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Well logging

(Summary)

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Acknowledgements

Special gratitude goes to Prof. Paul Glover from the University of Leeds for approving to use his teaching materials that provide important additives to this course.

2019

Introduction

Wireline logs are tools that are placed into the borehole to measure the rock properties. They may be run down the borehole on a cable (traditional) or attached to the drilling assembly to provide real time measurement whilst drilling (Measurement Whilst Drilling MWD or Logging while Drilling LWD).

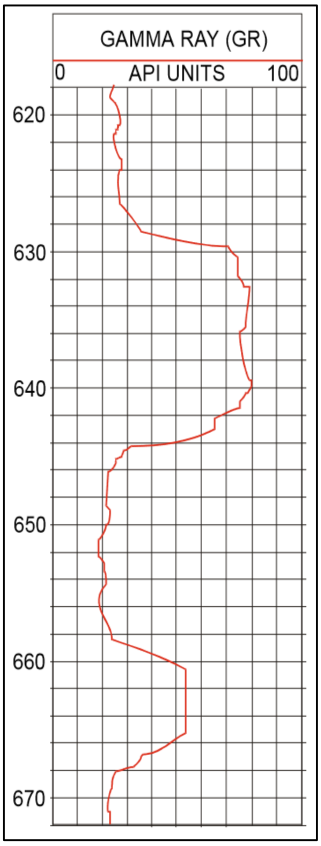


Figure 1

A log is a continuous recording of a geophysical parameter along a borehole. The value of the measurement is plotted continuously against depth in the well. Figure 1 shows a single track of natural gamma log. Note that depth is arranged vertically in feet or metres, and the header contains the name of the log curve and the range while the continuous measurements are represented by smooth curves. This figure is only 50 m of borehole, but real logs are often much longer (thousands of metres), and contain multiple curves on a single track such as this, and multiple tracks (Figure 2).

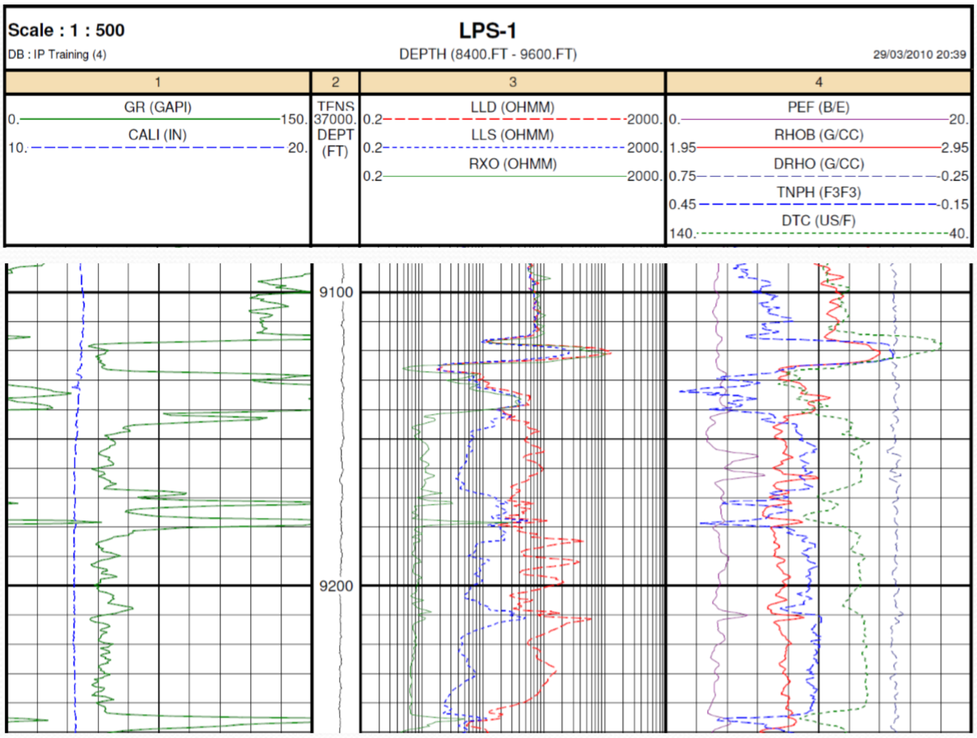


Figure 2

The presentation of log data

Logs are presented on a standard grid defined by the American Petroleum Institute (API). This grid consists of 3 tracks and a depth column as shown in Figure 3. Track 1 on the leftmost side is always linear and is often reserved for drill bit size, caliper and gamma ray tool information. The right side usually has 2 tracks (linear, logarithmic, or hybrid).

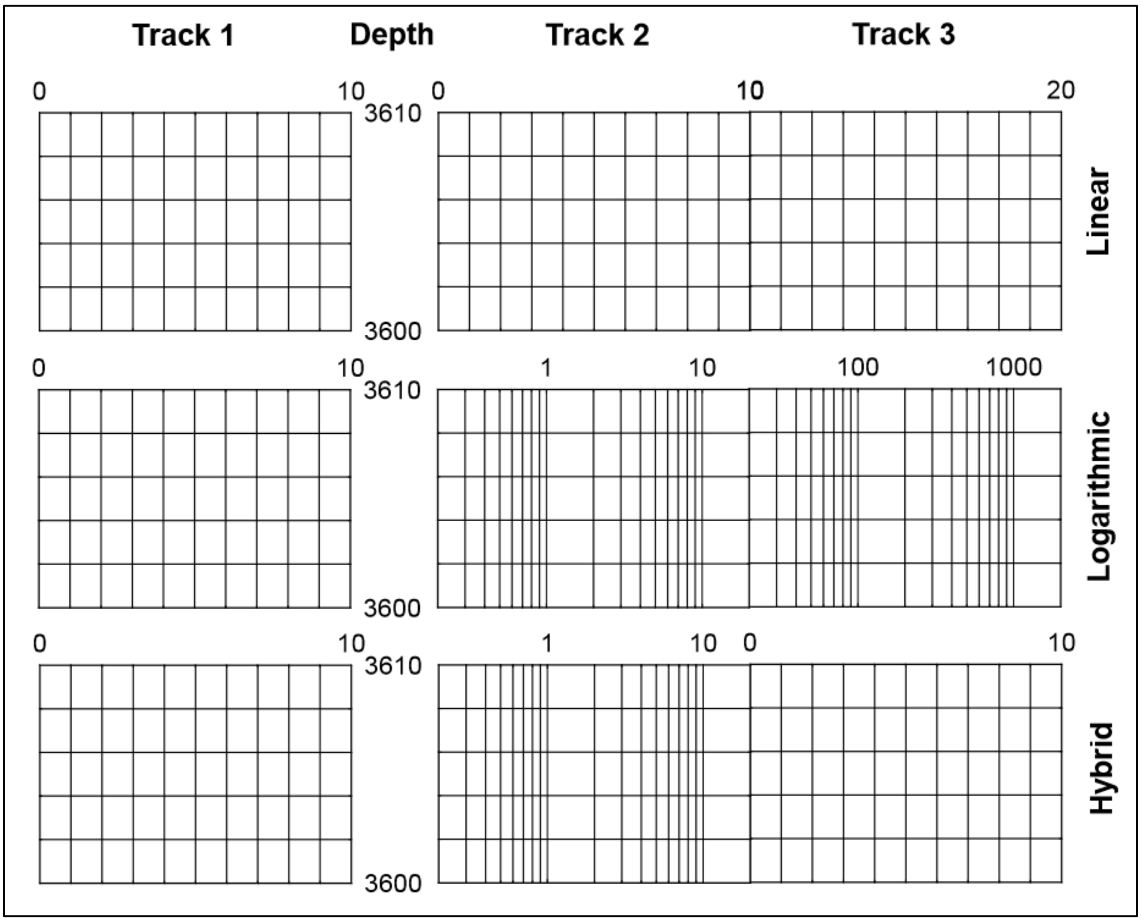


Figure 3

Tracks 2 and 3, which may have either a linear or a logarithmic scale. These tracks are used for density, neutron, and sonic, and resistivity log.

All tracks can take multiple colour (i.e., black, blue, red, green, …etc) and style (i.e., dashed line or solid line). The scale units are given at the top of the log and every log grid is headed by a log heading which allow the suitable interpretation of the log (Figure 4).

