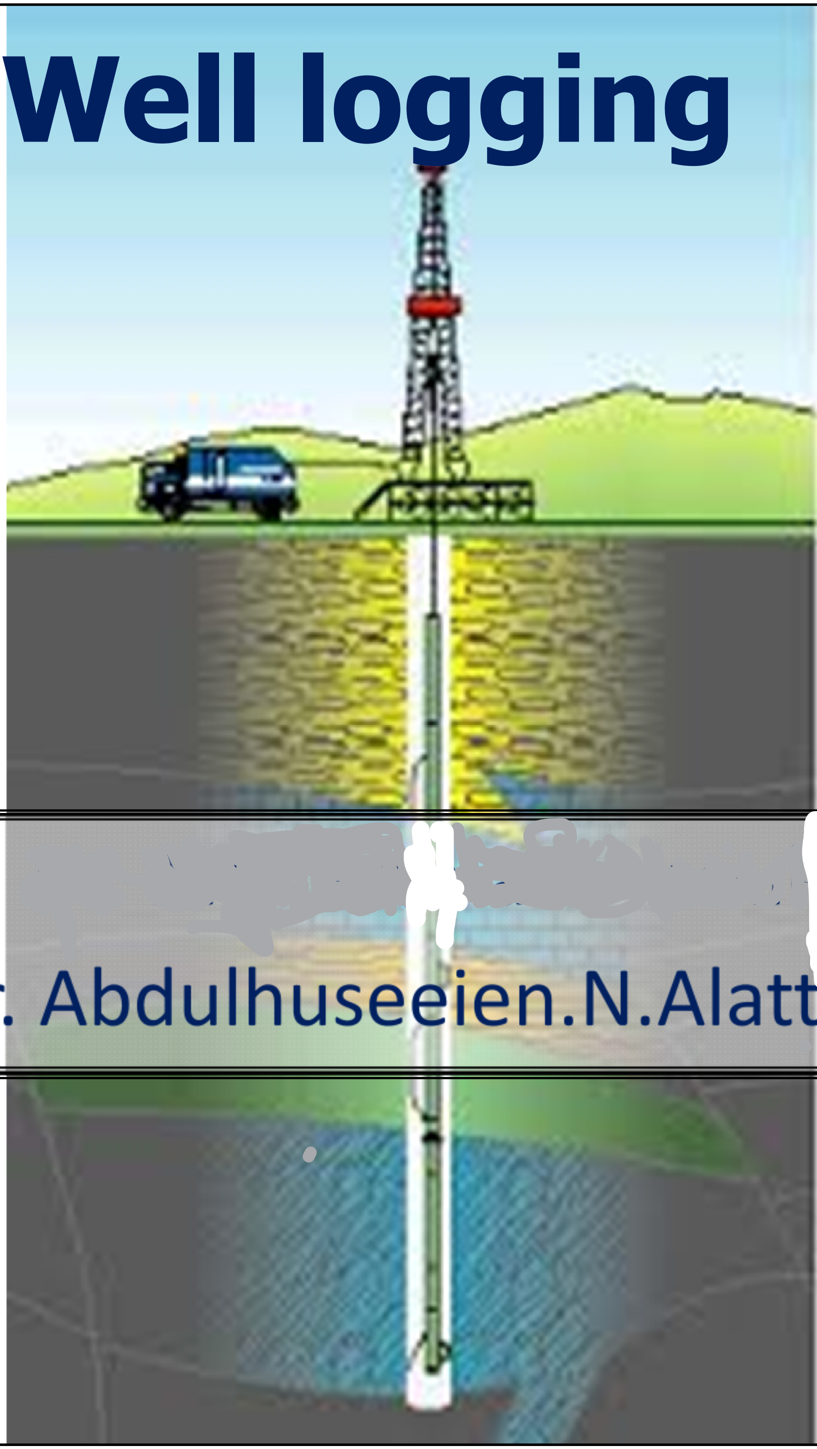
Well logging



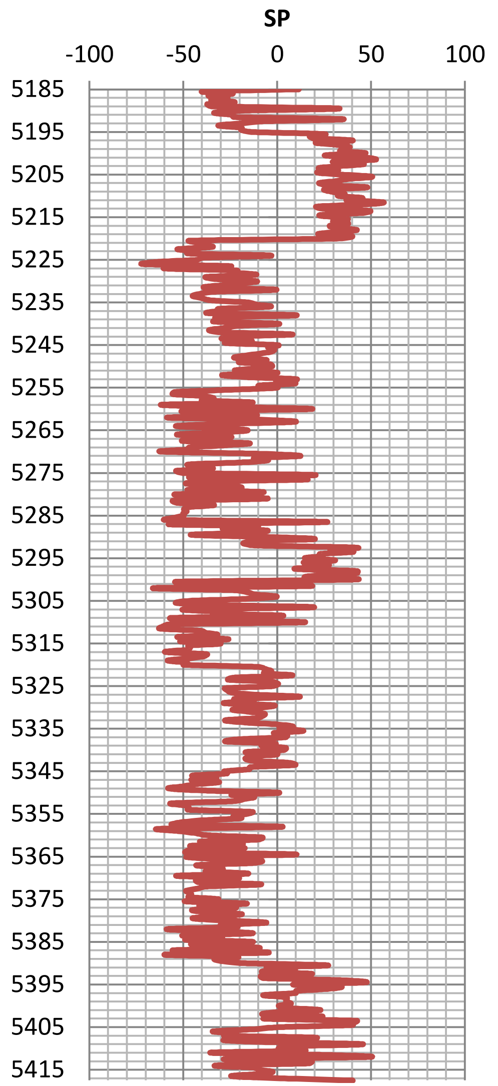
Dr. Abdulhuseeien.N.Alattabi

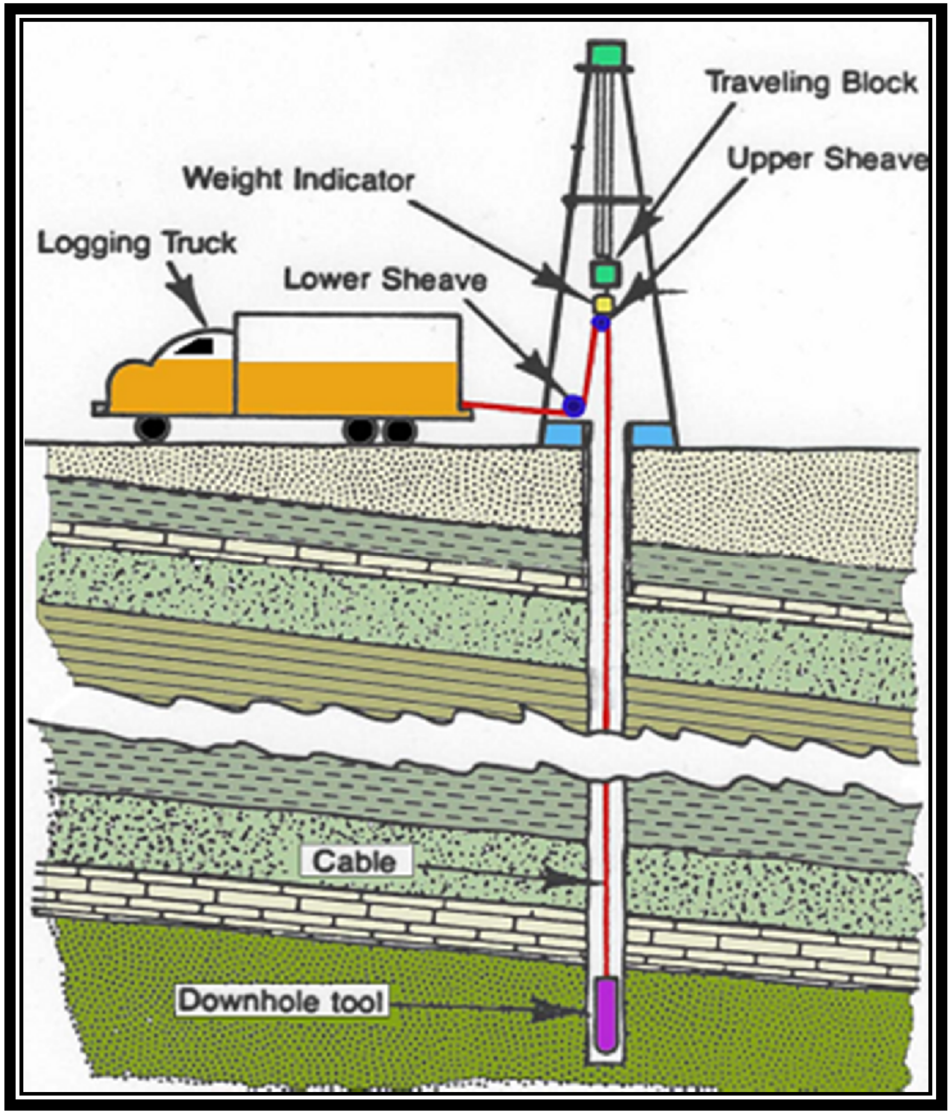
Well logging

Well logging, is the practice of making a detailed record (a *well log*) of the *geologic formations* penetrated by a borehole. Or (a continuous record of a formation's properties along borehole).

The log may be based either on visual inspection of samples brought to the surface (*geological* logs) or on physical measurements made by instruments lowered into the hole (*geophysical* logs). Some types of geophysical well logs can be done during any phase of a well's history: drilling, completing, or producing. Well logging is performed in boreholes drilled for the oil and gas, and groundwater exploration.

Well logging





