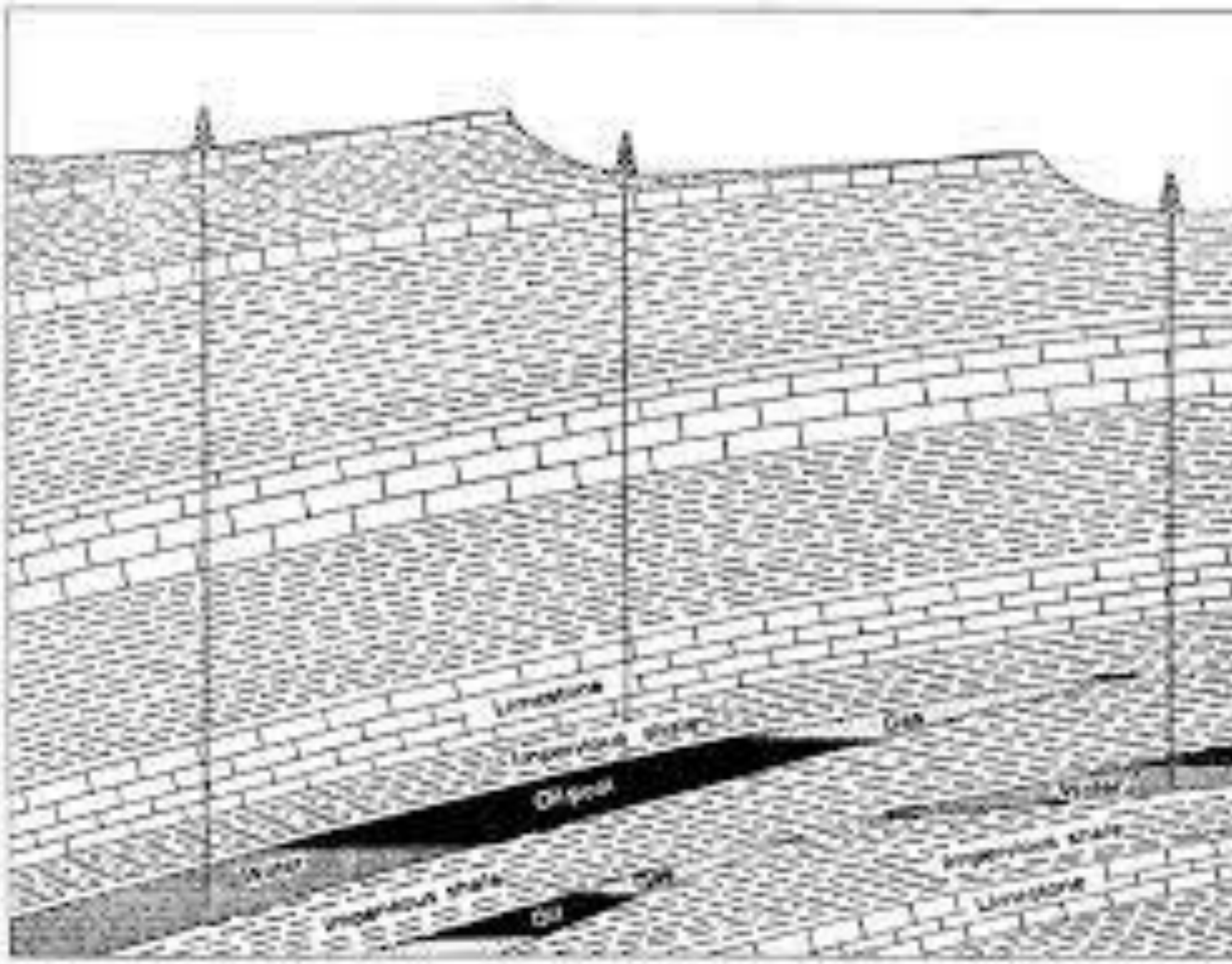
بسم الله الرحمن الرحيم

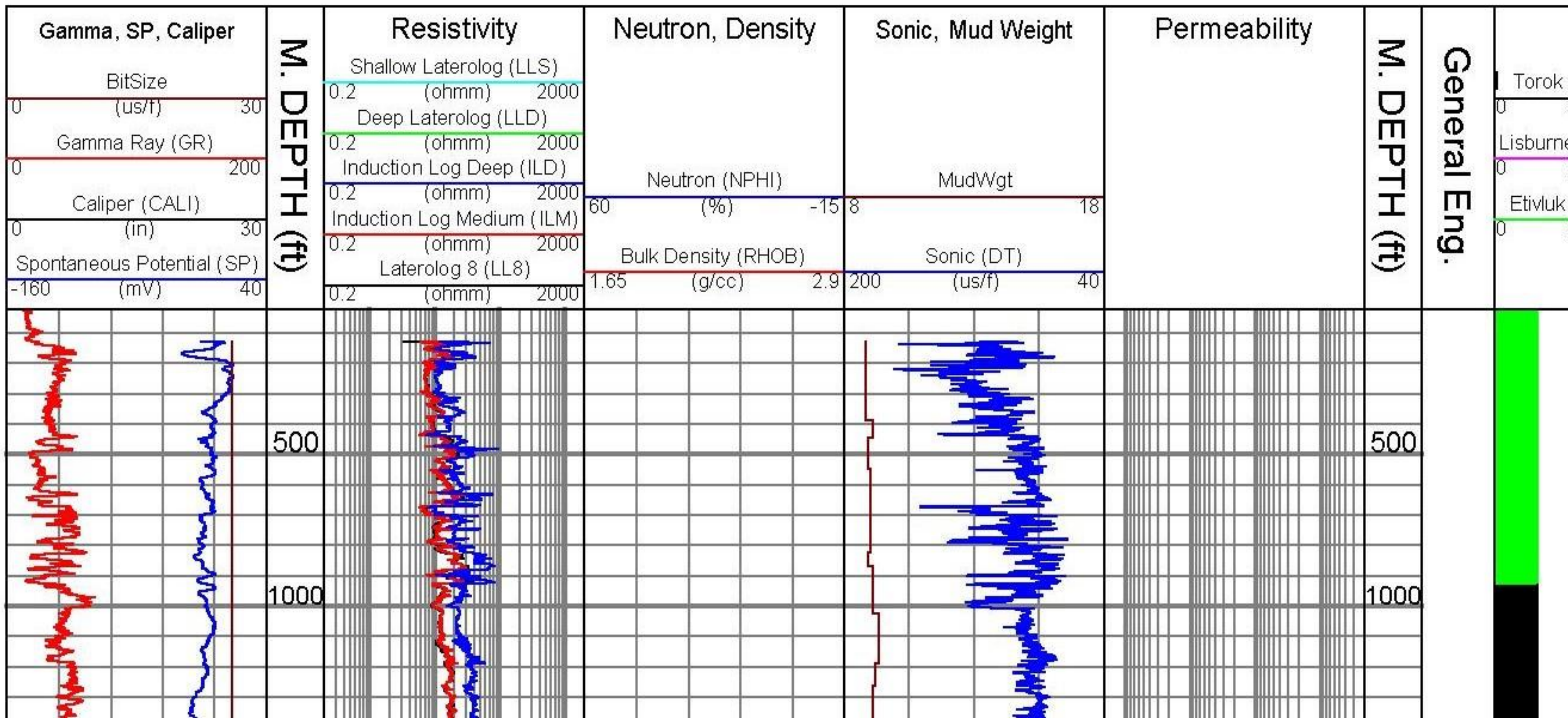
RESISTIVITY LOG

Dr. Abdulhussien Neamah Alattabi
Alayen university

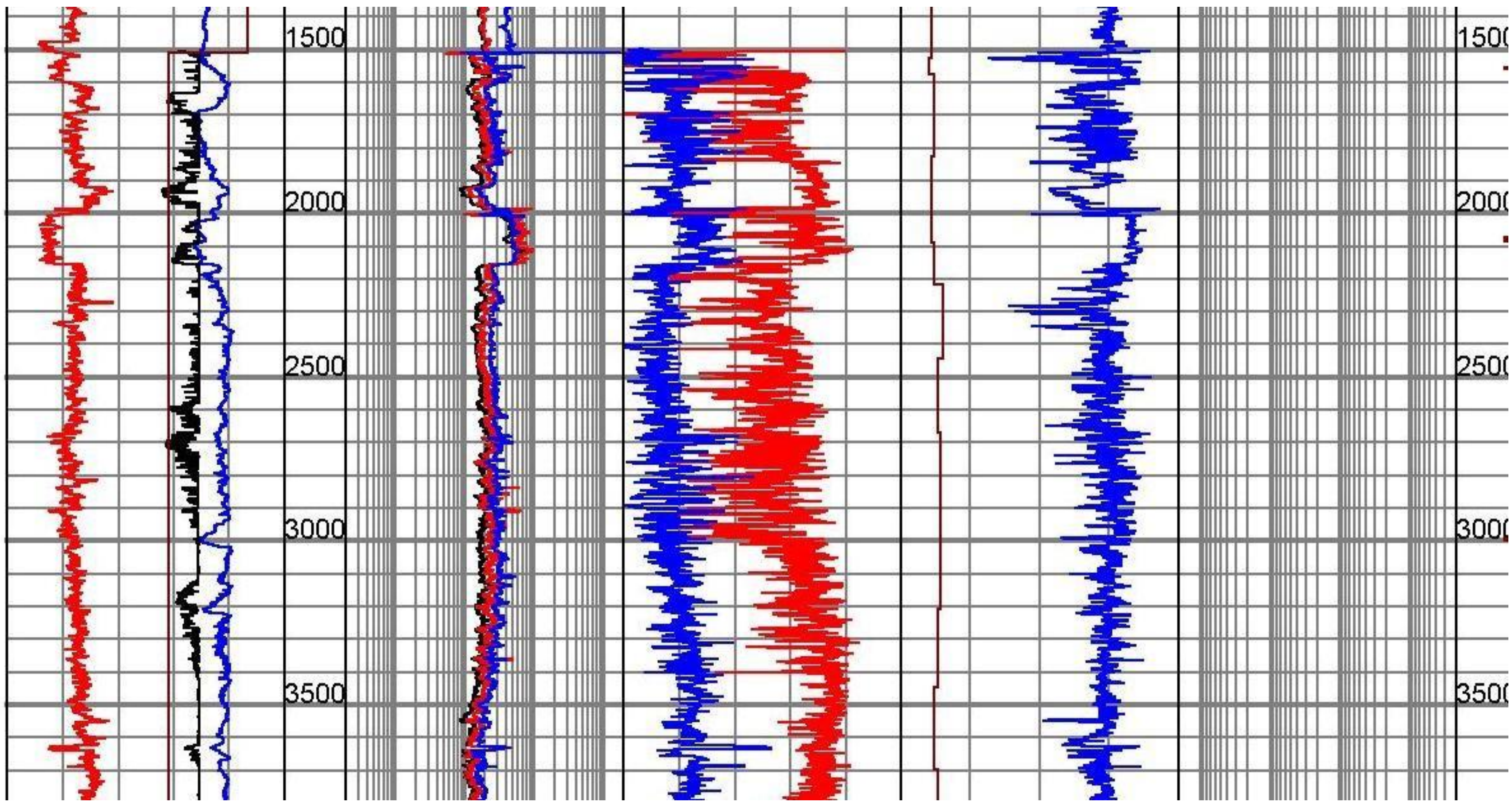
Formation Evaluation and Different Types of Logs



