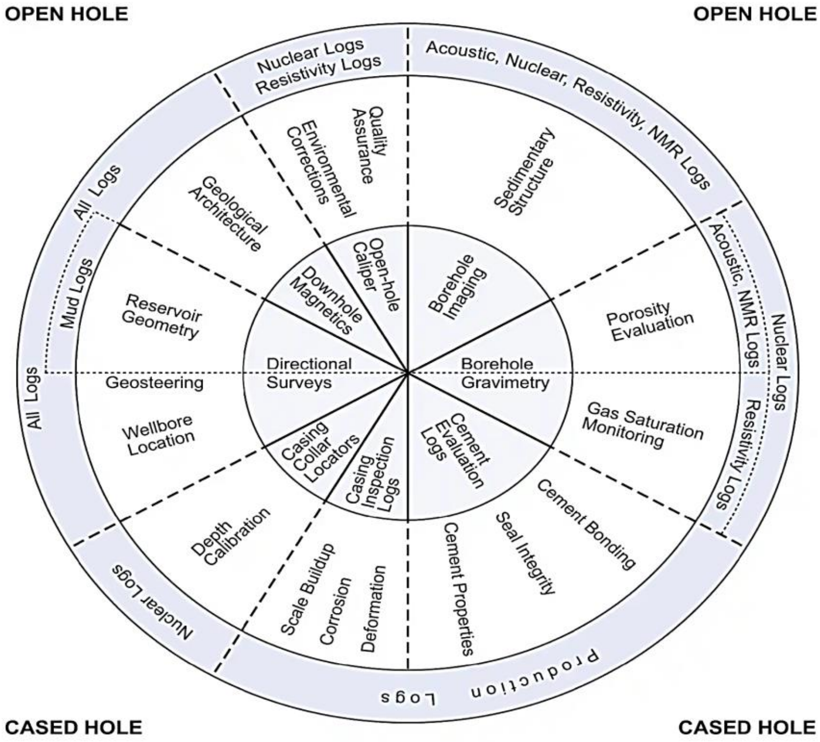

Figure 1. Well-logging types. **(Oil Well Glossary, 2020).**

2. TYPE OF WELL LOGS

2.1. Spontaneous Potential

This is an integral part of electrical observations and is the self-voltage. It measures the difference in voltage between two electrodes, one on the surface and the other passing through the drilling fluid in the drilling hole **(Suman, 1923)**. The voltage arises from electrochemical currents at the points of contact of the drilling fluid with the water of the permeable layers and through the mud layers above and below those permeable layers **(Pratt and Weeks, 1939).** Self-monitoring usually consists of a reasonably straight baseline and includes some bulges or peaks to the left. The baseline represents the clay layers in most cases, while the peaks are opposite the perforated layers. The intensity of the peaks varies with different geological formations, but there is no relationship between their intensity and the porosity values or the water conductivity of those formations. In medium-deep boreholes penetrating layers containing fresh water, the self-effort curve is sometimes relatively featureless and provides little useful information **(Shearin and Latimer, 1955).** It should be noted that quality resistance monitoring devices have developed a lot and have more accurate applications. Examples of these developments include; Micro Log, Induction Log, and Laterolog **(Assi, 2021).**

2.2. Electrical Logs

They are the most common observations and usually consist of a record of the apparent specific resistance of the formations and the intrinsic effort generated in wells **(Moore, 1940).** Both properties have an indirect relationship to the nature of the formations and the quality of the water they contain, and it can be measured only in unsealed drilling holes where these holes are filled with drilling fluid. That is, in direct contact with the layers and in the presence of an electrical conductor (drilling fluid) **(Doll, 1950).**

2.3. Resistivity Logs

As for monitoring the specific resistance, the sandy and clay layers show very high resistances if they are dry, but when one of them is saturated with water, it will lead to a different reduction in the component for each material. This is because water is a conductor of electricity, and its presence in the inter-holes of the rocky material makes it a medium that conducts electricity and thus reduces the resistance of the layer **(Doll, 1951).** The degree to which the resistance decreases depends on the quality of the water, that is, on the sum of the solid salts dissolved in it. The saturation water in the clay layers is usually saline because it dissolves minerals from the chemically active surfaces of the millions of clay particles that make up the layer. As a result, the clay layers show low resistance. Sand layers saturated with fresh water show high resistance, but if the water is salty, it shows low resistance, like clay layers. As a result, it is difficult and almost impossible to differentiate between sand layers that contain salty water and clay layers using only the monitoring of the qualitative component **(Carll, 1980).**