Objectives of wireline logging

1-Lithology identification

2-Determination of reservoir characteristics (e.g. porosity, saturation, permeability).

3-Discrimination between source and non source rocks

4-Identification the fluid type in the pore space of reservoir rock (gas, oil, water)

5-Identification of productive zones.

6-Determination the depth and thickness of productive zones.

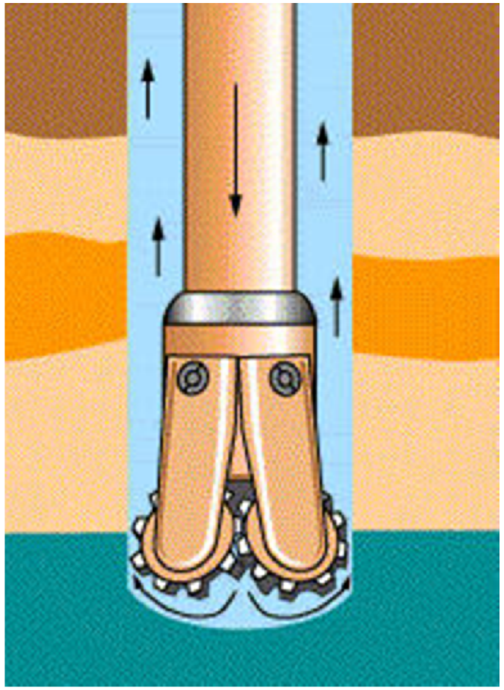
7-Locating reservoir fluid contacts.

8-Well to well correlation for determining the lateral extension of subsurface geologic cross sections.

9-Determination formation dip and hole angle and size.

FORMATION EVALUATION

1. Mud Logging
2. Coring
3. Open-hole Logging
4. Logging While Drilling
5. Formation Testing
6. Cased Hole Logging



What is Formation Evaluation?