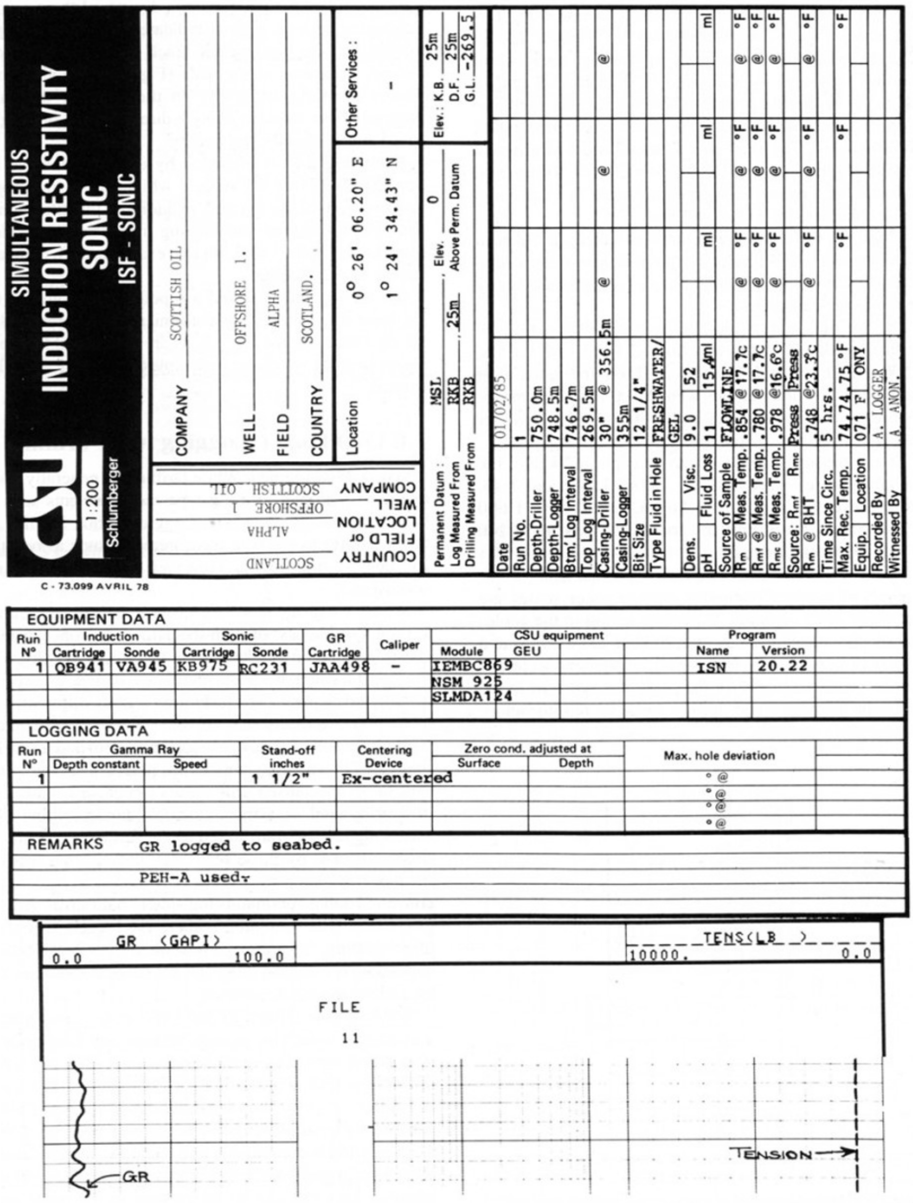


Figure 4

Borehole types

Well Logging Measurements are carried out through the drilled borehole. The drilled borehole may be either an Open Hole or a Cased Hole.

1- Open Hole: A borehole available immediately after drilling. Measurements concern with formation evaluation.

2- Cased Hole: A borehole after placed the casing pipes and cementing. Measurements concern with reservoir development and production well logs are made when the drill-bit is removed from the borehole. This can be either between drilling episodes, or at the end of drilling.

Mud Logging

Mud logging, is the creation of a detailed record (well log) of a borehole by examining the bits of rock brought to the surface by the circulating drilling medium. This provides information about the lithology and fluid content of the borehole while drilling. The drilling mud must be dense, viscous and should have PH of at least 9.

Mud additives:

- Bentonite: which used to increase the viscosity
- Barite: which used to increase the density
- Caustic Soda: which used to increase the alkalinity

Functions of drilling Mud:

- Cleaning the hole
- Cooling the drill bit
- Lifting cuttings to the surface
- Control the formation pressure
- Providing information about formations
- Helps in the invasion process

Types of Drilling Fluids:

1. **Water-Base Mud:** Water is the liquid phase of water-base Mud. Water is used may be fresh water, sea water or saline water.
2. **Oil-Base Mud:** Oil is the liquid phase of oil-base Mud. Advantages of oil-base mud:

- Stabilizing formation
- Reduce downhole drilling problems

3. **Drilling with air:** Dry air or natural gas is used. In this case, we use arrangements of air compressors instead of mud pump. Advantages of this technique:

- Prevent formation damage.
- Allows the bit to drill fast.
- Severe lost circulation problems.

4. **Foam drilling:** This technique is used if small amount of water are present in formation is been drilled. The drilling foam is water containing air or gas bubbles.

Basic well logging equipment

Basic well logging equipment consists of

1- Logging Unit. A special truck installed with a full computer system.

2- Logging cable or the wireline

3- Logging tool or sonde

The logging tool (sonde) is lowered into the wellbore by the logging cable (wireline) and when it reaches the bottom of the interval to be logged, it is slowly withdrawn at a specific speed. Log measurements are made continually during this process where the measurements acquired by the sonde are transmitted to the surface system by the logging. Then, the surface computer records, processes and plots these data as a function of well depth (Figure 5).

- Instruments mounted in steel sondes to protect from downhole pressures and temperatures
- Several sondes combined in a single logging tool string
- Sonde diameter approximately 4 -6" (10-15 cm), combined string lengths can extend over 60 ft (19 m)
- Instruments typically rated to 20,000 psi pressure and 350ºF (177ºC)

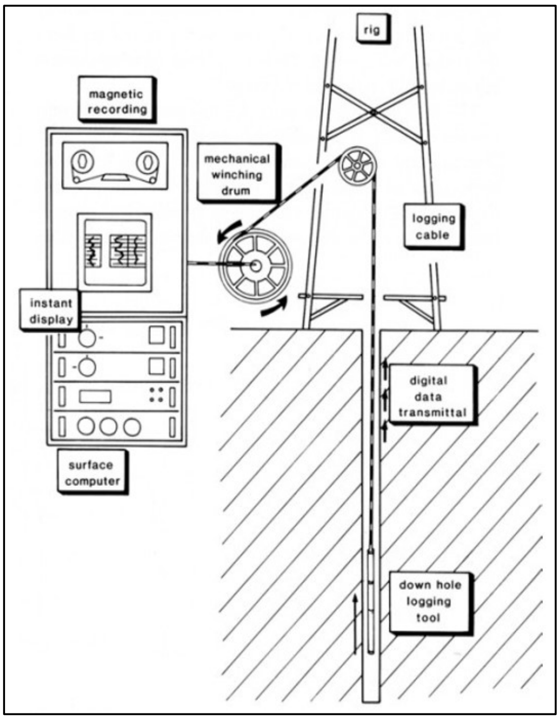


Figure 5

Wireline log tools

Tool or "sonde" is an instrument probe that automatically transmits information about its surroundings underground. The tool contains various pieces of equipment to measure the properties of the rock formation (Figure 6). Examples of the basic physical parameters that can be measured down-hole with logs include:

- The size of the borehole
- The orientation of the borehole
- Temperature
- Pressure
- The natural radioactivity of the rocks
- The acoustic properties of the rocks
- The attenuation offered by the rocks to radioactivity generated from the tool
- The electrical properties of the rocks

While examples of information that derived from logs include:

- Lithology derived from the combination gamma ray and density-neutron logs
- Shale volume from gamma ray or spontaneous potential (SP) logs
- Porosity derived from the sonic, neutron or density logs
- Fluid saturation calculated from the porosity and the electrical logs