2.4. Neutron Log

The complementary part of these observations is neutron monitoring, which is recorded by dropping a radioactive source into the well that bombards some activated neutrons into the geological formations. These neutrons are monitored on the surface. If the layers are dry, they will show the maximum intensity on neutron detection, while the clay layers record the minimum intensity, and the permeable water-bearing layers show medium intensity. By using gamma-ray monitoring, there is confusion between layers that are very saturated with water and between layers of clay and differentiation between them. By monitoring the neutron, it is possible to estimate the porosity of the water-bearing layers. In general, the response to the neutron monitoring contrasts in a logarithmic manner as the porosity increases. This theory applies in particular to water reservoirs that consist of limestone and do not contain any clay layers. Usually, gamma ray and neutron observations are made together. The advantage of these observations can be recorded in the encapsulated parts of the wells **(NIOC, 1981).**

2.5. Sonic Logs

The idea of these observations depends on the transmission and reception of sound waves, the most important of which is the monitoring of the cement bond and the monitoring of the places where the packaging tubes are fetched Casing Collar Locator **(Antwan, 1988).**

2.6. Cased-hole logging

Open-hole logging refers to operations performed on a well before the wellbore has been cased and cemented. On the other hand, cased-hole logging involves retrieving logging measurements through the well casing or the metal piping that is inserted into the well during completion operations. It is used to help the operators to get extra data from a well that has already been finished. For instance, the well is just ongoing production, and a cased-hole log will help decide what has obstructed the flow. The purpose of using the logging is different, as the purpose of the open hatch logging is to know the characteristics of the composition of the water-bearing oil and gas; however, the purpose of using the casing logging is to examine the casing and also monitor the profile of the fluid, in addition to fluid production definition, perforation inspection, an inspection of the string and so on **(Antwan, 1988).**

2.7. Bulk Density Log

This type of monitoring is used to measure the porosity of rocks because different types of rocks often have the same grain density. Still, the total density varies from one rock to another and from one point to another within the same formation. These differences are due to the porosity, and this monitoring is considered complementary to the neutron monitoring in this matter, especially when the porosity increases above 15%, as the neutron monitoring becomes less accurate. In this case, satisfactory results can be obtained from monitoring the total density. Although monitoring of the total density may, in some cases, show lithological changes behind the casing, it is mainly useful only in uncased wells **(Zaki, 1994).**

2.8. Geophysical Logging

It is useful to conduct a geophysical survey of wells, especially in locations where previous information is not available, as it is in addition to being a reliable tool for determining stratigraphy. Indirectly, they explain many of the hydrogeological characteristics of the water-bearing layers, and the characteristics of the rocks **(Asquith and Krygowski, 2004)**

2.9. Nuclear Magnetic Resonance (NMR) Logging

It is a type of well logging; the NMR reaction is used to find its permeability and porosity directly, provided that the log is continuous along the well **(Wayne, 2008).**

2.10. Gamma-Ray Log

Gamma rays are monitored by measuring the natural radiation of these rays, which are emitted by some radioactive materials present in different quantities in the layers. In most cases, the clay layers contain much greater amounts of radioactive materials than what is contained in limestone or sandstone **(Assi, 2017).** Therefore, monitoring gamma rays is mainly used to determine the layers. Clay and gamma rays are not affected much by changes in water quality, so they can be relied upon in deciding the clay layers, especially when electrical observations fail to do so. **(Assi, 2018).**

2.11 Other Logs

In addition to the above, there are several types of meteorology, such as diameter, temperature log, caliper, and production log, each of these types has its own devices, applications, and uses **(Assi, 2022). Fig. 2** to **Fig. 7** show some of the logging devices used in the logging operations of oil wells.

