iJRASET
International Journal For Research in
Applied Science and Engineering Technology

INTERNATIONAL JOURNAL FOR RESEARCH

IN APPLIED SCIENCE & ENGINEERING TECHNOLOGY

Volume: 6 **Issue:** I **Month of publication:** January 2018

DOI: http://doi.org/10.22214/ijraset.2018.1337

International Journal for Research in Applied Science & Engineering Technology (IJRASET)
ISSN: 2321-9653; IC Value: 45.98; SJ Impact Factor :6.887
Volume 6 Issue I, January 2018- Available at www.ijraset.com

Well Logging Importance in Oil and Gas Exploration and Production

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I. INTRODUCTION

Logging is a continuous recording of the physical properties of rocks in the well with respect to depth. These physical properties are porosity, resistivity, density, conductivity, saturation etc. Logging was started with simple electric logs measuring the electric conductivity of rocks, but it is now a technically advanced and sophisticated method. Logging plays a crucial role in exploration and exploitation of hydrocarbons.

Well logging in oil industry has its own meaning; log means "record against depth of any of the characteristics of the rock formations traversed by a measuring apparatus in the well bore". The value of the measurement is plotted continuously against depth in the well (Fig1). For example, the resistivity log is a continuous plot of a formation resistivity from the bottom of the well to the top.

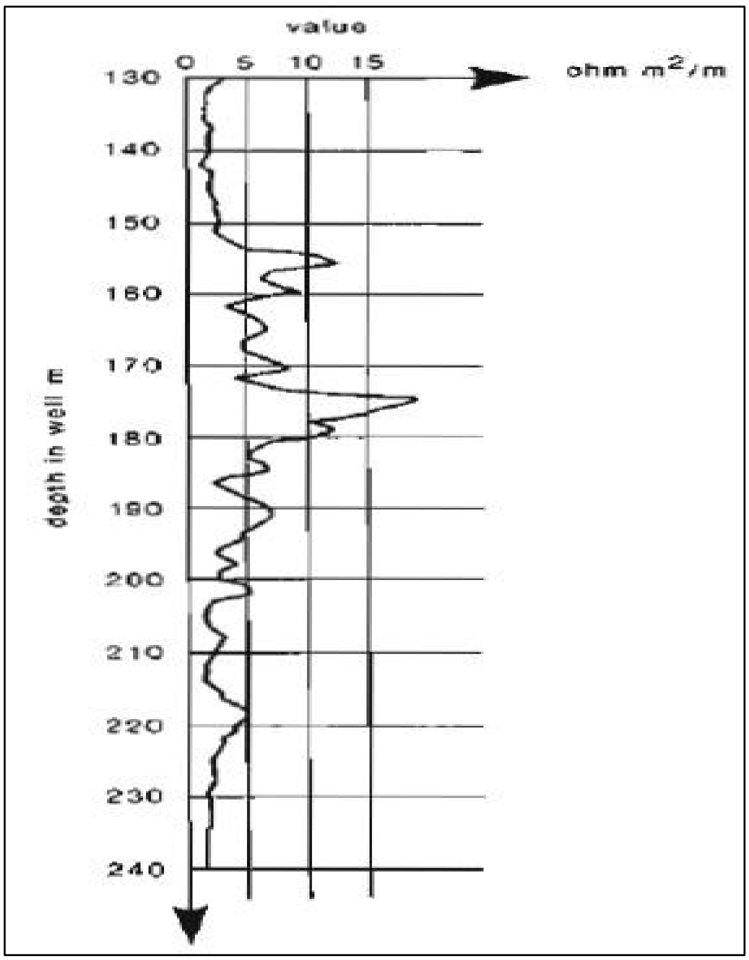

Fig- 1: A well log

The most appropriate name for this continuous depth related record is a wire- line geophysical well log, conveniently shortened to well log or log.

Generally, we go for geophysical methods for identifying the structures present beneath the earth subsurface over a few kilometres. One of the geophysical methods, that is logging is used to study the physical parameters of the formations inch by inch. Whenever an interesting zone is encountered we go for coring. This is the direct analysis of the formations. But it is not possible to take core analysis for entire well. So logging will give adequate data of entire well in indirect analysis.