Log tool types

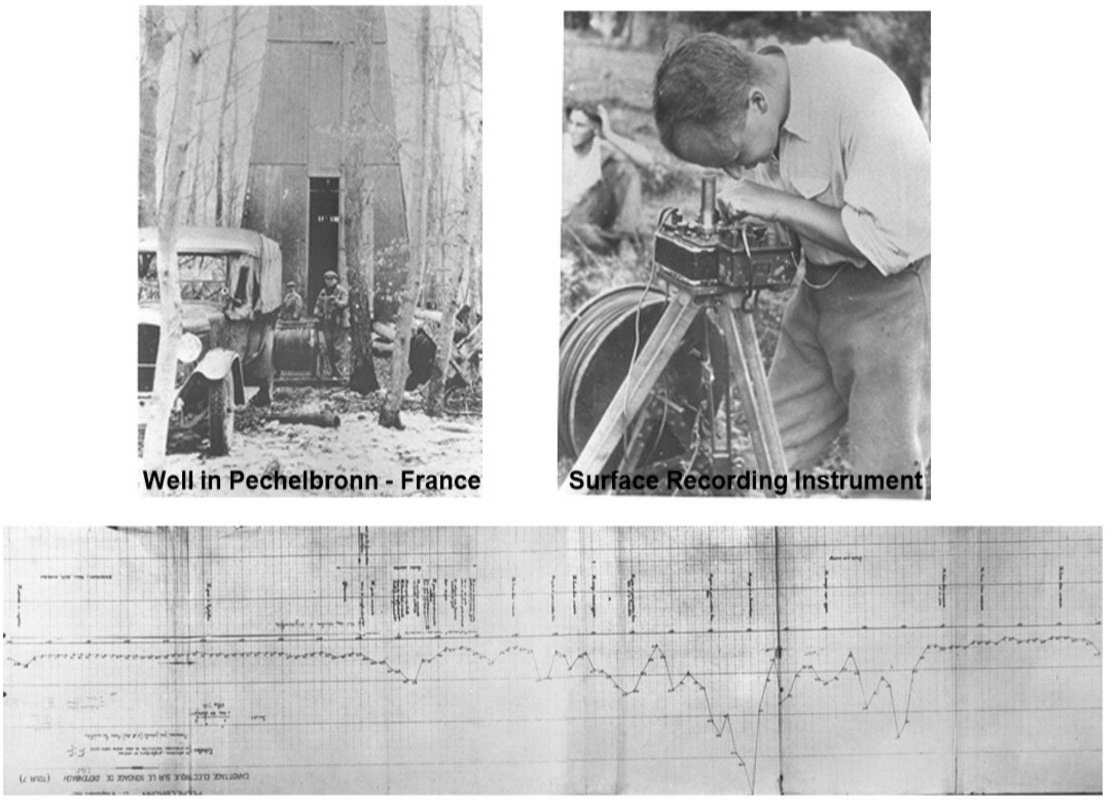
The tools of logging can be classified into:

- **Electrical Logs:**
  - ➢ Spontaneous Potential Log (SP)
  - ➢ Resistivity Logs
- **Mechanical Logs:**
  - ➢ Caliper (Cp)
- **Radioactive Logs**
  - ➢ Gamma Ray (GR),
  - ➢ Neutron (CNL)
  - ➢ Density (FDC),
- **Acoustic Logs**
  - ➢ Sonic (D T)

Figure 6

Well Logging History

- The first electrical log was introduced in 1927 in France using stationed resistivity method (Figure 7).
- The first commercial electrical resistivity tool in 1929 was used in Venezuela, USA and Indonesia.
- SP was run along with resistivity first time in 1931.
- Schlumberger developed the first continuous recording in 1931.
- GR and Neutron logs was started in 1941.
- Microresistivity array dipmeter and lateralog were first time introduced in 1950's.
- The first induction tool was used in 1956 followed by Formation tester in 1957 Formation Density in 1960's, Electromagnetic tool in 1978 and most of Imaging Logs were developed in 1980's.
- Advanced formation tester was commercialized in early 1990's.



Well in Pechelbronn - France

Surface Recording Instrument

The "First" Log recorded in 1927

Figure 7

Advantages and Limitations of Well Logging

Advantages:

- Continuous measurements
- Easy and quick to work with
- Short time acquisition
- Better resolution than seismic data
- Economical

Limitations:

- Indirect measurements
- Limited by tool specification
- Affected by environment

The borehole environment

A schematic borehole showing a cylindrical invasion of borehole fluids into the surrounding rock as indicated by the dotted lines (Figure 9 and 10).

Symbols

□	*Resistivity of the zone*
○	*Resistivity of the water in the zone*
△	*Water saturation in the zone*