Formation Evaluation (FE) also known as hydrocarbon well 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 (most commonly mud). to detect and quantify oil and gas reserves in the rock adjacent to the well. **FE** data can be gathered with wireline logging instruments or logging-while-drilling tools.

- Study of the physical properties of rocks and the fluids contained within them.
- Data are organized and interpreted by depth and represented on a graph called a log (a record of information about the formations through which a well has been drilled).

Why Formation Evaluation?

- To evaluate hydrocarbons reservoirs and predict oil recovery.
- To provide the reservoir engineers with the formation’s geological and physical parameters necessary for the construction of a fluid-flow model of the reservoir.
- Measurement of in situ formation fluid pressure and acquisition of formation fluid samples.
- In petroleum exploration and development, formation evaluation is used to determine the ability of a borehole to produce petroleum.

I. Mud Logging

- Mud logging (or Wellsite Geology) is a well logging process in which drilling mud and drill bit cuttings from the formation are evaluated during drilling and their properties recorded on a strip chart as a visual analytical tool and stratigraphic cross sectional representation of the well.
- Provide continuous record of penetration rate, lithology and hydrocarbon shows.
- These information supports wireline log data.
- From the cuttings, an oil stains or odor of oil may be detected, become an excellent qualitative indicator.
- The fluorescent lamp is also a great help in detecting oil shows.

- The gas record and lithological sample are plotted along with surface parameters such as rate of penetration (ROP), Weight On Bit (WOB),rotation per minute etc. on the mudlog which serve as a tool for the drilling engineers and mud engineers.

- **Some problem**: a difference between the time the rock was drilled and the time it reached the surface – particularly for deep wells, where it take two or move hours to reach the surface.

II. Coring

- One way to get more detailed samples of a formation is by coring, where formation sample is drilled out by means of special bit.
- This sample can provide:
  - Detailed lithological decscription.
  - Porosity, permeability, and fluid saturation.
- These parameters are measured in the laboratory and serve as a basis for calibrating the response of the porosity logging tools and to establish a porosity/permeability relationship.

- Two techniques commonly used at present. The first is the "whole core", a cylinder of rock, usually about 3" to 4" in diameter and up to 50 feet (15 m) to 60 feet (18 m) long.

- Taking a full core is an expensive operation that usually stops or slows drilling operation, and can be done only before the drilling has been done.

Coring Tool & Core Barrel

Coring

- The other, cheaper, technique for obtaining samples of the formation is "Sidewall Coring". In this method, a steel cylinder—a coring gun—has hollow-point steel bullets mounted along its sides and moored to the gun by short steel cables.
- The coring gun is lowered to the bottom of the interval of interest and the bullets are fired individually and the core will be retrieved.
- Advantages of this technique are low cost and the ability to sample the formation after it has been drilled.

❖ Core Preservation

- Once the core is retrieve to surface then it is important that it should remain as unchanged as possible.
- The core should be prevented from drying out, coming into contact with oxygen or being mechanically damaged.
  - Core barrel is filled with resin to prevent the core from moving and to minimize the exposed surface area.
  - Freezing the core in freezer containers.
  - Core sample is wrapped in a plastic film, aluminium foil and then dipped in molten wax.

Core Analysis

Can be divided into two categories:

- Conventional Core Analysis.
- Special Core Analysis.

- **Conventional Core Analysis.**
  - The core is usually slabbed, cut lengthwise to make the structure visible.
  - Provides information on lithology, residual fluid saturation, ambient porosity, ambient gas permeability and grain density.

Core Analysis

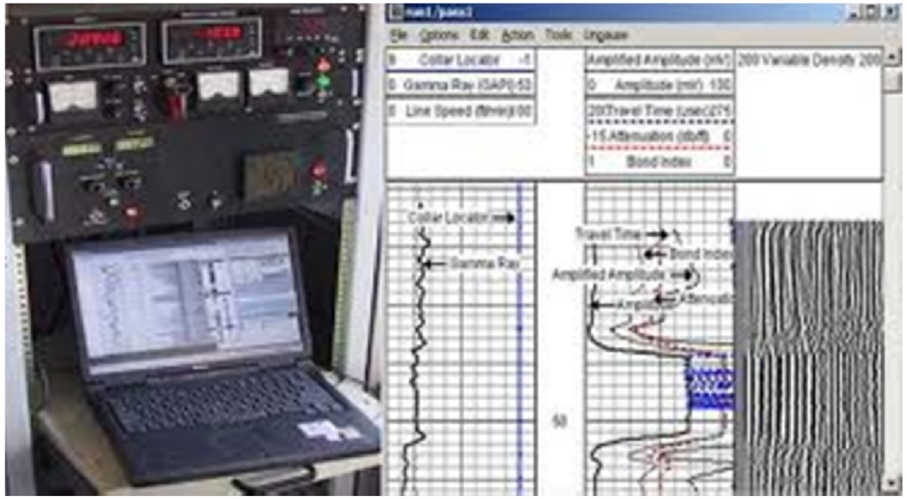
- **Special Core Analysis :**

Provides the following information:

- Porosity and permeability at elevated confining stress.
- Electrical properties such as formation factor and resistivity index.
- Capillary pressure.
- Wettability and relative permeability.
- Mechanical rock properties such as compressibility.
- Waterflood sensitivity for injectivity and well performance.