A. petro Physical Parameters

1) *Porosity:* Porosity is defined as a measure of the pore spaces present in a rock. These pore spaces within the reservoir rocks could be filled with gas, oil or water. High porosity values indicate high capacities of the reservoir rocks to contain these fluids, while low porosity values indicate the opposite. Porosity is calculated as the pore volume of the rock divided by its bulk volume. Expressed in terms of symbols, is represented as:

$$\emptyset = V_P/V_B$$

Where $\emptyset -$ *porosity*

$V_P -$ *pore volume*

$V_B -$ *bulk volume*

Pore volume is the total volume of pore spaces in the rock, and bulk volume is physical volume of the rock, which includes the pore spaces and matrix materials (sand and shale, etc.) that compose the rock. Porosity has no units. It is expressed in percentages. Two types of porosities can exist in a rock. These are termed as

2) *Primary porosity:* Primary porosity is described as the porosity of the rock that formed at the time of its deposition.
3) *Secondary porosity:* Secondary porosity develops after deposition of the rock. Secondary porosity includes vugular spaces in carbonate rocks created by the chemical process of leaching, or fracture spaces formed in fractured reservoirs. Porosity is further classified as:
4) *Total porosity*: is defined as the ratio of the entire pore space in a rock to its bulk volume
5) *Effective porosity is* the ratio of interconnected pore space to the bulk volume of the rock.

Rock porosity data are obtained by direct or indirect measurements. Laboratory measurements of porosity data on core samples are examples of direct methods.

Determinations of porosity data from well log data are considered indirect methods.

6) *Factors effecting porosity*
   a) Grain Shape
   b) Grain size
   c) Grain Packing
   d) Distribution Of Grains

B. Permeability

Permeability is a measure of the ability of a porous medium, to transmit fluids through its interconnected pore spaces. Permeability is three types.

1) *Effective Permeability:* When the pore spaces in the porous medium are occupied by more than one fluid, the permeability measured is the Effective permeability of the porous medium to that particular fluid. For instance, the effective permeability of a porous medium to oil is the permeability to oil when other fluids, including oil, occupy the pore spaces.
2) *Relative Permeability***:** the ratio of effective permeability to absolute permeability of a porous medium.
3) *Absolute permeability:* If the porous medium is completely saturated (100% saturated) with a single fluid, the permeability measured is the absolute permeability. It is an intrinsic property of the porous medium, and the magnitude of absolute permeability is independent of the type of fluid in the pore spaces.

II. WIRE-LINE GEOPHYSICAL LOGS

Wireline geophysical well logs (Open-hole log) are recorded when the drilling tools are no longer in the hole. Wireline logs are made using highly specialized equipment entirely separate from that used for drilling. Onshore, a motorized logging truck is used which brings its array of surface recorders, computers and logging drum and cable to the drill site. Offshore, the same equipment is installed in a small cabin left permanently on the rig. Both truck and cabin use a variety of inter-changeable logging tools, which are lowered into the well on the logging cable as shown in the below (Fig .2)

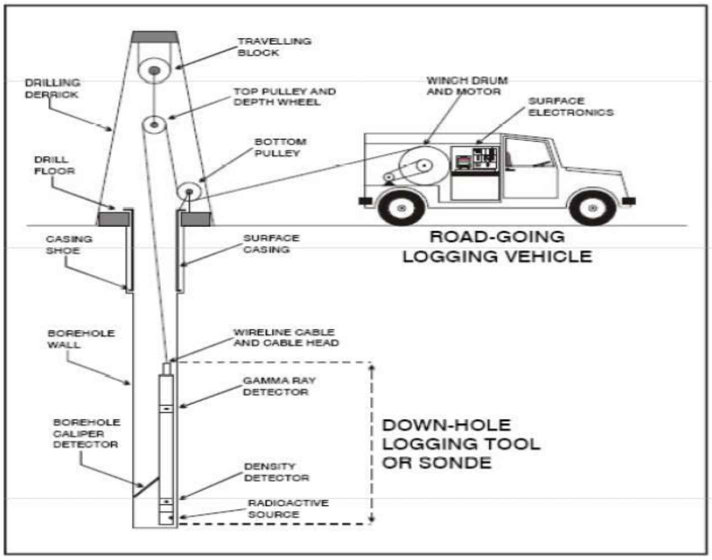

Fig -2.:Modern Wire line logging set up

Most modern logs are recorded digitally. The sampling rate will normally be once every 15 cm (6inch). At typical logging speeds, data transmission rates will vary from 0.05 kilobits per second for simpler logs to over 200 kilobits per second for the new complex logs. The huge amount of data representing each logging run is fed into the computer of the surface unit.