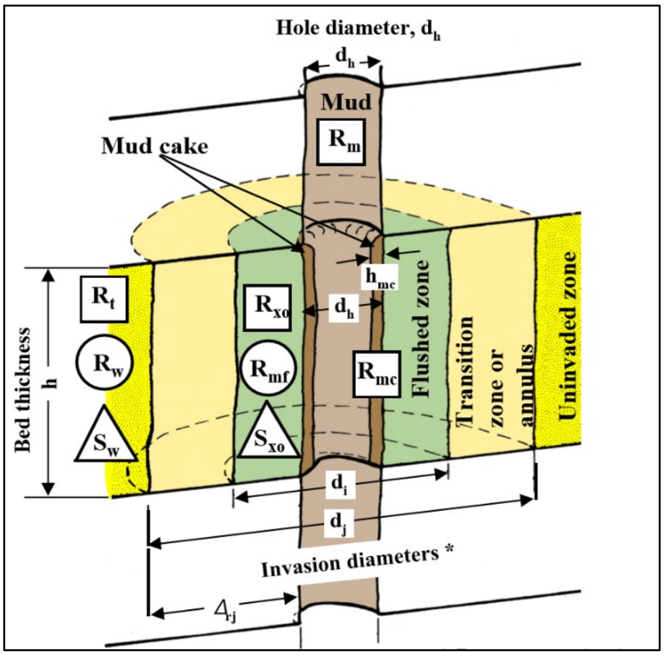


Figure 9

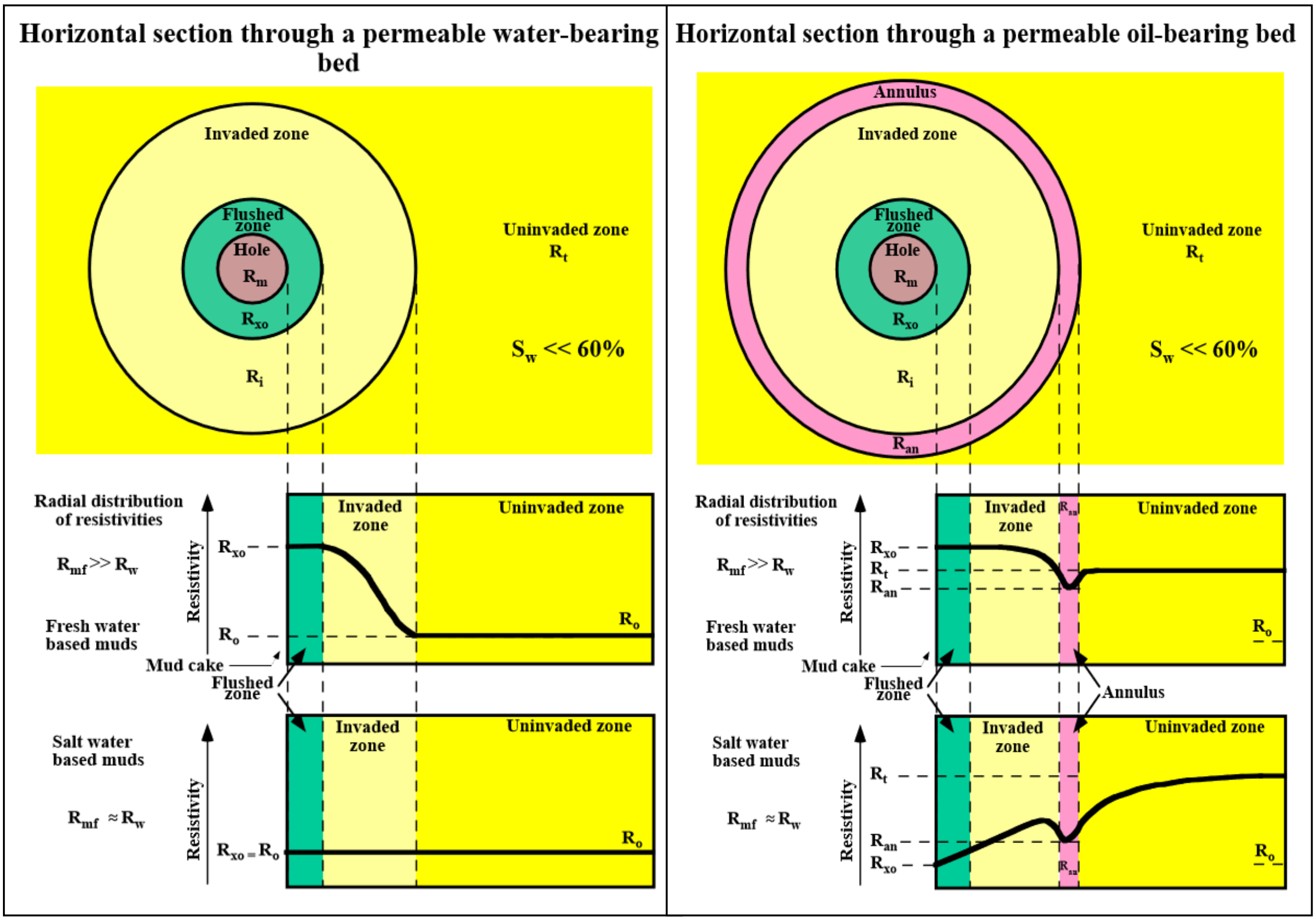


Figure 10

Basic definitions

- **Drilling mud:** circulating fluid used in drilling. Removes cuttings from the well bore, lubricate and cool the drill bit, maintain an excess of borehole pressure over formation pressure. The excess pressure forces the drilling fluid to invade porous and permeable formations.
- **Invasion:** the process when drilling fluids invade into the formation.
- **Mud cake:** as invasion occurs, many of the solid particles from the drilling mud are trapped on the side of the borehole and form mud cake.
- **Mud filtrate:** fluid that filters into the formation during invasion.
- **Invaded zone:** the zone which is invaded by mud filtrate. It consists of a flushed zone and an annulus zone.
- **Uninvaded zone:** the area beyond the invaded zone where a formation's fluids are uncontaminated by mud filtrate.
- **Flushed zone:** a zone close to the borehole where the mud filtrate has almost completely flushed out a formation's hydrocarbons and/or water.
- **Transition zone:** the zone between the flushed zone and the uninvaded zone where a formation's fluids and mud filtrate are mixed.

Hydrocarbon saturation

Hydrocarbon saturation is defined as the amount of pore volume in a rock that is occupied by gas or oil. The hydrocarbon saturation can be calculated by the following equation;

$$S_h = 1 - S_w,$$

whereas, the residual hydrocarbon saturation in the flushed zone is calculated by the following equation;

$$S_{hr} = 1 - S_{xo},$$

where;

S_h= hydrocarbon saturation,

S_w= water saturation,

S_{hr}= residual hydrocarbon saturation, and

S_{xo}= water saturation in the flushed zone.

Electrical Logs

The electrical logs measure the electrical properties of the formation. These measurements deal with the resistivity of the formation or the measurement of spontaneously generated voltages.

Electrical conduction takes place in rocks in two ways:

1. Electrolytic Conduction
2. Electronic Conduction

Electrolytic conduction is the most common method where the current moves through the ions in the pore water. In electronic conduction, the current is carried by the free mobile electrons in the metals. The low resistivity (high conductivity) of metals is, therefore, explained by the large number of free electrons in their structure.

Factors affecting electrical properties of reservoirs

- Salinity
- Temperature
- Saturation
- Presence of hydrocarbons
- Lithology

Electrical properties of reservoirs vary strongly with porosity and characteristics of the fluids in the pore space; usually, basic properties are determined assuming that; the reservoir rock is clean (non-shaly), and saturated by water Sw = 1.0 (water saturated rock).

There are many tools and techniques have been designed and developed to make a very accurate measurements of this parameter. Two main types of tool are measure the electrical rock properties.

- Tool measures resistivity directly, and the result is given in ohm.m (Ω.m).
- Tool measures conductivity directly, and the result is given in siemens per metre (S/m), or in millisiemens per metre (mS/m).

Resistivity Log types:

There are two main types; old resistivity logs, and modern resistivity logs.

A) Old resistivity logs

This type of simple devices have been largely superseded by later technology, but the logs will be seen in many old wells. The old resistivity logs consist of two types according to their electrodes arrangements

1) The Standard Normal Log (SNL)

The current flow circuit (the generator circuit) to be separated from the potential sensing circuit (the meter circuit). In this arrangement, a constant known current is flowed from A to B (or B to A), and the potential is measured between M and N.

The current emitting electrode (A) and the measure electrode (M) are placed close together on the sonde, and the current return electrode (B) and the measure reference electrode (N) far away (Figure 12). The response is determined mainly by the distance between A and M. The larger AM, the deeper the measurement. Although many distances have been used, the most common are 16 in (40 cm), known as the short normal, and 64 in (162 cm), known as the long normal.

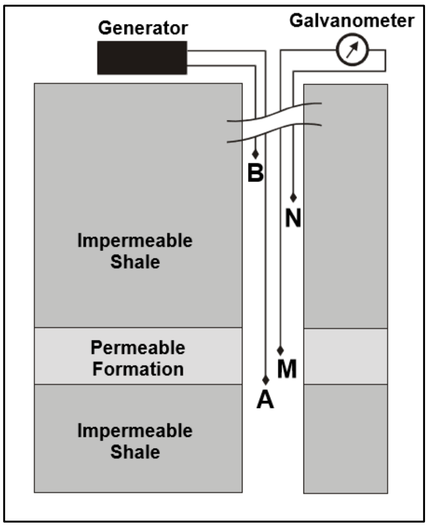


Figure 12

2) The Standard Lateral Log (SLL)

The current electrodes A and B are placed close together on the sonde with several feet away to the measuring electrode (M) and far away to the return measuring electrode (N).

The spacing is defined by the distance from M to the midpoint between A and B. The most common spacing is 18 ft, 8 in (5.7 m). The lateral gives a sharper response to a bed boundary than a normal log (Figure 13).

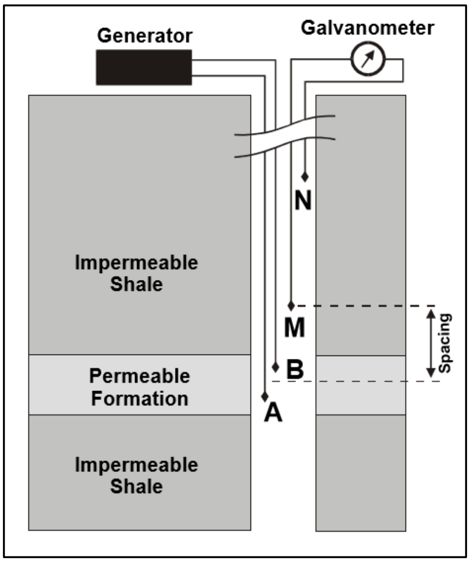


Figure 13

B) Modern resistivity logs

The modern resistivity logs is divided into two main types;

1) Laterologs

2) Micro-resistivity logs

1) Laterologs

The laterologs subdivided into three types;

1-1 The Basic Laterologs (LL3 and LL7)

1-2 The Daul Laterologs (DLL)

1-3 The Spherically Focussed Log (SFL)

2) The Micro resistivity Log (Microlog):

2-1 The MicroLog (ML)

2-2 The Microlaterolog (MLL)

2-3 The Proximity Log (PL)

2-4 The Micro Spherically Focussed Log (MSFL)

Induction Log

Induction Log measures formation conductivity (its ability to measure conduct the electrical current). These logs were originally designed for use in boreholes where the drilling fluid was very resistive (oil-based muds or even gas). It can be used also in water-based muds of high salinity but has found its greatest use in wells drilled with fresh water-based muds.

The sonde consists of two wire coils, a transmitter (Tx) and a receiver (Rx) (Figure 21). High frequency alternating current (20 kHz) of constant amplitude is applied to the transmitter coil. This gives rise to an alternating magnetic field around the sonde that induces secondary currents in the formation. These currents flow in coaxial loops around the sonde, and in turn create their own alternating magnetic field, which induces currents in the receiver coil of the sonde.

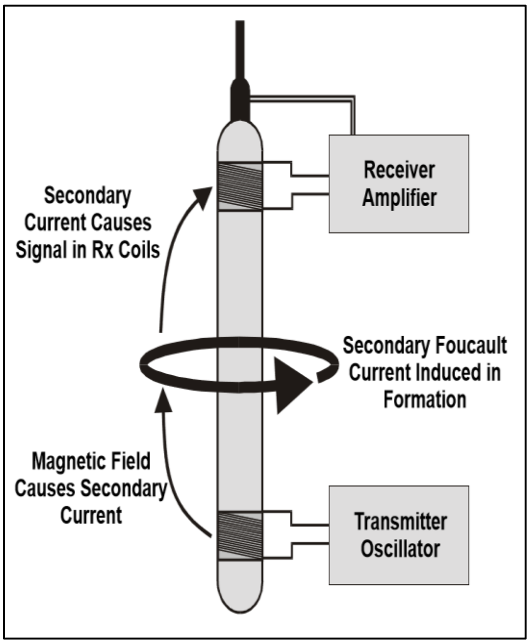


Figure 21

The received signal is measured, and its size is proportional to the conductivity of the formation.