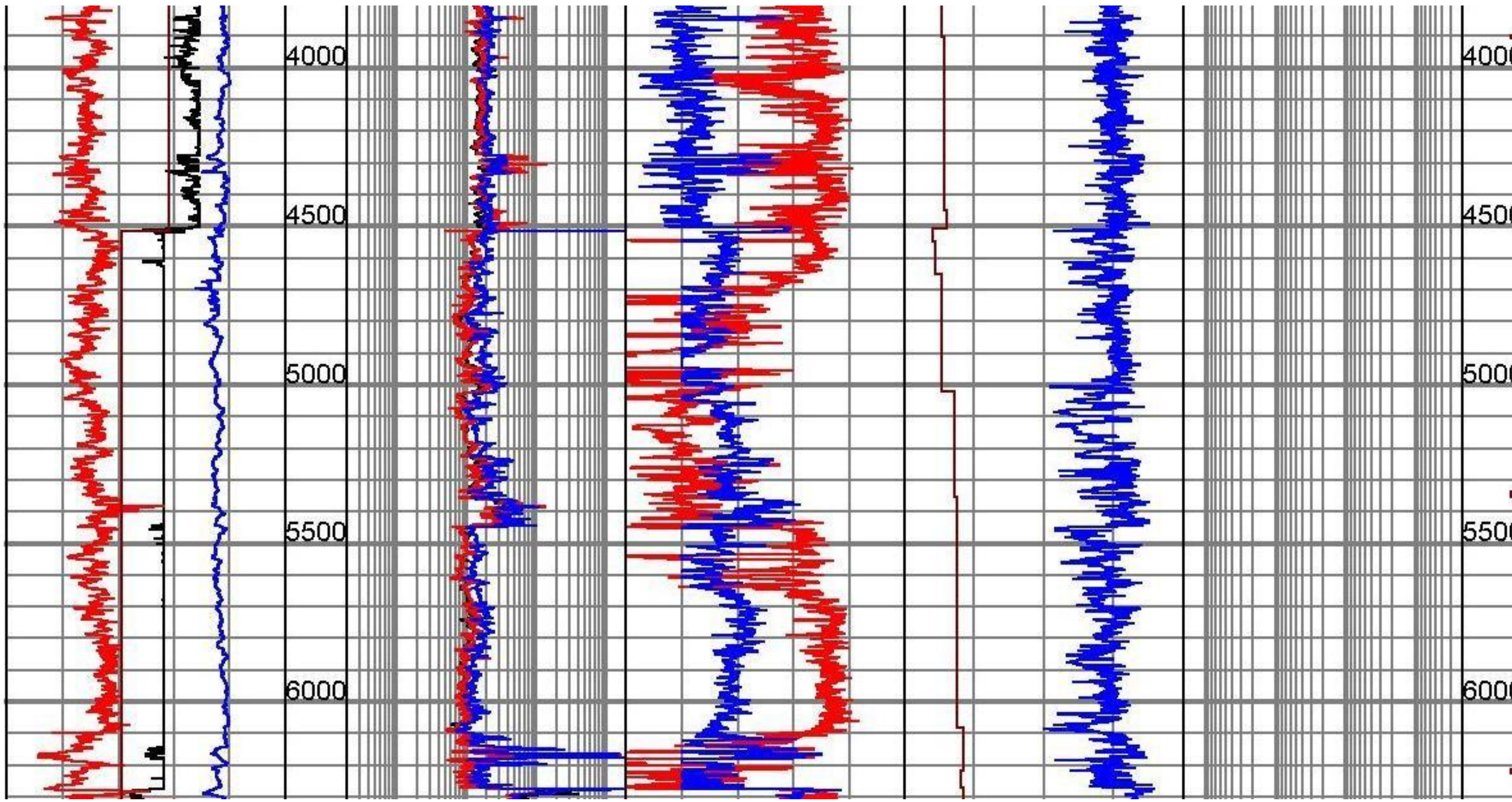
Different Types of Logs



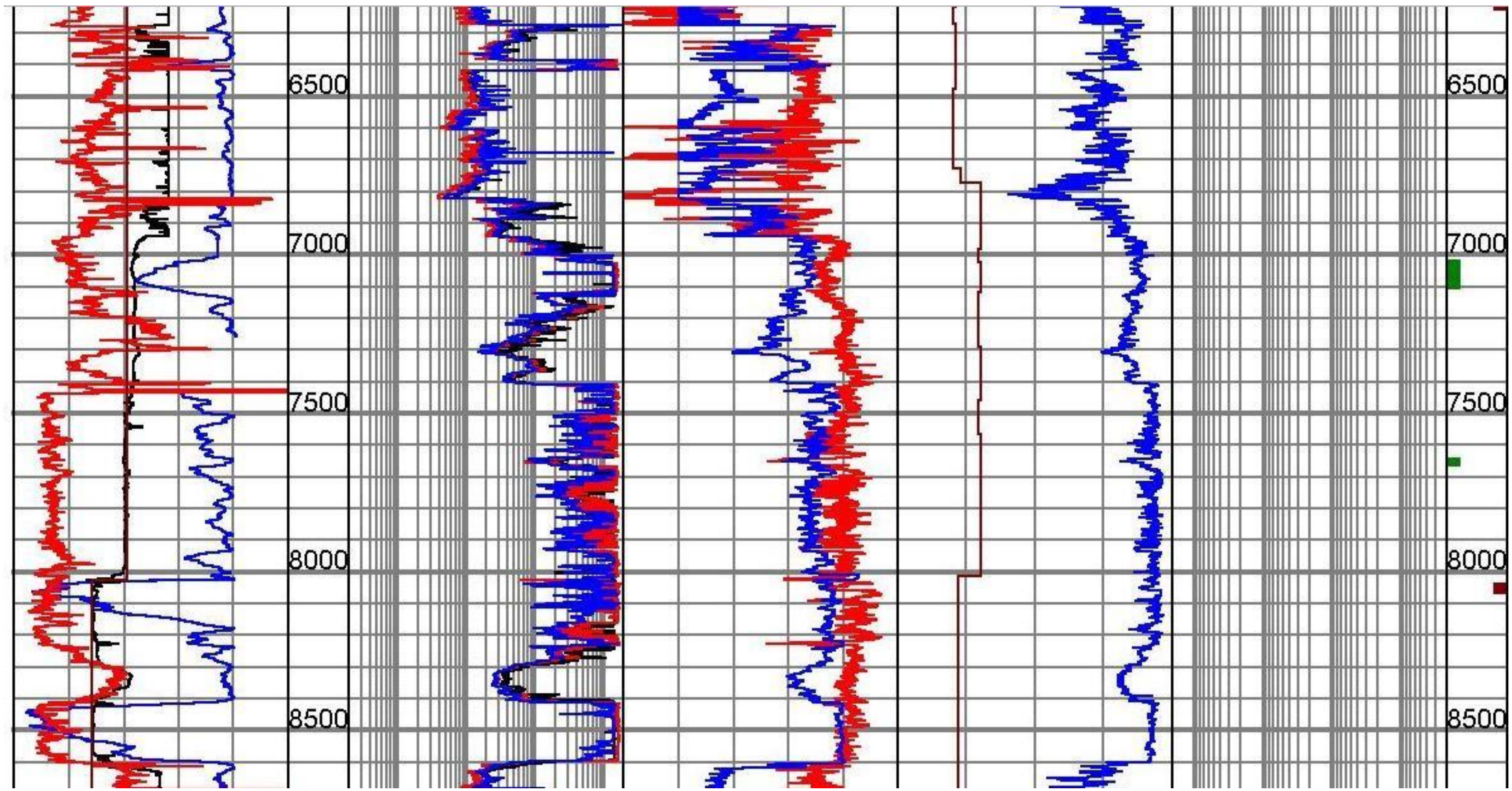
Different Types of Logs Cont'd



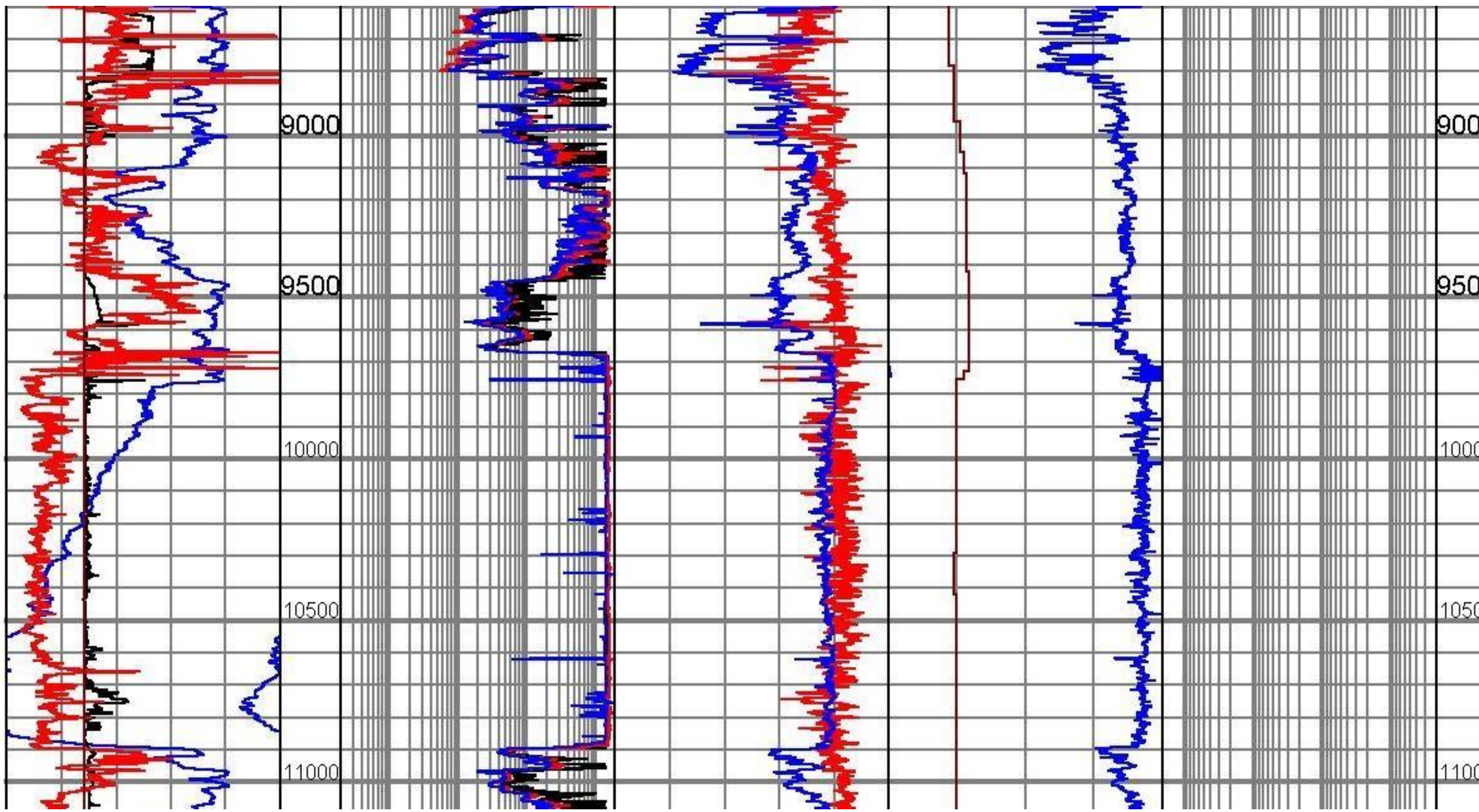
Different Types of Logs Cont'd



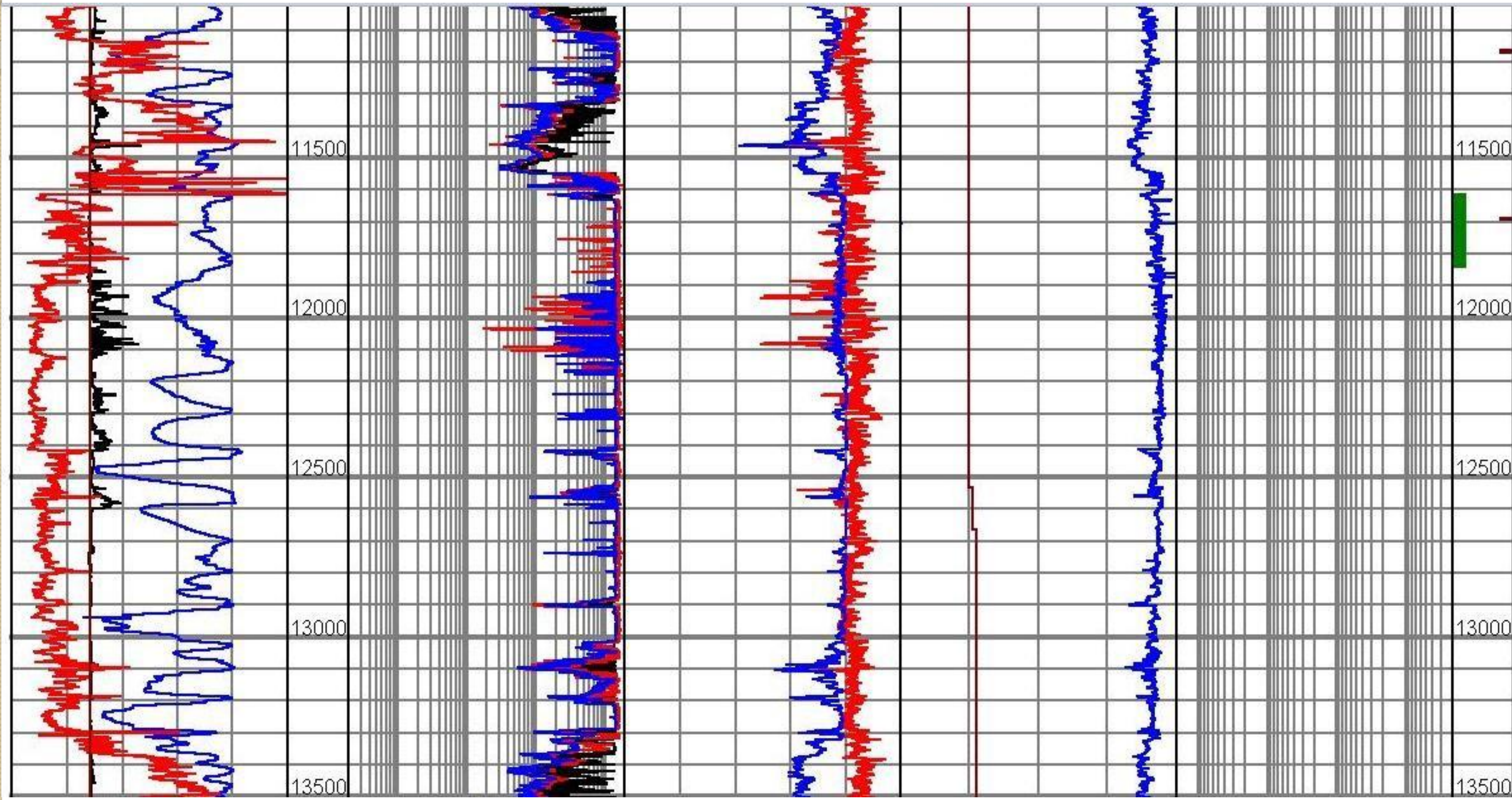
Different Types of Logs Cont'd



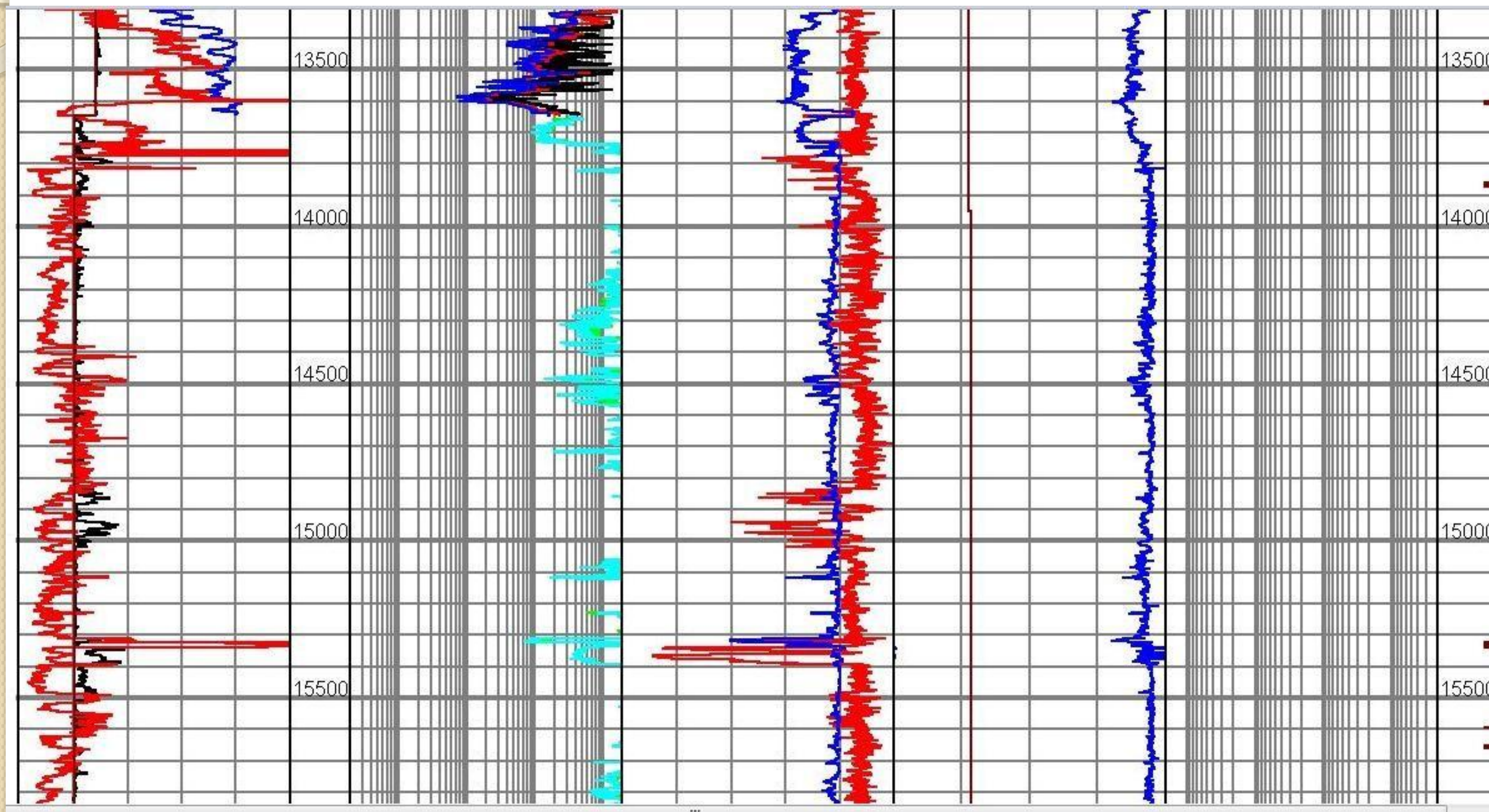
Different Types of Logs Cont'd



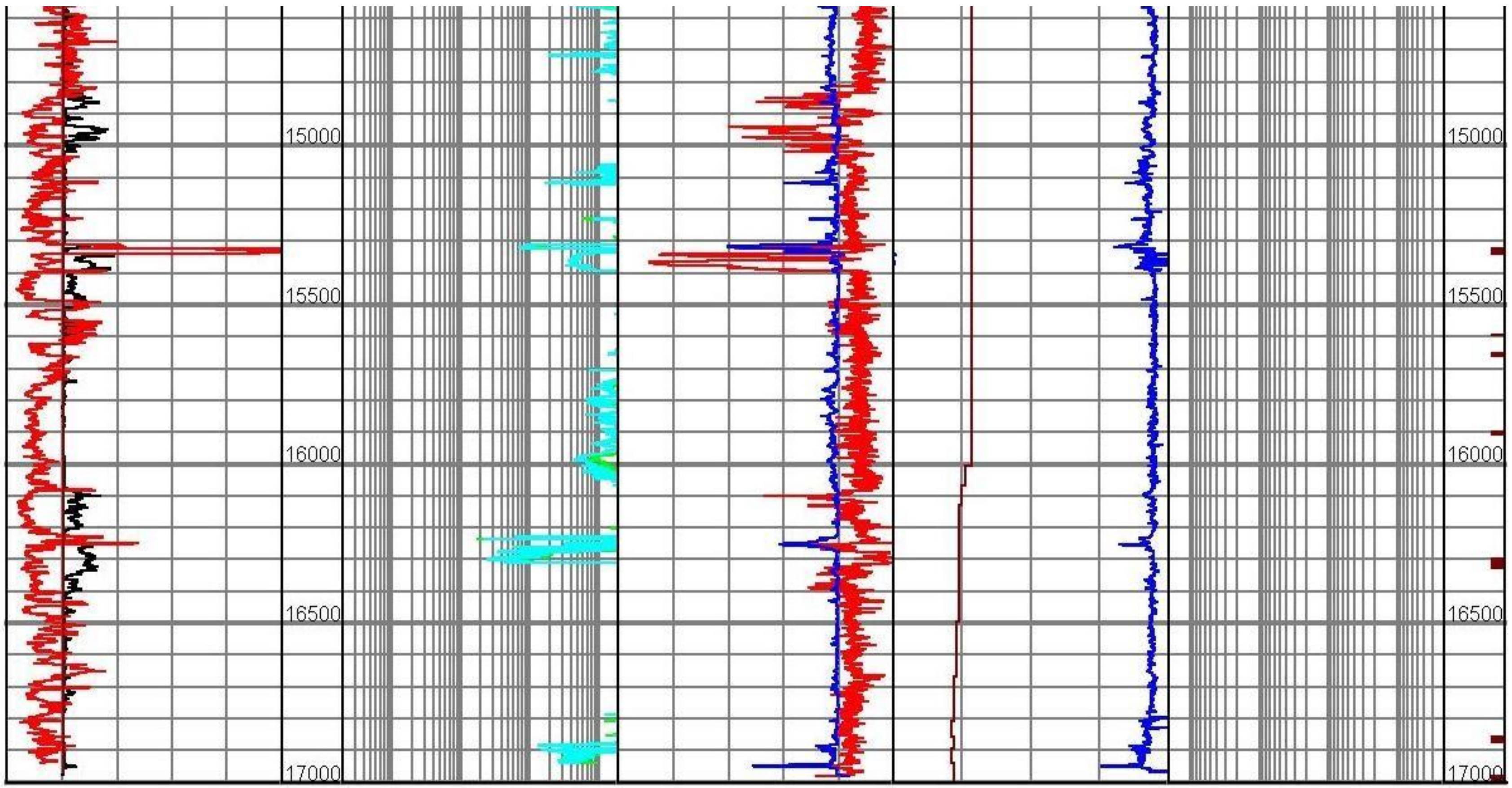
Different Types of Logs Cont'd



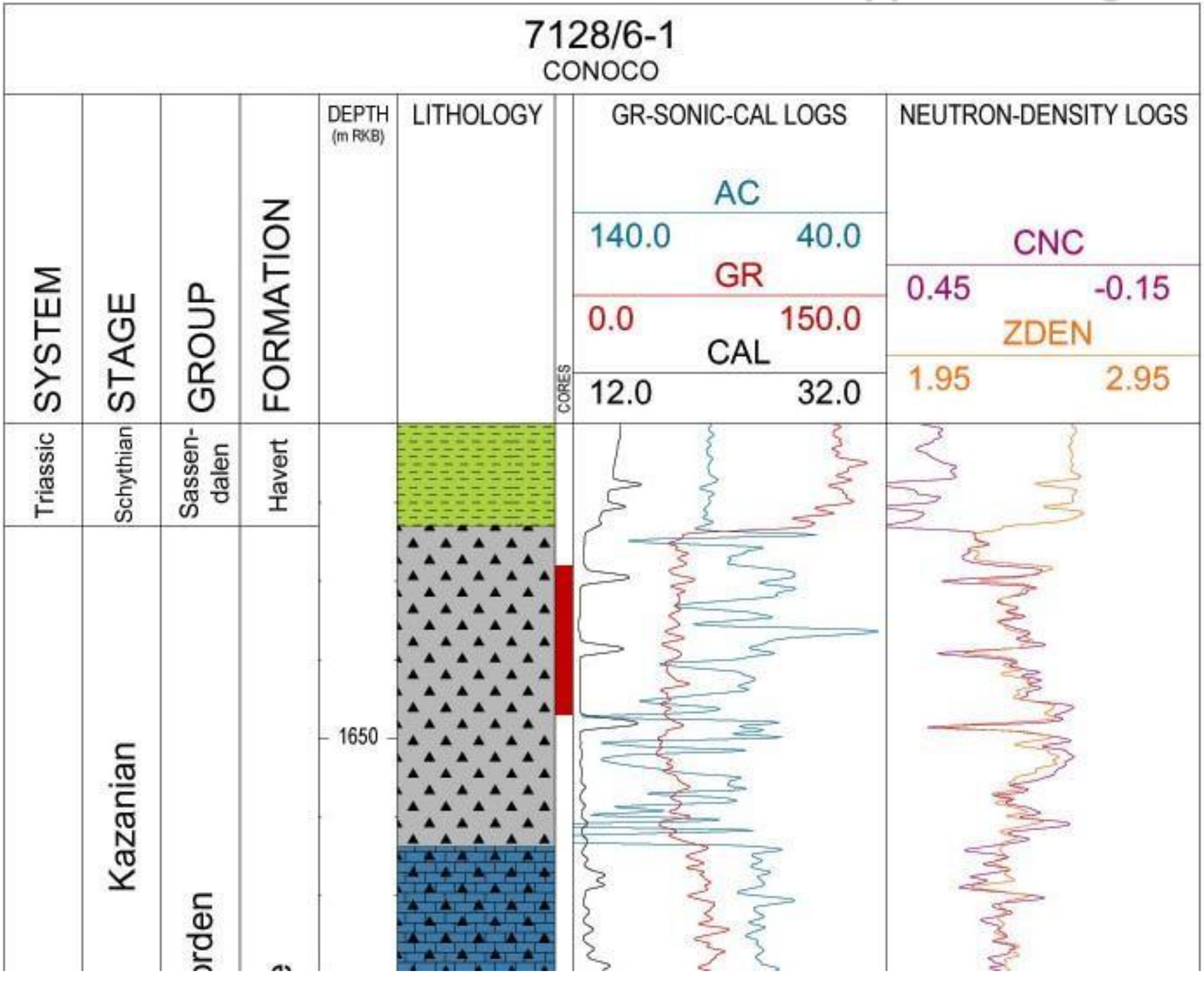
Different Types of Logs Cont'd



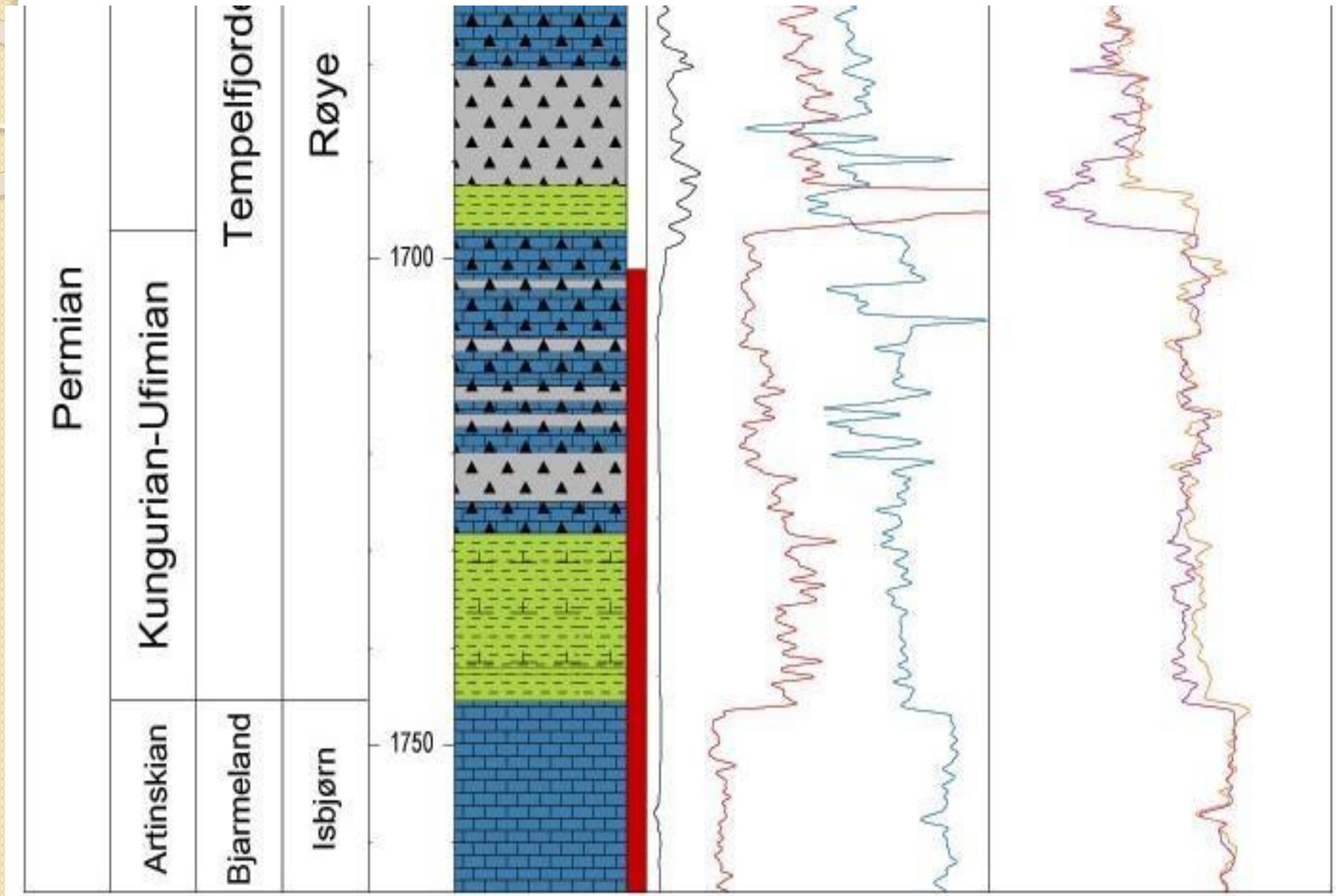
Different Types of Logs Cont'd



Formation Evaluation and Different Types of Logs



Formation Evaluation and Different Types of Logs



Resistivity Log

- The measurement of formation resistivity is fundamental to the evaluation of hydrocarbon saturation
- In most runs of a resistivity tool, the major purpose is to obtain measurements of R_t, the true resistivity of the formation.
- However, there are a variety of complicating factors involved which may require corrections to be made to the recorded values in order to obtain good estimates of the true resistivity.

Resistivity Log Cont'd

Resistivity

- R_l =Electrical resistance : $R_l = \frac{RL}{A}$ or $R = R_l \frac{S}{L}$
- S = Cross section area (1 m^2)
- L = length (1m)
- R = Resistivity (1Ωm)

  1000 (Ωm)> Formation Resistivity > 0.2 (Ωm)
- V= Potential difference
- I = Electrical current

$$V = R_l I$$

$$V = RI \frac{L}{S}$$

Electrolyte conductivity:

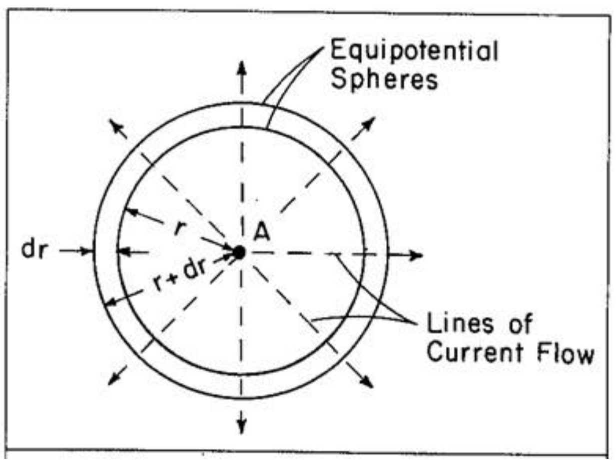
- Depend on water salinity
- And Ionic activity in formation
- K = depend on electod location

$$R = K \frac{\Delta V}{I}$$

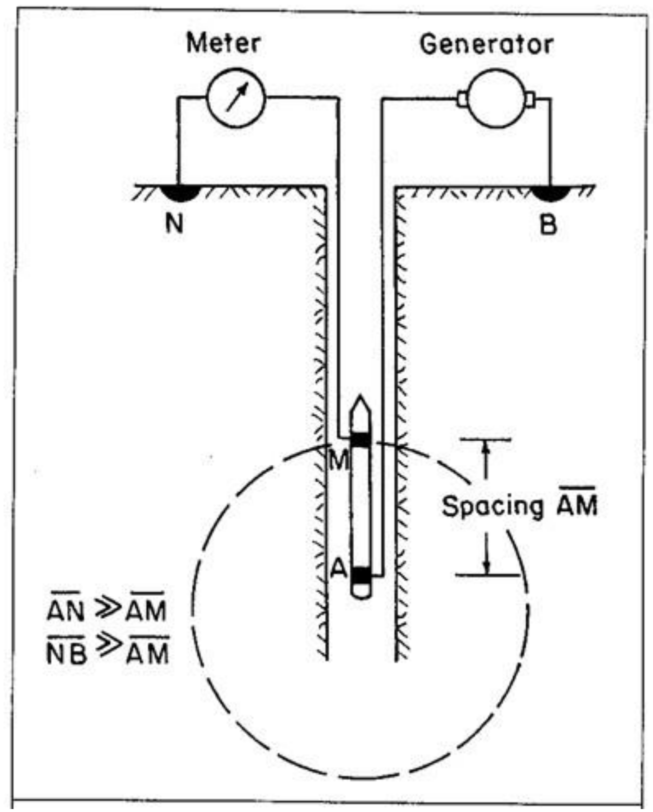
Basic electrode and power point

The resistance, $d\rho$, of the spherical shell between the radii r and $r+dr$ is given by

$$d\rho = R\frac{dL}{dA} = R\frac{dr}{4\pi r^2}.$$



Point Power electrode in a homogenous, isotropic and infinity extended medium



Basic arrangement of the normal device

Resistivity Log Cont'd

Measuring techniques:

- An emitter (electrode or coil)
- Sends a signal (electrical current, electromagnetic field) into the formation.
- A receiver (electrode or coil) measures the response of the formation at a certain distance from the emitter

Resistivity Log Cont'd

Long-spacing devices which are medium to deep reading include:

- **ES -**the conventional electrical survey, with normal and lateral (or inverse) electrode arrays
- **IL** -the induction log;
- **LL** -the laterolog;
- **SFL**- the spherically focused log.

The micro-tools include:

- **ML** -the microlog (normal and lateral);
- **MLL** -the microlaterolog (not to be confused with the microlateral of the ML);
- **PL** -the microproximity log;
- **MSFL**- the microspherically focused log;
- **HDT** -the high-resolution dipmeter tool

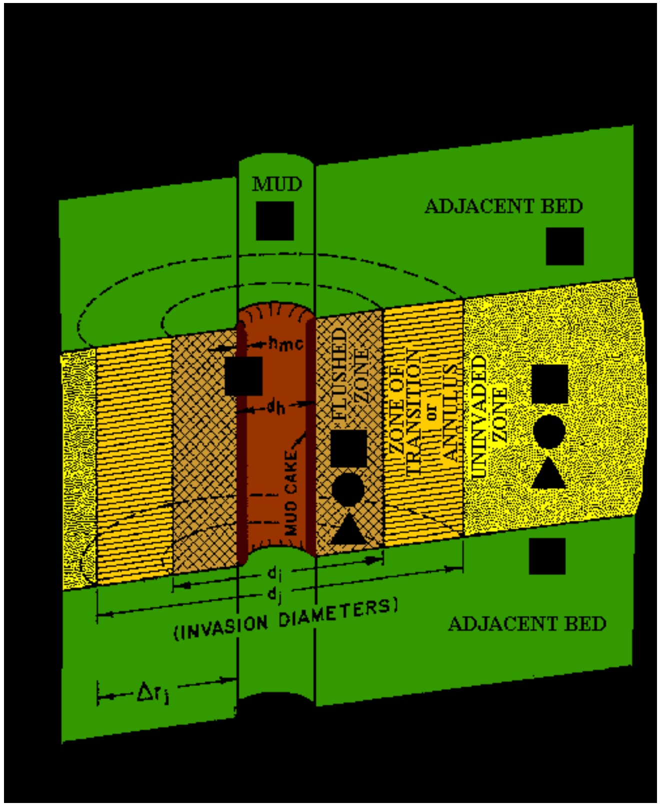
Resistivity Cont’d

- All resistivity tools are to some extent “averaging” devices that record resistivity of zones rather than resistivity of discrete points.

    - for example, the resistivity of a thin resistive horizon will generally be underestimated by most tools since its reading will be partly reduced by contributions of more conductive adjacent beds.

Resistivity Cont'd

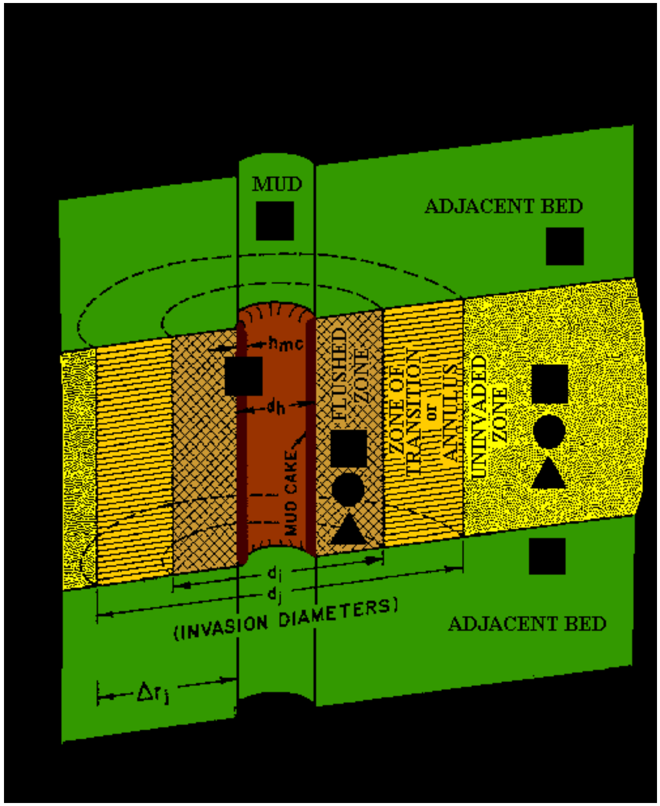
- The process of drilling actually modifies the resistivity of formations in the vicinity of the borehole through the process of "invasion".
- The drilling mud forms a mudcake seal on the borehole wall of permeable formation.
- Mud filtrate penetrates the formation, displacing formation water and oil or gas.



Resistivity Cont'd

- In a zone immediately adjacent to the borehole the mud filtrate displaces all the formation water and any "moveable oil saturation" (the "**flushed zone**").

- Beyond this, the mud filtrate displaces part of the formation water in a "transition zone" which ultimately peters out at a contact edge with the undisturbed formation.



Resistivity Cont'd

- The relative depth of invasion for resistivity tool is broadly a function of formation porosity/ permeability properties, so that less porous formations (typical carbonates) are more highly invaded than moderately porous units (typical sandstones).

- Pore volume appears to be a major control on invasion depth, because this dictates the volume available to accommodate invading mud filtrate.