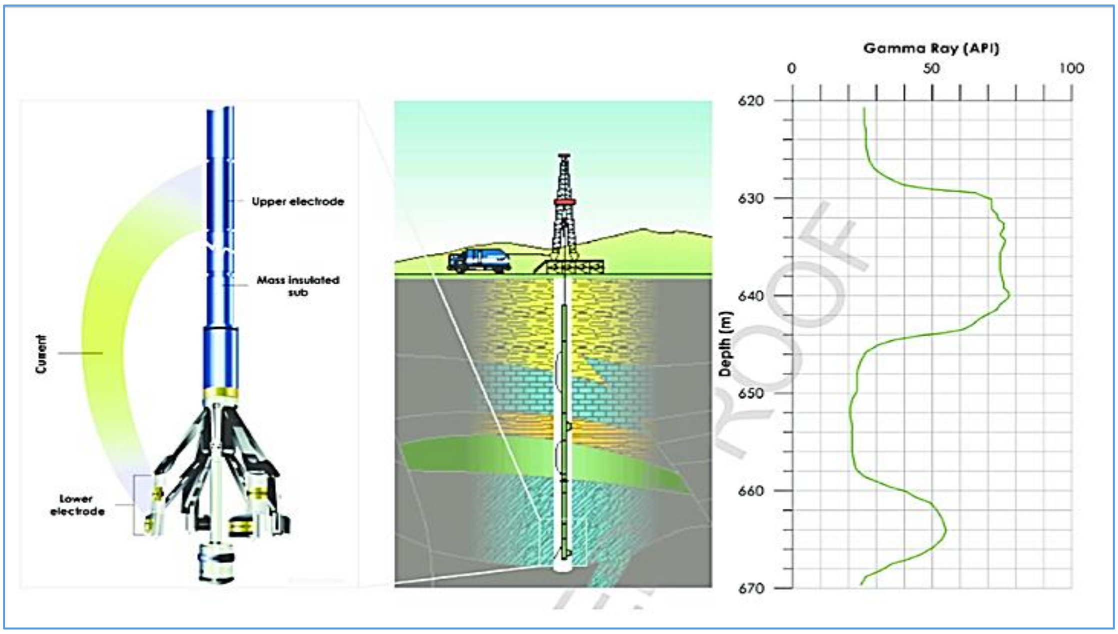

Figure 2. Example of displaying a recorded gamma ray log device. **(Zaki, 1994).**