III. Open-hole Logging

- Open-hole logging, also known as well logging is the practice of making a detailed record (a *well log*) of the geologic formations penetrated by a borehole.
- Open hole logs are run before the oil or gas well is lined with pipe or cased

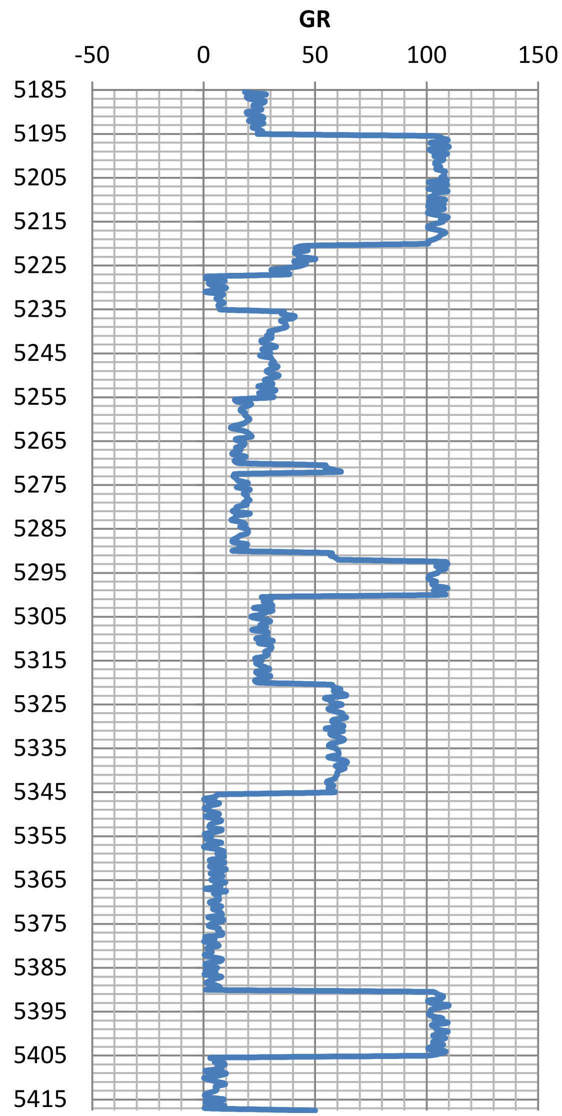


❑ Principal of Well Logging

- A well log is a record of certain formation data versus depth.
- The appropriate downhole logging tools instrument called 'sonde', about 3.5 inches in diameter is lowered into mud-filled hole on logging cable.
- This tools will measure the electrical, acoustic, and radioactive properties of the formation.
- The result will be analyzed to determine which of the layers are porous and permeable, and likely to contain hydrocarbon.
- A depth calibration wheel records the length of cable in the hole.

❖ Principal of Well Logging

- Survey is normally done from the bottom up. As the sonde is pulled up the hole, a continuous measurement signal is sent to the surface where the data is processed and recorded as a curve.



Types of boreholes

- **According to Casing operation**
  - Cased holes
  - Open holes
- **According to conductivity of the borehole**
  - ✓ Conductive (water base drilling mud)
  - ✓ Non-conductive boreholes (oil base mud, air drilled or cased holes)

Types of well logs

Wireline logs

(Electrical, Radioactive, Acoustic, mechanical, Thermal and Magnetic logs)

Formation Testers

(Repeated Formation Tester, Drill Stem Tests)

Types of Well Logging

Well logging is classified into three broad categories:

- Open Hole Logging
- Cased Hole Logging
- Production Logging

Open Hole Logging

Logging surveys taken before the hole is cased are called open hole logs. The logs included in this group are:

- Electrical surveys (induction, laterolog and microlog logs).
- Sonic logs. Caliper Logs.
- Dipmeter Logs. SP logs
- Radioactive surveys (density, neutron and gamma ray logs).

Electrical Logs

Electrical logs (Induction, laterolog, and microlog) measure the electrical properties of the formation along with the formation fluids.

Sonic/ Acoustic Logs

Sonic logs measure the elastic or (sound) wave Sonic logs measure the elastic or (sound) wave properties of the formation.

Caliper Logs

Caliper logs measure the size or geometry of the hole.

Dipmeter Logs

Dipmeter logs measure dip of the formations.

SP Logs

SP logs measure potential different between a shale-sand or shale-carbonate due to difference salinity of formation water shale-carbonate due to difference salinity of formation water and mud filtrate.

Radioactive Logs

Gamma ray & neutron logs measure radioactive and neutron absorption properties. Density logs measure electron density of

the formation which is related to formation density.

Cased Hole Logging

Logging surveys taken after the casing is lowered are usually categorized as cased hole logs. The surveys included in this group are:

- Gamma Ray
- Neutron
- Temperature
- Cement Bond Log

Some of these surveys like the gamma ray, neutron and temperature logs can be run in both open and cased hole wells.