To run wireline logs, the hole is cleaned and stabilized and the drilling equipment extracted. The first logging tool is then attached to the logging cable (wireline) and lowered into the hole to its maximum drilled depth. Most logs are run while pulling the tool up from the bottom of the hole.

The cable attached to the tool acts both as a support for the tool and as a canal for the data transmission. The outside consists of galvanized cell, while the electrical conductors are insulated in the interior (Fig 2) the cable is wound around a motorized drum on to which it is guided manually during logging.

The drum will pull the cable at speeds of between 300m/h (1000ft/h) and 1800m/h (6000ft/h). Logging cables have magnetic markets set a regular interval along their length and depths are checked mechanically, but apparent depths must be corrected for the cable tension and elasticity.

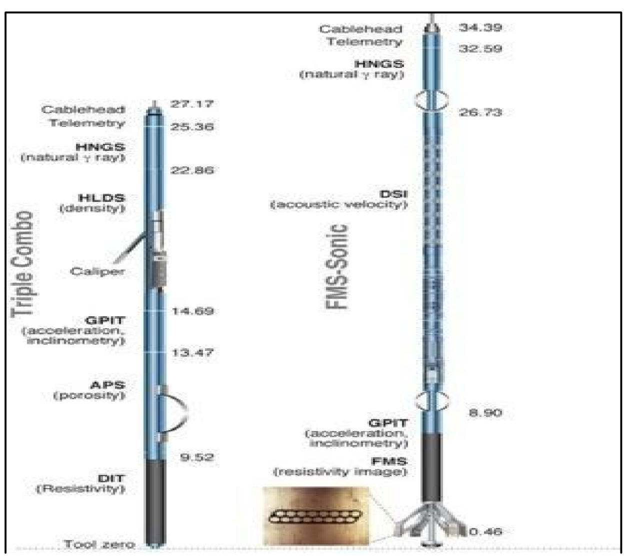

Fig- 3: Typical Modern Combinational logging tools

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Modern logging tools are multifunction (Fig. 3) they may be up to 28m in length, but still have an overall diameter of only 3-4 in. For example 3⅜ in diameter, is 55.5 ft (16.9m) long and gives a simultaneous measurement of gamma ray or calliper, SP, deep resistivity, shallow resistivity and sonic velocity. The complexity of this tool requires the use of surface computer, not only to record but also to memorize and to depth-match the various readings.

Despite the use of the combined tools, the recording of a full set of logs still requires several different tool descents. While a quick, shallow logging job may only take 3hours, a deephole, full set may take 2-3 days, each tool taking perhaps 4-5hours to complete.

A. *Borehole Environment*

Borehole environment provides the limitations for tool design and operations. A true vertical hole is rarely encountered, and generally the deviation of the borehole is between 0˚ and 5˚onshore. The temperature at full depth ranges between 100 ˚F and 300˚ F. The salinity of the drilling mud ranges between 3,000 and 2,00,000 ppm of NaCl. This salinity, coupled with the fact that the well bore is generally over pressured, causes invasion of a porous and permeable formation by the drilling fluid. In the permeable zone, due to the imbalance in hydrostatic pressure, the mud begins to enter the formation but is normally rapidly stopped by the build-up of a mud cake of the clay particles in the drilling fluid.