- Once the permeability of a formation exceeds a critical lower value (perhaps about 0.1 md), the formation will be invaded, but invasion depths appear to be insensitive to variations in permeability at higher values.

Resistivity Cont'd

- The replacement of formation water by mud filtrate involves a change of pore water resistivity from R_w to R_{mf}.
- In a typical logging operation, the mud is "fresh water" as contrasted with the formation waters encountered.
- The result of invasion is generally to create a more highly resistive annulus surrounding the borehole

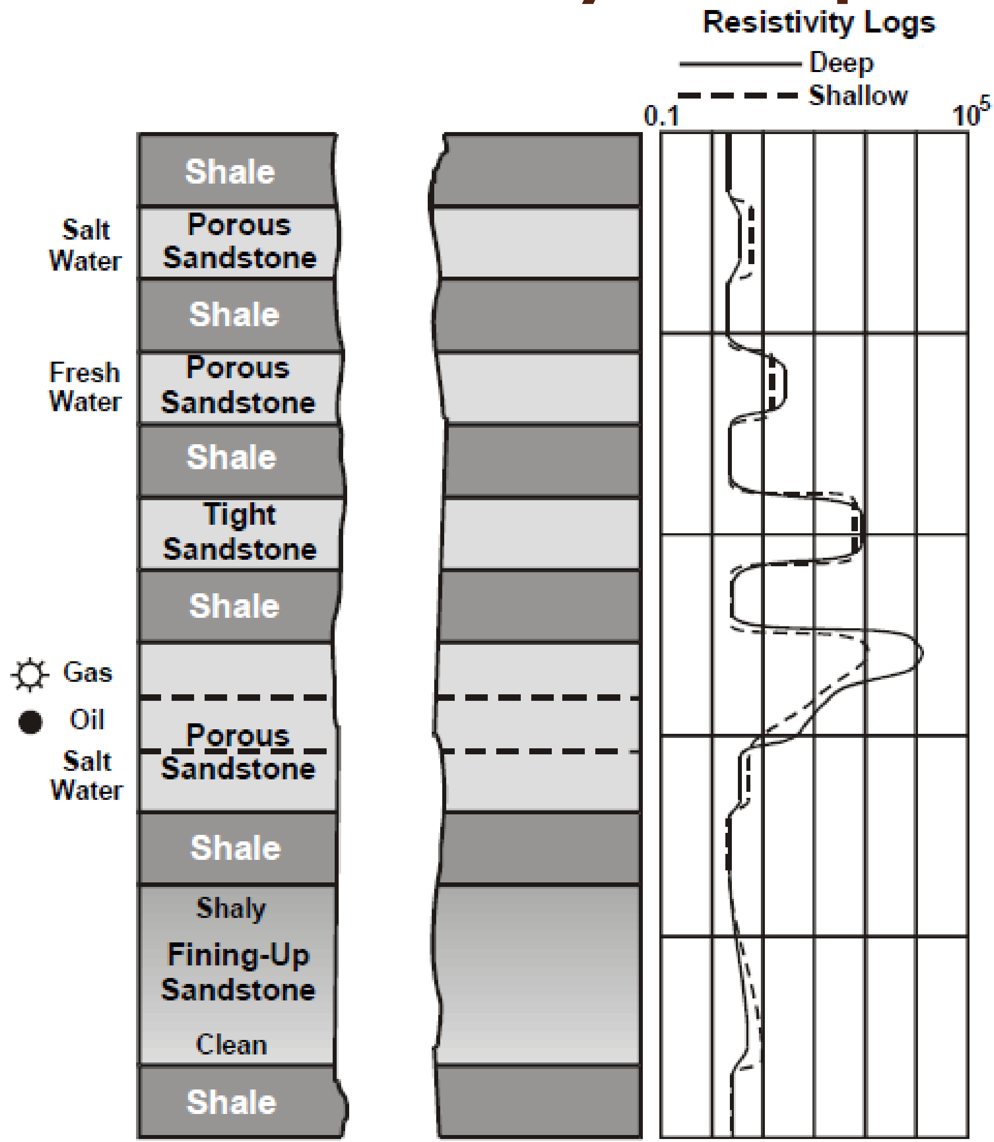
Resistivity Cont'd

- When the objective of most commercial logging is to evaluate the oil or gas potential of stratigraphic units, a resistivity tool is selected that will best estimate the true resistivity of the formation by taking into account:
  - characteristics,
  - drilling mud properties,
  - formation lithology,
  - degrees of invasion

Resistivity Cont'd

- The resistivity logs are usually presented in a logarithmic scale.
- The induction and laterologs both measure the resistivity of the uninvaded zone of the formation
- while the micro-resistivity logs measure the resistivity of the formation very close to the borehole, in the zone that has been flushed by the drilling fluid.

Typical Resistivity Response



Resistivity Cont'd

- Because the rock's matrix or grains are non-conductive, the ability of the rock to transmit a current is almost entirely dependent on water in the pores.

- And because hydrocarbons, like rock's matrix, are non-conductive, as hydrocarbon saturation of the pores increases, the rock's resistivity also increases .

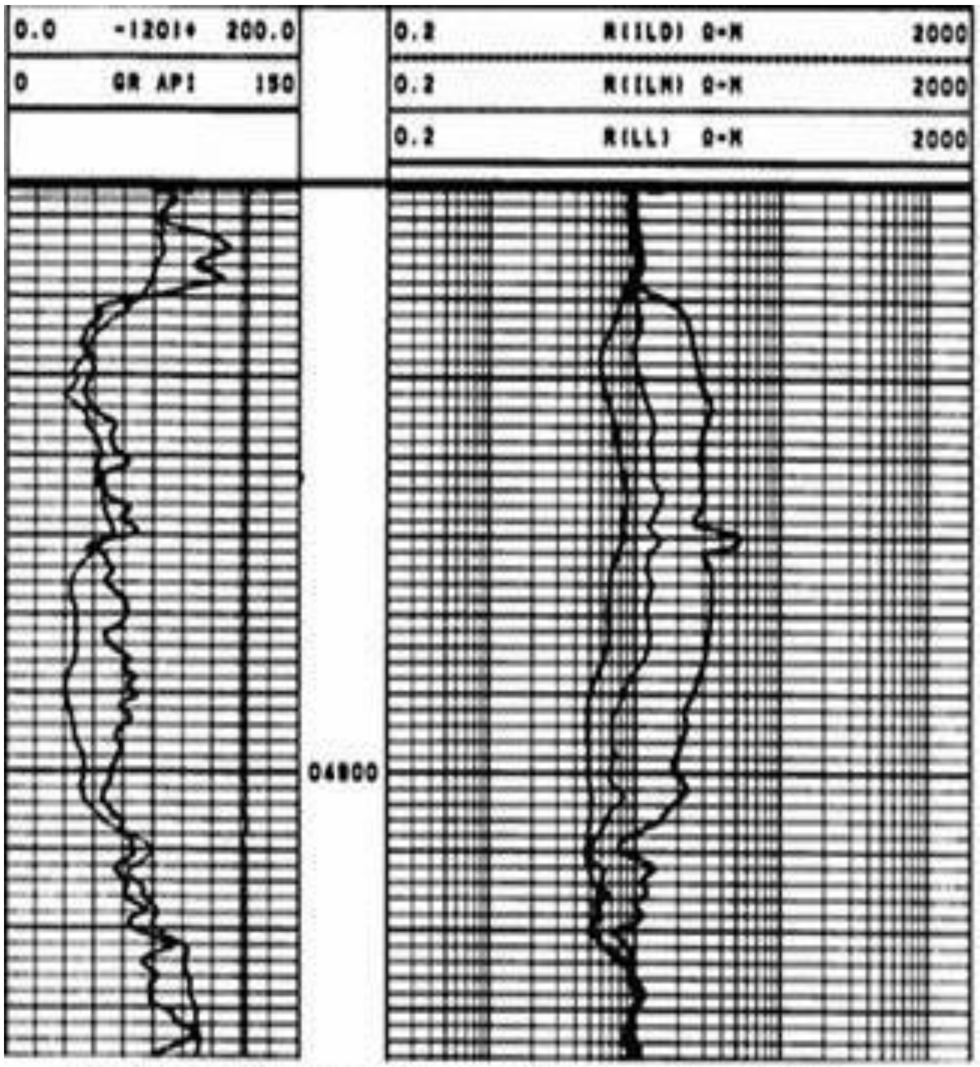


Fig.4: Resistivity logs, showing HC-bearing reservoir

Determination of Hydrocarbon Saturation

- With the knowledge of the formation's water resistivity, porosity, the formation's water saturation (Sw) can be determined from the Archie equation.
  - $$S_w^n = \left[\frac{aR_w}{\phi^m R_t} \right]$$
- Once the water saturation is known the hydrocarbon saturation can be determined thus:
  - $$S_o = (1.0 - S_w)$$

Summary of Resistivity

- Resistivity Logs are electric logs that measure a formation's resistivity, and is, resistance to the passage of an electric current.

- The key important use of resistivity logs is the determination of hydrocarbon vs. water-bearing zones of a formation.

- The resistivity logs are usually presented in a logarithmic scale.

- The induction and laterologs both measure the resistivity of the uninvaded zone of the formation

- while the micro-resistivity logs measure the resistivity of the formation very close to the borehole, in the zone that has been flushed by the drilling fluid.

Summary of Resistivity Con't

- There are some categories of resistivity logs :
  - Normal logs
  - Induction logs,
  - Laterologs, LL3, LL7, LL8, DLL
  - Spherically Focused Log
  - Micro-resistivity (R_{xo}) measurements.

Normal Logs

- A and B electrode transmit current
- M and N electrode are receiver
- B and N electrode are in the surface
- A and M are inside of the sonde
- Different potential are:

$$\Delta V = \frac{RI}{4\pi}\left(\frac{1}{AM} - \frac{1}{BM} + \frac{1}{BN} + \frac{1}{AN}\right)$$

A to N and B to M and N are infinite

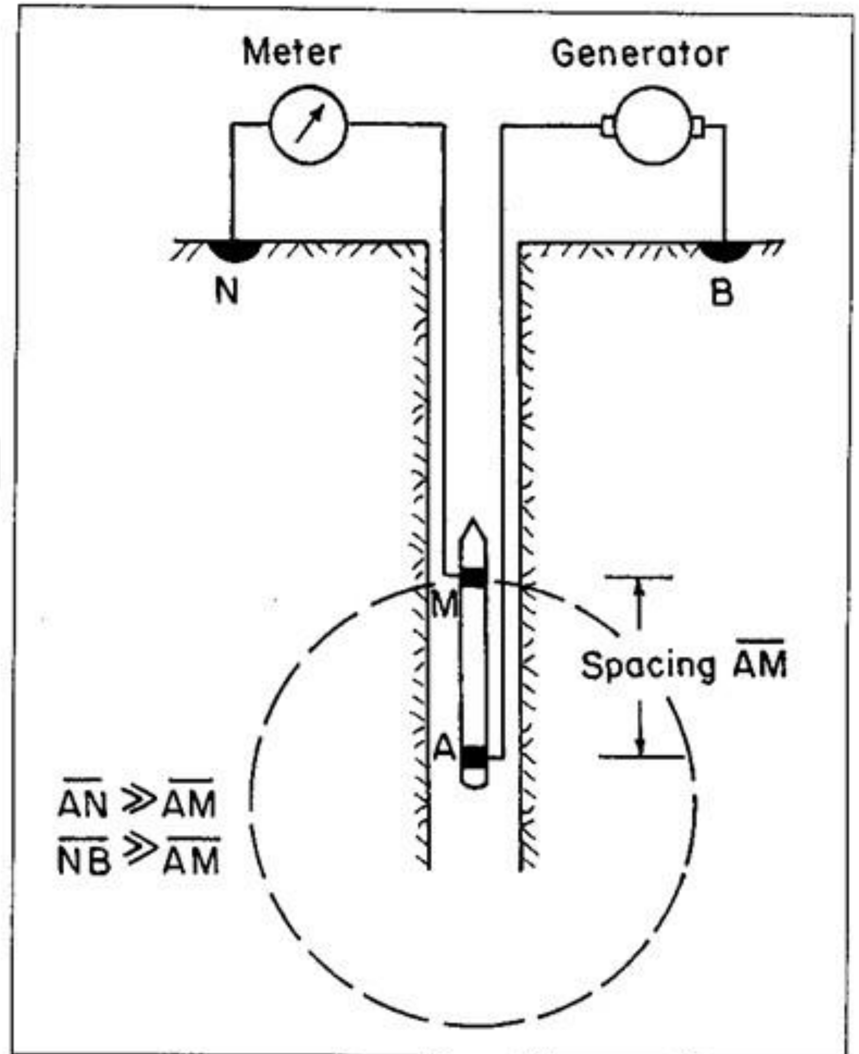
$$\frac{1}{BM} = \frac{1}{BN} = \frac{1}{AN} = 0$$

$$\Delta V = \frac{RI}{4\pi(AM)} \Rightarrow R = 4\pi AM \frac{\Delta V}{I}$$

Normal Logs Cont’d

Spacing:

Distance between A and M (in general 16” or 8”, 10”, 16”, 32” 40”,64’ and ….



Induction Resistivity or Deep Laterolog

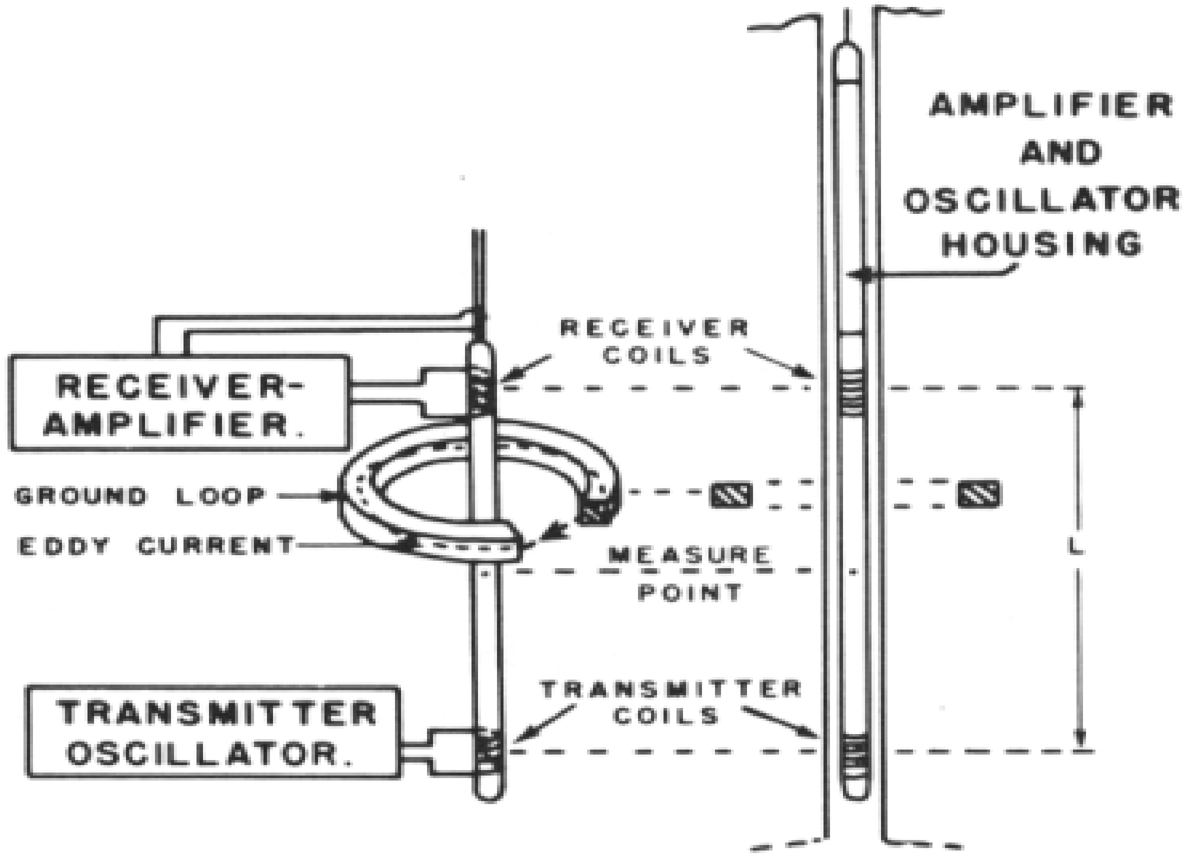
Induction History

- The induction log was invented by Henry Doll of Schlumberger and described in 1946 for the logging of the wells drilled in the **oil base mud.**

- It was developed from electromagnetic research undertaken during World War II on mine detectors. The first commercial success for the tool began in 1956.

Induction Resistivity or Deep Laterolog

- High frequency AC current
- Current constant
- eddy currents



Induction Log Equipment
(Courtesy of Schlumberger)

Induction Resistivity

- Conventional induction logs measure conductivity (Reciprocal of resistivity) perpendicular to the axis of the tool.
- In a vertical well, this is the horizontal direction. Vertical conductivity may be quite different.
- Recent developments have introduced a log that can measure vertically as well as horizontally. It is in the commercialization phase of development, and promises to be very useful in thin bedded and dipping reservoir rocks.
- The tool works in **air, or gas, oil, or mid filled open holes** but salt muds give poor results due to the greatly increased contribution of the borehole to the total conductivity reading. It does not work in cased holes.

Induction

- The focused induction tool was developed to measure conductivities deep within the formation with minimal disturbance by the invaded zone.
- The tool contains transmitter coils with a high frequency AC (Alternating Current) which induce eddy currents in the adjacent section.
- Most of these eddy currents are focused beyond the diameter of the typical flushed zone and their magnitude is an approximation of the conductivity of the virgin formation.
- In turn, they induce voltages in the receiver coil which are translated to estimates of formation conductivity and, as a reciprocal, resistivity.

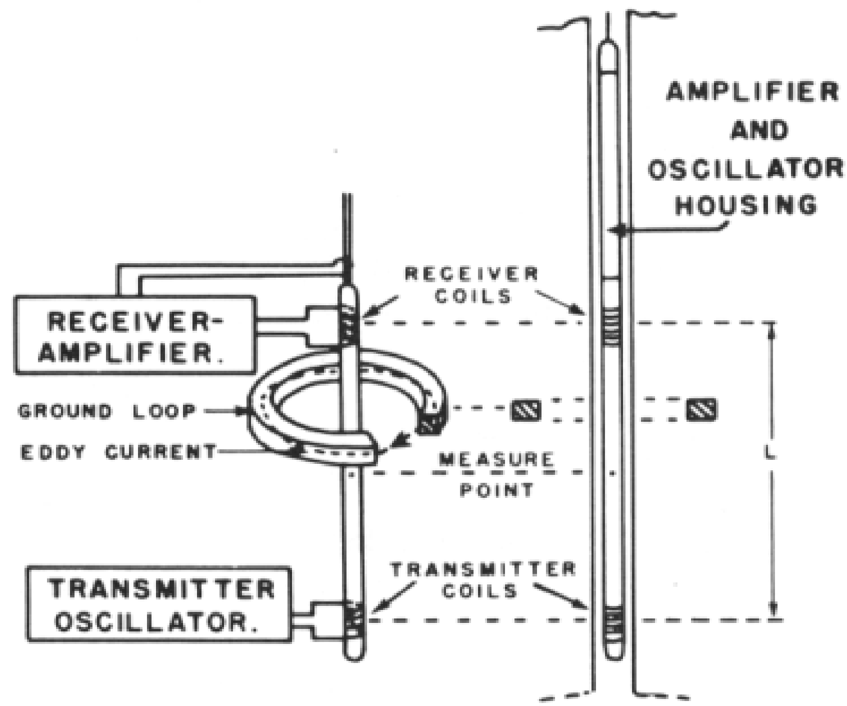
Induction (Cont'd)

- Since the induction tool actually measures conductivity directly, rather than resistivity, more reliable readings tend to be made within lower resistivity sections.

- As a result, the induction tool is ideally suited for *sandstone sections*, which typically have high porosities, but may not be a satisfactory first choice in highly resistive sequences such as low-porosity carbonates.

Induction Log Equipment

- The figure shows a simple induction logging system in which a transmitter coil and a receiver coil are wound coaxially on a supporting insulating mandrel.
- The distance between the coils, noted on the figure as "L" is called the "Spacing."
- The point of measurement is halfway between the two coils.



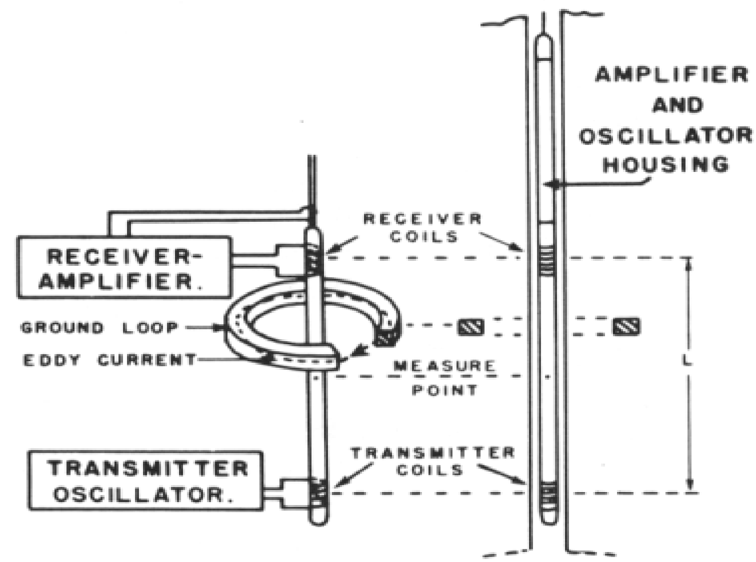
Induction Log Equipment
(Courtesy of Schlumberger)

Induction Log Equipment

- An alternating current of constant magnitude and frequency is fed to the transmitter coil from an oscillator.

- The altering magnetic field due to this current induces "current Loops" in the formation surrounding the sonde.

- These currents, in turn, have their own magnetic field, which induces an e.m.f referred to as a signal in the receiver coil.



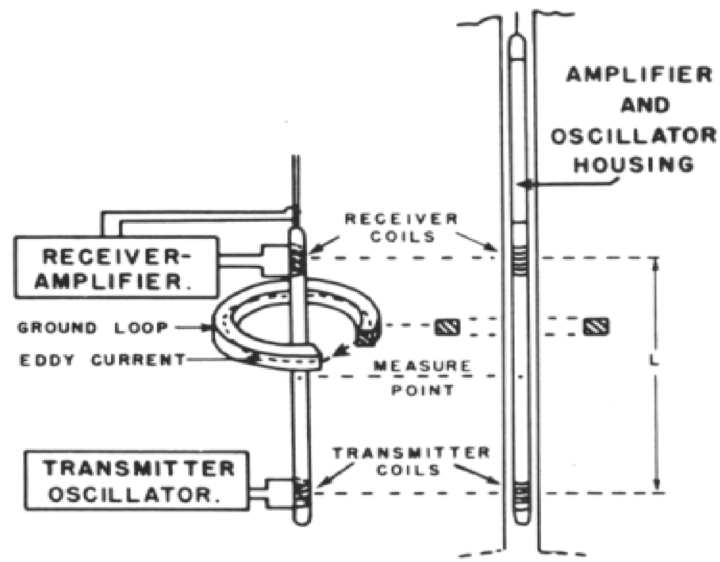
Induction Log Equipment
(Courtesy of Schlumberger)

Induction Log Equipment

- The intensity of the current induced in the formation is proportional to its conductivity. It follows that the signal induced in the receiver coil is also proportional to the conductivity of the formation, hence inversely proportional to its resistivity

- The signals are amplified, rectified to direct current then transmitted to the surface recording equipment

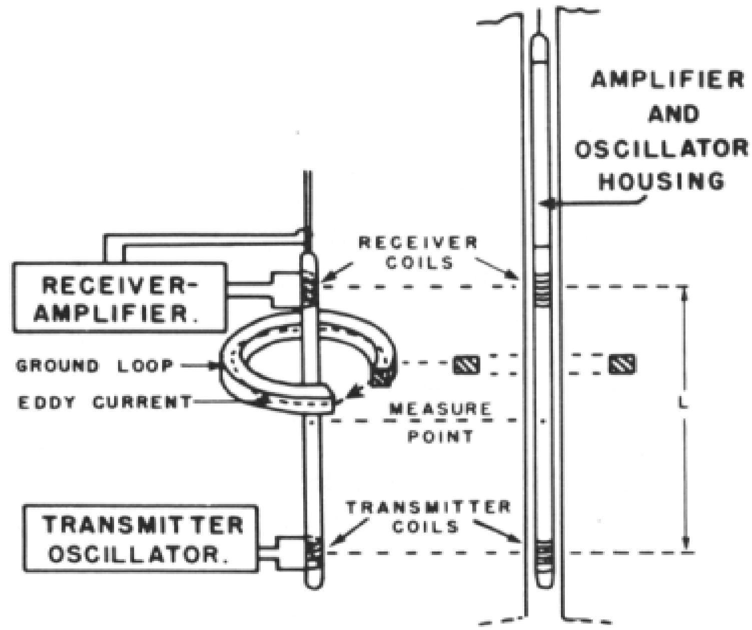
- Any direct coupling between the transmitter and receiver coil is balanced out.



Induction Log Equipment
(Courtesy of Schlumberger)

Induction Log Equipment

- The instrument in standard use in the field at the time of writing is the 5FF40 sonde.
- This designation means: a total of five coils.
- This instrument also permits the simultaneous recording of the sp curve and the 16” normal curve.