Spontaneous Potential (Self- Potential)

The Spontaneous potential (SP) log is a measurement of the natural electrical potential in the formation caused by salinity difference between the drilling mud and the formation water. Curve records the naturally occurring electrical potential (voltage) produced by the interaction of formation connate water and conductive drilling fluid.

It is a very simple log that requires only an electrode in the borehole and a reference electrode at the surface. These spontaneous potentials arise from the different access that different formations provide for charge carriers in the borehole and formation fluids, which lead to a spontaneous current flow and hence to a spontaneous potential difference (Figure 22). The SP log has four main uses:

- Identify the permeable and impermeable beds.

- The determination of Rw.
- The indication of shale content.
- Correlation.

The measured SP value is influenced by bed thickness, bed resistivity, borehole diameter, invasion, shale content, hydrocarbon content, and the ratio of Rmf to Rw.

In a thin formation (i.e., less than about 10 ft [3 m] thick), the measured SP is less than SSP. The SP curve can be corrected by chart for the effects of bed thickness. As a general rule, whenever the SP curve is narrow and pointed, the SP should be corrected for bed thickness before being used in the calculation of Rw. To calculate the shale volume (V shale) we use the following equation;

$$V\ shale = \frac{PSP - SSP}{SP\ shale - SSP}$$

$V\ shale$ = volume of shale

PSP = pseudostatic spontaneous potential (maximum SP of shaly formation)

SSP = static spontaneous potential of a nearby thick clean sand

$SP\ shale$ = value of SP in a shale (usually assumed to be zero)

In hydrocarbon-bearing zones, the SP deflection is reduced. This effect is called hydrocarbon suppression. Hydrocarbon suppression of the SP is a qualitative phenomenon, and cannot be used to determine the hydrocarbon saturation of the formation. The SP response of shales is relatively constant and follows a straight line called a shale baseline.

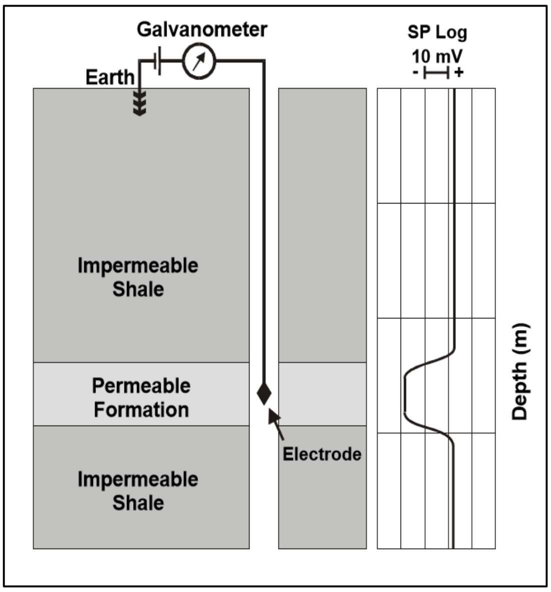


Figure 22

The SP value of the shale baseline is assumed to be zero, and SP curve deflections are measured from this baseline. Permeable zones are indicated where there is SP deflection from the shale baseline. For example, if the SP curve moves either to the left (negative deflection; Rmf > Rw) or to the right (positive deflection; Rmf < Rw) of the shale baseline, permeable zones are present.

Permeable bed boundaries are placed at the points of inflection from the shale baseline. Rocks other than shale (e.g. sandstones) will also result in poor or no response on the SP curve because of no ion exchange. SP can only be acquired in open hole, and conductive fluids are necessary in borehole to create a SP response, so the SP log cannot be used in nonconductive drilling muds (e.g. oil-based mud).

When mud filtrate salinities are lower than connate water salinities (i.e., Rmf is > Rw), the SP deflects to the left (the SP potential is negative). This is called a normal SP. When the salinities are reversed (i.e., salty mud and fresh formation water, Rmf < Rw), the SP deflects to the right. This is called a reverse SP. Other things being equal, there is no SP (and no SP deflection) at all when Rmf = Rw (Figure 23).

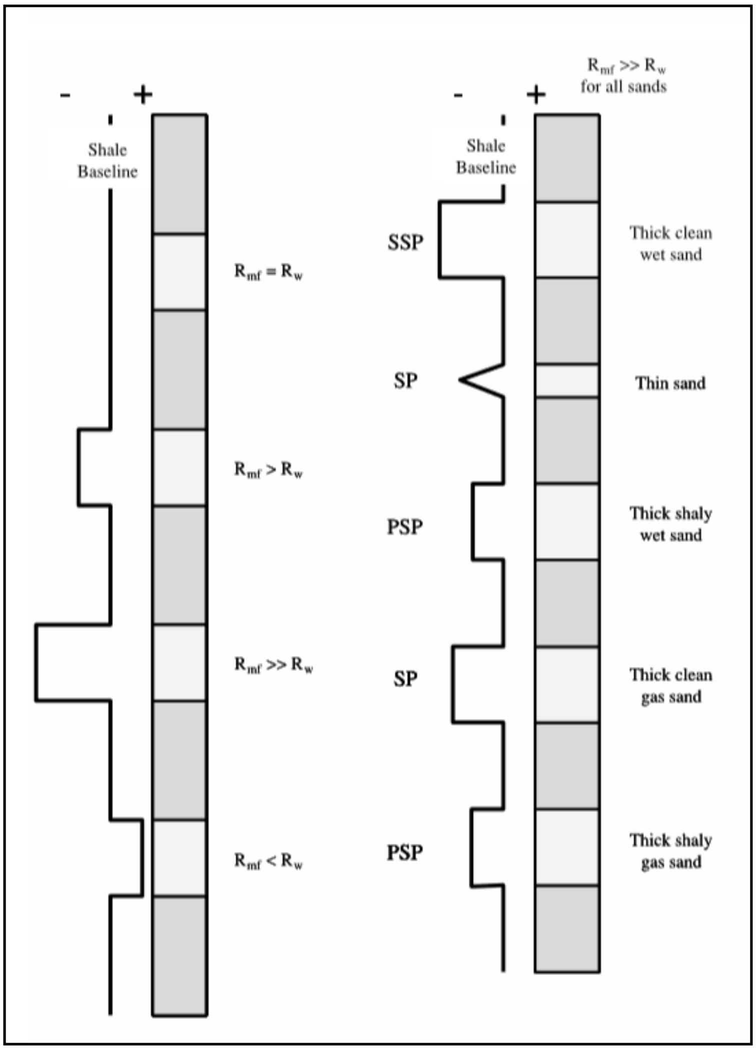


Figure 23

Caliper log

The Caliper Log is a tool for measuring the diameter and shape of a borehole. It uses a tool which has 2, 4, or more extendable arms (Figure 24). The arms can move in and out as the tool is withdrawn from the borehole, the arms are linked to a potentiometer, and the movement is converted into an electrical signal by the potentiometer.

In the two arm tool, the borehole diameter is measured and shown in the log together with the bit size for reference. Borehole diameters larger and smaller than the bit size are possible. Many boreholes can attain an oval shape after drilling. This is due to the effect of the pressures in the rocks being different in different directions. In oval holes, the two arm caliper will lock into the long axis of the oval cross section, giving larger values of borehole diameter than expected. In this case tools with more arms are required.

Two arm caliper Four arm caliper tool Multi-arm caliper tool

Figure 24

The caliper logs are plotted with the drilling bit size for comparison (Figure 25 – 1&2), or as a differential caliper reading, where the reading represents the caliper value minus the drill bit diameter. The scale is generally given in inches, which is standard for measuring bit sizes. The 4 arms (or dual caliper) tools are presented in a range of formats, an example of which is given in Figure 25 - 3. Note that data from the caliper pairs are shown together and that they are different indicating an oval hole.