Production Logging

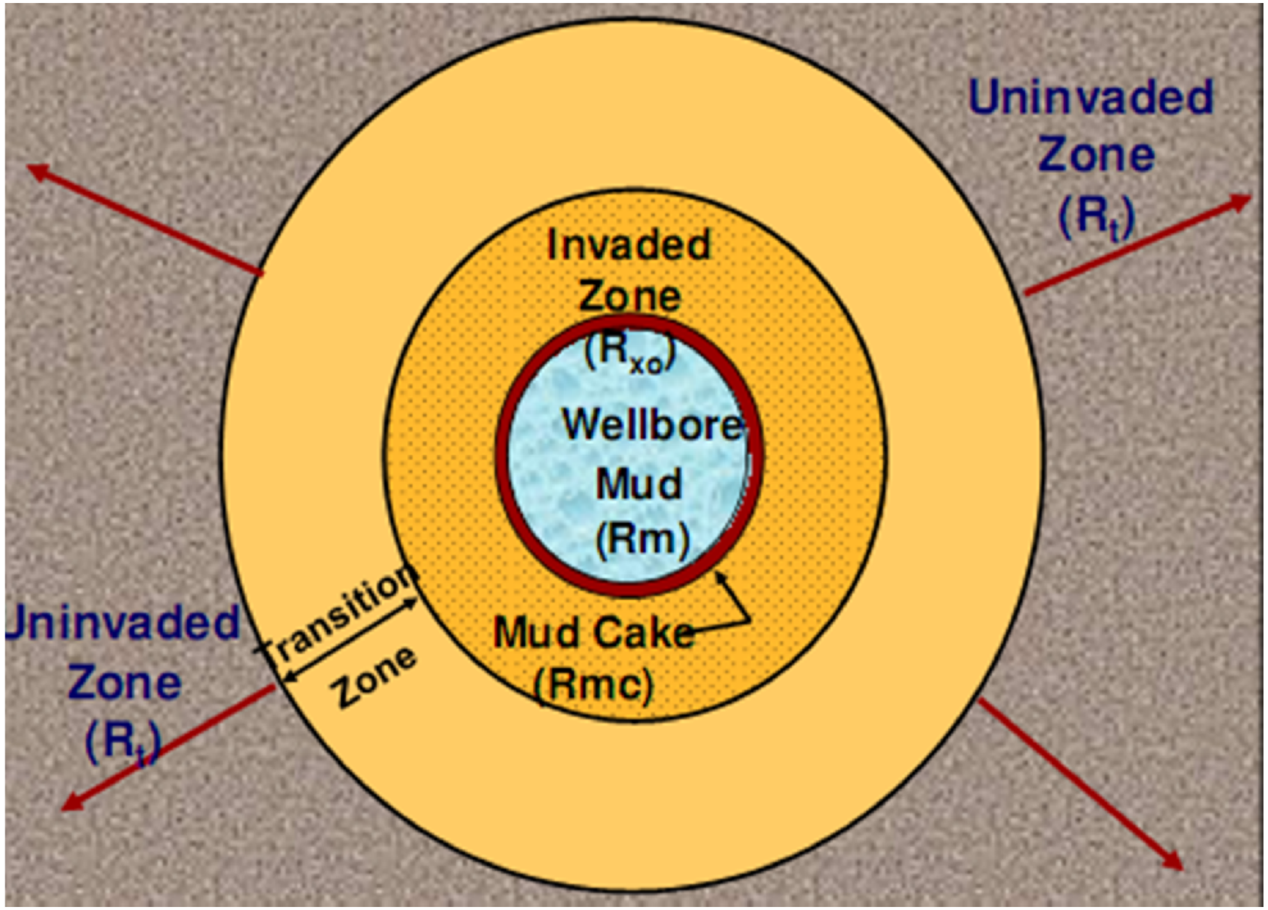
Well logging surveys taken to improve production or repair the well are termed as production logs. Surveys included in this category are:

- Flowmeter
- Pressure
- Temperature
- Fluid Density

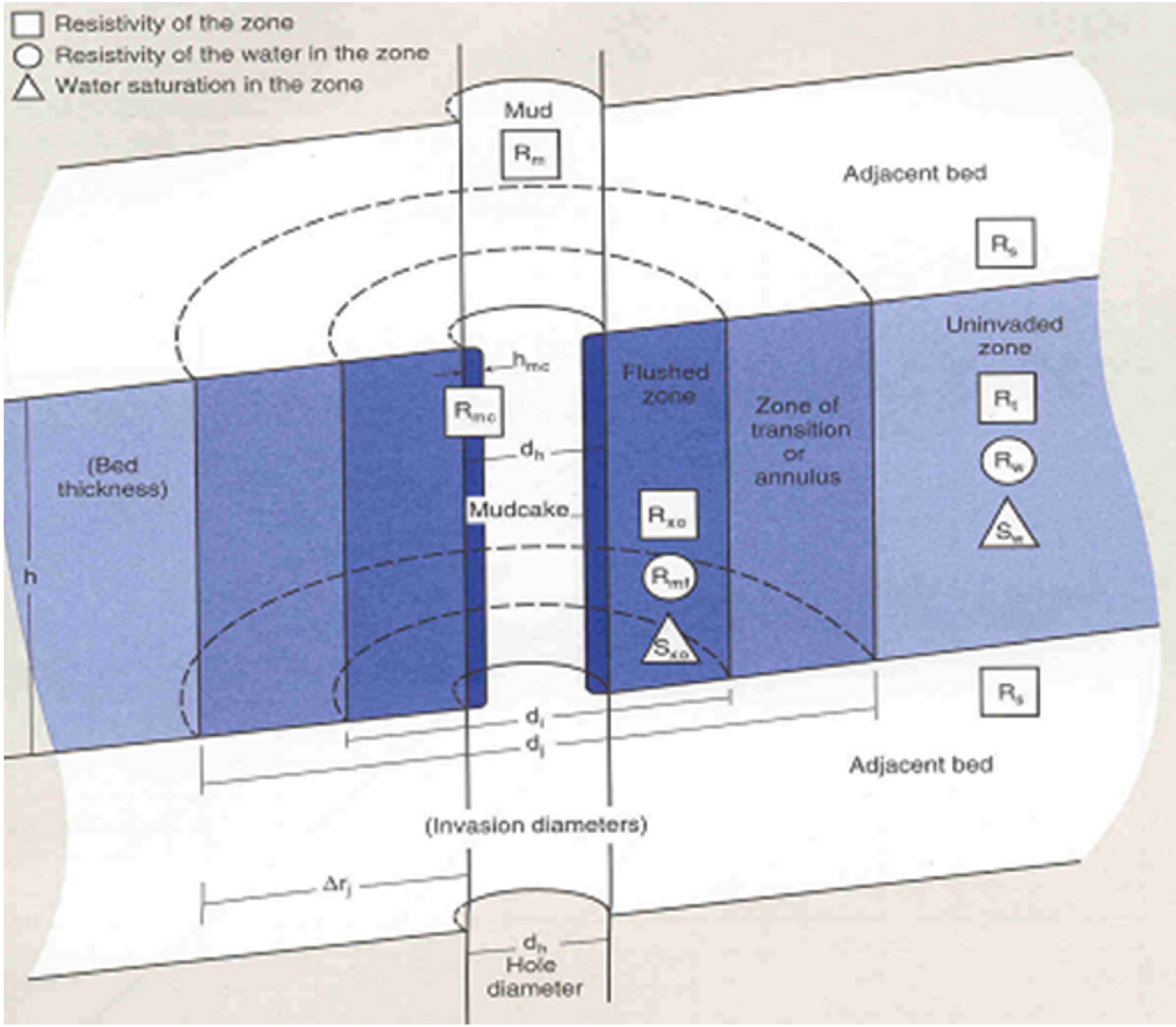
Petrophysical Logging Tools

Log Type	Tool Type	Physical Measurement	Derived Parameter	Interpreted Parameter
Resistivity				
-Induction	Array	Voltage (V)	R_t	S_w
-Laterolog	Array	V and Current (I)	R_t	S_w
-Micro laterolog	Pad	Current	R_{xo}	S_{xo}
Acoustic				
- Sonic	Array	Transit Time	PHI_s	Lithology
Nuclear				
-GR (Density)	Pad	Gamma Ray	RHO_B, PHI_D	Lithology
- Neutron	Mandrel	Neutron	RHO_N	Lithology