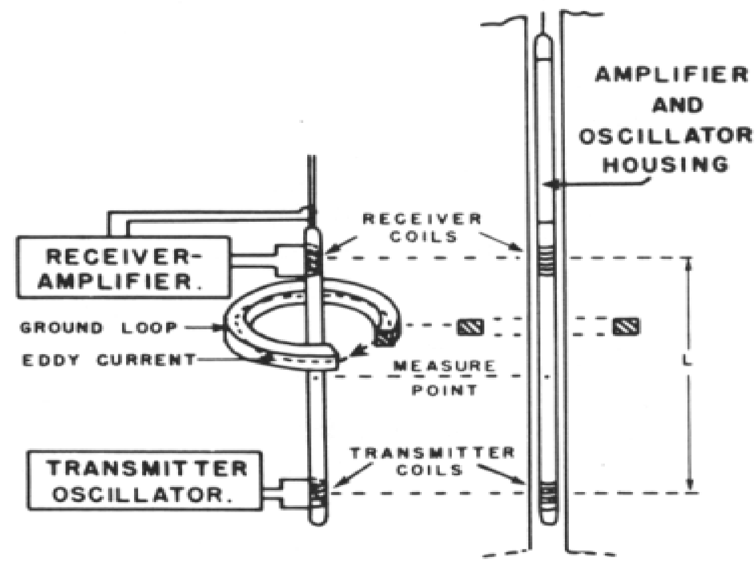


Induction Log Equipment
(Courtesy of Schlumberger)

Induction Log Equipment

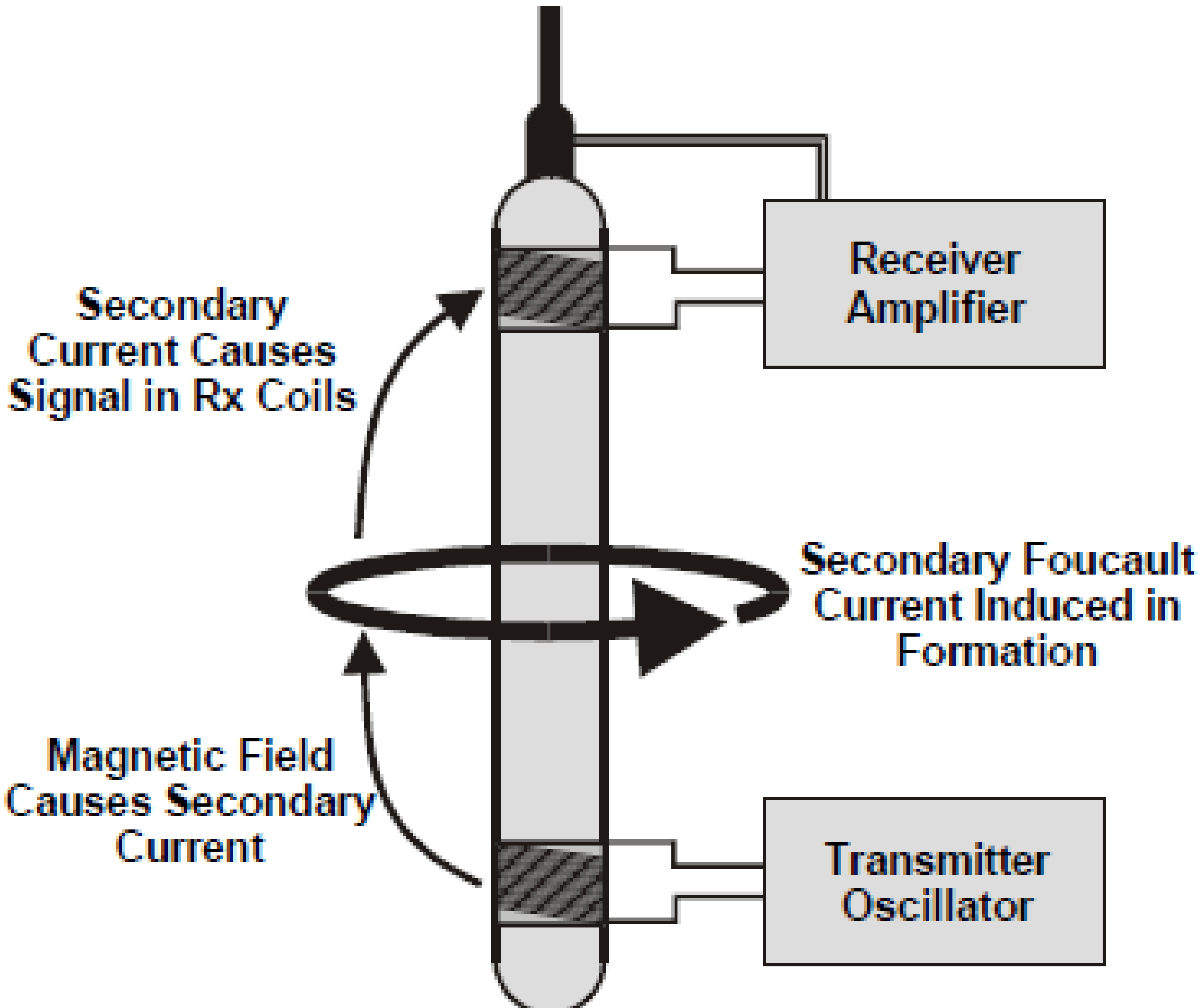
- This instrument provides an accurate and detailed record of the formations over a wide range of conductivity values.

- The accruracity is excelled for conductivity values higher than 20 mmho/m (Resistivity values < 50 ohm-m|)



Induction Log Equipment
(Courtesy of Schlumberger)

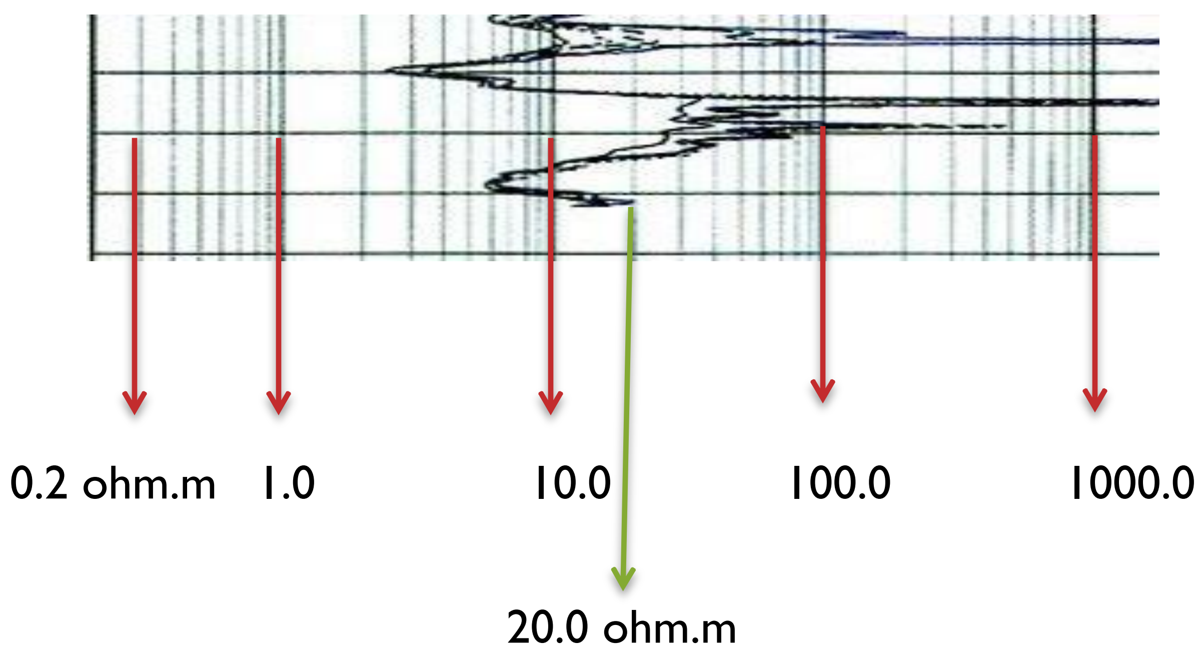
The Mode of Operation of Induction Log



Induction Log Scale

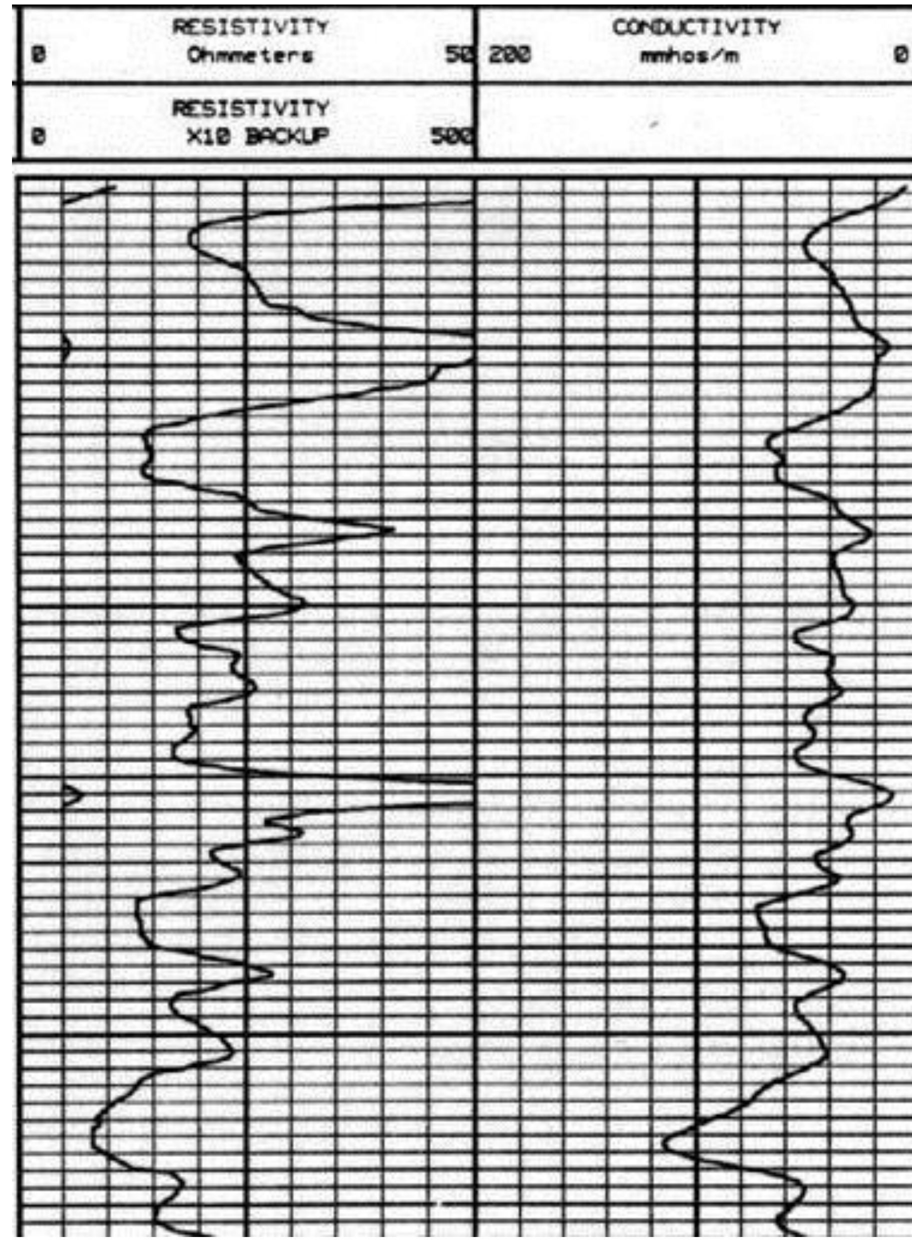
- Since conductivity is the reciprocal of resistivity therefore logging unit of conductivity would be
  1/ ohm-m or mho/m.

- The induction log readings are expressed in milliohms/meter. Thus the formation having resistivities of 10, 100 or 1000 ohm-m which would have conductivities of 100, 10, 1 mmho/m respectively.

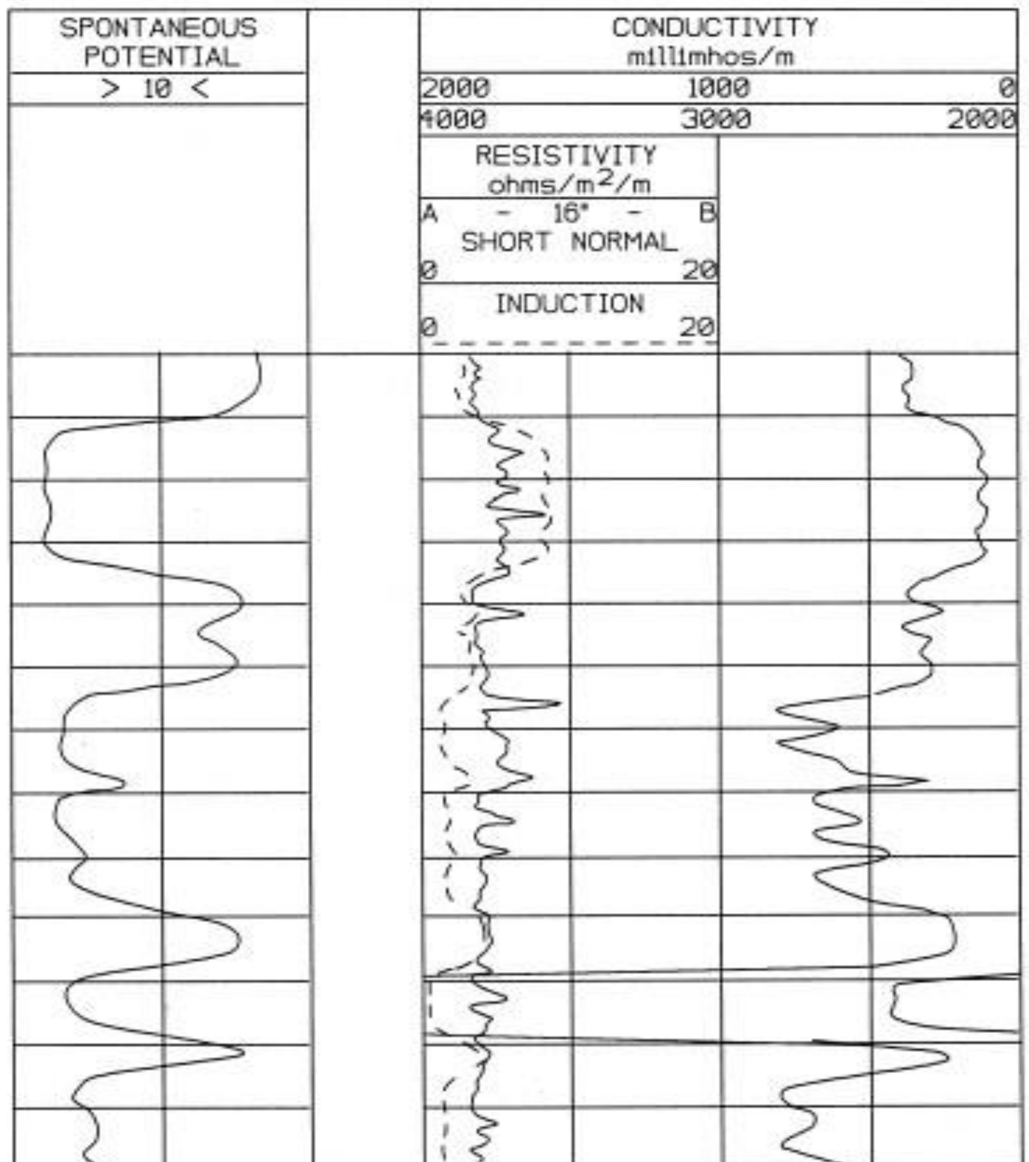


Induction Log Scale

- Induction log contains a conductivity curve in the right hand track and a resistivity curve in the middle track.
- The conductivity zero, corresponding to infinite resistivity, is set on a line at the right-hand side of the film.
- As conductivity increases, resistivity decreases and the curve deflects towards left. 2

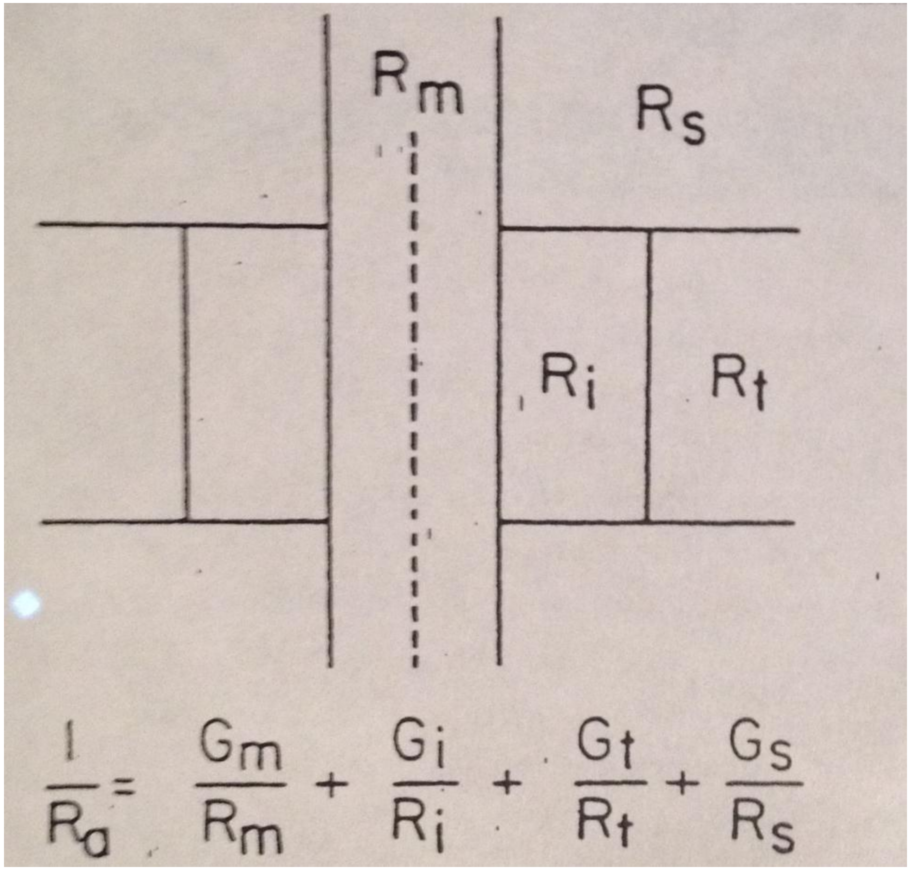


Example of Induction log



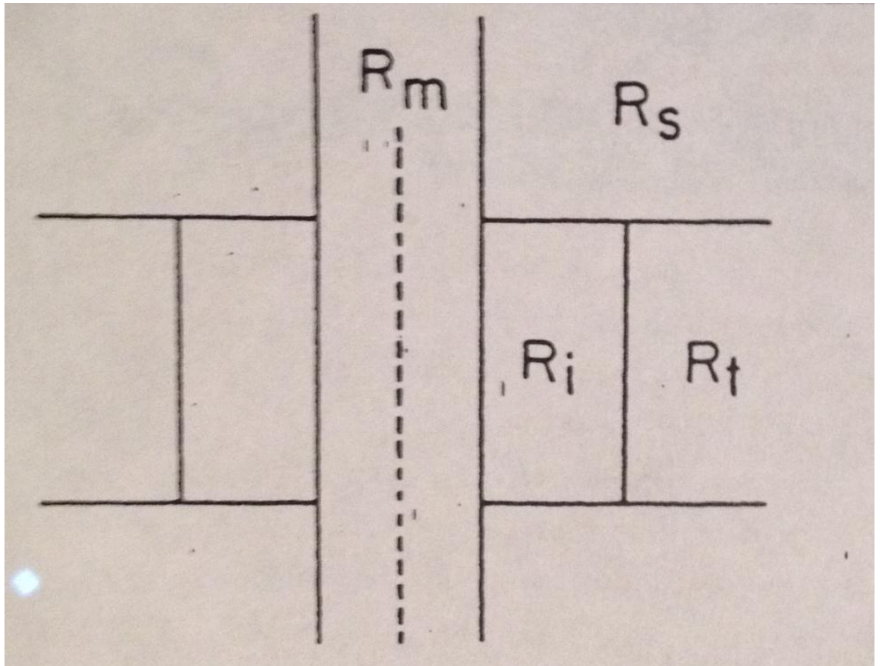
Geometrical Factor

- Lets compute mathematically the response of the instrument
- Such computation show that each medium involved in the measurement of conductivity given by the induction log contributes a part of the signal proportional to the product of its conductivity by geometrical factor G which depends on the geometry of the medium.



Geometrical Factor

- These G factors are fractions and add up to unity for whole space.
- Figure shows a schematic representation of a permeable bed, resistivity Rt, with an invaded zone of resistivity Ri, bounded by adjacent formations of resistivity Rs, and penetrated by a borehole containing mud of resistivity Rm.
- Each of these medias will have certain geometrical factors, Gt, Gi, Gm, and Gs

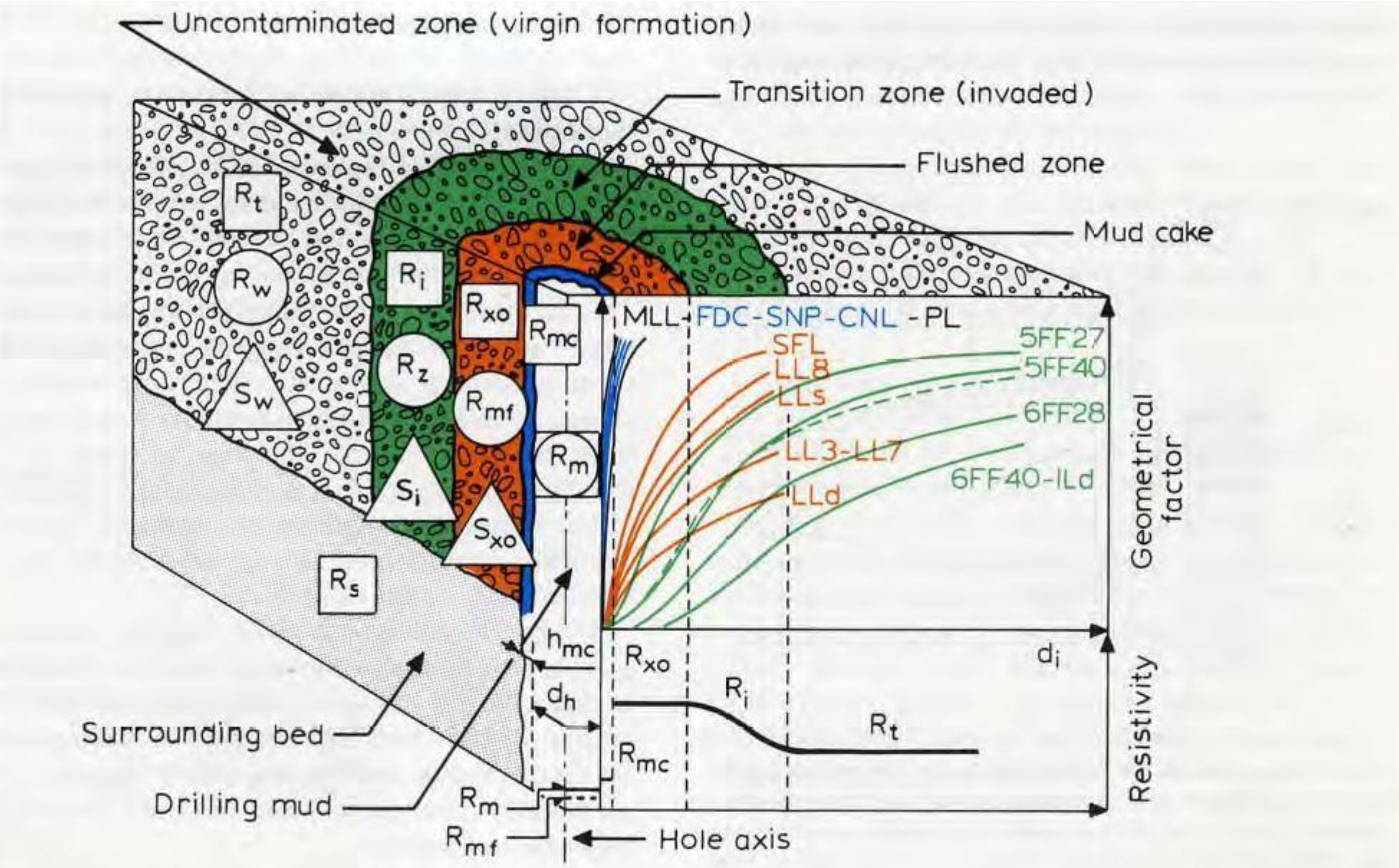


$$\frac{1}{R_a} = \frac{G_m}{R_m} + \frac{G_i}{R_i} + \frac{G_t}{R_t} + \frac{G_s}{R_s}$$

Geometrical Factor

- G factors = fractions and add up to unity for whole space.
- G_m = mud geometrical factor
- G_{xo} = G_i = Invaded zone geometrical factor
- G_s = bounded by adjacent formations of geometrical factor
- G_t = permeable bed or uninvaded zone geometrical factor

The radial geometrical factors of the principal resistivity tools, shown with the fluid and resistivity distributions near the well-bore.



Effect of Mud

- The conductivity signals due to the mud column increases with increasing hole size and with decreasing mud resistivity
- The factor G_m/R_m increases as G_m increases or as R_m decreases.
- The proportion of the total signal contributed by the mud column becomes greater as the formation resistivity increases.