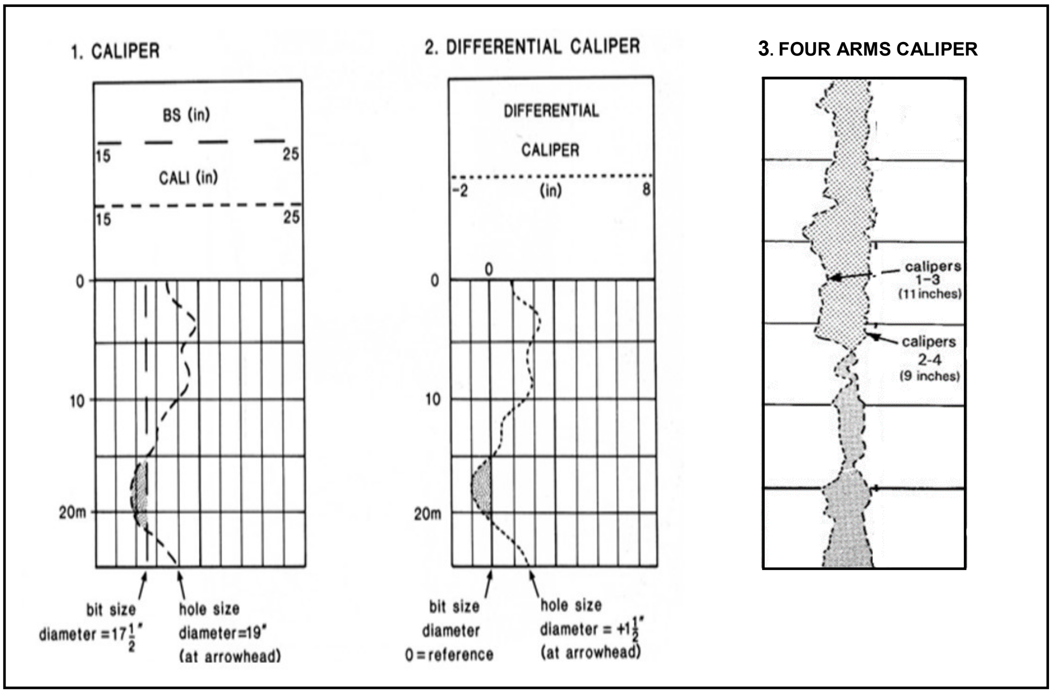


Figure 25

The differences between the caliper and bit size logs can be used to identify that part of the log quality which depends on the presence of caving and mudcake and is used to apply the borehole environmental corrections to the affected tool measurements (Table 1), (Figure 26).

Table 1

Borehole condition	Logs quality
Caliper – Bit size = 0%	Excellent, no correction
Caliper - Bit size < 10%	Good quality, refer to DRHO log
Caliper – Bit size = 10 – 30%	Moderate, may require correction
Caliper – Bite size > 30 – 50%	Bad, requires correction
Caliper – Bite size > 50%	Very bad, requires correction

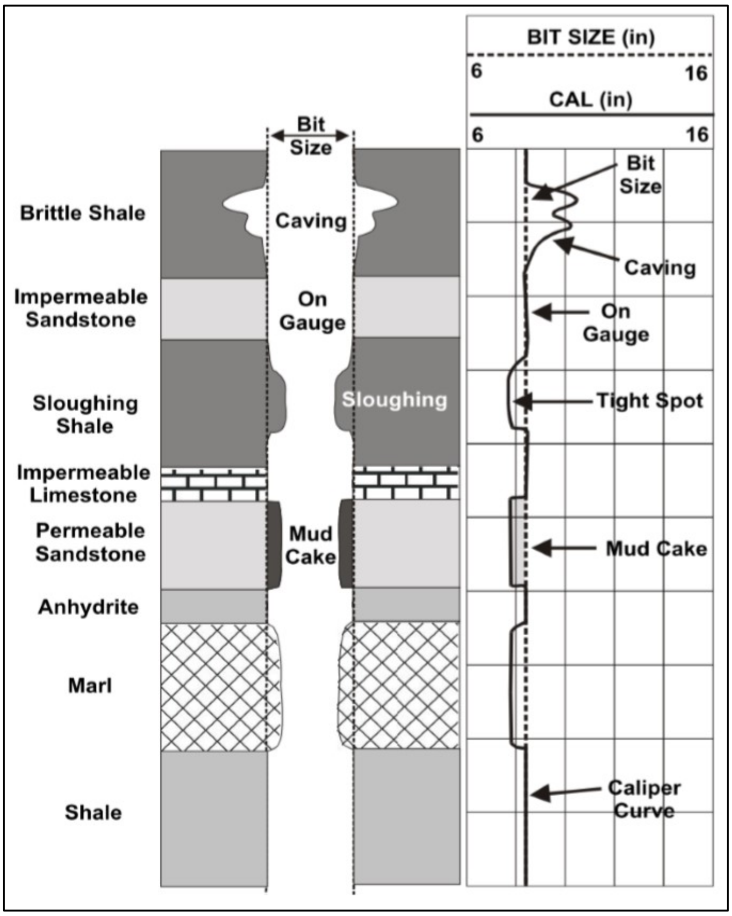


Figure 26

Gamma Ray

Gamma ray (GR) logs measure the natural radioactivity in formations and can be used for identifying lithologies and for correlating zones. Shale-free sandstones and carbonates have low concentrations of radioactive material and give low gamma ray readings. As shale content increases, the gamma ray log response increases because of the concentration of radioactive material in shale. However, clean sandstone (i.e., with low shale content) might also produce a high gamma ray response if the sandstone contains potassium feldspars, micas, glauconite, or uranium-rich waters (Figure 27).

Consequently, low natural radioactivity identifies in sandstone, limestone, dolomites and high natural radioactivity in shale, and organic rich rock (source rock). In most reservoirs the lithologies are quite simple, being cycles of sandstones and shales or carbonates and shales. Once the main lithologies have been identified, the gamma ray log values can be used to calculate the shaliness or shale volume Vsh of the rock. This is important as a threshold value of shale volume is often used to help discriminate between reservoir and non-reservoir rock.

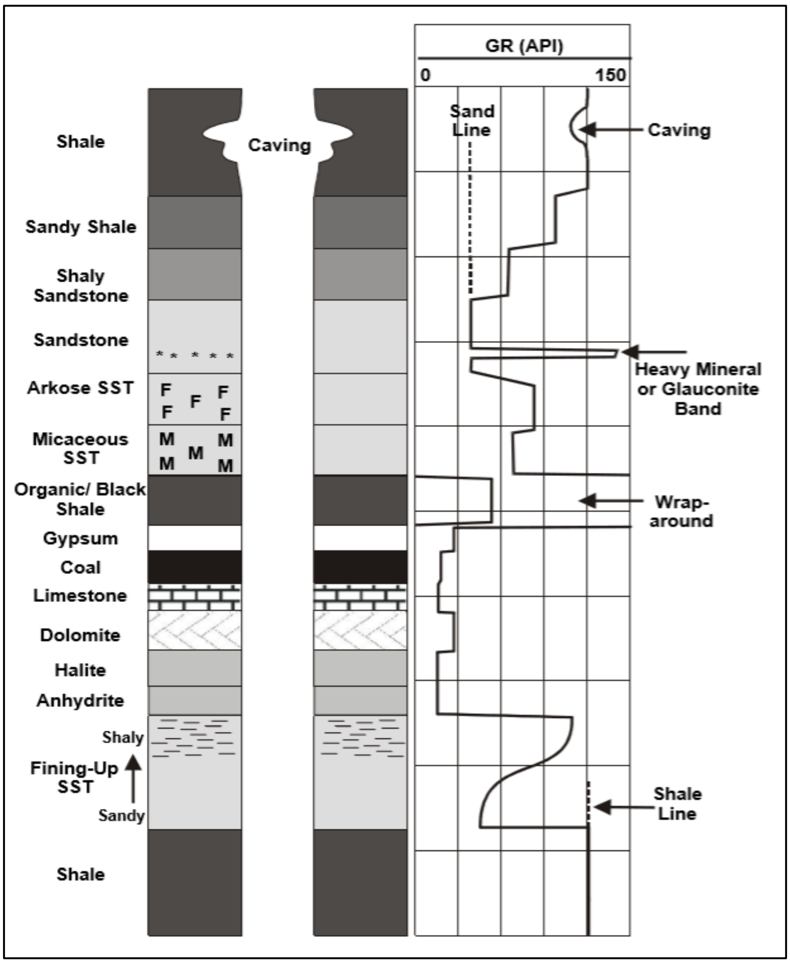


Figure 27

Shale volume is calculated in the following way: First the gamma ray index IGR is calculated from the gamma ray log data using the relationship.

$$I_{GR} = \frac{GR_{Log} - GR_{min}}{GR_{max} - GR_{min}}$$

where:

I_{GR}: the gamma ray index

$GR_{Log:}$ the gamma ray reading at the depth of interest

$GR_{min:}$ the minimum gamma ray reading. (Usually the mean minimum through a clean sandstone or carbonate formation.)

GR_{max}: the maximum gamma ray reading. (Usually the mean maximum through a shale or clay formation.)

Density Log (RHOB)

The density log emits medium-energy gamma radiation. These high velocity particle collide with electrons in the matrix, and with each collision lose energy (Compton Scattering) (Figure 29). The scattered returning gamma rays are counted and can be used to measure the formation density.

It measures the total rock matrix density (g/cm^3), and density of the pore fluids. Variations in total density will be due to variations in the amount of matrix available to absorb the gamma radiation, thus the tool is a porosity tool.