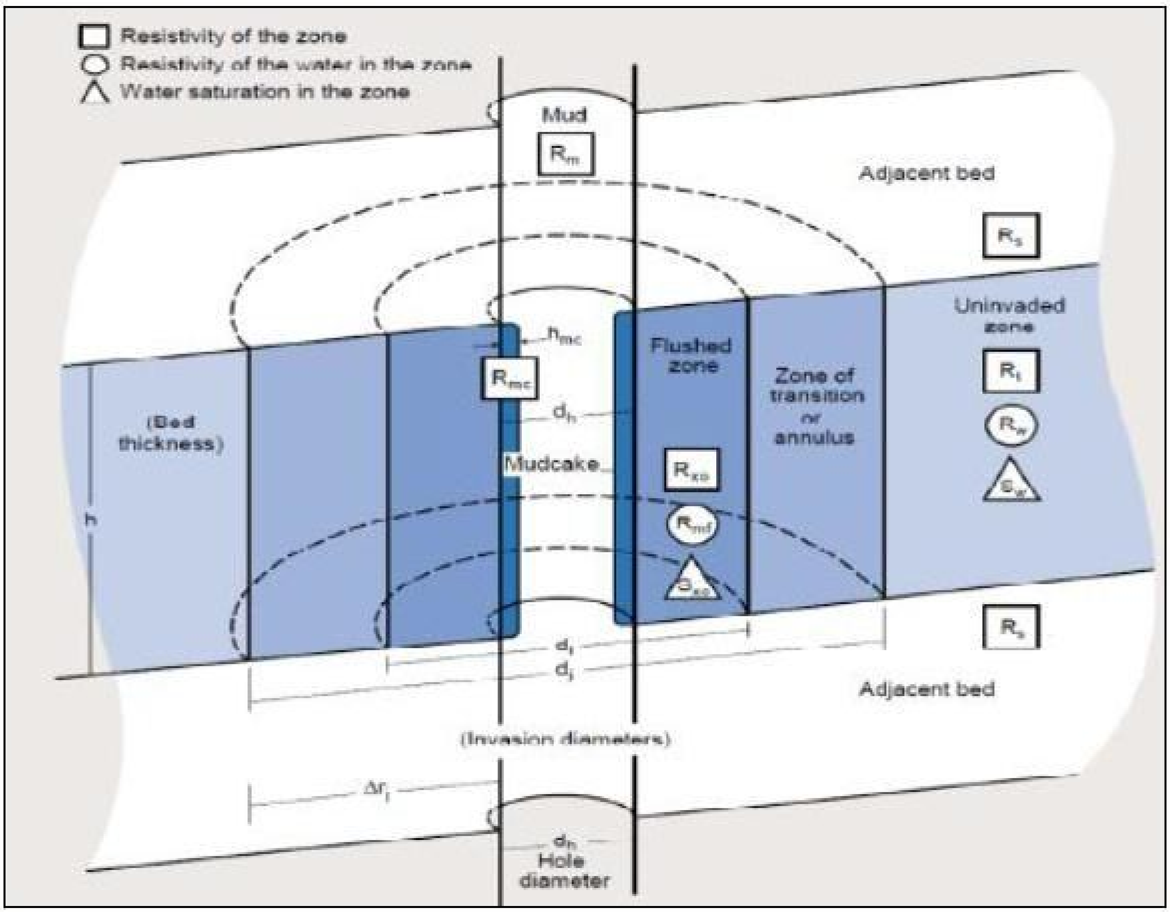


Fig-4: Bore Hole Environment

Where,

dh– hole diameter

d_i – Diameter of invaded zone (inner boundary; flushed zone)

d_j – Diameter of invaded zone (outer boundary; invaded zone)

D_{rj} – Radius of invaded zone (outer boundary)

h_{mc}–Thickness of mud cake

R_m – Resistivity of the drilling mud

R_{mc} – Resistivity of the mud cake
R_{mf} – Resistivity of mud filtrate **Rs –** Resistivity of shale
R_t – Resistivity of uninvaded zone (true resistivity) R_w – Resistivity of formation water
R_{xo} – Resistivity of flushed zone
S_t– Water saturation of uninvaded zone
S_{xo} – Water saturation flushed zone

B. Invasion

A Pressure induced migration of drilling mud fluids (mud filtrate) in to permeable formations. Mud cake is deposited on the borehole wall. Partially sealing the formation and slowing further invasion.

Very close to the borehole most of the original formation water and some of the hydrocarbons may be flushed away by the filtrate. This zone is referred to as the flushed zone (Invaded zone).