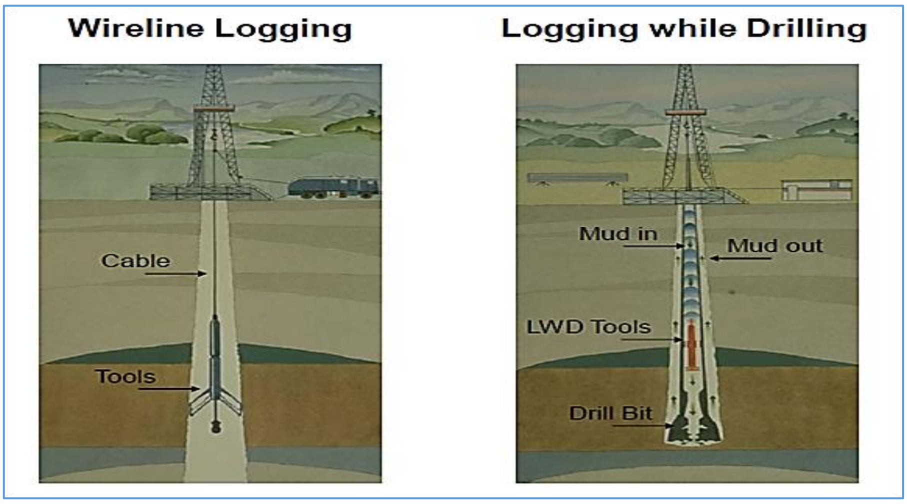

Figure 3. Logging during drilling and wireline log. **(Zaki, 1994).**

Figure 4. Some cased hole logging tools**. (Wayne, 2008).**

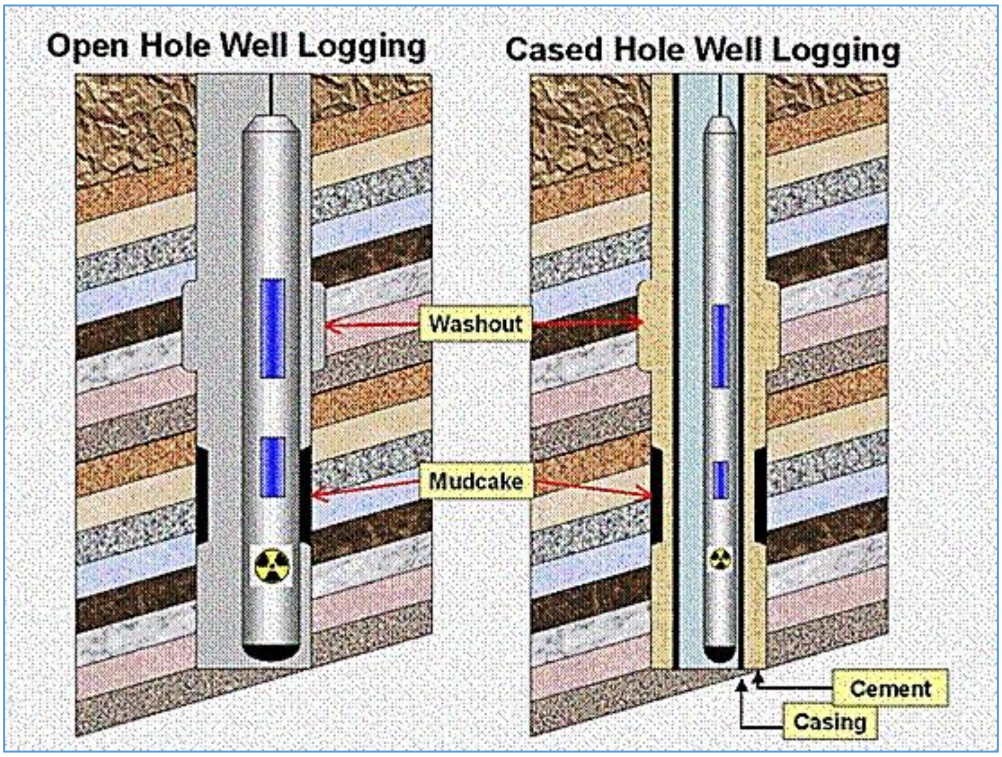

Figure 5. Open hole well logging and cased hole well logging. **(Wayne, 2008).**

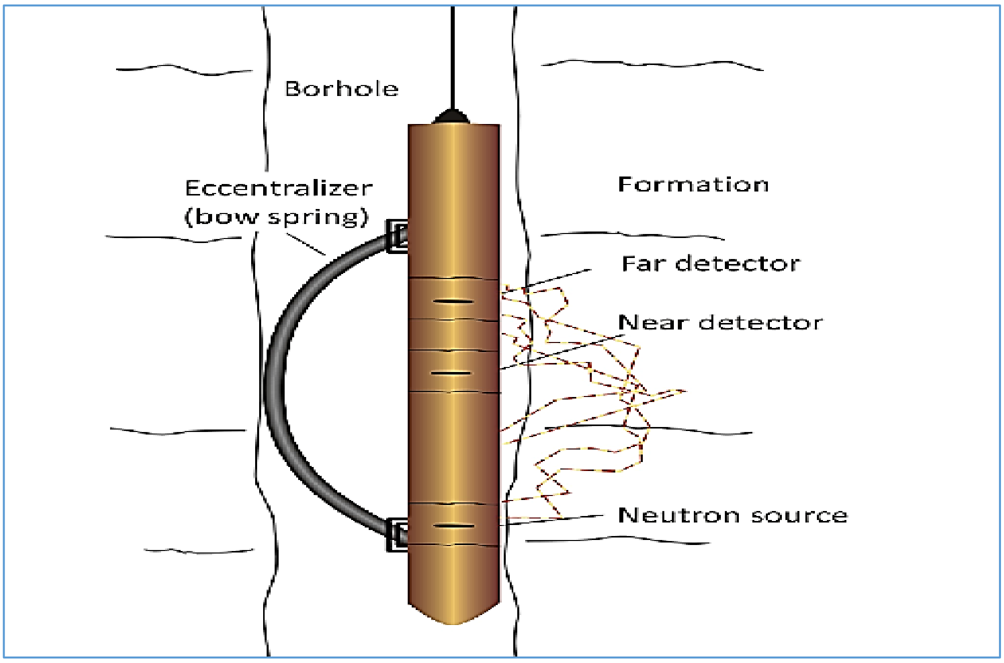

Figure 6. Neutron logging Tool. **(Worthington,1985).**

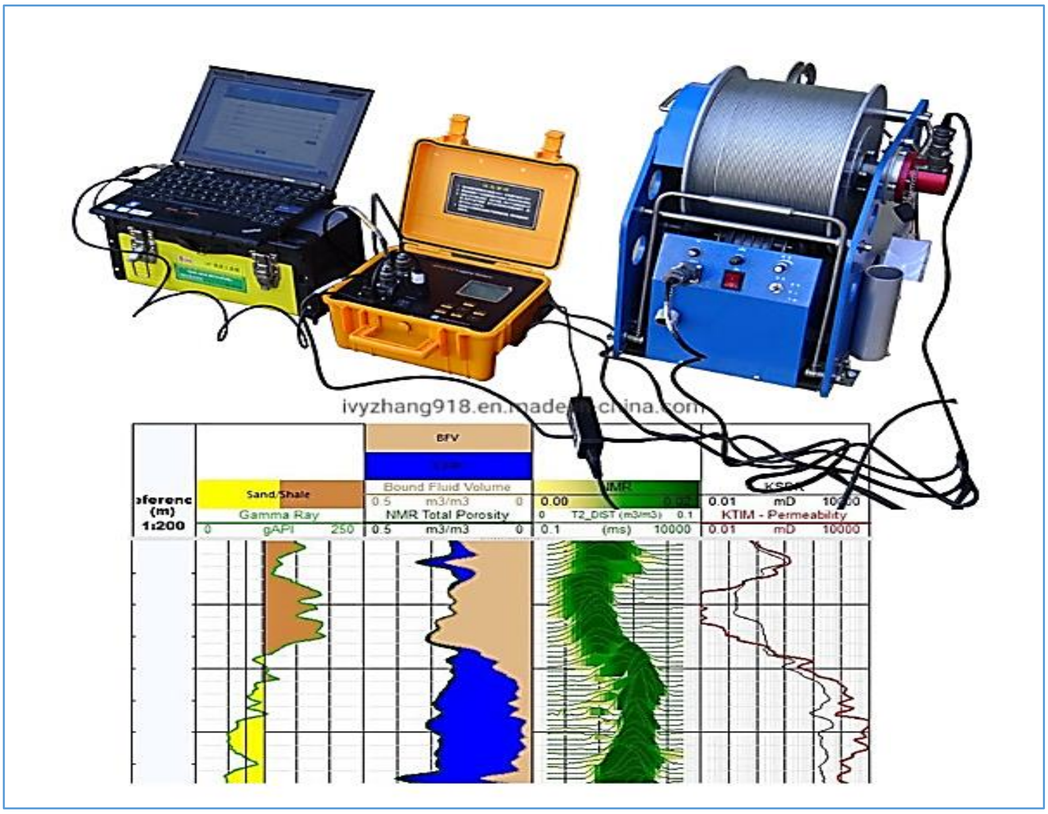

Figure 7. Digital well logging equipment with well log recorder. **(Wayne, 2008).**

3. BASICS OF INTERPRETATION OF OIL WELL LOGGING

The logging operations that take place on the wells are of two types:

1. Measurements that take place in the (open hole)

2. Measurements made in the cased hole

Concerning the density sensor, this sensor measures the density of rocks, which has an inverse relationship with porosity, so the more porosity increases, the lower the density. As for the neutron probe, this probe also measures the porosity, but indirectly, if it measures the number of hydrogen atoms in the rock, which is related to the porosity through the source of a torrent of neutrons that collide with the hydrogen in the rock **(Assi, 2021).** Knowing the number of neutrons that were caught, we can estimate the number of hydrogen atoms in the rock and, therefore, the rock's porosity. The gamma-ray sensor is considered one of the most important sensors because it expresses the extent to which the rock contains radioactive materials (shale) or its cleanliness. The rocks differ in their gamma rays to the extent that they contain shale and other clay minerals. Anhydrite and limestone are considered clean compared to shale, shale, and silt, which are considered to contain radioactive materials. The gamma-ray probe is useful for making geological comparisons to know the sequence of layers, as well as for fixing the depths of drilling when performing the perforation process. It records the gamma radiation in APT units ranging from zero to 100. As for the Sonic log: This sensor is useful for estimating the primary porosity of the rock, which is not affected by subsequent processes such as cracking and cracking. This sensor is based on the idea that dense, hard rocks without porosity have a speed of sound more than light porous rocks, where a sound wave is created that is directed to the rocks and received in another place.