A radiation emitter and one detector are all that is necessary for a simple measurement. The early tools had only one detector, which was pressed against the borehole wall by a spring-loaded arm. This type of tool was extremely inaccurate because it was unable to compensate for mud-cake of varying thicknesses and densities through which the gamma rays have to pass.

All the newer tools (compensated formation density logs) have two detectors to help compensate for the mud-cake problem (Figure 29).

The compensated formation density tools have one focused (collimated) radiation source, one short spacing detector at 7 inches from the source, and one long spacing detector 16 inches from the source. The gamma ray source is either Cobalt-60 or Cesium-137 emitting 0.662 MeV from the source.

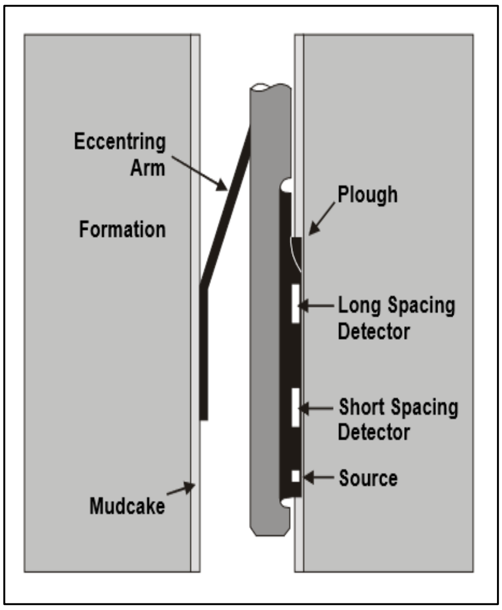


Figure 29

The source and both detectors are heavily shielded (collimated) to ensure that the radiation only goes into the mudcake and formation, and that detected gamma rays only come from the mud-cake or formation. The leading edge of the shield is fashioned into a plough which removes part of the mud-cake as the tool is pulled up the well. The tool is pressed against one side of the borehole using a servo-operated arm with a force of 800 pounds force. Under this pressure and the pulling power of the wireline winch the plough can make a deep impression in the mud-cake.

The formation density log is recorded in tracks 2 and 3 of the standard API log presentation on a linear scale. The scale is in g/cm3, and usually spans 1.95 to 2.95 g/cm3 as this is the normal range for rocks (Figure 30).

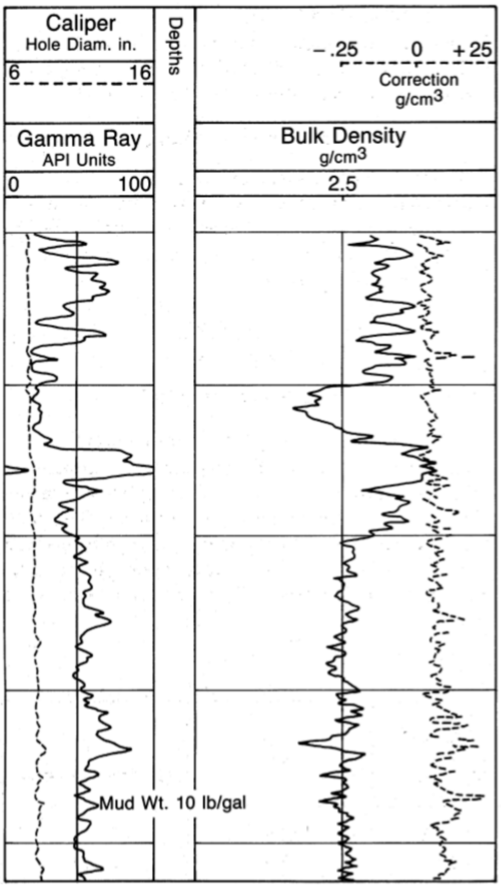


Figure 30

Density Porosity ($\emptyset_D$)

The density porosity can be calculated using the following equation;

$$\emptyset_D = \frac{(\rho ma - \rho b)}{(\rho ma - \rho f)},$$

where;

$\emptyset_D$= density-derived porosity (fractional)

ρb = formation bulk density (the log reading)

ρf = pore fluid density

ρma = matrix density

Matrix densities values of common lithologies are shown in Table 2.

Table 2

Lithology/Fluid	ρ_{ma} or ρ_{fl} g/cm^3 (Kg/m^3)
Sandstone	2.644 (2644)
Limestone	2.710 (2710)
Dolomite	2.877 (2877)
Anhydrite	2.960 (2960)
Salt	2.040 (2040)
Fresh water	1.0 (1000)
Salt water	1.15 (1150)
Oil-based drilling mud	0.85 (850)

Neutron log

Neutron logs are made of a source of neutrons in the probe detectors. Logging tool emits high energy neutrons of several million electron volts (MeV) into formation to collide with nuclei of formation's atoms. Neutrons lose energy (velocity) with each collision and the most energy is lost when colliding with a hydrogen atom nucleus. The largest loss of energy occurs when the neutrons collide with hydrogen atoms as the electrically neutral neutron has a mass that is practically identical to that of the hydrogen atom. The rate at which the neutrons slow-down depends largely on the amount of hydrogen in the formation (Figure 31).

At this energy the neutrons are in thermal equilibrium with other nuclei in the formation. Then, the neutrons will eventually be captured by a nucleus. Log records porosity based on neutrons captured by formation. If hydrogen is in pore space, porosity is related to the ratio of neutrons emitted to those counted as captured.

There are two type of the Neutron logs; Sidewall Neutron Porosity Tool (SNP), and Compensated Neutron Log Tool (CNL). The (SNP) tool has a source and a single detector with 16 inch spacing, which are mounted on a skid that is pressed against the borehole wall. Because the tool is pressed against the borehole wall, the drilling mud does not affect the measurement, and the attenuation due to the mud cake is reduced. This tool is designed for use in open holes only.

The (CNL) tool has two detectors situated 15 inch and 25 inch from the source. The detector further from the source is larger to ensure that adequate count rates are observed. The critical measurement for this tool is the difference in the thermal neutron population, which results from neutron capture and neutron scattering. The tool readings are presented in limestone porosity units in the same way as the sidewall neutron porosity tool.

The CNL tool has a very strong source of neutrons allowing the tool to operate in cased holes. The CNL tool is run eccentred in the hole by an arm which presses the tool against the side of the borehole. This means that the tool is insensitive to the type of mud in the hole, but implies that the readings are only for one portion of the borehole wall. The data from all tool types are recorded in tracks 2 and 3 in equivalent limestone porosity units, with the scale running from –15% to 45% (Figure 32).

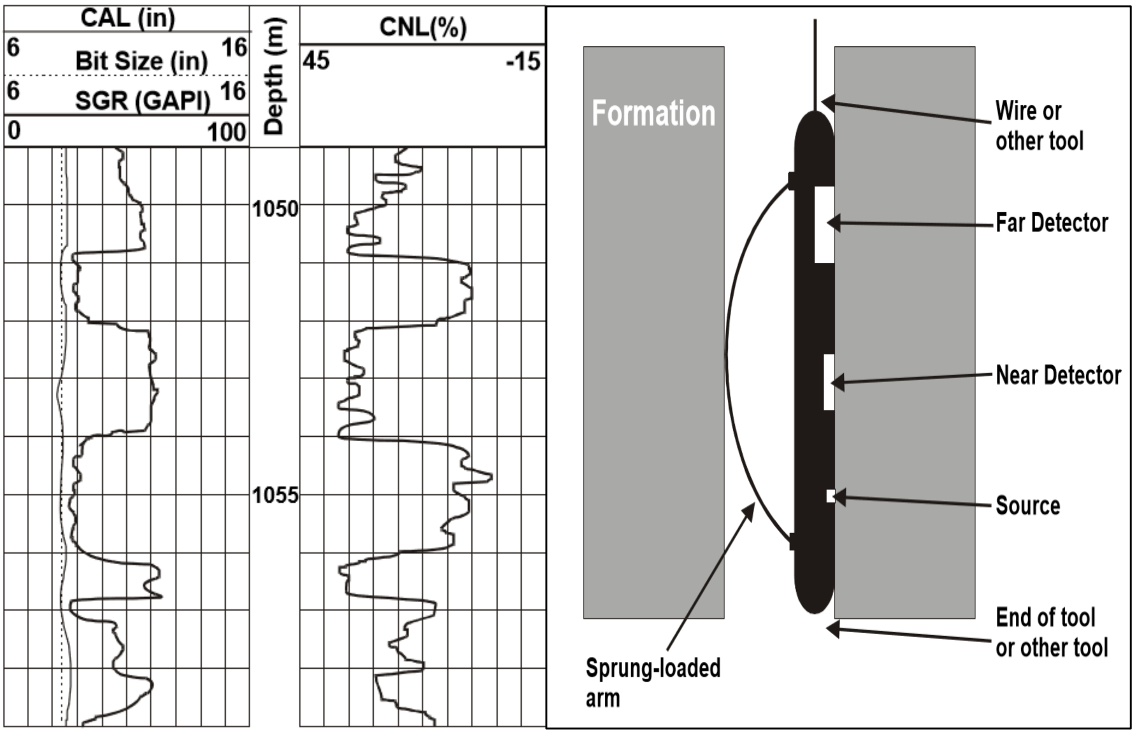


Figure 32

Neutron Log applications

Neutron tools are used primarily to determine:

1- Porosity, usually in combination with the density tool.