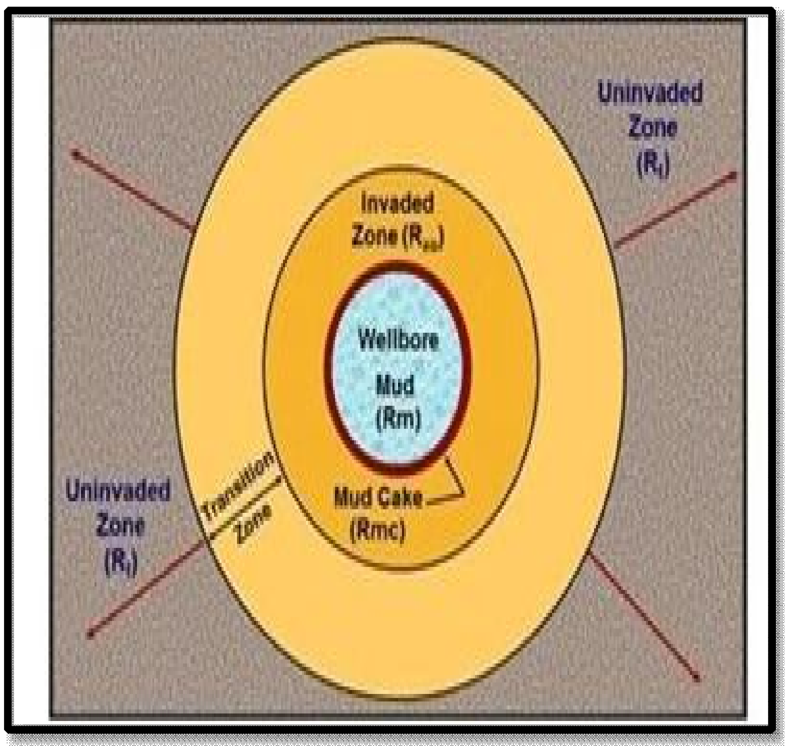


Fig-5: Invasion

Further out from the borehole, the displacement of the formation fluids by the mud filtrate becomes lesser and lesser, resulting in a transition from mud filtrate saturation to original formation. This zone is referred to as the transition zone.

The undisturbed formation beyond the transition zone is referred to as the non-invaded, virgin, or uncontaminated zone.

C. Log representation

A standard API (American Petroleum Institute) log format exists (Fig. 4). The overall log width is 8.25 in (21cm), with three tracks of 2.5 in (6.4cm), track 1 and 2 being separated by a column of 0.75 in (1.9cm) in which the depths are printed.

There are various combination of grids. Track one is always linear, with ten standard divisions of 0.25in (0.64 cm). Depth track is presented after Track1. Track 2 and 3 may have a 4-cycle logarithmic scale, a linear scale of 20 standard divisions, or a hybrid of logarithmic scale in track 2 and linear scale in track 3.