Effect of Invasion

- Mud column and adjacent formation have comparably small influence on the induction log.
- Water-bearing formation:
  - Usually $R_{mf} > R_w$ and accordingly the resistivity of the invaded zone is higher than the true resistivity.
  - In this case most of the induced currents tend to flow in the uncontaminated zone and contribution of this latter to the total signal is large.
  - Induction log is well adapted to the detection of water-bearing beds.

Effect of Invasion Cont'd

- Oil-Bearing Formation
  - If an oil bearing formation contains a large amount of interstitial water or if $S_w > 60\%$, R_t is most often appreciably lower than R_{xo} and there is no annulus present (treated same as water bearing zones)
  - If $S_w < 60\%$, it is important to take the effect of the annulus into account.
  - The effect is determined for various numerical values of the factors involved initial water saturation, radius of invasion and R_{mf}/R_w.

Dual Induction

- The modern induction log is called the Dual Induction Focused and it can measure both deep and shallow resistivity reading.
- The Dual Induction Focused Log is used essentially in formations that are deeply invaded by mud filtrate. Because of deep invasion, a deep reading induction log (RILd) may not accurately measure the true resistivity of the formation.
- The Dual Induction logs should be corrected for borehole, bed thickness and invasion effects if three curves are present.

Dual Induction Cont'd

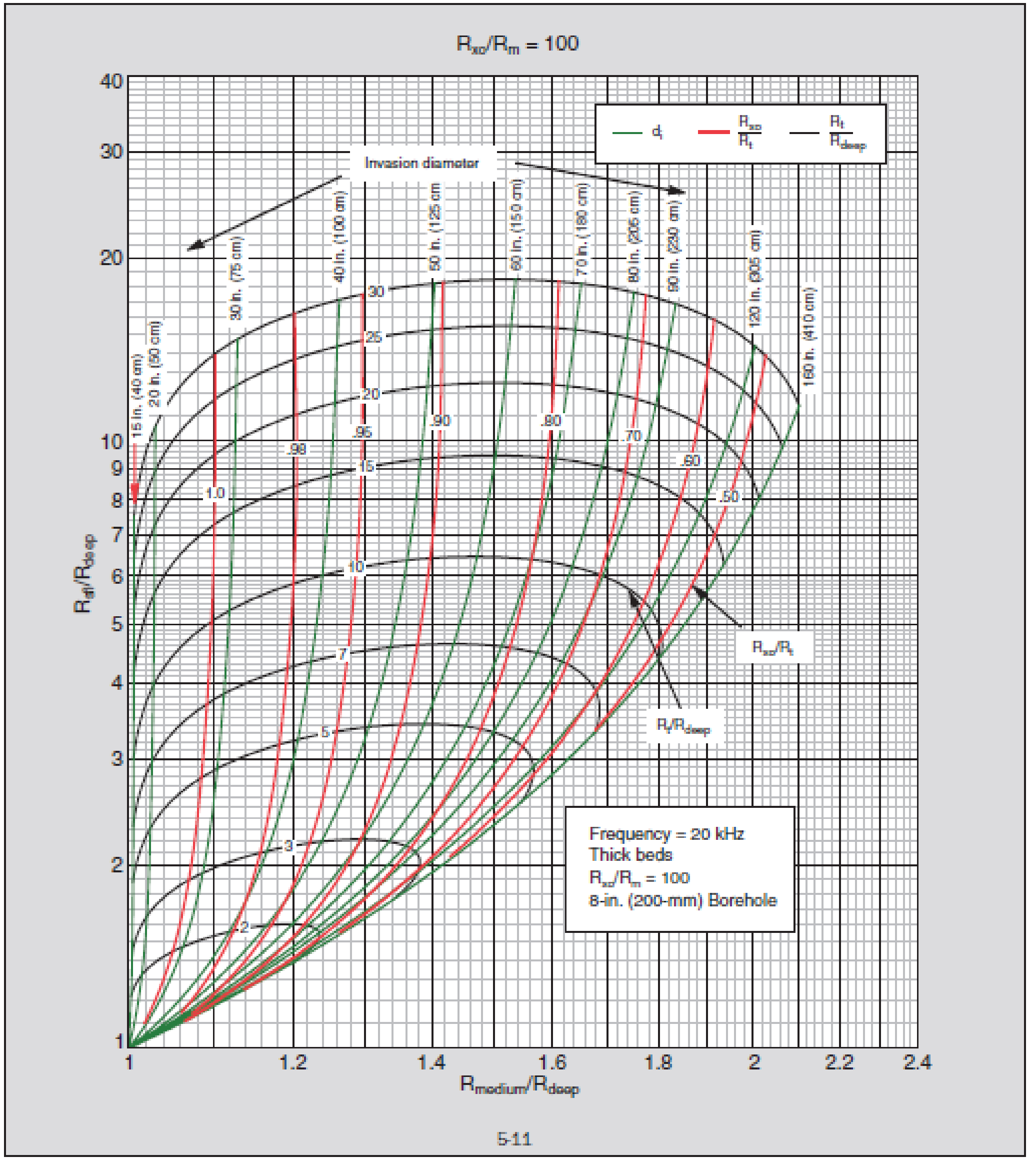
- Resistivity values obtained from the three curves on a Dual Induction Focused Log are used to correct deep resistivity (RILd) to true resistivity (Rt) from a Tornado chart.

- The induction system works best where the undisturbed formation has lower resistivity than the invaded zone (this is typical of logging in a fresh mud system).

Dual Induction - SFL or DIL names

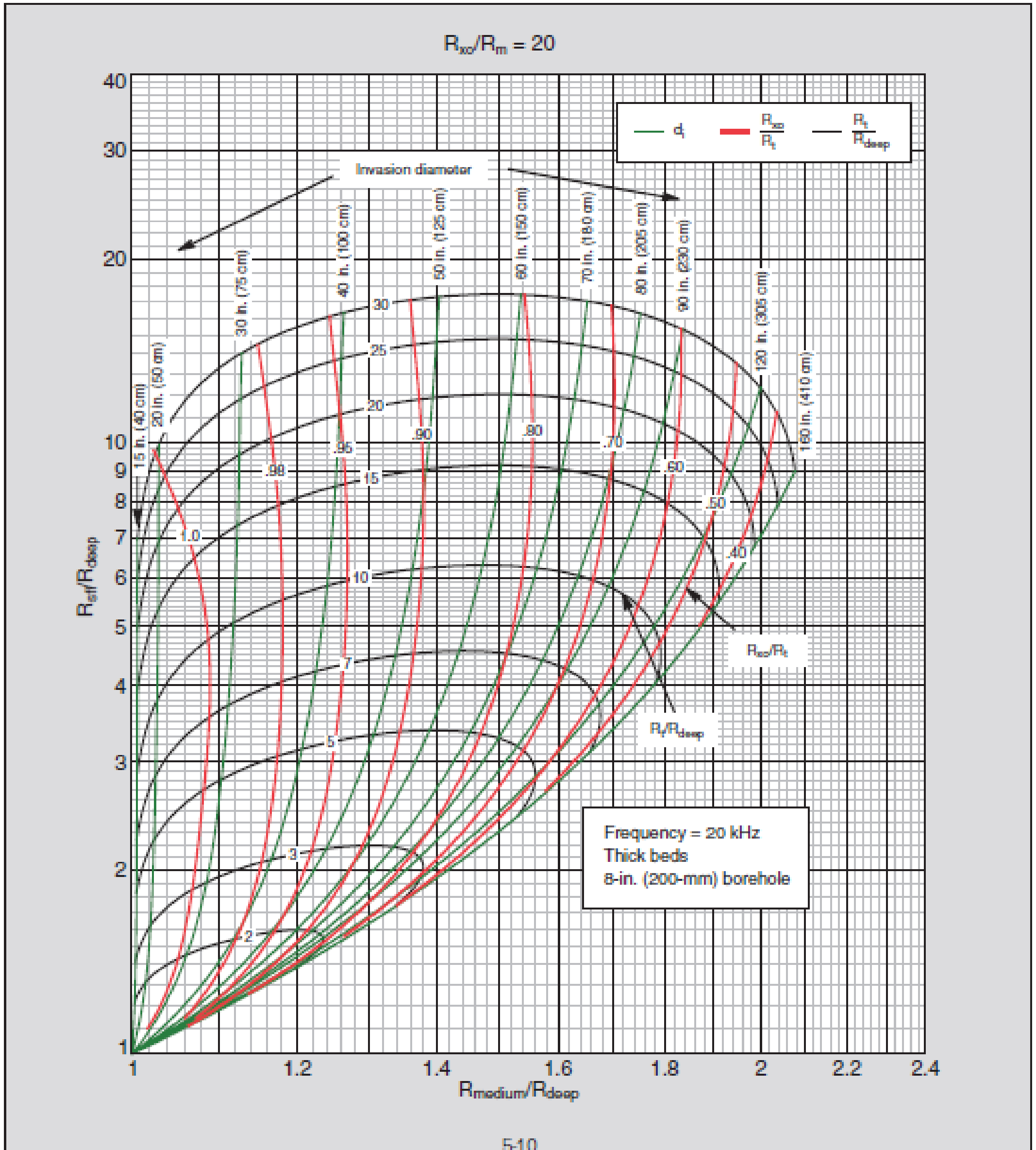
Curves	Units	Abbreviations
deep induction resistivity	ohm-m	ILD or RESD
medium induction resistivity	ohm-m	ILM or RESM
shallow resistivity	ohm-m	RLL8 or RSFL or RESS
spontaneous potential	mv	SP
* gamma ray	API	GR
* quick look ratio	frac	Rxo/Rt
* apparent water resistivity	ohm-m	R_{wa}
* formation factor ratio	frac	Fr/Fs
* sonic travel time	usec/ft	DELT or DTC
* sensity	gm/cc	RHOB or DENS

R_t and R_{xo} from Simultaneous Triple Induction (STI) – Spherically Focused Log (SFL)



- $R_{xo}/R_m = 100$
- D_i = diameter of invasion

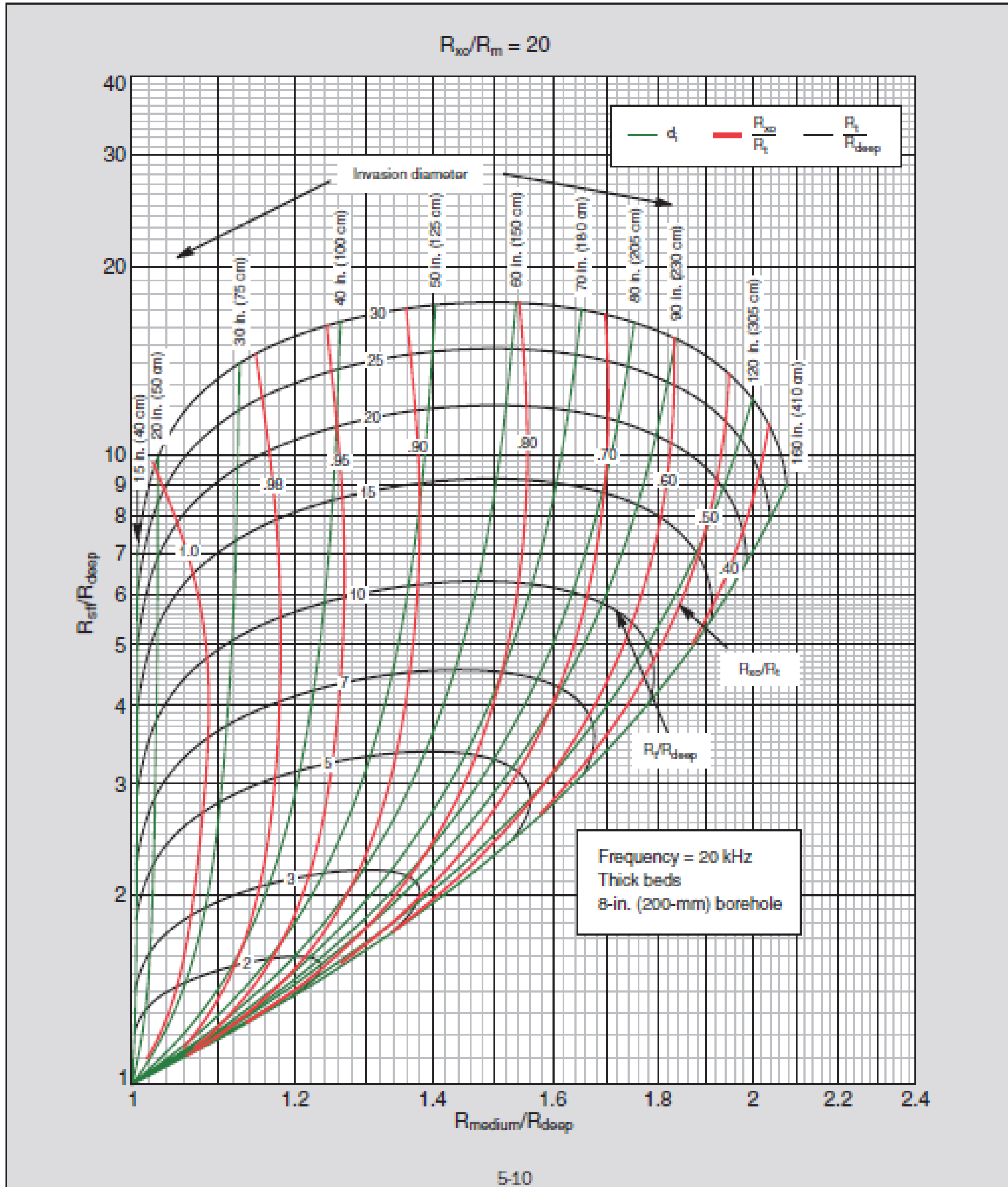
Rt and Rxo from Simultaneous Triple Induction (STI) – Spherically Focused Log (SFL)



- R_{xo}/R_m=20
- Example
  - RILD = 10 Wm
  - RILM = 14 Wm
  - RSFL = 90 Wm

Example :

- RILD = 10 ohm.m
- RILM = 14 ohm.m
- RSFL = 90 ohm.m

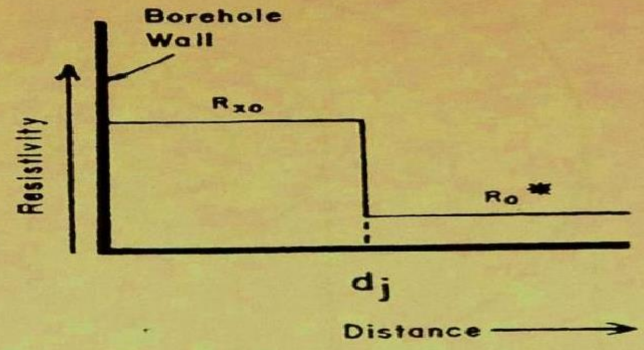


Induction resistivity summary

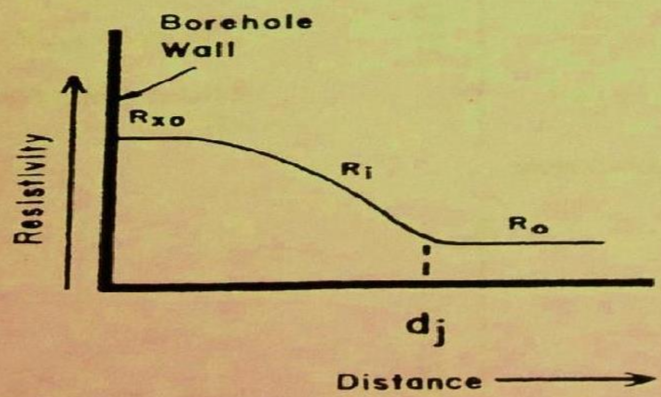
- Induces magnetic field into formation
- Magnetic field is a function of formation conductivity
- Resistivity is reciprocal of conductivity
- Vertical resolution of deep induction curve is 4 ft (DIL)

- Depth of investigation of DIL is 5 ft
- Always use deepest reading curve for Rt
- Induction Log is the best method used for the investigation of true formation resistivity, particularly for thin beds in wells drilled with comparably fresh muds, provided the resistivity to be measured are not exceedingly high.

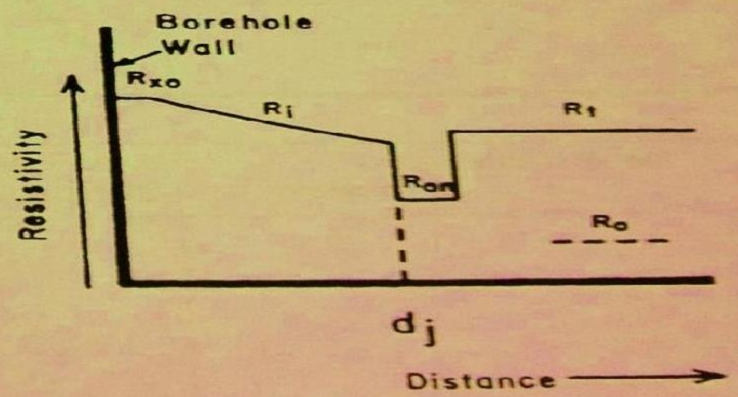
STEP PROFILE



TRANSITION PROFILE

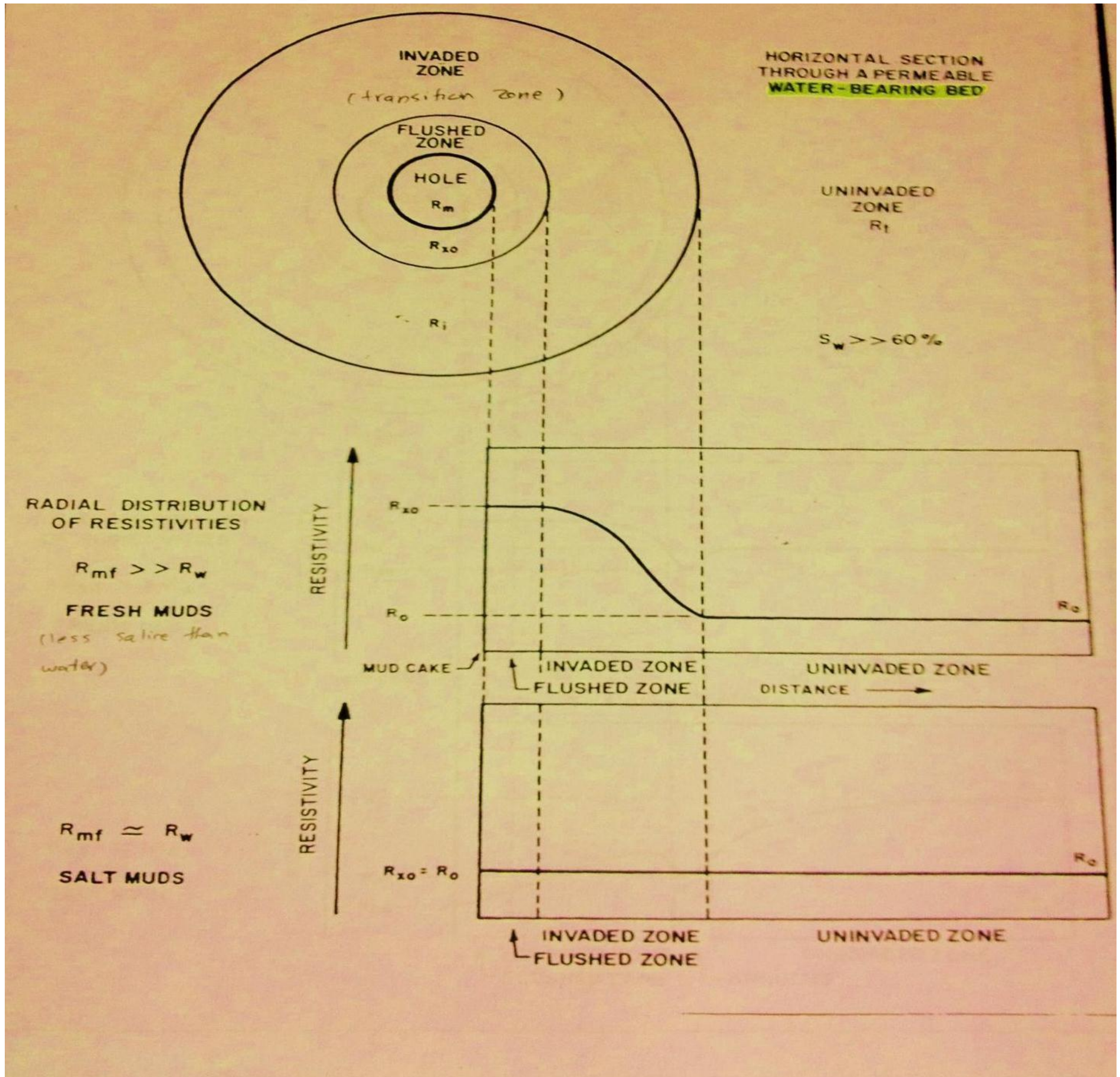


ANNULUS PROFILE

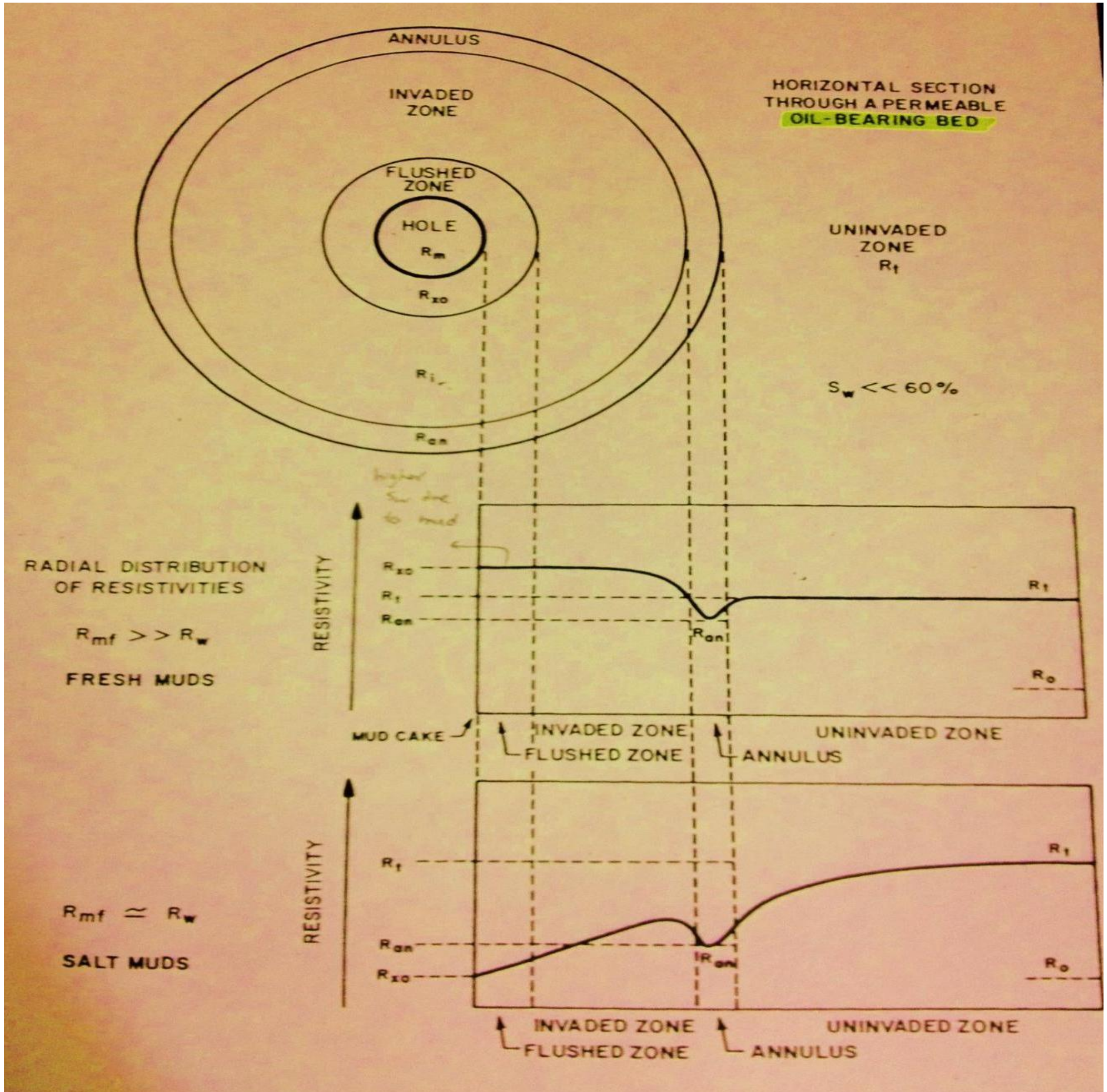


* R_o = resistivity of the zone with pores 100% filled with formation water (R_w). Also called wet resistivity.

Resistivity Profile in Water Zone



Resistvity Profile- Hydrocarbon Zone



Induction Log Summary

- Induction Log is the best method used for the investigation of true formation resistivity,

- particularly for thin beds in wells drilled with comparably fresh muds, provided the resistivity to be measured are not exceedingly high.