Auxiliary				
-Natural GR	Mandrel	Gamma Ray	None	V_{sh}
-SP	Electrode	mV	None	V_{sh}
-Caliper		(*various)	D_h, Volume	

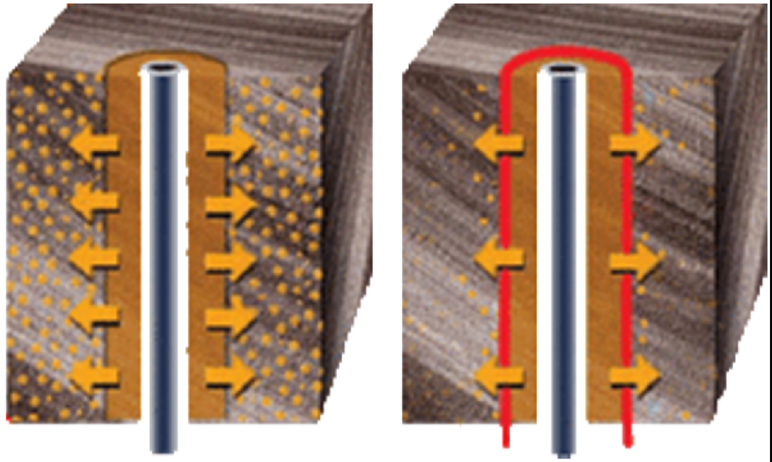
MUD FILTRATE INVASION



MUD FILTRATE INVASION



COMMON TERMINOLOGY



Borehole

- **Rm** : Borehole mud resistivity
- **Rmc** : Mudcake resistivity

Invaded zone

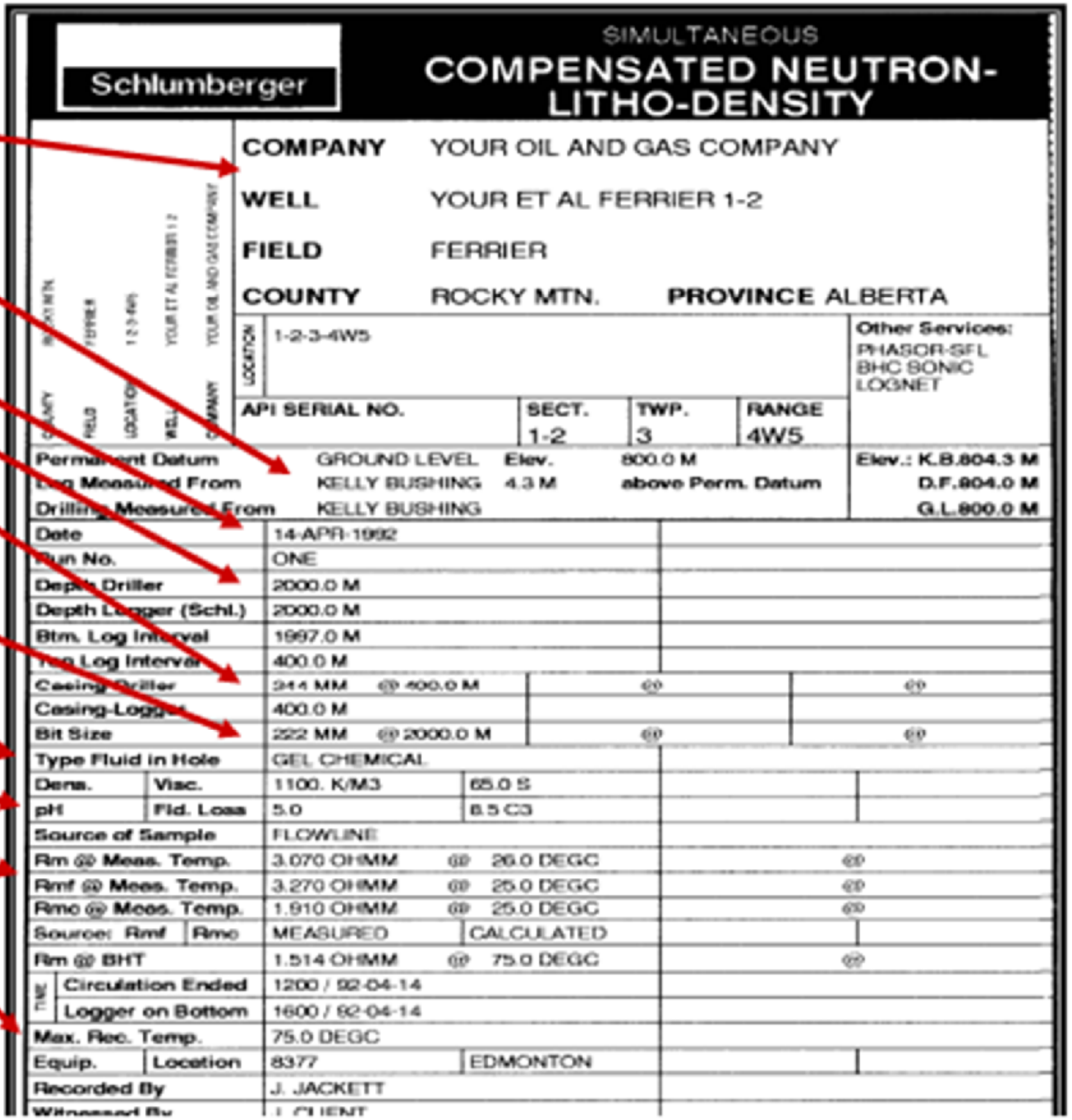
- **Rmf** : Mud filtrate resistivity
- **Rxo** : Invaded zone resistivity
- **Sxo** : Invaded zone water saturation