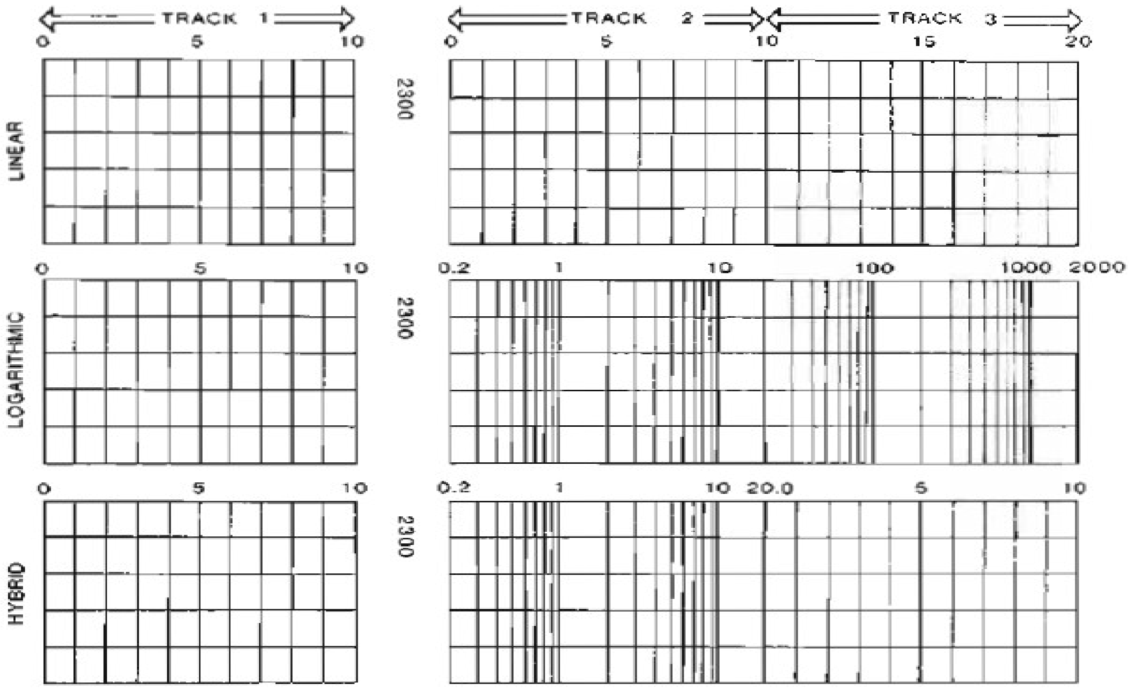
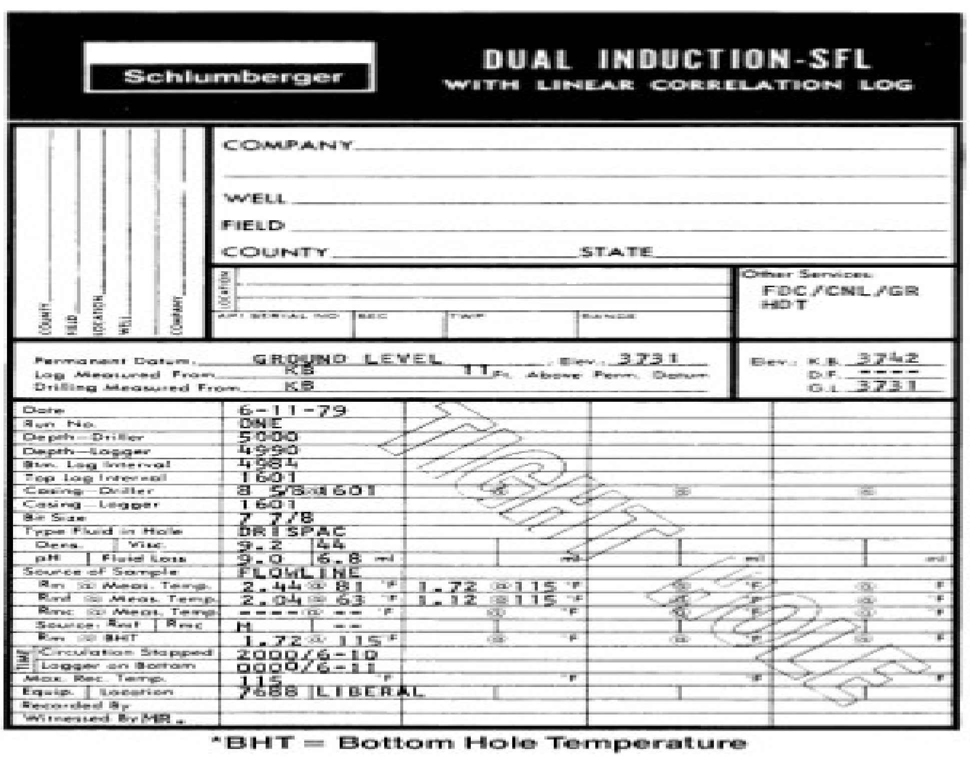


Fig-6: Three typical API log formats

On the old analog logging system, the choice of vertical or depth scales was limited to two of 1:1000, 1:500, 1:200 , 1:100 , 1:40 and 1:20. From these, the most frequent scale combinations were 1:500(1cm = 5m) for correlation logs and 1:200(1cm=2m) for detailed reservoir presentation.

One of the final aspects of log grid is for markers which indicate real time during logging. The markers can be dashed or ticks or spikes on the grid, time markers allow a direct control of logging speed and indirectly on log quality.


