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| **COURSEWORK**  **DUE DATE** | 12/04/2022 |
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| **COURSE TITLE** | **IT for Oil and Gas Industry** |
| **MODULE NUMBER**  **& TITLE** | **ENM502 PART A - Technical Report** |
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**TITLE PAGE**

**(APPLICATION OF SONIC AND DENSITY LOG)**

**1.0 Summary**

This report examines the application and implementation of sonic and density logging in assessing rock geochemical properties and fundamental qualities to enhance drilling operations. This study demonstrates the application of sonic and density logging. It describes the basic tools used in information formation, log interpretation using technological tool, and common errors encountered in sonic and density logs.

**1. FORMATION OF SONIC LOG**

**1.1 INTRODUCTION**

The sonic log is also known as the acoustic log. This log measures the interval transit flow of an elastic wave travelling through a rock formation. It also determines the velocity of the wave obtained through the rock formation. The measure it takes to travel back and forth across the formation is called the interval transit time or slowness, and it is inversely proportional to speed.

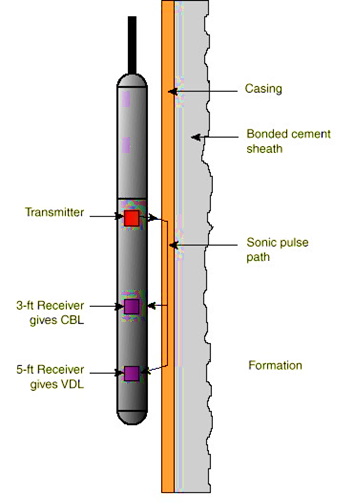
**1.2. PRINCIPLE OF ACOUSTIC LOG**

There are three main principle of sonic log. This is designed to gather data in the subsurface rock formation.

The pressure wave (P-wave) is the fastest wave with small amplitude. The pressure waves penetrate through a solid and liquid medium. The transmitter generates a signal and converts it into vibration. With the help of a monopolar source, the pressure moving wave travels through the rock parallel to the energy in time and space around the tool boundary. The wave energy generated changes direction back into the formation recorded at the receiver.

Share wave (S-wave) also known as the second wave, is slower compared to pressure wave but with high amplitude. This wave cannot penetrate through a liquid medium. The secondary waves move particles of rock side to side at the right angle direction equal to the wave. These are the two important waves that occur during the sonic log process.

Stoneley waves are waves of energy propagating along a borehole and produced by a monopolar source. These waves always arrive after the arrival of pressure and shear waves. These waves transmit in the form of tubes and lose their amplitude when they come into contact with porous formations. The higher the porosity of the formation, the higher the energy absorbs.

**1.2.1 SONIC LOG TOOLS**

A sonic detector tool generates acoustic energy and estimates the travelling time to traverse the rock formation with the aid of a transmitter and receiver mounted on the tool. The sonic logging became a standard technique when useful empirical methods were developed for the calibration of acoustic velocity information porosity (Guyod and shane 1969).

**Figure 1**

**1.2.2 SINGLE RECIEVER TOOLS**

A single tool design has a single transmitter and a receiver. The log has low velocity and high interruptions that prevent sound waves from propagating along with the tool to the receiver. This log is no longer in use because the time it will take to travel through the rock formation was included in the calculation.

**1.3 TWO RECIEVER TOOLS**

The dual tool was designed because of issues found in the single sonic tool. These tools use dual receivers to calculate the time change of the arrival wave from the transmitter to the receiver. The count it takes for a sound wave to pass through the receiver is called the sound interval travel time. This tool will require some modification because there will be changes in the hole size.

**1.3.1 BOREHOLE COMPENSATED TOOLS**

The borehole compensation tool is designed with dual transmitters and receivers, one of which is inverted. The tool measures pressure waves and averages the distance. This value compensates for tool interference and borehole size variation.

**1.3.2 APPLICATION OF SONIC LOG**

The sonic log is applicable to determine the pore spaces in the rock formation, even so, the dual-spacing log (CNL) and the compensated formation density log (FDC) value, are superior because these logs determine the type of hydrocarbon and identify the oil/gas contact in the zone of interest. This log is applicable in the following techniques:

1. As a standard check on the CNL and FCD log determinations.
2. As a quality method in determining the borehole measurement
3. Secondary porosity can be determined in carbonates.
4. It is used to determine fracture porosity

**1.4 SONIC POROSITY EQUATION**

Ø = sonic porosity of clean sand

Δt = interval transit time in the zone of interest

Δtma = interval transit time of the rock matrix

(Sandstone=55.5, limestone=47.6, dolomite=43.5, anhydrite=50)

Δtp = interval transit time of the pore fluid in the well bore

(Fresh mud= 189, salt mud =185)

The unit of measurement is microsecond per feet (**µs/ft**)

**The sonic log is used to determine a stratigraphic correlation:** The log is sensitive to small changes in grain; texture, size, mineralogy, carbonate content, and quartz content same as porosity. This makes it a great log for facial analysis and correlation.