The sonic probe is also useful in detecting abnormal pressures, mainly if the geological section contains shale, as the shale has a certain pressure gradient with increasing depth. As for the resistance sensor, these sensors record the resistance of the rocks to the passage of electric current through them. The fluids in the pores of the rocks (oil, gas, water) are of different resistance to the passage of electric current. Oil and gas are more resistant to the passage of electric current than water, and freshwater is more resistant to current than salt water. As for the caliper well log, this probe consists of several arms, four or two, that open with a specific diameter commensurate with the diameter of the well at that point. If the section is a ruined shale, the probe arms open as much as they can because the diameter of the well is wide, and this opening is recorded on the probe as an expansion in the diameter of the well.

As for the porous and permeable rock areas where the drilling mud deposits a thin layer on the walls of the mud cake as a result of filtering drilling fluid into the formation, The diameter of the well narrows in this case, and the probe arms shrink, which gives an indication on the probe that there is a narrowing in the well. The expansion and narrowing in the diameter of the well are measured in relation to a fixed diameter, which is the diameter of the bit size that drilled the well.

As for the cement bond log, this sensor helps us to know the quality and quantity of cement behind the lining, as it expresses the extent of the lining's attachment to the wall of the well if there is good cement or if it remains suspended in the well cavity if there is no cement. **Fig. 8** shows a summary of well logging, while **Table 2** illustrates the abbreviation and benefit of logs **(Schlumberger, 1989).**