Schlumberger
DUAL INDUCTION-SFL
WITH LINEAR CORRELATION LOG

COMPANY
WELL
FIELD
COUNTY STATE
Other Services:
FDC/CNL/GR
HDT
API SERIAL NO. SEC TWP RANGE
Permanent Datum: GROUND LEVEL Elev.: 3731
Log Measured From: KB 11 Ft. Above Perm. Datum
Drilling Measured From: KB
Elev.: K.B. 3742
D.F. ----
G.L. 3731

Date	6-11-79
Run No.	ONE
Depth—Driller	5000
Depth—Logger	4990
Btm. Log Interval	4984
Top Log Interval	1601
Casing—Driller	8 5/8@1601
Casing—Logger	1601
Bit Size	7 7/8
Type Fluid in Hole	DRISPAC
Dens. | Visc.	9.2 | 44
pH | Fluid Loss	9.0 | 6.8 ml
Source of Sample	FLOWLINE
Rm @ Meas. Temp.	2.44@81 °F 1.72 @115 °F
Rmf @ Meas. Temp.	2.04@63 °F 1.12 @115 °F
Rmc @ Meas. Temp.	----@-- °F
Source: Rmf | Rmc	M | --
Rm @ BHT	1.72@115 °F
Circulation Stopped	2000/6-10
Logger on Bottom	0000/6-11
Max. Rec. Temp.	115 °F
Equip. | Location	7688 | LIBERAL
Recorded By	
Witnessed By	MR.

TIGHT HOLE

*BHT = Bottom Hole Temperature

Fig-7: Log Header

Every log is preceded by a comprehensive log heading. It covers all aspects which allow the proper interpretation of the log and identification of well, rig, logger and logging unit. The log heading (Fig.6) is an example, each company having its own format Many surface geophysical methods such as seismic, gravity magnetic, magneto-telluric, geological field survey etc. are all indirect methods. They indicate the structural and stratigraphic location, where hydrocarbon accumulations might occur. They give no evidence, whether there is a significant accumulation at a depth of few miles below the surface of earth and their quantitative estimation. The only method that is available for answering these questions is the exploratory wells. Well log data provide all these parameters in-situ required to estimate the hydrocarbon reserves and their producibility. A large number of physical rock properties can now be measured by using different down hole tools and surface recording system also called logging unit or truck. They include resistivity, bulk mass density, interval transit time (just reciprocal of sonic velocity), spontaneous potential, natural radioactivity and hydrogen content of the rock.

III. TYPES OF LOGGING

Logging is carried out by sending probe into the borehole and receiving the data by receivers. Logging is basically divided into three types.

A. Open Hole Logging

Natural gamma ray log
Spontaneous potential log
Resistivity log
Density log
Neutron log
Sonic log

B. Cased Hole Logging

Gamma ray logging
Cement bonding log (CBL-VDL)

C. Production Logging:

Gamma ray logging
Flow meter
Gradio manometer
Well bore temperature

IV. CONCLUSION

Well logging plays an essential role in petroleum exploration and exploitation. It is used to identify the pay zones of gas or oil in the reservoir formations. It gives continuous down hole record and detailed picture of both gradual and abrupt changes in physical properties of subsurface lithology Logging has a central role in the successful development of a hydrocarbon reservoir. Its measurements occupy a position of central importance in the life of a well, between two milestones: the surface seismic survey, which has influenced the decision for the well location, and the production testing Logging is able to adequately reveal the whole of the drilled sequence and has the added advantage that it measures, in situ, rock properties which cannot be measured in a laboratory from either core samples or cuttings. From this data, it is possible to obtain good estimates of the reservoir size and the hydrocarbons in place. According to the measurements of well logging there are three kinds of data: electrical, nuclear and acoustic. Electrical logging is used to analyze oil saturation and water saturation of the formation. Nuclear logging is used to analyze the porosity and permeability. Acoustic logging provides information about porosity and also indicates whether a liquid or gas phase occupies the pore spaces. Logging techniques in cased holes can provide much of the data needed to monitor primary production and also to gauge the applicability of water flooding and to monitor its progress when activated. In producing wells, logging can provide measurements of flow rates, fluid type, pressure, residual oil saturation. From these measurements, dynamic well behavior can be better understood and remedial work can be planned and secondary or tertiary recovery proposals can be evaluated and monitored. Thus no hydrocarbon can be produced without the intervention of logs.