**Identifying rock types:** Sonic and other logs are used to determine the type of hydrocarbons in a special rock type. However, high-speed logging data indicates the existence of carbonate rocks in the area, medium-speed data indicates the existence of sandstone in the area, and low-velocity data indicates the existence of shale in the area. Sonic log data is a characteristic of coals and evaporates which have a persistent, well-recognized velocity and travel time.

**1.4.1 ERROR THAT AFFECT SONIC LOG**

**LITHOLOGY:** Sonic logging captures only primary porosity and follows the rapid path to the receiver to avoid fractures.

**HYDROCARBON EFFECT:** The presence of hydrocarbons can affect porosity measurements. Hydrocarbons have different interval travel times, so the interval travel time in gas is different from the interval travel time in oil. It affects the calculated porosity and can be correct by multiplying the porosity by 0.7 (gas) and 0.9 (oil).

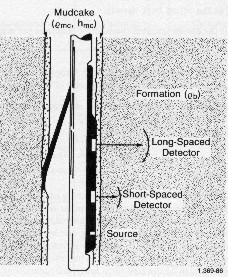
1**.4.2 DENSITY LOG**

A density log is a porosity log that measures the mass density and porosity of a reservoir formation through the emission and retention of gamma-rays. The more gamma-ray count that is absorbed in denser rock, the insignificant is the transmitted and detected ray count.

**1.4.3 PRINCIPLE OF DENSITY LOG**

The density log tool requires a radioactive source and short-range and long-range detectors. The radioactive source emits gamma-rays into the formation. This gamma-ray undergoes Compton scattering, which reduces the energy of the gamma-ray and scatters the gamma-ray in all directions. If the energy in the formation becomes denser, more energy is lost, and this response is directly related to porosity.

**1.5.1 DENSITY LOG TOOL**

****Unlike the sonic log, the density log tool uses a radioactive emitter and a detector for simple measurement. First, the early tools are made up of one detector that was compressed against the borehole formation employing spring tension. Unfortunately, the type of tools was erroneous and unable to compensate for a mud cake of different depths and densities through which the gamma rays have to pass if a measurement of the true formation is to be achieved. To compensate for the mudcake, newer tools consist of two detectors called Formation Density Compensation Logs (FDC). This tool has one emission source, one short spacing detector, and a long spacing detector from the source. To ensure that the emitted rays enter the mudcake, both the light source and the detector are protected.

**Figure 1**

**1.5.2 APPLICATION OF DENSITY LOG**

**Determination of porosity**: The porosity of a formation can be determined from the bulk density if the matrix density of the fluid is known. Below is the porosity equation

**Ø =**

= bulk density of the formation

= matrix density

= fluid density

Ø = density porosity of the rock

**Identification of evaporate minerals:** Carbonates, sulphates, and chlorides are examples of evaporating minerals, which are less dense than typical minerals. So when found within a log section, evaporate is easily determined from the formation, as density logs can identify less dense minerals.

**Identification of lithology:** Density logs combined with neutron and resistivity logs are more effective in identifying the presence of hydrocarbon zones in reservoir rocks. Most rocks have a wide range of densities, depending on their mineral composition and variable porosity.

**Identification of gas bearing zone:** To detect the gas-bearing area in the rock formation, density logging and neutron logging form a large volume circulation, and the resistivity of the gas layer is higher than that of the oil-brine area.

**1.5.3 ERROR THAT AFFECT DENSITY LOG**

**The Effect of Gas:** The presence of gas in a formation affects the porosity of the rock formation because gas is dense compared to oil and water. Furthermore, the bulk density of oil is higher than that of gas. Therefore, when calculating porosity, you take readings from the reservoir to avoid porosity errors.

**The Effect of Oil:** Oil is denser compared to aqueous fluids. However, oil had no significant effect on the porosity calculations, as the mud filtrate replaced oil and water in the invasion zone.

**The Effect of Shale:** The density of shale varies widely, and if present in the formation, it can affect the bulk density and also the measured porosity. To avoid this and get the correct density, we can use the bulk density in shale and the bulk density of clean sandstone versus the volume of the shale.

**1.6.1 CONCLUSION**

In conclusion, sonic log measures the interval transit flow of an elastic wave travelling through a rock formation. While density log measures the mass density and porosity of a reservoir formation through the emission and retention of gamma-rays. Note both log can’t determine porosity, without the introduction of other logs.

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