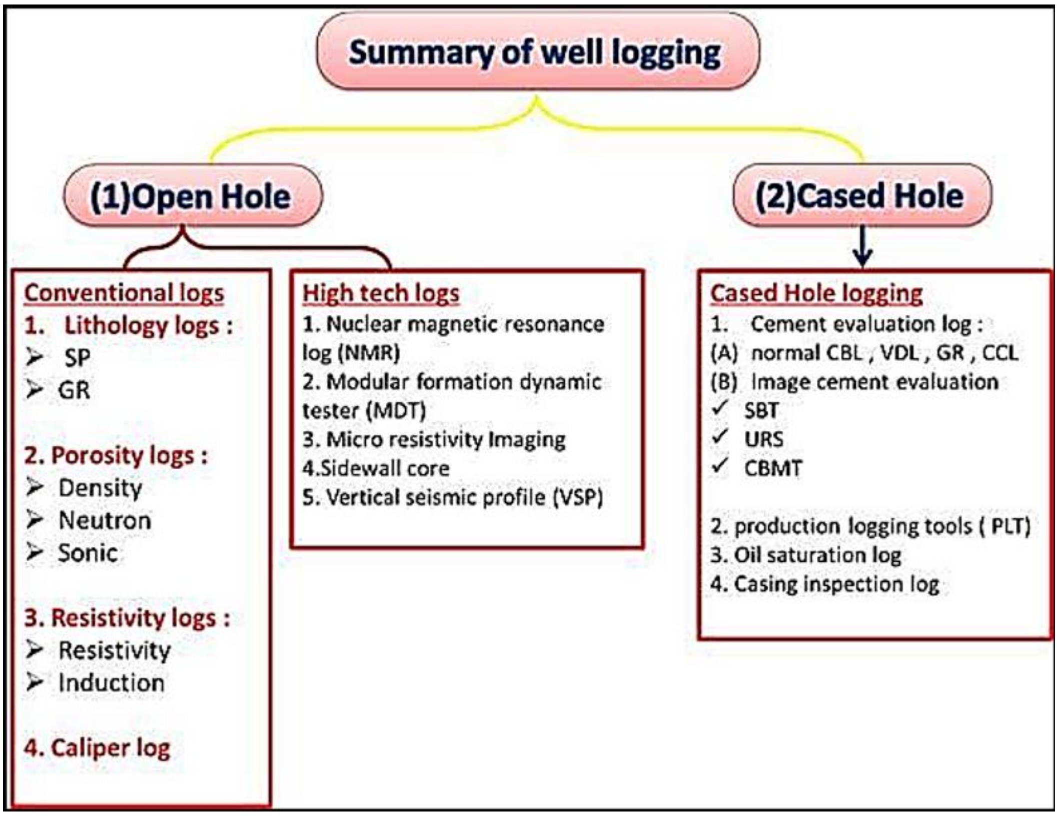

Figure 8. Summary of well logging. **(Schlumberger, 1989).**

4. THE MOST IMPORTANT EQUATIONS USED IN WELL LOGS OPERATIONS

A lot of equations are used in logging the wells, and here in this part, the most important and most famous of these equations will be listed. Equation 1 is used to measure porosity

$$\phi = (GD - BD)/GD * 100 \quad (1)$$

where: GD: The density of the particles g/cm^3, BD: the total density of the sample gm/cc, ϕ: porosity percentage. To find the temperature at any depth inside the well, equation 2. is used:

$$TF = T^{*} + (G.G * D)/100 \quad (2)$$

Table 2. The main types of well logs and their benefits and uses.

No.	Log Form	Benefit
1	Dual LateroLog (DLL)	Resistivity tool to determine the fluid type(water &oil)
2	Micro spherical focused later log(MSFL)	
3	Digital Acoustic Log(DT)	Determine Porosity (Porosity Log)
4	Sonic Tool(ST)	
5	Compensate Density Log(DEN)	
6	Compensate Neutron Log(CNL)	
7	Gamma Ray (GR)	Determine Shale, Depth correlation (open hole &cased hole)
8	Spontaneous Potential (SP)	Porosity, permeability, and Hydrocarbon indication
9	Caliper (CAL)	The volume of the Hole due to the caving
10	Cement Bond Log (CBL)	Cement Bond Tools (Cement Quality)
11	Cement Bond Log (CMBT)	
12	Shoe Bond Test Log(SBT)	
13	Casing Collar Locator (CCL)	
14	Variable Density Log (VDL)	
15	Enhance Micro Resistivity Test Image(EMRT)	Determine the Effective Porosity
16	Nuclear Magnetic Resonance (NMR)	
17	Rotary Sidewall Core(RCOR)	Take Formation Sample
18	Vertical Seismic Profile (VSP)	Confirm the lithology to support 3Dseismic
19	Enhance Formation Dynamic Tester	Determine the Formation of Fracture

where: TF= Formation temperature at what depth$^{\circ}$= Adjusted surface temperature, G.G.= Geothermal temperature gradient factor F$^{\circ}$ /100Ft., D = Depth. To calculate the specific resistance of the rock, equation 3. is used:

$$R^{\circ} = F * RW \quad (3)$$

where: R$^{\circ}$ is the specific resistance of rock saturated 100% with water Ohm, F is formation resistivity factor dimension less, RW is formation water resistivity, Ohm. To calculate the spontaneous static potential, equation 4 is used:

$$SSP = -K\, Log\, (Rmf\ /RW) \quad (4)$$

where: SSP is spontaneous static potential, K is constant and is proportional to the absolute temperature, Rmf is Specific resistance to mud filtrate Ohm. To calculate the porosity of the sonic recording, equation 5 is used:

$$\Phi S = (\Delta t\ log - \Delta t\ mat)/(\Delta tf - \Delta tmat) \quad (5)$$

where: ϕS is sonic-derived porosity, Δt mat. is the interval transit time in the matrix, Δt log is the interval transit time in the formation, Δtf is the interval transit time in the fluid in the formation. To calculate the porosity from the density registration, equation 6 is used for this purpose

$$\Phi = \rho mat. - \rho b/\ \rho mat. - \rho f \quad (6)$$

where: ρmat.is the total density gm/cc, ρb is the density as seen by tool gm/cc, ρf is the fluid density gm/cc. To correct the porosity of the shale effect, equation 7 must be used

$$\Phi e = \phi - Vsh * \phi sh \quad (7)$$

where: Φe is the corrected porosity, ϕ is the porosity from the tool, Vsh is the shale volume, ϕsh is the shale porosity. To calculate the water saturation, equation 8 is used :

$$Swn = F * RW/Rt \quad (8)$$

where: Sw is water saturation, n is the saturation exponent usually taken as 2, and Rt is the true formation resistivity Ohm **(Tixire, et al., 1960).**

5. DISCUSSION

Most of the oils in the world are formed in sedimentary rocks, where organic materials are deposited under certain conditions of heat and pressure in an ocean devoid of oxygen. Millions of years ago, when it lived in salty waters and lakes, and the evidence for this is the presence of salt water in the areas of oil exploration or during drilling, in addition to the presence of marine excavations after which the oil moves from the generated rocks to the reservoir rocks. Probes are one of the main indirect sources for providing such information in describing and diagnosing sedimentary rocks and liquids that fill their pores. From the analysis of the probes, petrophysical properties are extracted, such as lithology, porosity, shale ratio, water saturation and oil, presence of oil and gas, extraction of permeability, and presence of water. The logs process is the placement of one or several devices inside the borehole that can transmit physical information about the properties of the formation, which can be interpreted later to know the presence of hydrocarbons, and each of these devices can provide information.
The analysis of logs data is carried out in three main stages: data logging, data transmission, and data processing. Special recorders are used at the well site to record data or measurements that are carried out on special tapes, and the measurements are recorded as optical tapes. These types of recordings are important to determine the depths and give readings about some areas through rapid analysis. They are considered useful in terms of making a connection between the wells. Converting the curves in the optical recordings to numbers is

important to transfer them to the computer to become valid in the data analysis center for later use in interpretation operations. Using analysis programs such as the computer processed interpretation (CPI), which calibrates recordings, matches depths, corrects measurements for well conditions, analyzes formations, and converts inclined depths to vertical depths. Probe operations have developed at present to become an essential part of the drilling conclusions in addition to the productive probing operations, which give us information about the productivity of the well and its distribution in the productive layer. The importance of palpation operations lies in giving the necessary information about the condition of the well when it is being drilled for well completion operations or other operations. This information includes measuring the depth of the well, the depth of the lining, the diameter of the well, the quality and hardness of the cement, its height behind the lining, and the degree of inclination of the well. From the geological point of view of the reservoir, identifying the types of excavated rocks, their characteristics and levels, and determining the effective layers.

How to read the well analysis recording easily and accurately is very important, as the correct reading leads to the correct interpretation. Let's take, for example, **Fig. 9**. The petroleum engineer seeks to transform these broad lines into knowledgeable facts. **Fig. 9** consists of a gamma-ray record, resistance records, density records, and neutron records placed in the same record. Just by looking at how the curve in the figure is skewed with respect to each other, it is possible to tell the difference between whether we have oil, gas, or water, as below:

The First Curve

To search for the reservoir, a gamma-ray log should be found. Usually, the reservoir gives a small gamma-ray reading. A high gamma ray reading likely points to rocky areas (shale) or non-reserving rocks.

The Second Curve

Second, after knowing the location of the reservoir now, it is better to find out whether the reservoir contains oil, gas, or water. For that, here, the need for a record of resistance arises. However, if it is a hydrocarbon-bearing region, the resistance reading will be higher than that in the water-bearing region.

The Third Curve

After defining the location of the reservoir, now it is necessary to know the quality of the reservoir. This is generally done by knowing the value of the porosity. A good reservoir always has an effective porosity, and to be able to know if the studied reservoir is porous, there is the need for recording tools that can give us an indication of the porosity value. The most representative porosity tools are neutron, density, and sonic, occasionally using Nuclear Magnetic Resonance (NMR) log.