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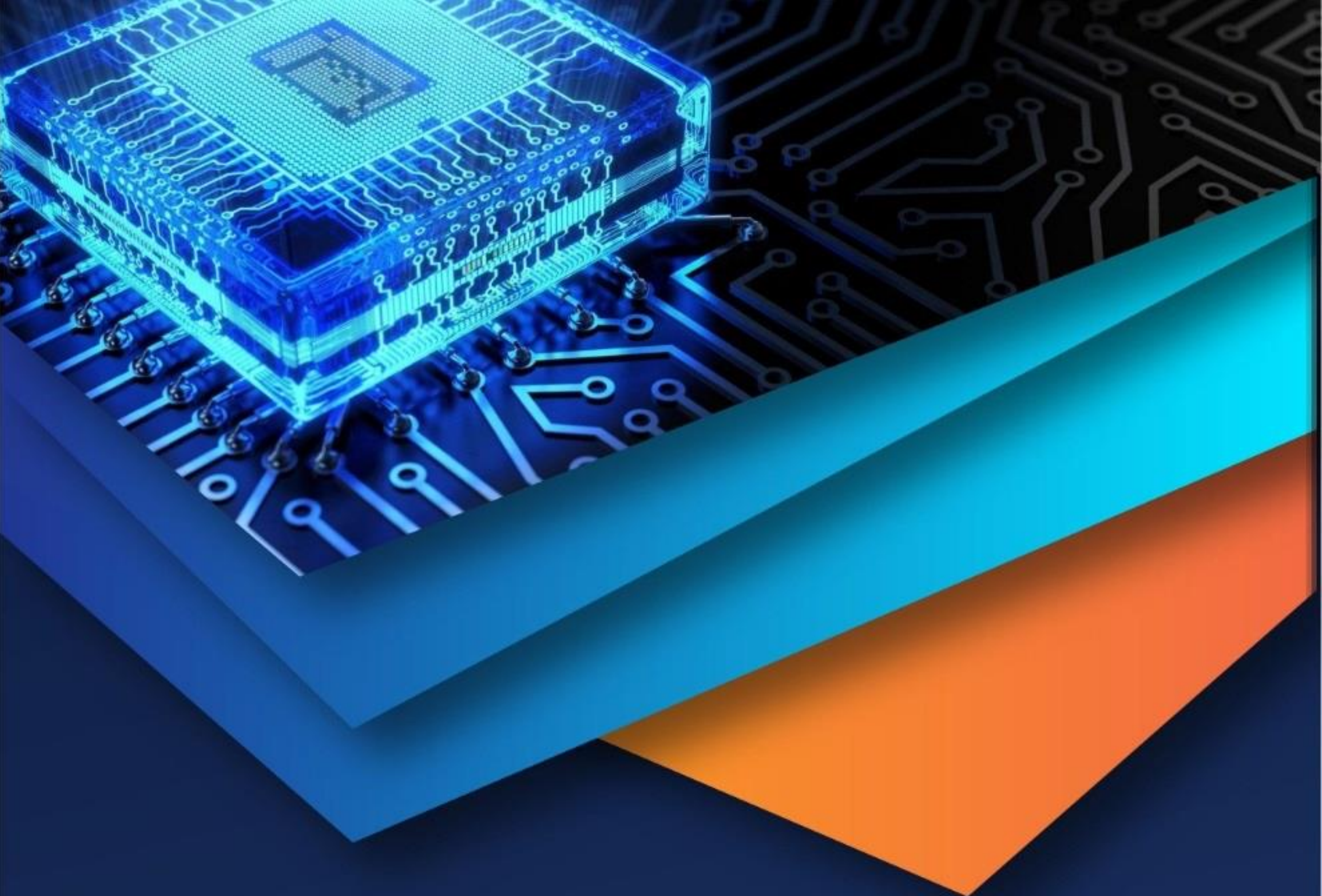

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