LATEROLOG

RESISITIVITY

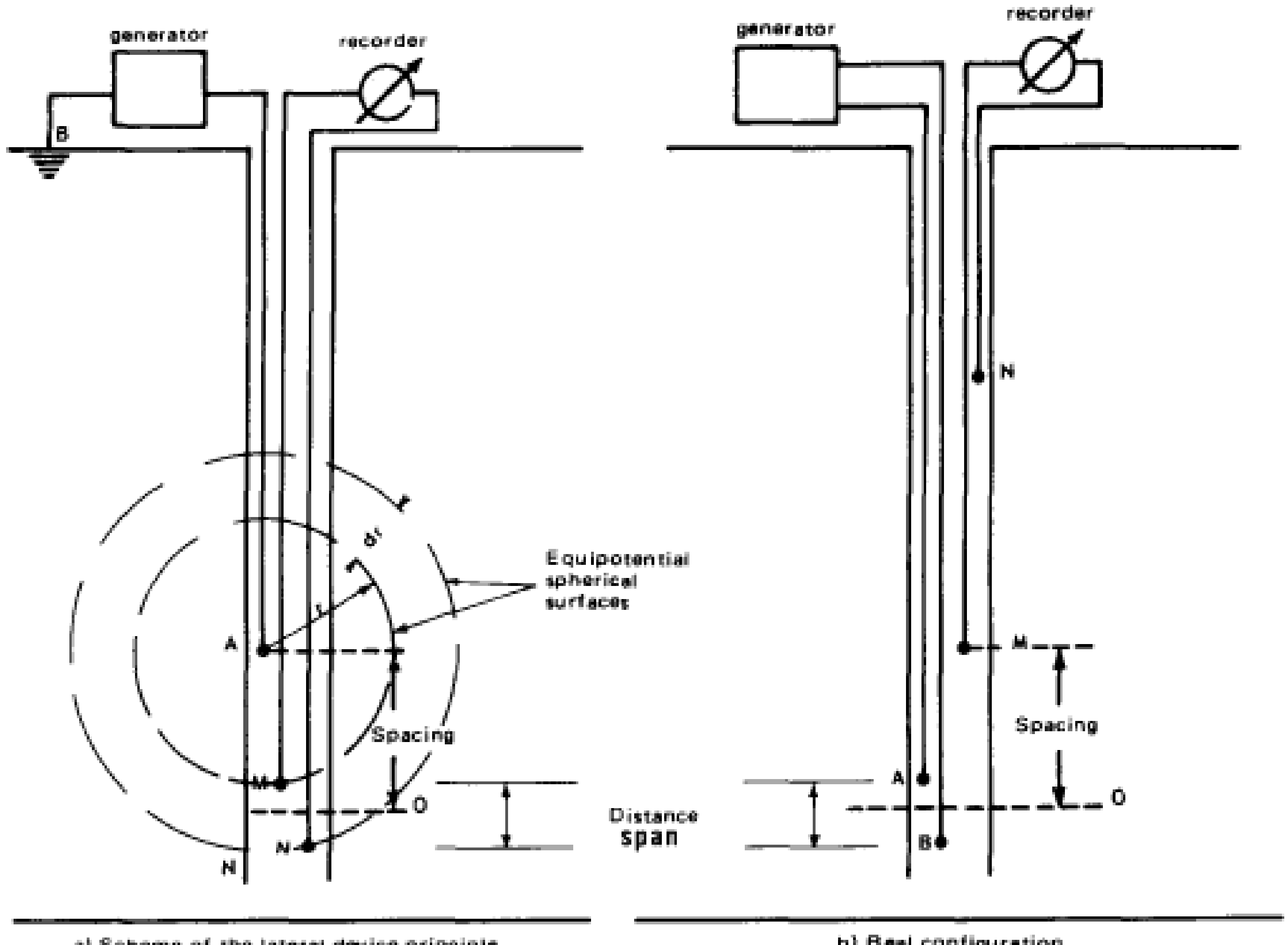
Laterolog Resisitivity

- The laterolog (or guard log) was developed to provide accurate readings of formation resistivity in holes drilled with salt water muds.

- Spacing 8” and 18” or 9”, 13”15”, 19”,24”

$$R = k\frac{\Delta V}{I}$$

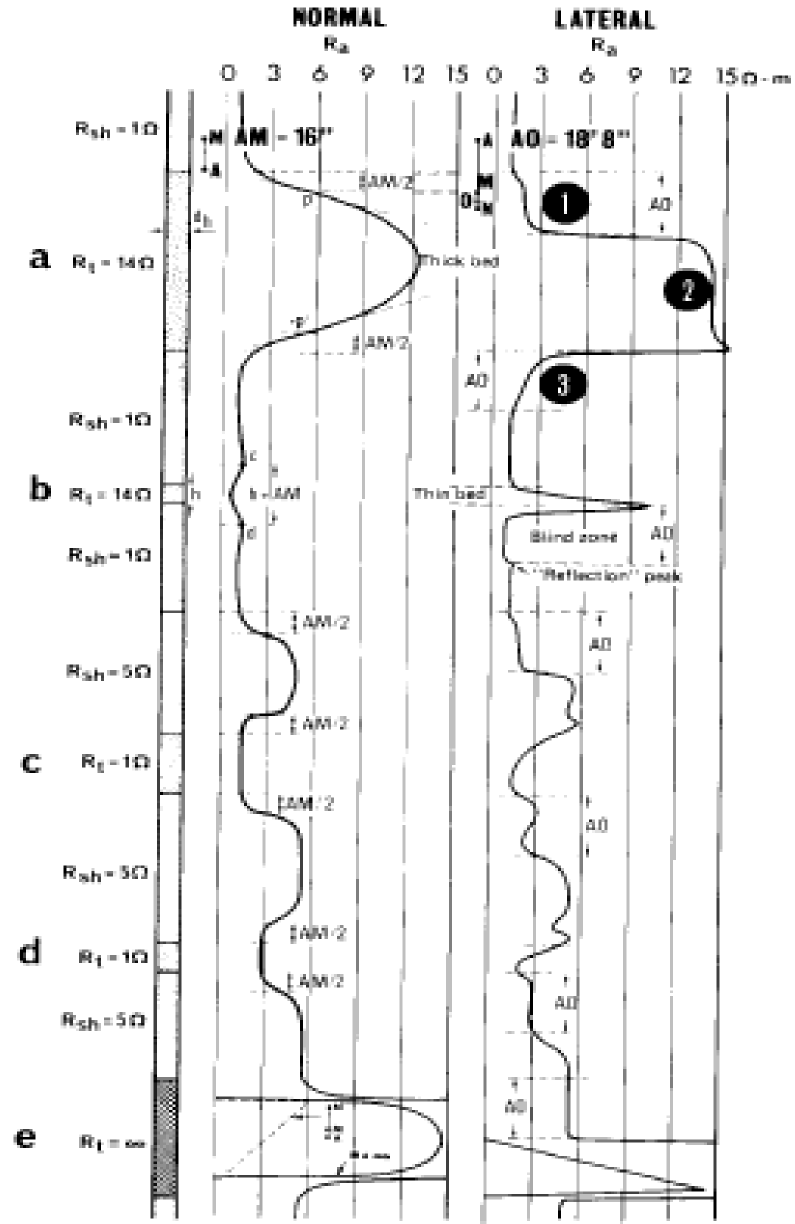
Laterolog Resisitivity Cont'd



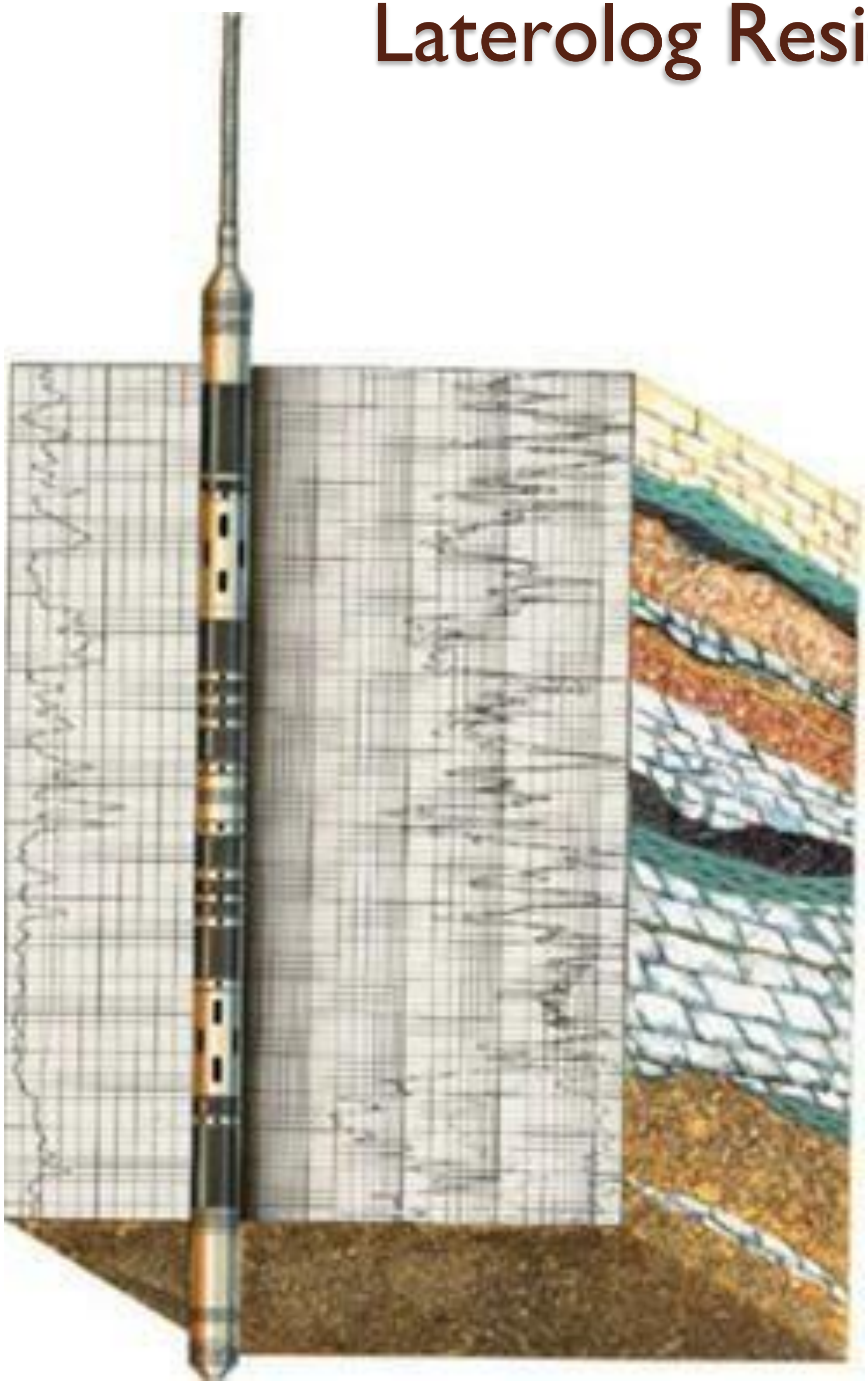
The Laterolog configuration

Laterolog Resisitivity Cont'd

- The influience of bed-thickness and resistivities on the shapes of the Laterolog and normal responses

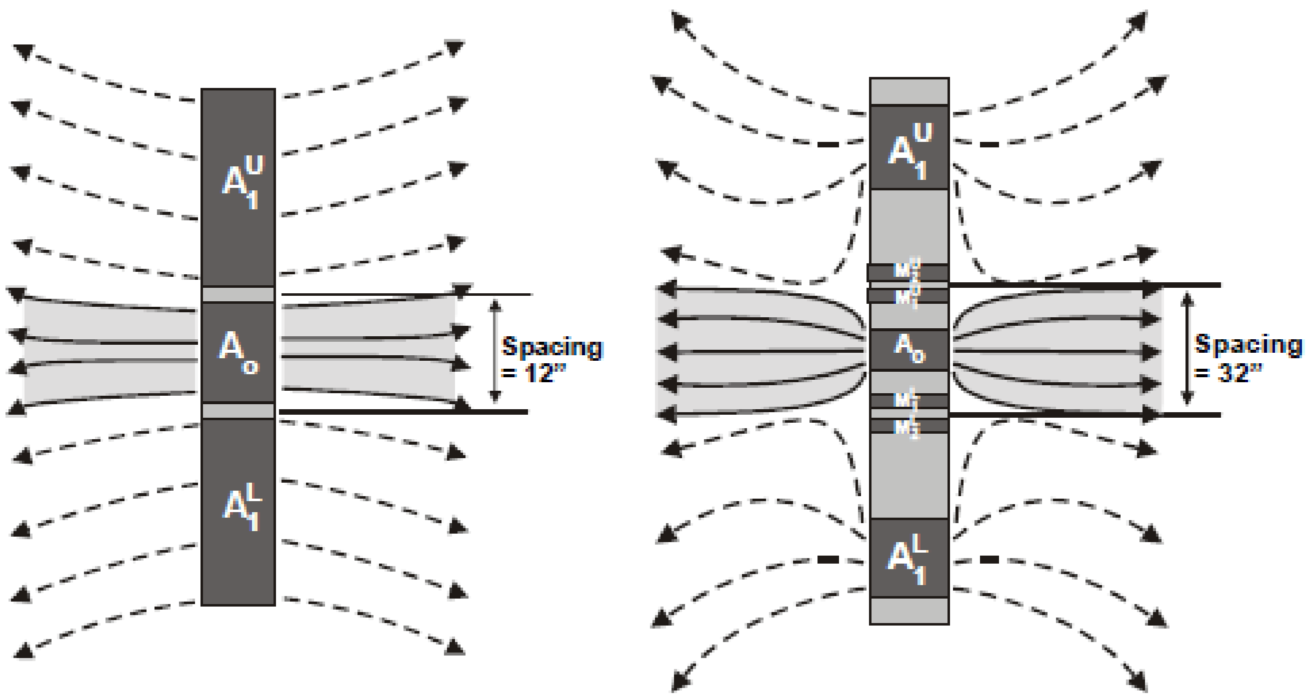


Laterolog Resisitivity Cont'd



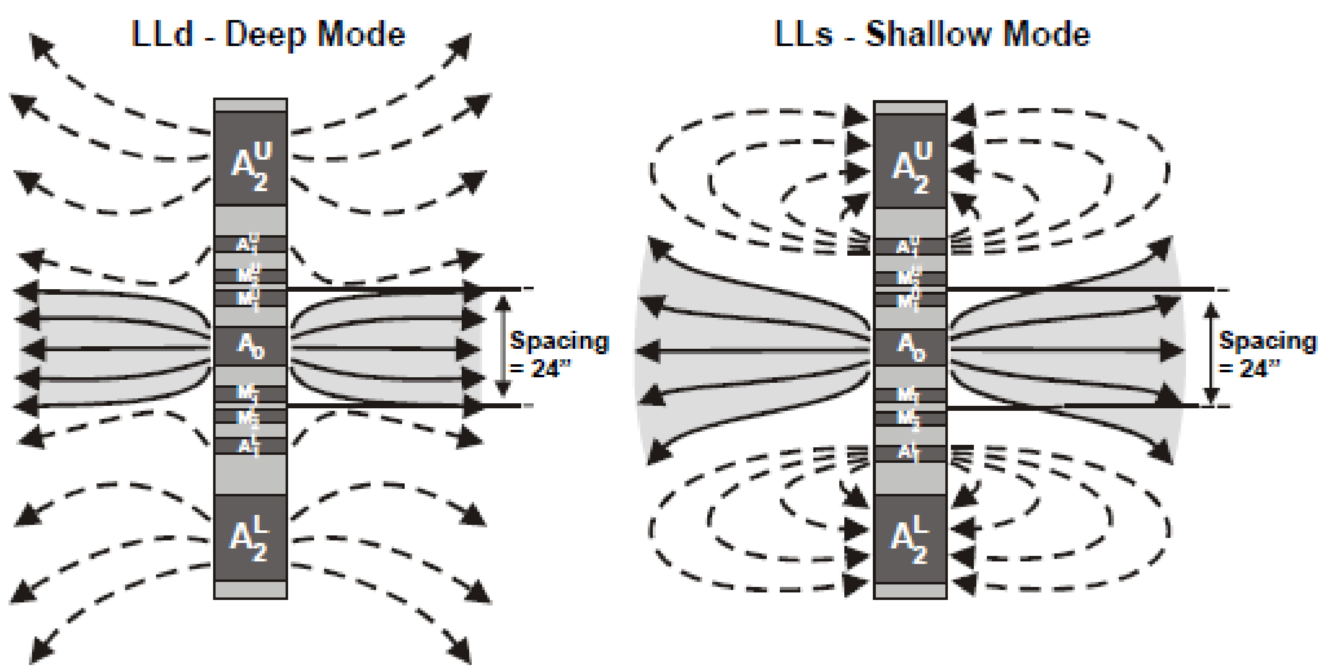
Basic Laterlog

- The LL3 and LL7 tool electrode configurations.
- The vertical resolution of the LL3 is 1 ft.



Dual Laterolog

- The *dual laterolog* (DLL) is the latest version of the laterolog.
- As its name implies, it is a combination of two tools, and can be run in a deep penetration (LLd) and shallow penetration (LLs) mode.
- These are now commonly run simultaneously and together with an additional very shallow penetration device.
- Both modes of the dual laterolog have a bed resolution of 2 feet,



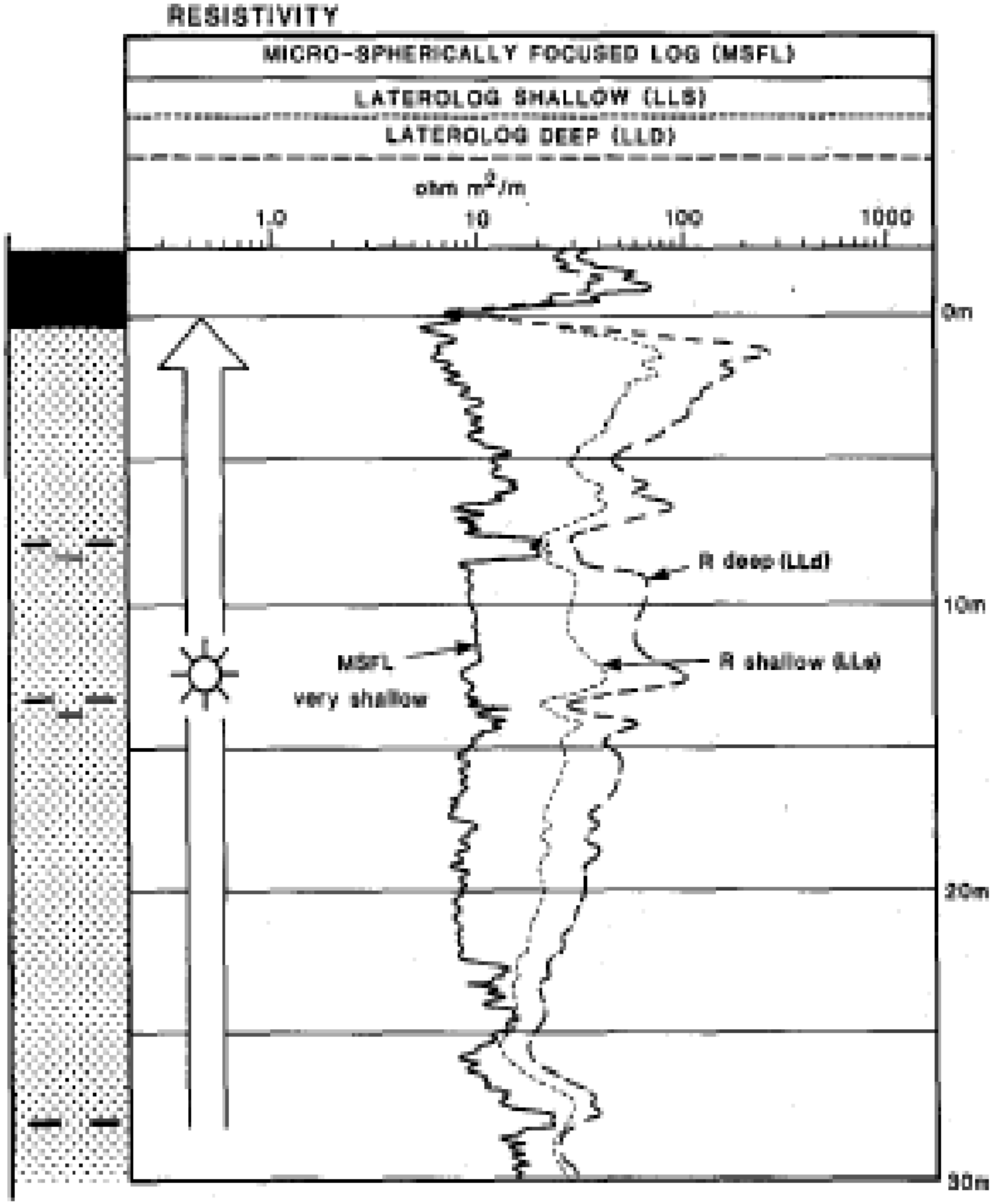
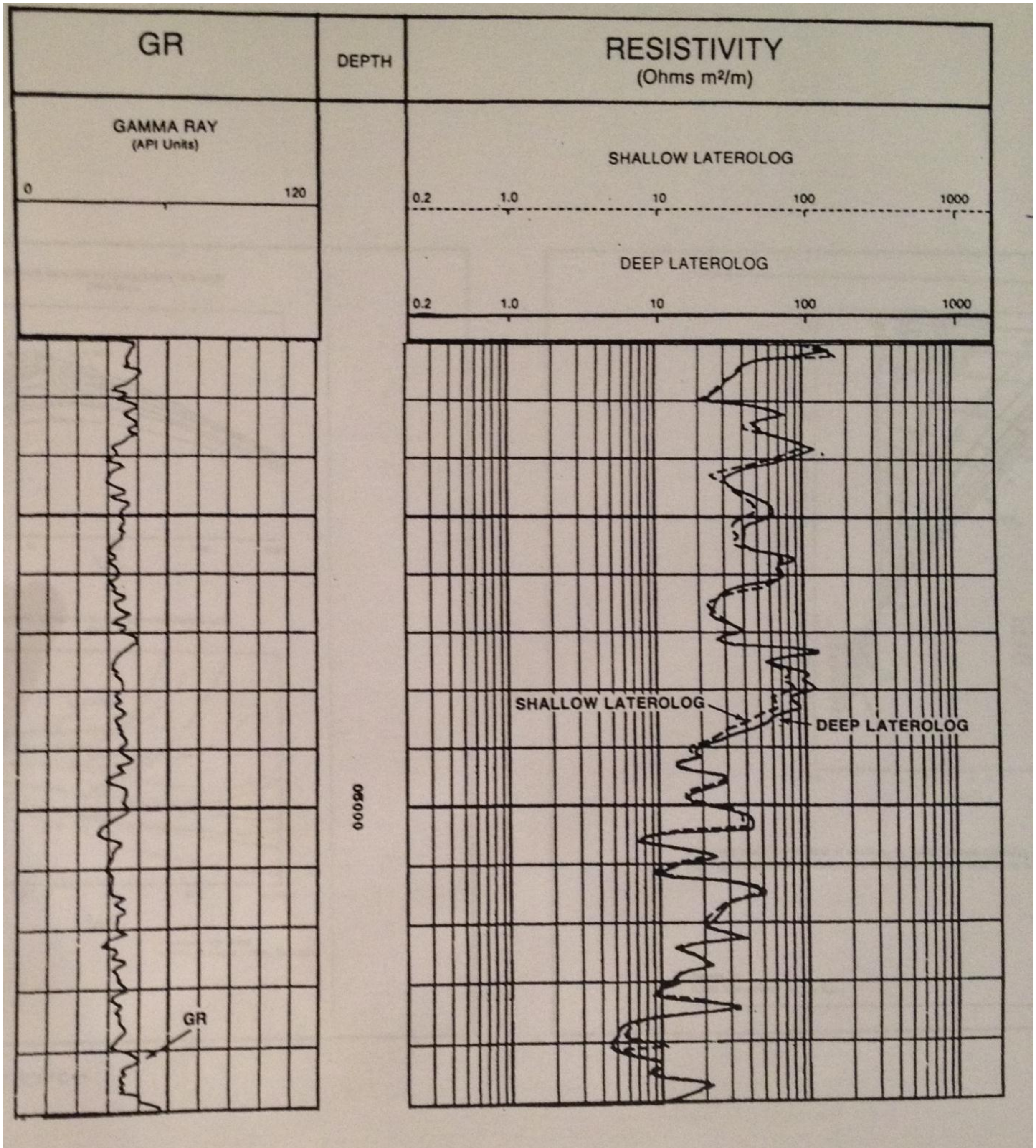


Fig. 19.7 An example of a DLL log. This shows good separation of the LLs and LLd from each other and from the MSFL, indicating the presence of a permeable formation with hydrocarbons (gas in this case in a formation of about 15% porosity). (Courtesy of Rider [1996]).


GR
DEPTH
RESISTIVITY
(Ohms m²/m)
GAMMA RAY
(API Units)
0
120
SHALLOW LATEROLOG
0.2
1.0
10
100
1000
DEEP LATEROLOG
0.2
1.0
10
100
1000
SHALLOW LATEROLOG
DEEP LATEROLOG
GR

Laterolog Resisitivity (Cont'd)

- There are various designs of laterolog tools but the central principle of operation is a three electrode arrangement in which a current supply of constant intensity is supplied to the central electrode.
- A variable current intensity is transmitted to the two surrounding ("guard") electrodes whose magnitude is adjusted so that there is a zero potential with the central electrode.
- As a result, current in the central electrode is constrained to flow radially outwards as a "current disc" into the surrounding formation.