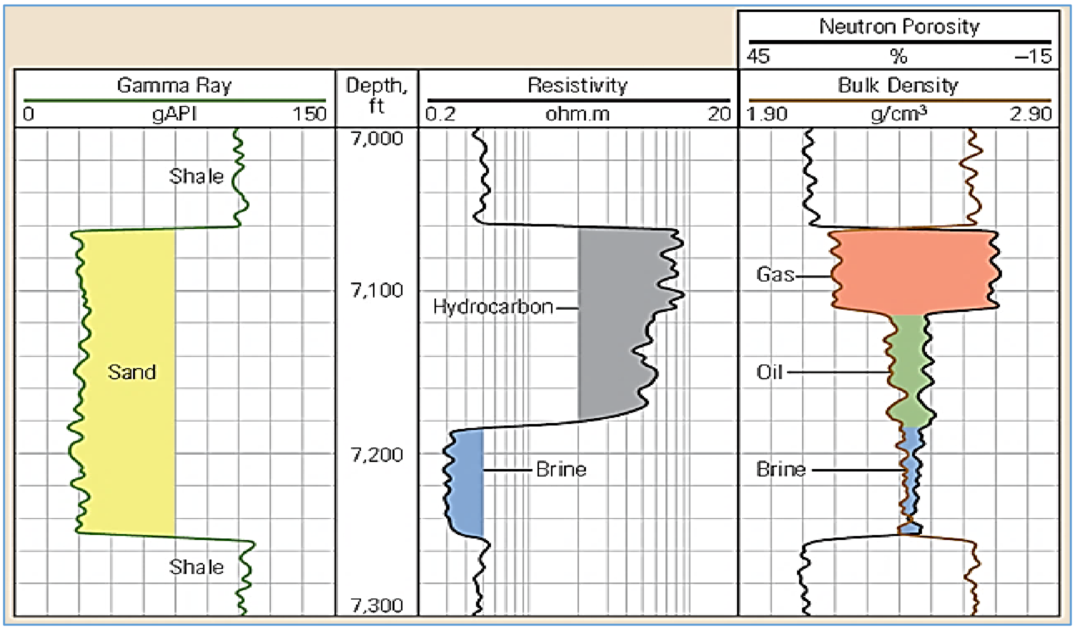

Figure 9. Sample of log for interpretations. **(Bigelow, 2002).**

For the charts that are used in oil well logging, the following can be noted:

1- All probes, as soon as they are lowered into the well, whether lined or not and from which probe company, will be affected by the type of mud present, well temperature, well diameter, pressure, lining, and cement (for lined wells), because the supplying companies have calibrated this equipment with experimental wells with diameter, mud, and certain controlling specifications. It is well known, and the jar is built on its basis, and this correction represents a departure from these ideal conditions.

2- Charts change over the years as equipment evolves. Therefore, a petroleum engineer or petro physicist must know the type of equipment and year of manufacture in order to be able to correct it. For example, using the available chart from the 1970s to debug a 2000 model sensor will lead to fatal errors and vice versa as well, i.e., using a 2000 chart. To debug a home probe in the 1970s, the main reason is that the type of transponders in any probe is good. It evolves and changes over time, and the name of the device or the actual way it works remains the same

3- Modern charts can sometimes be ambiguous, as it is recommended to refer to older charts, where you can find even correction equations given. Therefore, when dealing with a specific company, try to get their corrections for different years.

6. CONCLUSIONS

1- Well logging is considered one of the most important operations associated with drilling wells, whether the well is horizontal, inclined, or vertical. All kinds of palpation equipment are lowered into the bore of the open well dug to evaluate the formations or to evaluate the cement behind the lining after the cementing process.

2- The well logging process is also important to study the rocks' physical or chemical properties by lowering the palpation equipment into the well, where the information is transmitted to the surface and then interpreted by the sensor's interpretation engineers.

3- The importance of logging operations comes from giving them information about the determination of the oil reserves, the pressure, and inclination of the layers, the areas of cracks in the layers, the determination of the areas of water presence, and the water-oil contact line, in addition to their ability to determine the porosity, permeability, water saturation, the stony and the size of the shale.

4- Well logs exist, a summarizing, comprehensive plot of the parameters of the formation versus the depth. From those plots, interpretations identify the lithology, distinguish between the porous and the nonporous rock, and rapidly distinguish the pay zones for the subsurface formations.

5- After taking the reading from the log, it is better to correct using the appropriate correction equations for each type of probe or using correction jars. For example, shale inside the pores affects the calculated porosity, as there is an equation for correction.

NOMENCLATURES

BHT: Bottom Hole Temperature
TD: Total Depth
Rm: mud resistivity
Rmf: filtrate resistivity
Rmc: mud cake resistivity
Rw: water resistivity
Rwa: Apparent water resistivity
Rt: true resistivity
NMR: Nuclear magnetic resonance
LWD: Logging While Drilling
GG: Geothermal Gradient
CBL: Cement Bond Log

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