Uninvaded zone

- **Rw** : Interstitial water resistivity
- **Rt** : Uninvaded zone resistivity
- **Sw** : Uninvaded zone water saturation

LOG PRESENTATION - THE HEADING

- Well location
- Depth references
- Date of log
- Well depth
- Casing shoe depth
- Bit size
- Mud data
  - Type
  - Properties
  - Resistivities
- Max. Temperature



Schlumberger

SIMULTANEOUS
COMPENSATED NEUTRON-
LITHO-DENSITY

COMPANY	YOUR OIL AND GAS COMPANY
WELL	YOUR ET AL FERRIER 1-2
FIELD	FERRIER
COUNTY	ROCKY MTN. PROVINCE ALBERTA

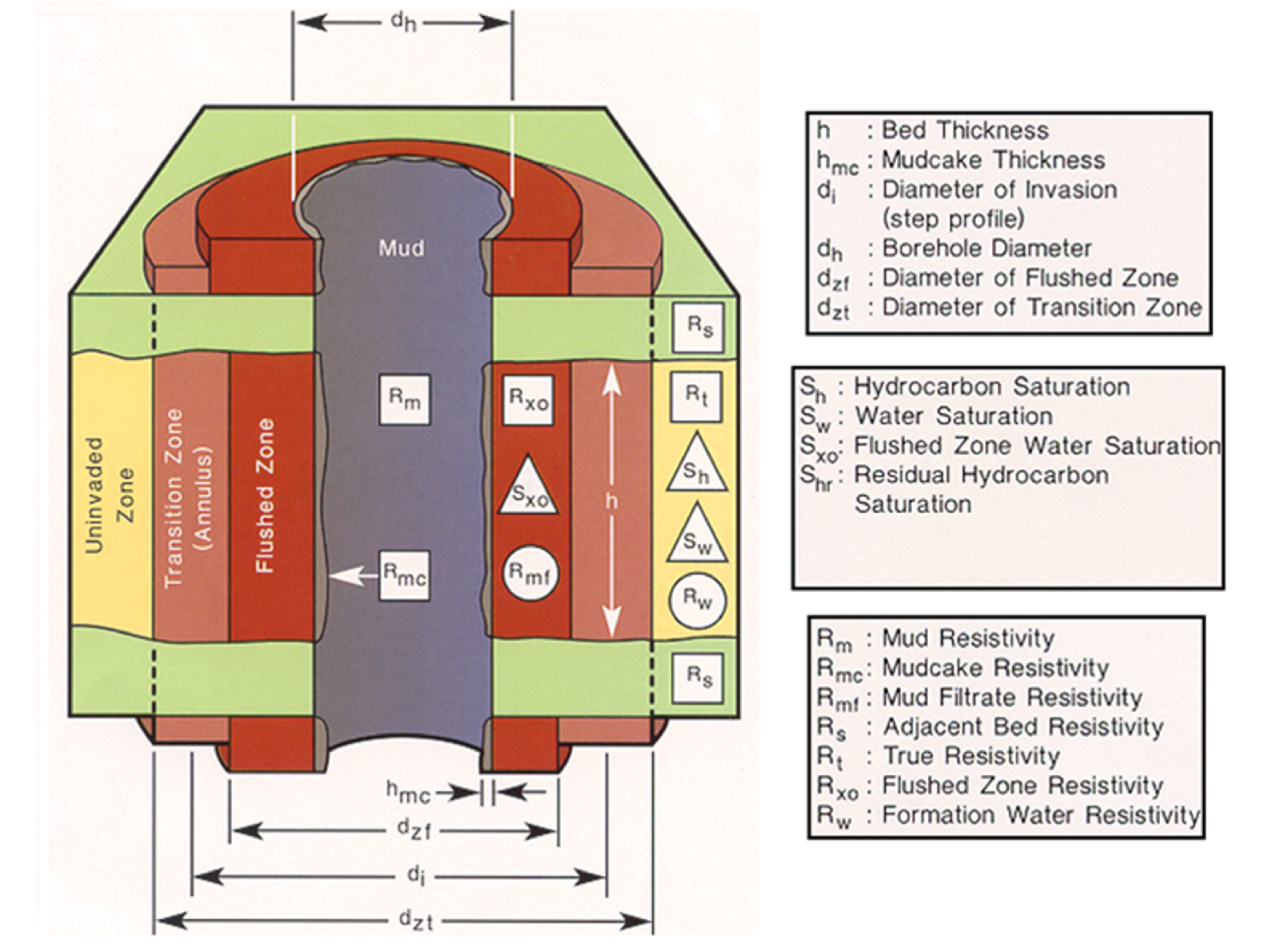
LOCATION: 1-2-3-4W5

Other Services: PHASOR-SFL, BHC SONIC, LOGNET

API SERIAL NO.	SECT.	TWP.	RANGE
	1-2	3	4W5

Permanent Datum	GROUND LEVEL	Elev.	800.0 M	Elev.: K.B.804.3 M
Log Measured From	KELLY BUSHING	4.3 M	above Perm. Datum	D.F.804.0 M
Drilling Measured From	KELLY BUSHING			G.L.800.0 M

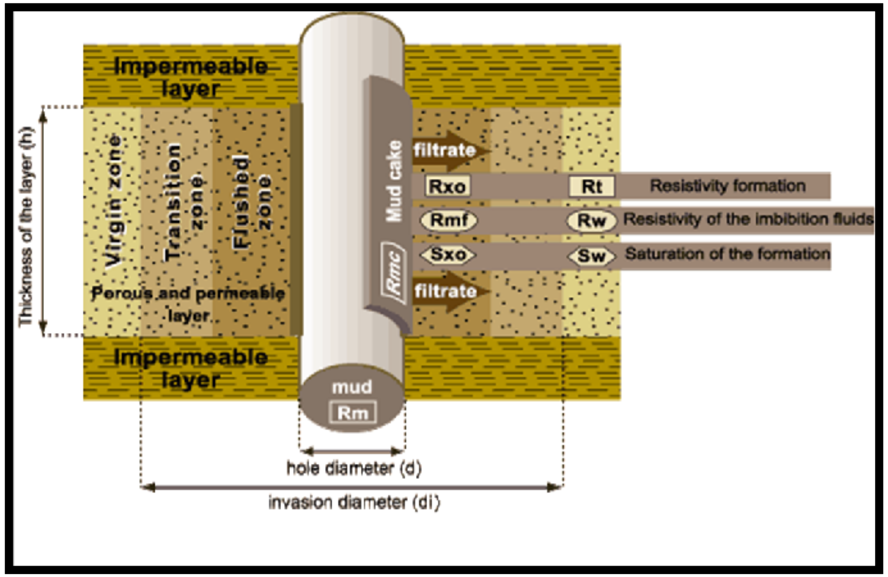
Date	14-APR-1992		
Run No.	ONE		
Depth Driller	2000.0 M		
Depth Logger (Schl.)	2000.0 M		
Btm. Log Interval	1997.0 M		
Top Log Interval	400.0 M		
Casing Driller	244 MM @ 400.0 M	@	@
Casing-Logger	400.0 M		
Bit Size	222 MM @ 2000.0 M	@	@
Type Fluid in Hole	GEL CHEMICAL		
Dens. / Visc.	1100. K/M3	65.0 S	
pH / Fld. Loss	5.0	8.5 C3	
Source of Sample	FLOWLINE		
Rm @ Meas. Temp.	3.070 OHMM @ 26.0 DEGC	@	
Rmf @ Meas. Temp.	3.270 OHMM @ 25.0 DEGC	@	
Rmc @ Meas. Temp.	1.910 OHMM @ 25.0 DEGC	@	
Source: Rmf / Rmc	MEASURED	CALCULATED	
Rm @ BHT	1.514 OHMM @ 75.0 DEGC	@	
TIME Circulation Ended	1200 / 92-04-14		
TIME Logger on Bottom	1600 / 92-04-14		
Max. Rec. Temp.	75.0 DEGC		
Equip. / Location	8377	EDMONTON	
Recorded By	J. JACKETT		
Witnessed By	J. CLIENT		


d_h
Mud
Uninvaded Zone
Transition Zone (Annulus)
Flushed Zone
R_s
R_m
R_{xo}
R_t
S_{xo}
S_h
h
S_w
R_{mc}
R_{mf}
R_w
R_s
h_{mc}
d_{zf}
d_i
d_{zt}
h : Bed Thickness
h_{mc} : Mudcake Thickness
d_i : Diameter of Invasion (step profile)
d_h : Borehole Diameter
d_{zf} : Diameter of Flushed Zone
d_{zt} : Diameter of Transition Zone
S_h : Hydrocarbon Saturation
S_w : Water Saturation
S_{xo}: Flushed Zone Water Saturation
S_{hr} : Residual Hydrocarbon Saturation
R_m : Mud Resistivity
R_{mc}: Mudcake Resistivity
R_{mf} : Mud Filtrate Resistivity
R_s : Adjacent Bed Resistivity
R_t : True Resistivity
R_{xo} : Flushed Zone Resistivity
R_w : Formation Water Resistivity

Drilling Fluid Invasion Model

The traditional abbreviations and definitions listed below describe conditions found within the near-wellbore environment:

Rxo = resistivity of the flushed zone
Ri = resistivity of the invaded zone
Rt = resistivity of the undisturbed zone
Ro = resistivity of the undisturbed zone which is 100% water saturated
Rz = resistivity of unknown mixture in the transition zone
Rw = resistivity of formation water
Rm = resistivity of mud
Rmf = resistivity of mud filtrate
Rmc = resistivity of mud cake
Rs = resistivity of surrounding beds
Rsh = resistivity of shale beds
Dh = borehole diameter
Di = invasion diameter
Dj = diameter of the flushed zone
Bitz = drill bit diameter (bit size)
Hmc = mud cake thickness



Sources of information