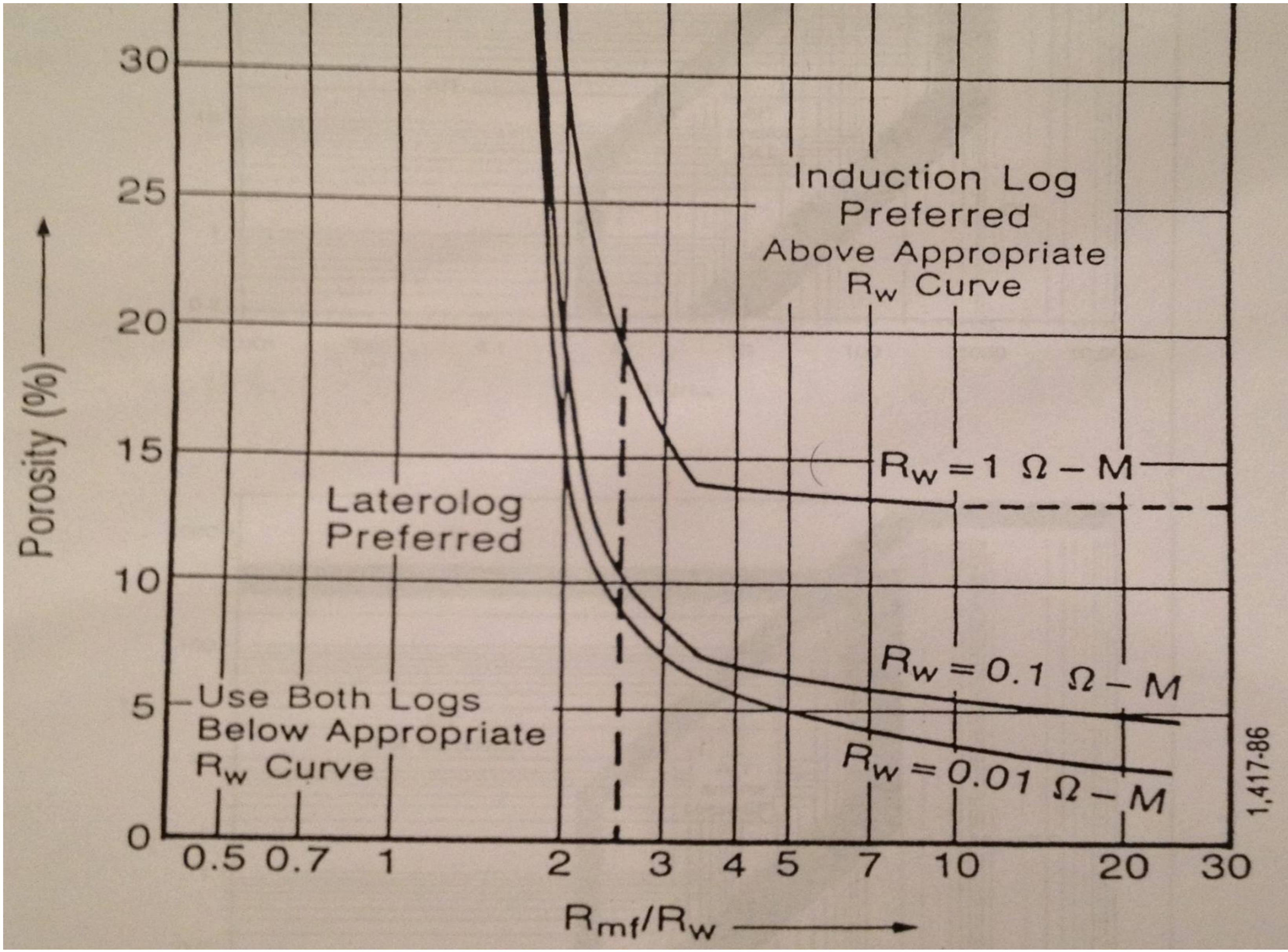
Laterolog Resisitivity (Cont'd)

- The thickness of the disc is determined by the spacing of the guard electrodes while the current density at any lateral distance from the central electrode is inversely proportional to this distance times the spacing. The drop in potential of the current disc radiating into the formation is monitored by a remote return electrode.

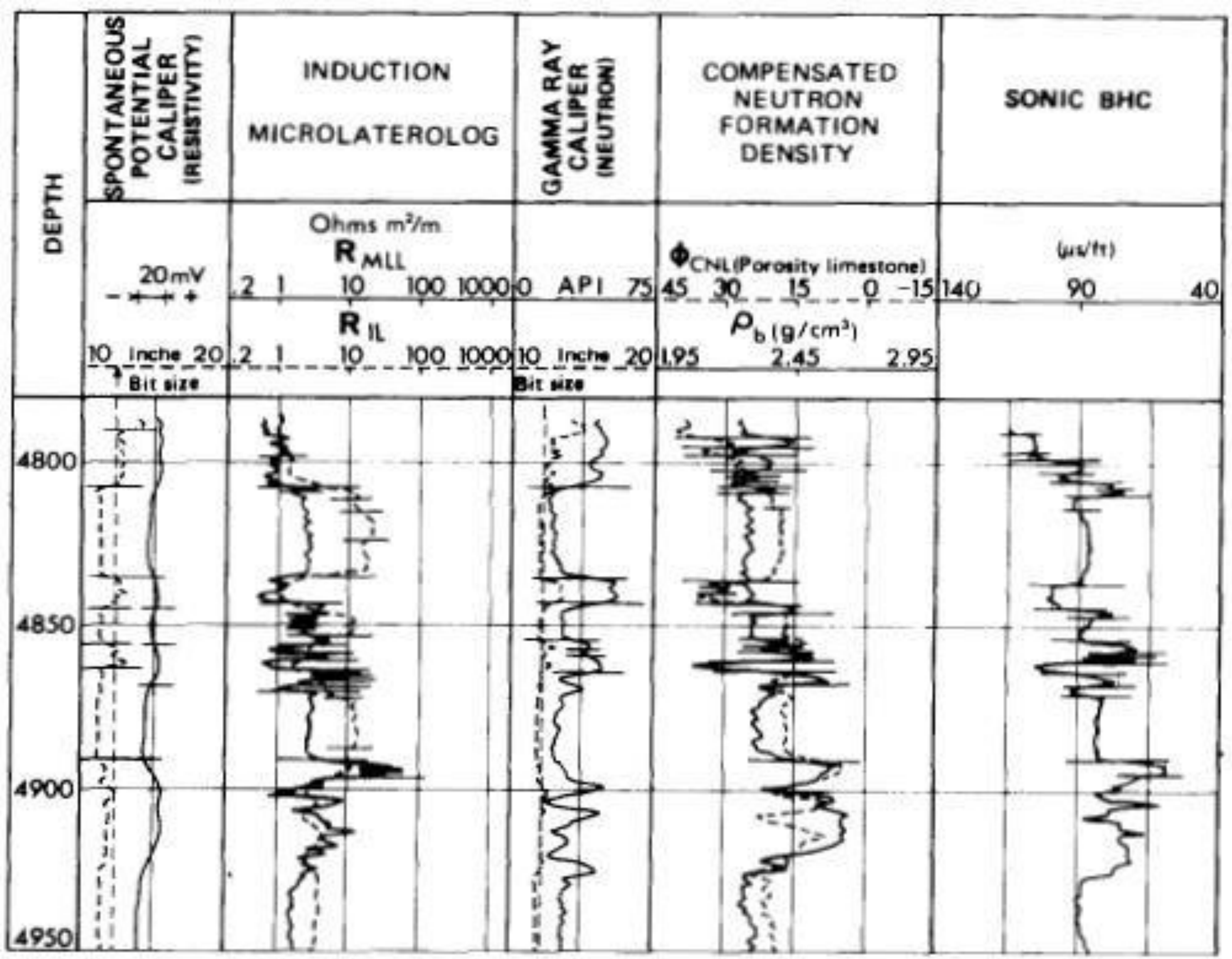
- As a result, an apparent resistivity is deduced which is the summation of resistivity contributions by the mud, invaded zone and virgin formation.

- In situations where the mud is relatively conductive, degree of invasion restricted and resistivity of the formation is fairly high, this apparent reading is a close approximation of the true formation resistivity.

Proffered ranges of application of induction logs and laterlogs for usual cases



An example of a composite log, and "electrobed" zoning.



Laterolog Summary

- The Laterolog is an electrode log that measures the true formation resistivity (R_t) in boreholes filled with saltwater muds (where $R_{mf} \sim= R_w$). Laterolog was actually introduced to cope with conditions of salty mud and high formation resistivity.

- A current from the surveying electrode is forced into the formation by focusing electrodes. This focuses the measuring current into a sheet to obtain the best tool resolution.

- The focusing current can be adjusted so that the tool measures both the deep resistivity and the shallow resistivity.

Laterolog Summary

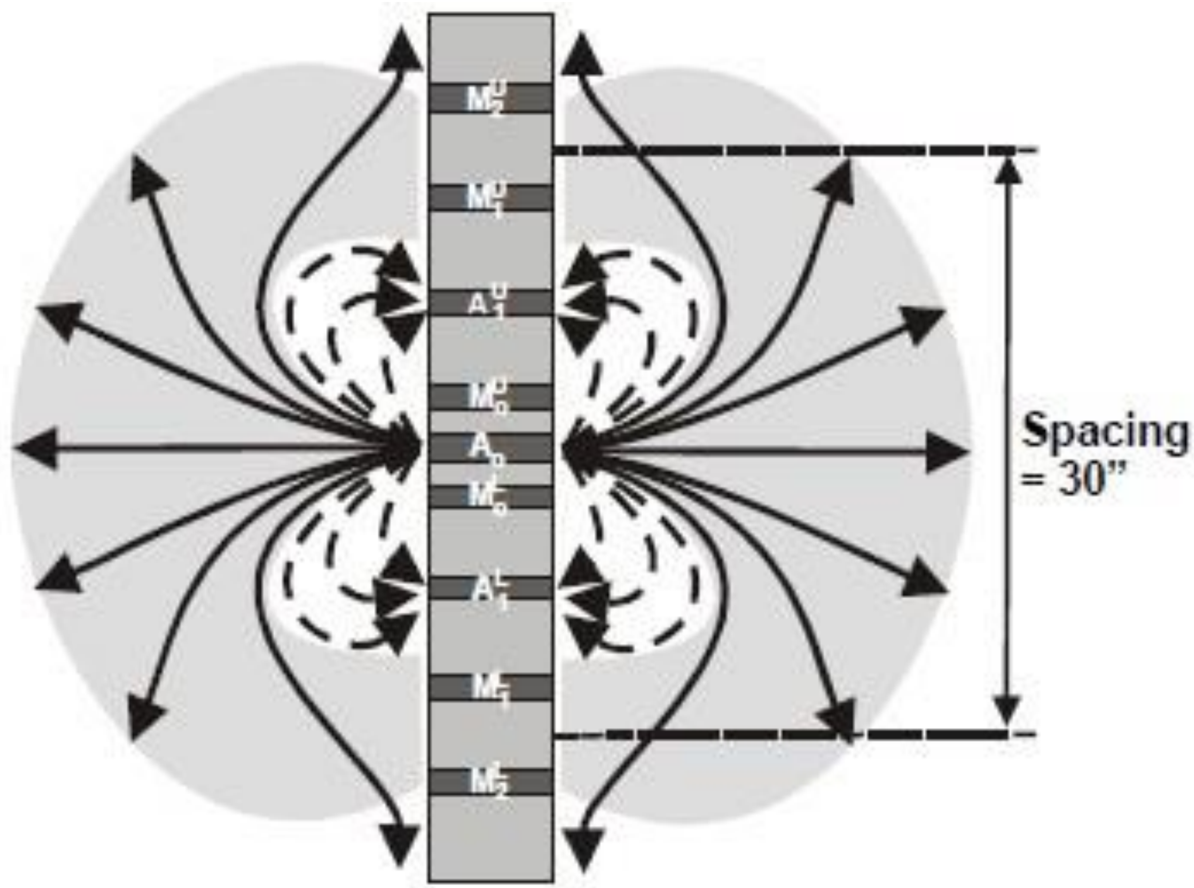
- The effective depth of Laterolog investigation is controlled by the extent to which the surveying current is focused. Deep reading laterologs are therefore more strongly focused than shallow reading laterologs.

- Laterolog can be influenced by invasion, but because resistivity of the mud filtrate is approximately equal to the resistivity of the formation water when a well is drilled with saltwater-based mud, invasion does not strongly affect Rt values derived from laterolog.

SPHERICALLY FOCUSSED LOG

Spherically Focused Log (SFL)

- The *spherically focussed log* (SFL) has an electrode arrangement (Fig.) that ensures the current is focused quasi-spherically. It is useful as it is sensitive only to the resistivity of the invaded zone.



MICRO-RESISTIVITY

Micro-Resistivity

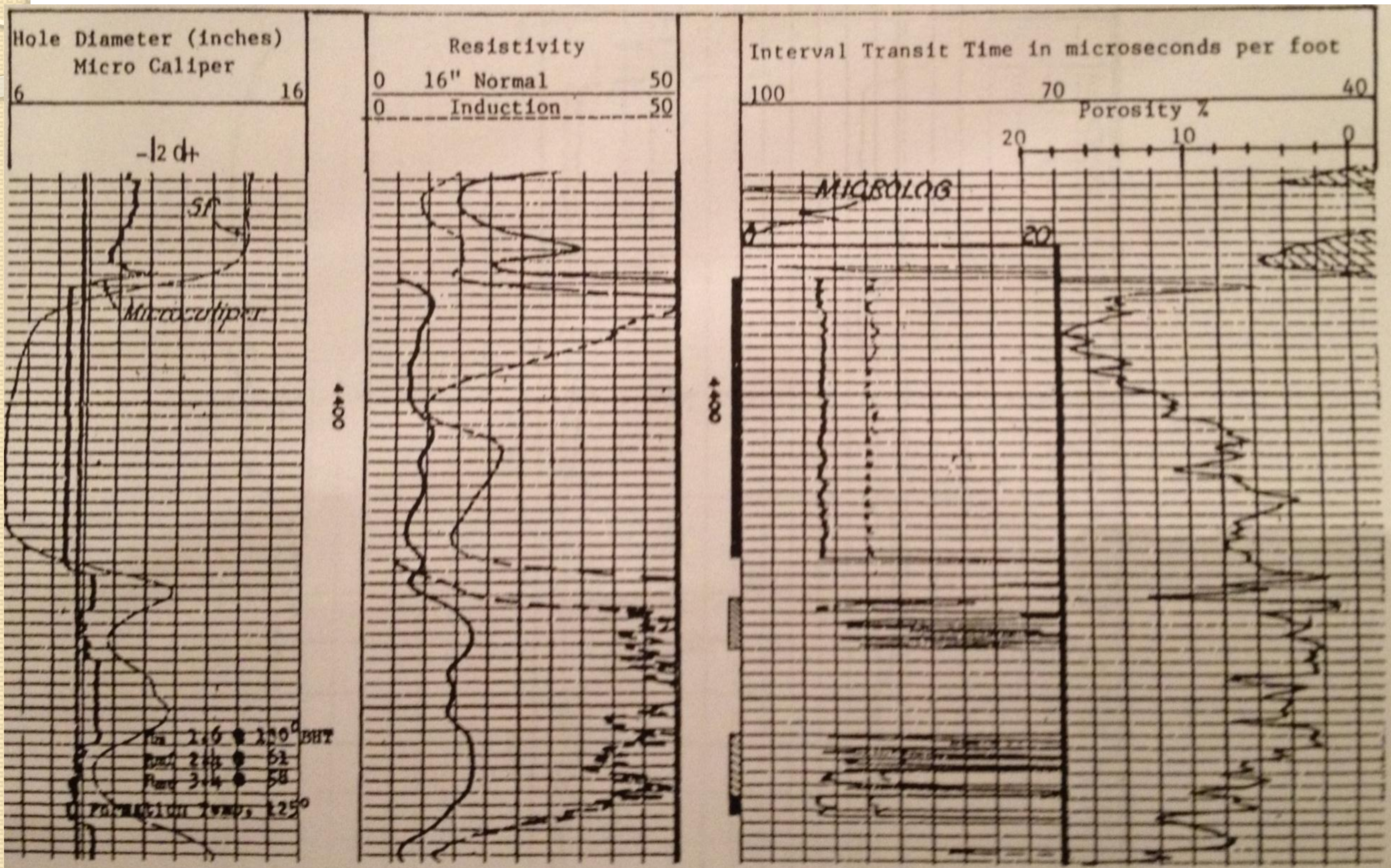
- Both the Laterolog and the Induction logs give two of the three independent resistivity measurements, a deep and an intermediate reading.
- A shallow resistivity reading is normally provided by the micro-resistivity Logs.
- The most widely used is the micro-spherically focused log (MSFL).

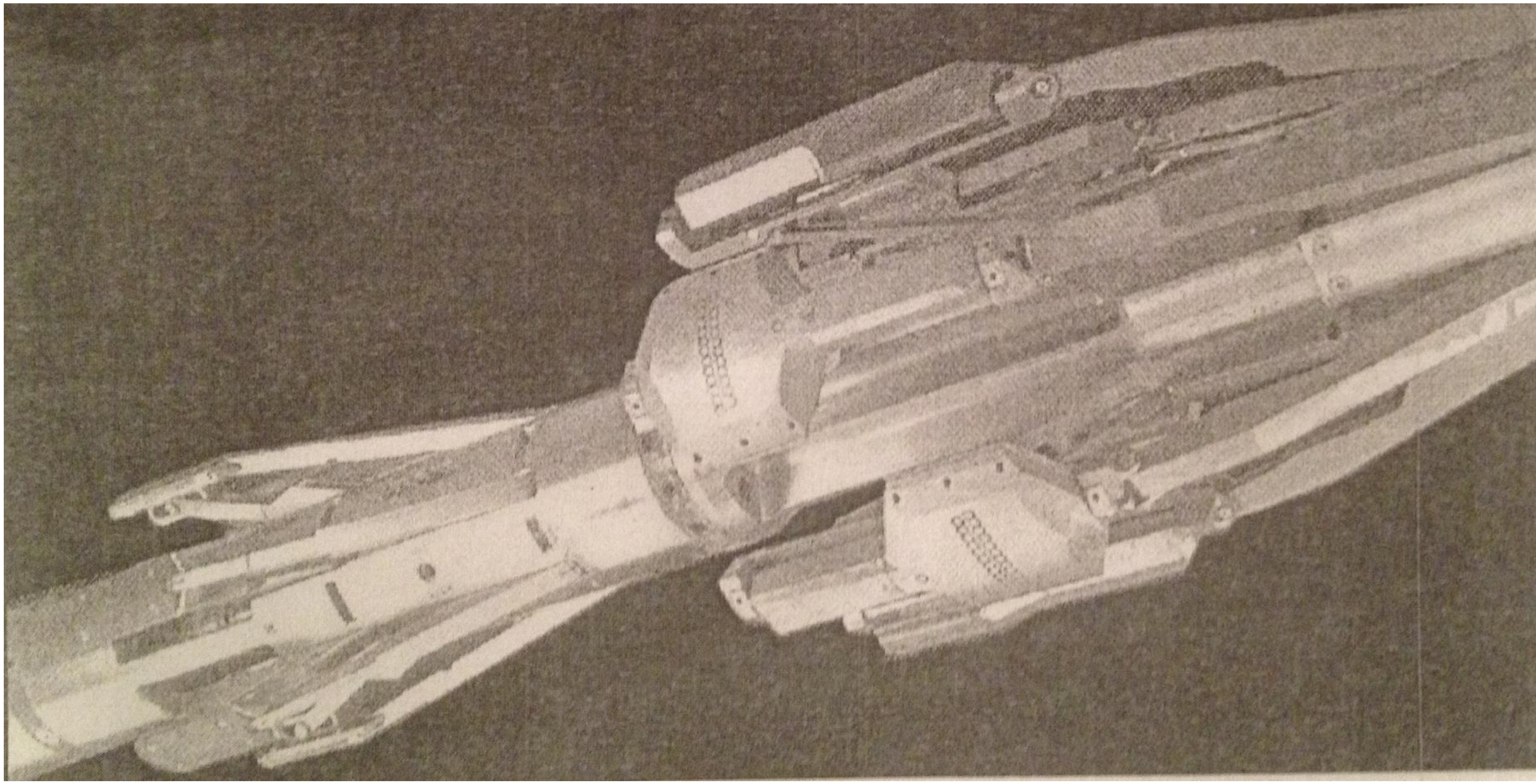
Micro-Resistivity

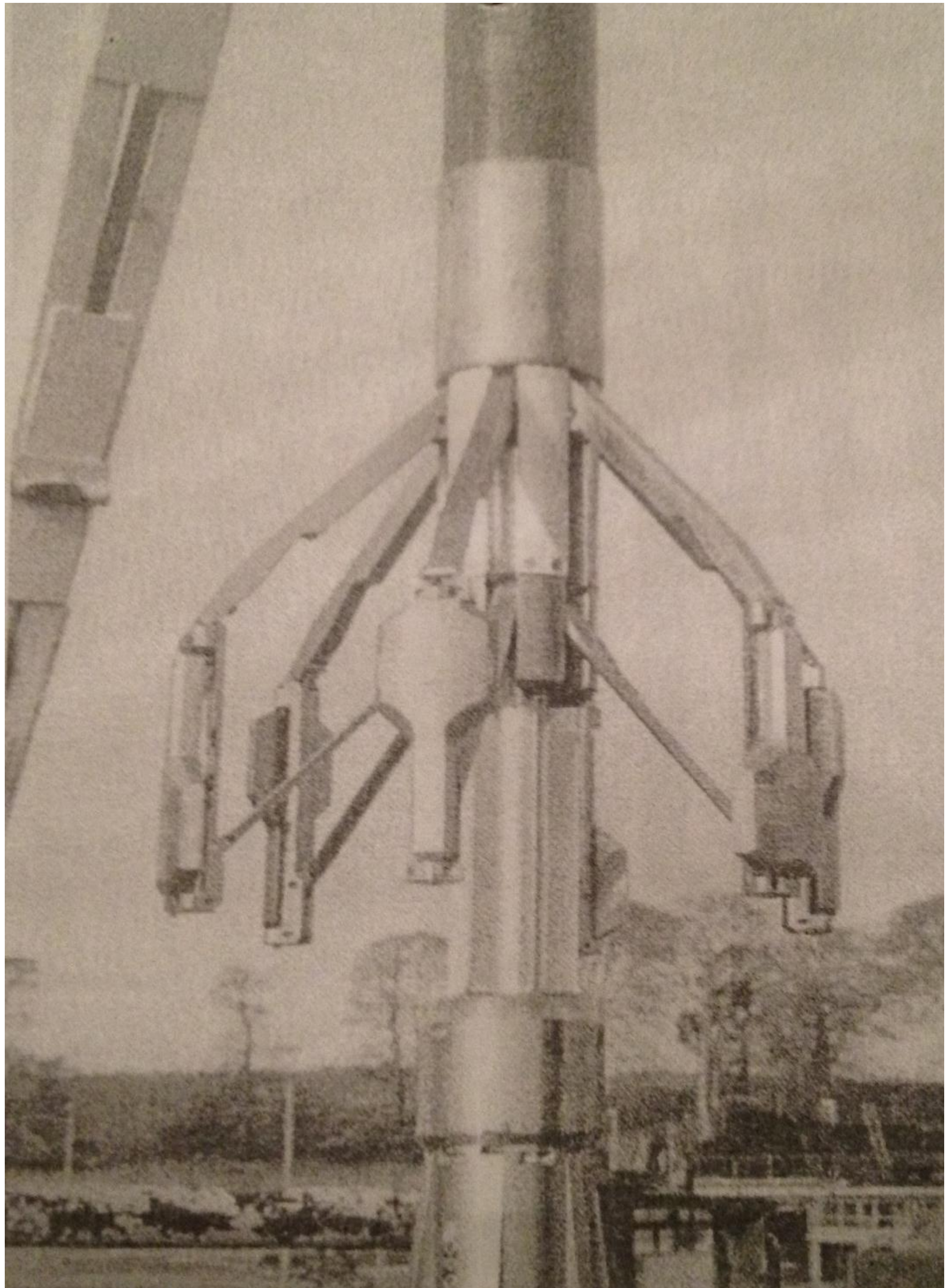
- The Micro-resistivity Logs (MFSL) are essentially used to measure resistivity of the flushed zone (R_{xo}),
- And to delineate permeable beds by detecting the presence of mudcake.
- The Micro-resistivity logs (MFSL) are characterized by short electrode distances (a few inches),
- Which permit a shallow depth of investigation, subsequently providing a value of the resistivity of the flushed zone (R_{xo}).

Microlog with little sensitivity to porosity

- Shows were as permeability goes up but does not show the value of permeability.