2- Gas detection, usually in combination with the density tool, but also with a sonic tool.

3- Shale volume determination, in combination with the density tool.

4- Lithology indication, again in combination with the density log and/or sonic log.

The hydrocarbon effect:

The presence of hydrocarbon liquid (oil) does not affect the tool response as it has approximately the same hydrogen index as fresh water. Hydrocarbon gas, however, has a much lower hydrocarbon index resulting from its low density, and its presence will give rise to underestimations in porosity (Figure 33).

The shale effect:

Shale contain clays that have a significant amount of bound water molecules on their surfaces. This increases the hydrogen index of the formation. Even very low porosity shales can give erroneously high porosity readings due to the presence of these bound waters.

The chloride effect:

Chlorine is a good absorber of neutrons, and can lead to overestimations of porosity if present either as formation fluid or mud filtrate.

Determination of Lithology

The direct use of the neutron log to identify lithologies depends upon the recognition of which lithologies may contain hydrogen atoms (Figure 34).

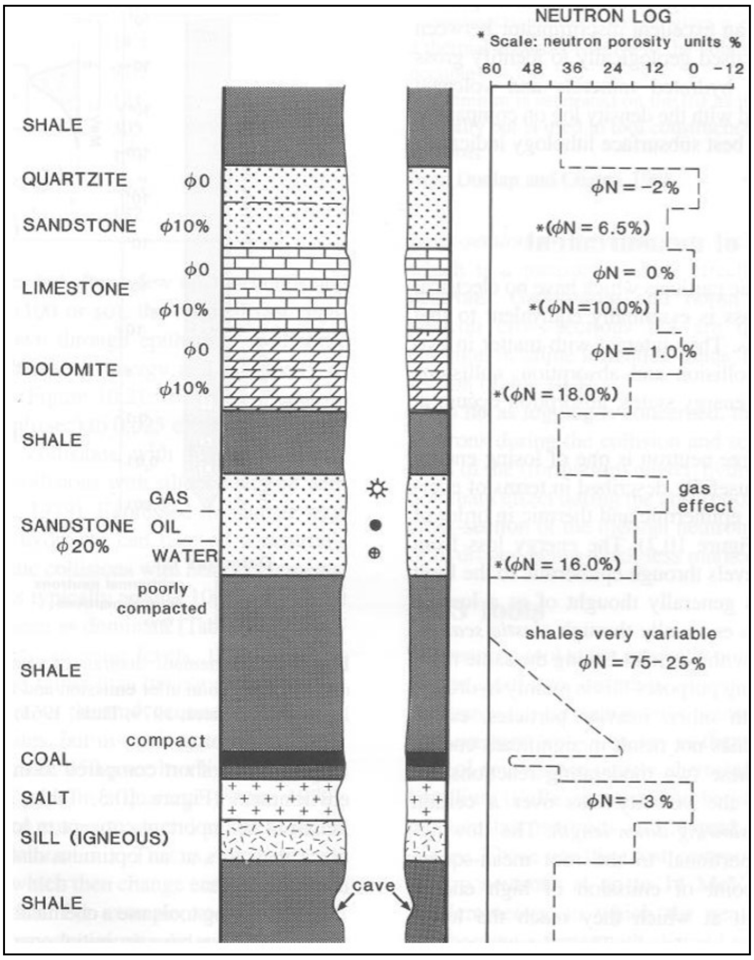


Figure 34

Sonic log

Acoustic tools measure the speed of sound waves in subsurface formations. In other words, it is a measure of a formation’s capacity to transmit sound waves. The acoustic log can be used to determine porosity in consolidated formations. Borehole compensated sonic tools (BHC) have two acoustic transmitters and four acoustic receivers.

The transmitters emit compressional sound waves into the formation and the receivers measure the time it takes for the wave to travel through the formation to the receiver. Travel time or ∆t is the time difference of the wave as it is received at both receivers. Travel time depends on formation lithology, porosity, and pore fluid.

The compensated sonic tool is consists of two transmitters and four receivers. Transmitter 1 starts to emit waves which received by two receivers. Then this process repeats again with transmitter 2 and the other two receivers (Figure 35). Tool is putted in center of borehole (no contact with hole).

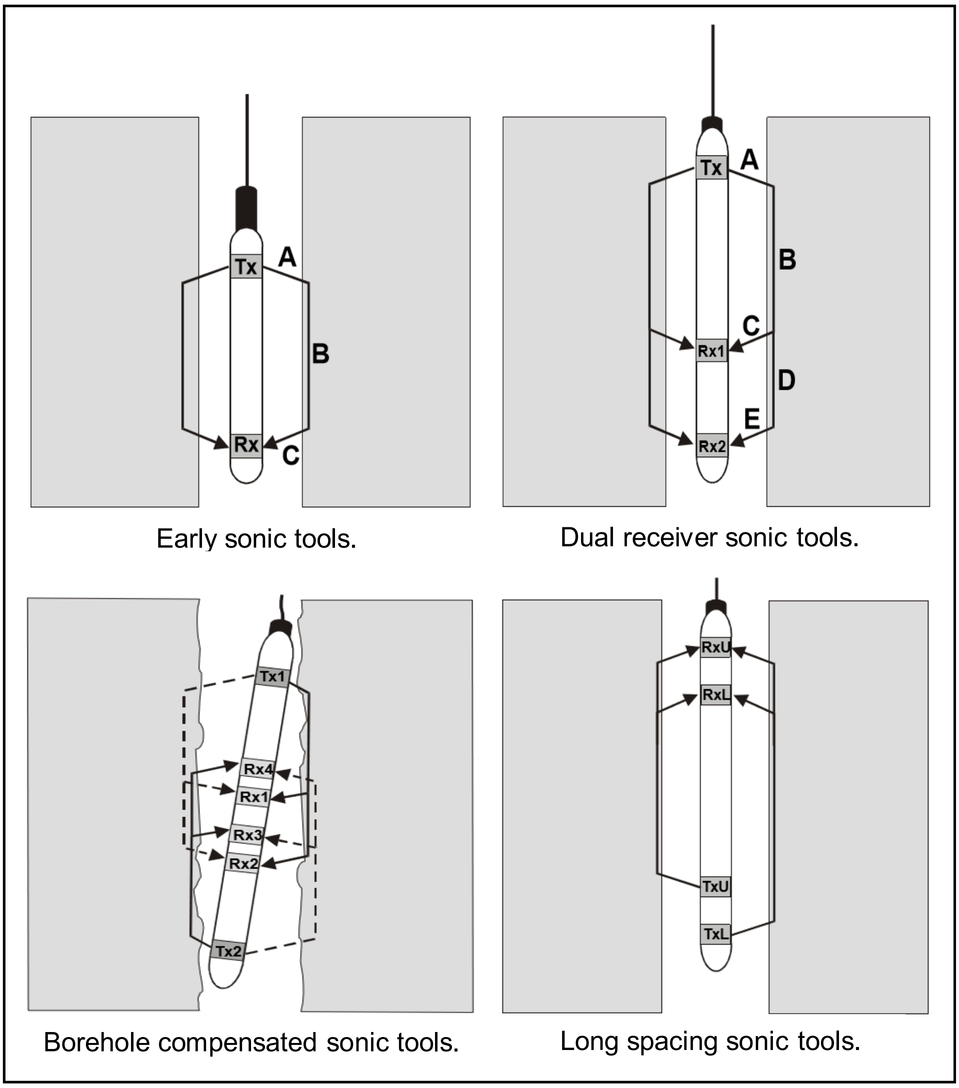


Figure 35

The interval transit time Δt is recorded on the log in microseconds per foot (μs/ft.). If the log is run on its own, the log takes up the whole of Track 2 and 3, if combined with other logs, it is usually put in Track 3. Most formations give transit times between 40 μs/ft. and 140 μs/ft., so these values are usually used as the scale (Figure 36).