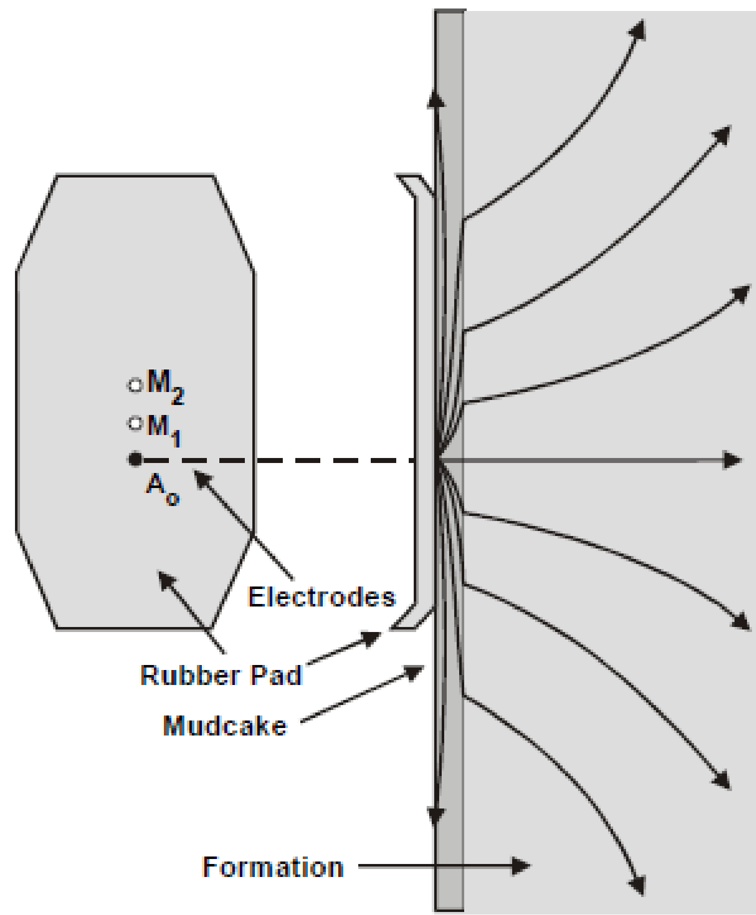


Microlog Electrode Configuration

- The *microlog* (ML) is a rubber pad with three button electrodes placed in a line with a 1 inch spacing

- A known current is emitted from electrode A, and the potential differences between electrodes M1 and M2 and between M2 and a surface electrode are measured. The two resulting curves are called the 2" *normal* curve (ML) and the *1½" inverse* curve (MIV).

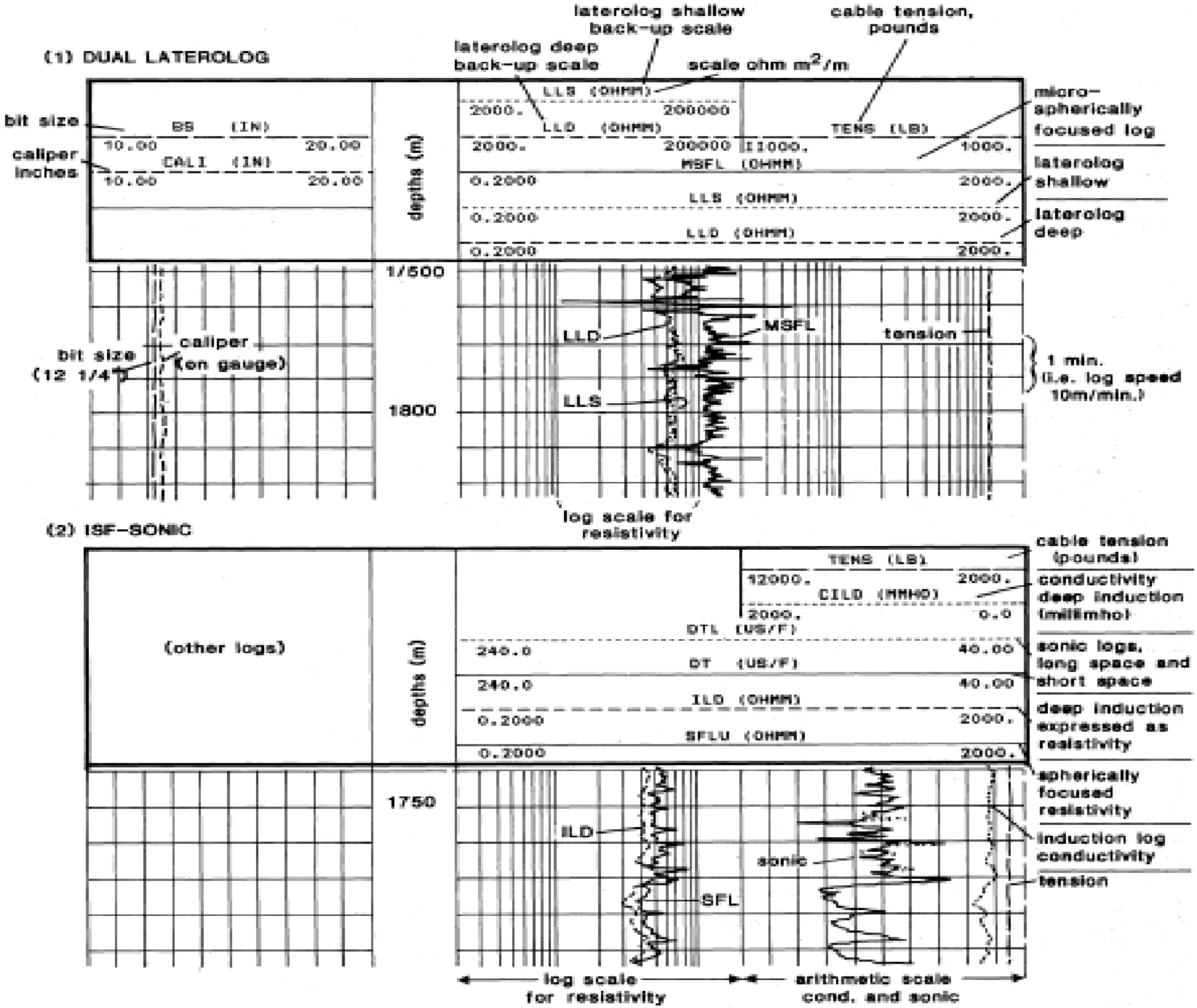
- The radius of investigation is smaller for the second of these two curves, and hence is more affected by mudcake. The difference between the two curves is an indicator of mudcake, and hence bed boundaries.



LOG PRESENTATION

Electrical tool penetration and resistivity measurement

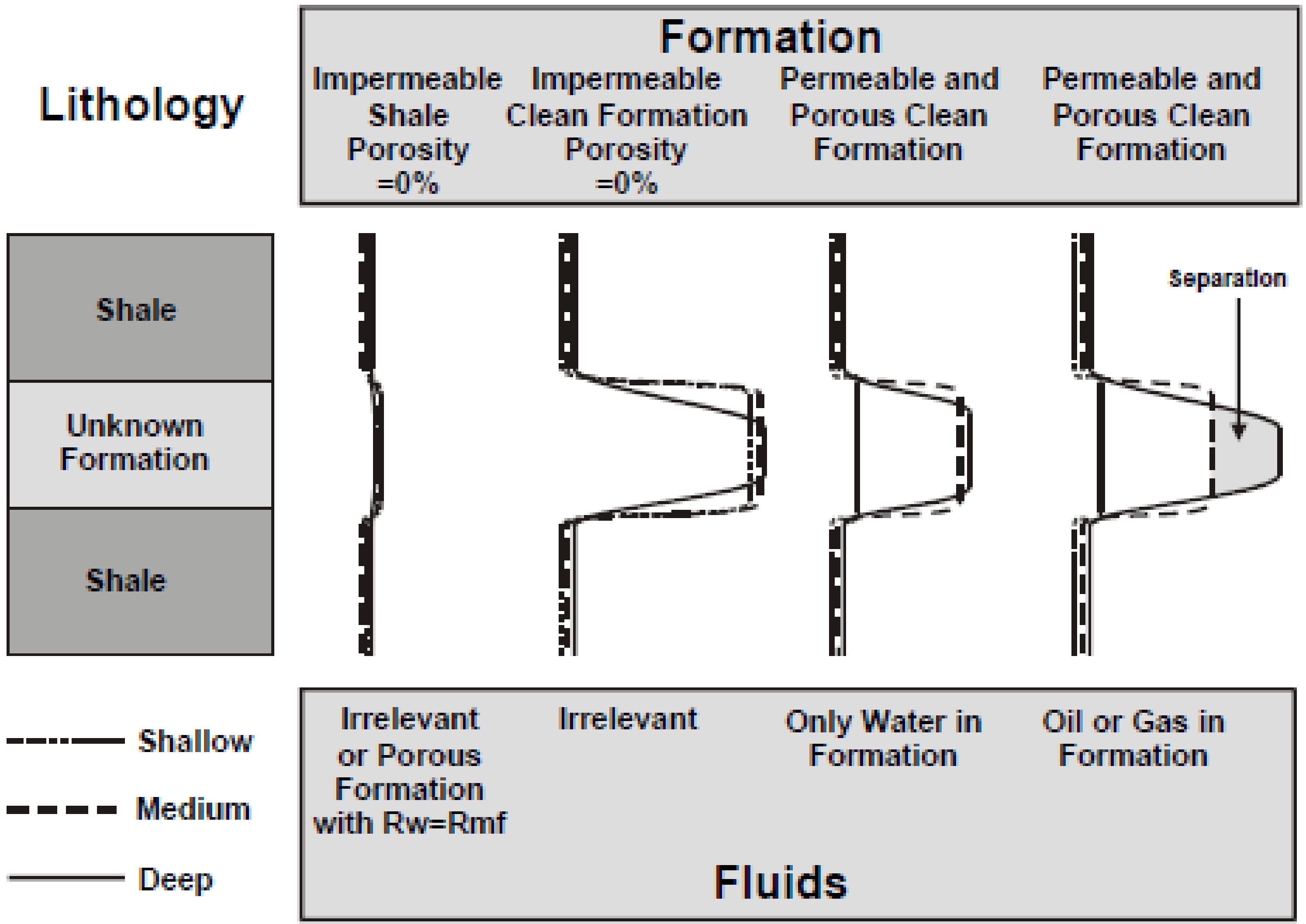
Tool	Mnemonic	Type	Commonly Measured	Possibly Measured
Laterolog3	LL3	Borehole	R_t	R_i
Laterolog7	LL7	Borehole	R_t	-
Dual Laterolog – deep	DLL-LLd	Borehole	R_t	-
Dual Laterolog – shallow	DLL-LLs	Borehole	R_i	R_t
Spherically Focussed Log	SFL	Borehole	R_i	R_t
Microlog - normal	ML	Pad	R_{mc}	R_{XO}
Microlog - inverse	MIV	Pad	R_{mc}	R_{XO}
Microlaterolog	MLL	Pad	R_{XO}	R_{mc}
Proximity Log	PL	Pad	R_{XO}	R_i
Micro Spherically Focussed Log	MSFL	Pad	R_{XO}	-
IES-40	IES-40	Borehole	R_t	-
IES-28	IES-28	Borehole	R_t	R_i
Dual Induction Log – deep	DIL-ILd	Borehole	R_t	-
Dual Induction Log - medium	DIL-ILm	Borehole	R_i	R_t
Induction Spherically Focussed Log	ISF	Borehole	R_t	-
Array Induction Tool	AIS, HDIL	Borehole	R_i to R_t	N/A



(1) DUAL LATEROLOG
laterolog shallow back-up scale
cable tension, pounds
laterolog deep back-up scale
scale ohm m2/m
LLS (OHMM)
2000. 200000
LLD (OHMM)
2000. 200000
bit size
BS (IN)
10.00 20.00
caliper inches
CALI (IN)
10.00 20.00
TENS (LB)
11000. 1000.
MSFL (OHMM)
0.2000 2000.
LLS (OHMM)
0.2000 2000.
LLD (OHMM)
0.2000 2000.
micro-spherically focused log
laterolog shallow
laterolog deep
depths (m)
1/500
1800
LLD
MSFL
tension
LLS
bit size (12 1/4")
caliper (on gauge)
1 min. (i.e. log speed 10m/min.)
log scale for resistivity
(2) ISF-SONIC
(other logs)
depths (m)
TENS (LB)
12000. 2000.
CILD (MMHO)
2000. 0.0
DTL (US/F)
240.0 40.00
DT (US/F)
240.0 40.00
ILD (OHMM)
0.2000 2000.
SFLU (OHMM)
0.2000 2000.
cable tension (pounds)
conductivity deep induction (millimho)
sonic logs, long space and short space
deep induction expressed as resistivity
spherically focused resistivity
induction log conductivity
tension
1750
ILD
sonic
SFL
log scale for resistivity
arithmetic scale cond. and sonic

RECOGNITION OF HYDROCARBON ZONE

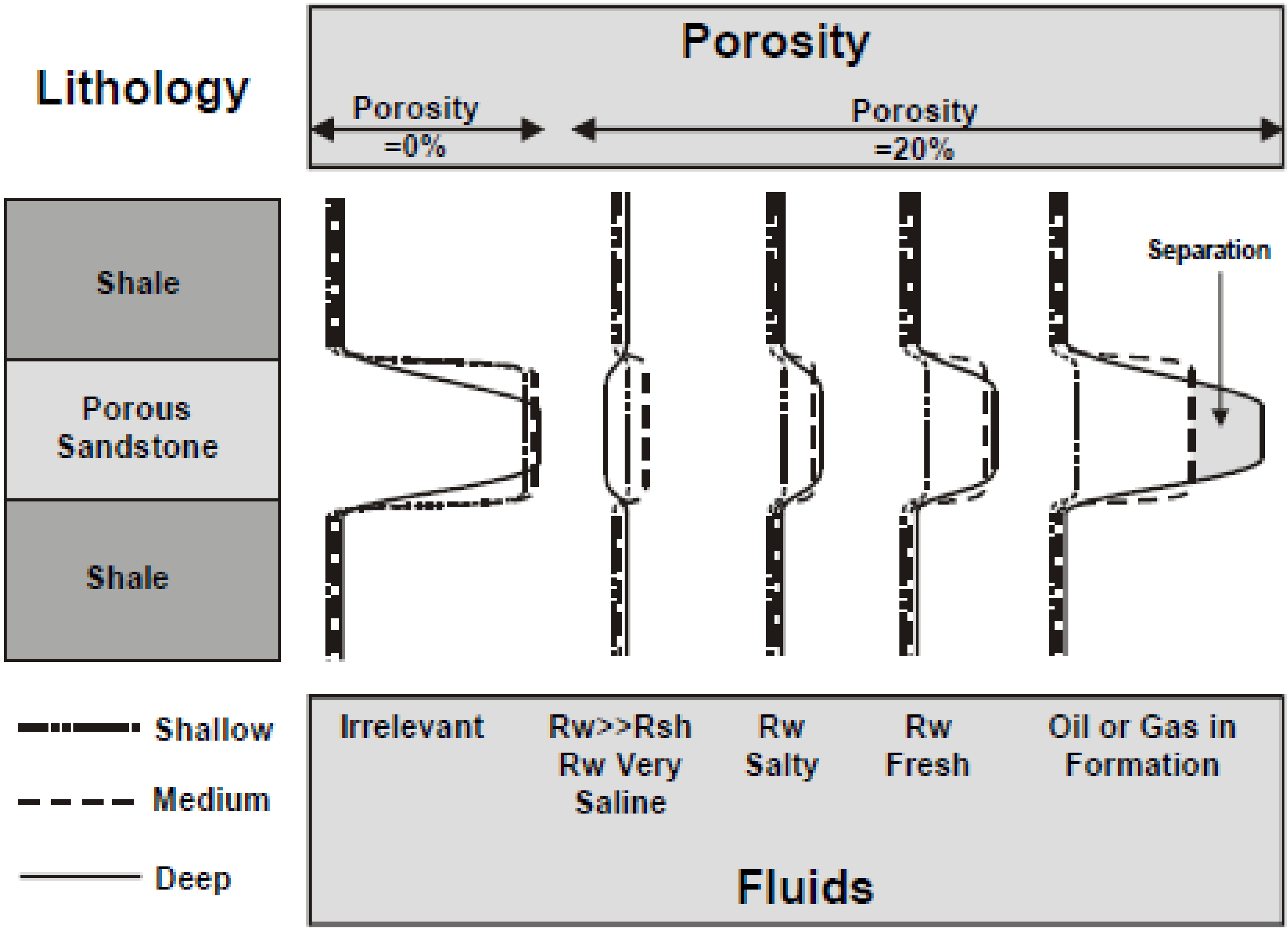
Response in different fluids



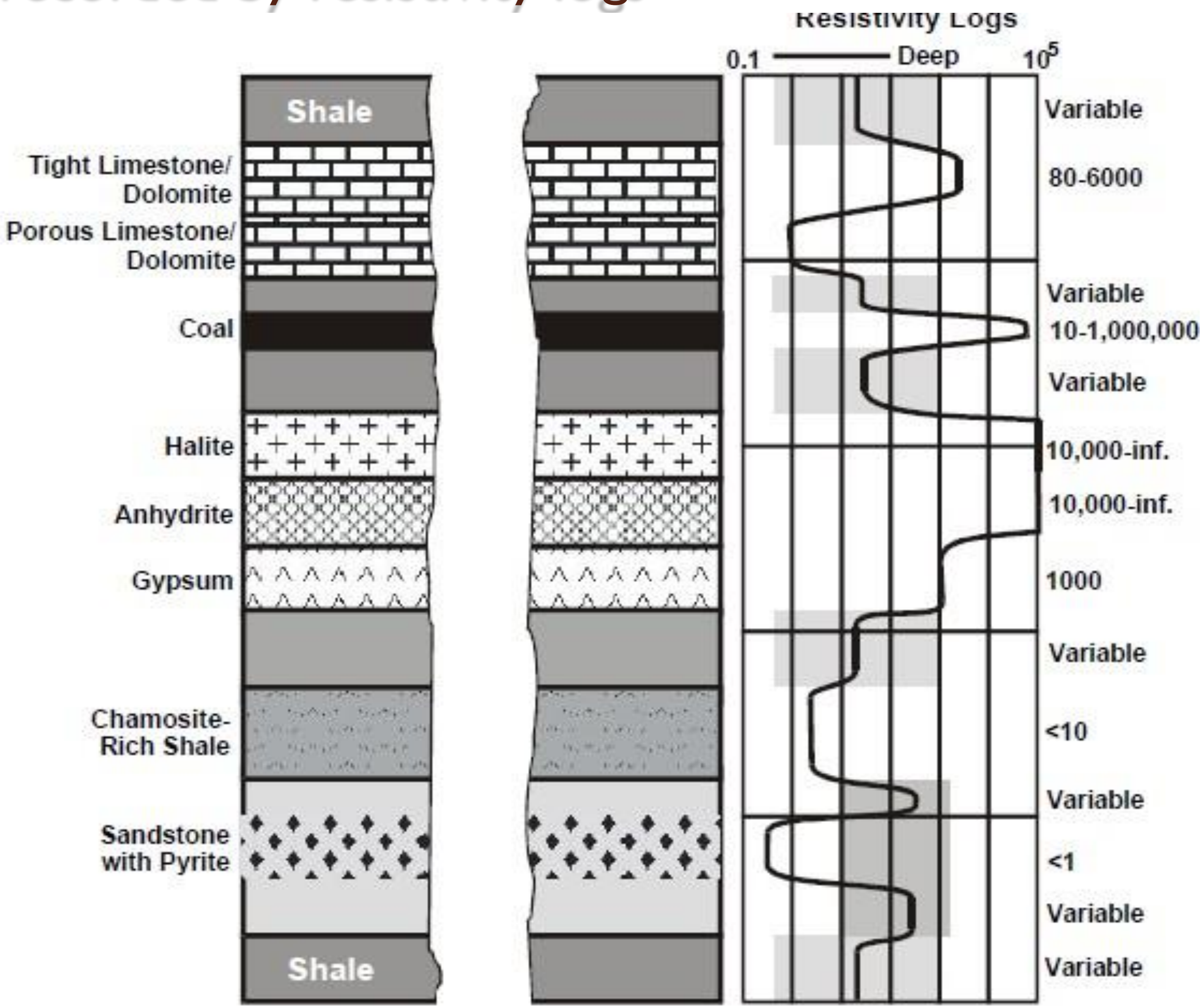
Response in different fluids

- If all three curves are low resistivity, and overlie each other, the formation is an impermeable shale, or, rarely, the formation is permeable and water-bearing but the mud filtrate has the same resistivity as the formation water.
- If all three curves are higher resistivity than the surrounding shales, and overlie each other, the formation is an impermeable cleaner formation (sandstone, limestone).
- If the shallow curve has low resistivity, but the medium and deep penetrating tools have a higher resistivity that is the same (they overlie each other), the formation is permeable and contains only formation water.
- If the shallow curve has low resistivity, the medium as a higher resistivity, and the deep one has an even higher resistivity (i.e., there is separation of the medium and deep tool responses), the formation is permeable and contains hydrocarbons.

Behavior of Res. Log in different formation water salinity



Characteristic resistivities from various lithologies recorded by resistivity logs



Resistivity Summary

Summary

Resistivity devices display apparent resistivity values. The apparent resistivity, R_a, measured at a depth of interest is affected by the resistivity and geometry of four zones that surround the tool: the borehole, adjacent beds, and the invaded and uninvaded zones of the bed of interest. The apparent resistivity value should be corrected for the borehole and adjacent-bed (also called bed-thickness) effects. The corrected value, R_a'', bears the influence of the invaded and uninvaded zones. Depending on the type and number of resistivity logs available, R_a'' is used to calculate R_t, R_{xo}, or both. Departure curves (charts) are usually used to perform these corrections and calculations.

Resistivity Summary

Determining R_t and R_{xo} requires three steps.

1. The apparent resistivity, R_a, is first corrected for borehole effects by use of R_m and d_h. Correction of readings of microresistivity devices requires R_{mc} and h_{mc} instead. For each resistivity tool, optimum measurement conditions exists in which the borehole effect is nil or negligible.

2. The value obtained from Step 1, R_a', is then corrected for bed-thickness effect with the resistivity of the adjacent bed, R_s, and the thickness of the bed in question. No adjacent-bed corrections are necessary when the bed thickness exceeds a certain value. This value depends on the tool's vertical resolution and the resistivity contrast R_t/R_s. Readings of microresistivity tools are free from this effect.

Resistivity Summary

3. The last step is to use the value R_a'' obtained in Step 2 to calculate R_t and R_{xo}. The calculation calls on the geometric factors. Departure curves (tornado charts) or a system of equations is used. If the diameter of invasion is small, the effect on invasion is negligible and $R_t = R_a''$. On the other hand, for microresistivity devices, when invasion is deep, the effect of the uninvaded zone becomes negligible and $R_{xo} = R_a''$.

In certain measurement environments, the three effects (borehole, bed thickness, and invasion) are negligible. In these cases, R_t or R_{xo} can be read directly from the log.

In some instances, the data available lead to unrealistic results, such as negative values, or the data fall off the tornado chart. In most instances, such an occurrence is the result of values improperly read or improperly corrected for borehole or bed-thickness effects. However, in cases of very deep invasion with an invasion profile

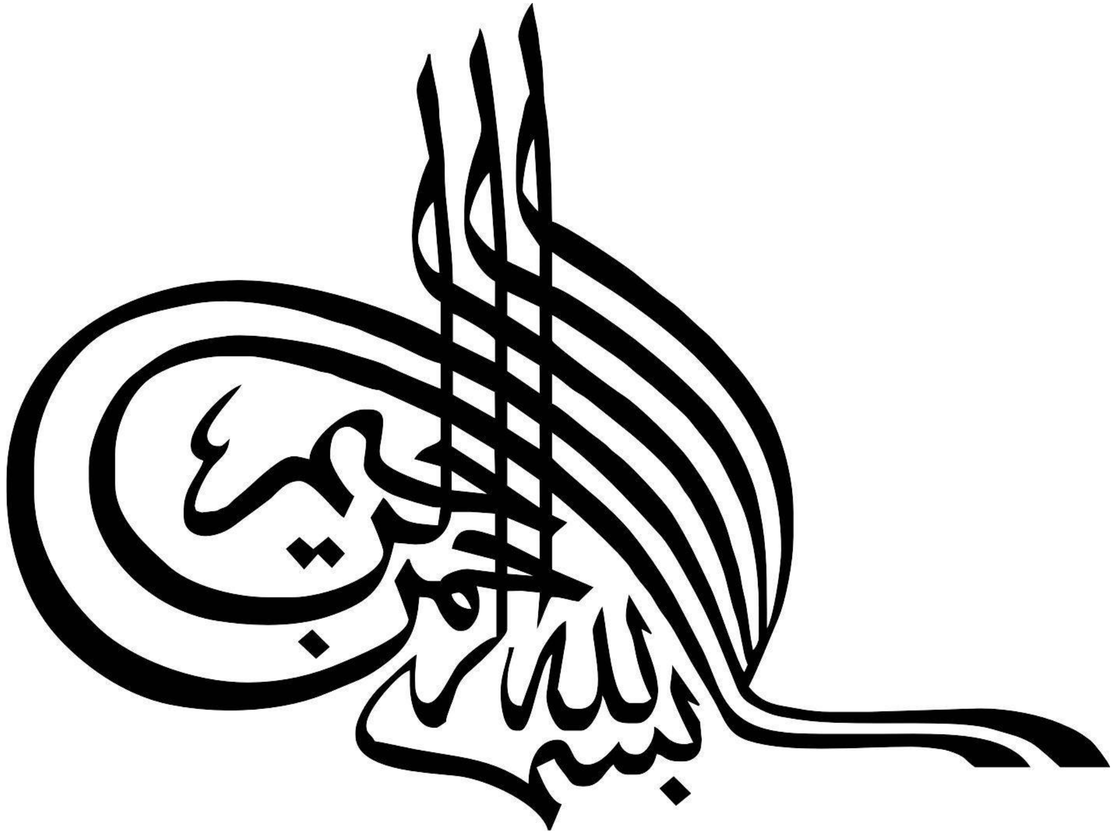
Resistivity Summary

presence of a conductive drilling fluid in the borehole? What happens to the quality of the recording as the drilling-fluid conductivity increases?

Thank you!

and

Any question ?


بسم الله الرحمن الرحيم