भारतीय प्रौद्योगिकी संस्थान
(भारतीय खनि विद्यापीठ)
धनबाद

IIT ISM

INDIAN INSTITUTE OF TECHNOLOGY
(INDIAN SCHOOL OF MINES)
DHANBAD

GPC510 - Well logging

Semester - Winter 2024; Lecture - 14

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TEACHING OUTLINE

Week 8

Tutorial 17 – Induction logging

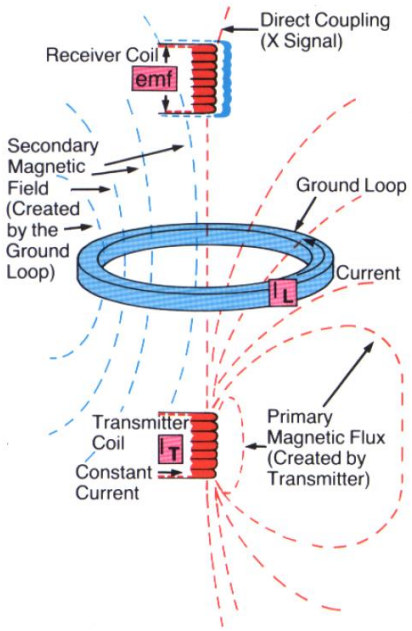
AGENDA

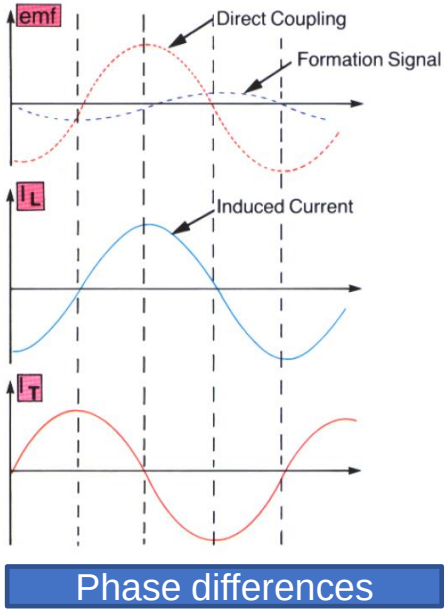
- Induction logging
- Application

INDUCTION LOGGING

- Originally developed for oil-based mud drilling scenario
- Works reasonably well in water-based muds with high salinity
- A constant alternating current is supplied to transmitter which creates alternating magnetic field

Logs: ILD, ILM
Tool: DIL (Dual-induction-laterolog) & PHASOR
Units: Ohm-m
Used for determination of R_t

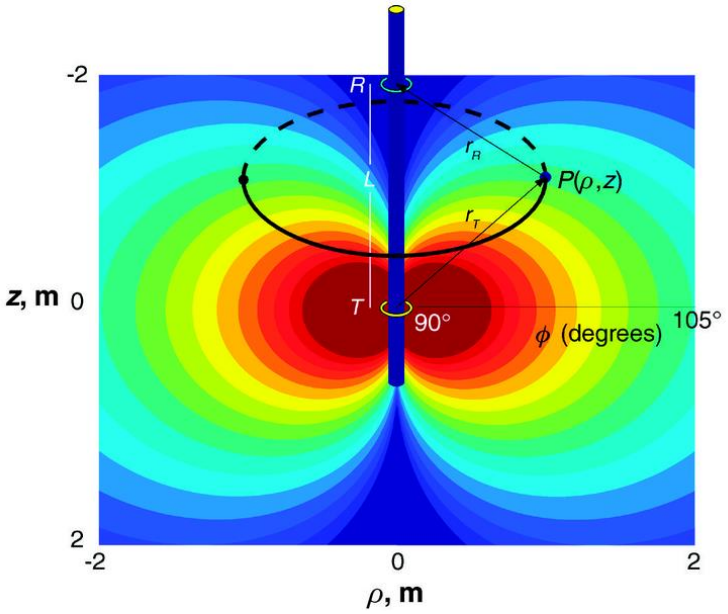




Phase differences

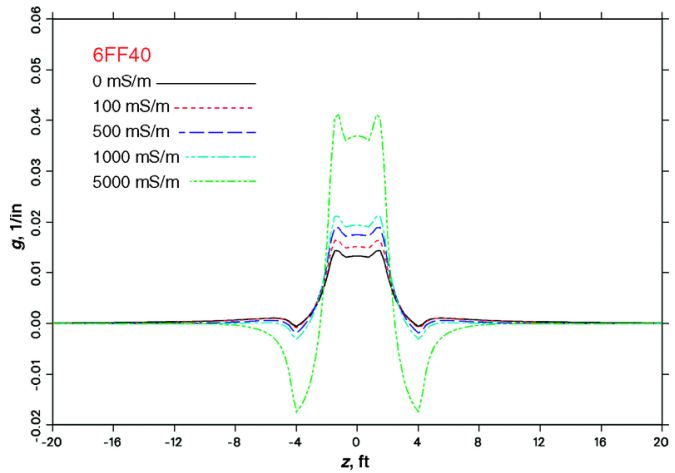
INDUCTION LOGGING

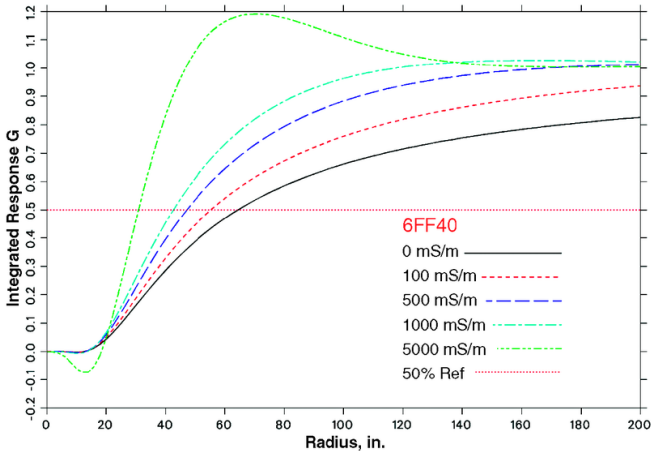
- The sonde consists of 2 wire coils, a transmitter (T) and a receiver (R).
- High frequency alternating current (20 kHz) of constant amplitude is applied to the transmitter coil. This gives rise to an alternating magnetic field around the sonde that induces *secondary currents (***Eddy or Foucault currents***)* 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 .
- The received signal is measured, and its size is proportional to the *conductivity* of the formation.
- There will be direct coupling of the transmitter coil and the receiver coil signals (X-signals). This is removed by additional coils, which also serve to improve the vertical and depth of penetration focusing of the tool.



INDUCTION RESPONSE

- Doll defined the geometrical factor as a 2D function $g(\rho,z)$, which defines the part of the total signal that comes from an infinitesimally thin loop around the borehole.
- The response to formation layers is given by the vertical response function $g_V(z)$, which is defined as the integral of the 2D response function $g(\rho,z)$ over radius ρ. The response to radial variations in a thick bed is given by the radial response function $g_R(\rho)$, which is defined as the integral of $g(\rho,z)$ over z.





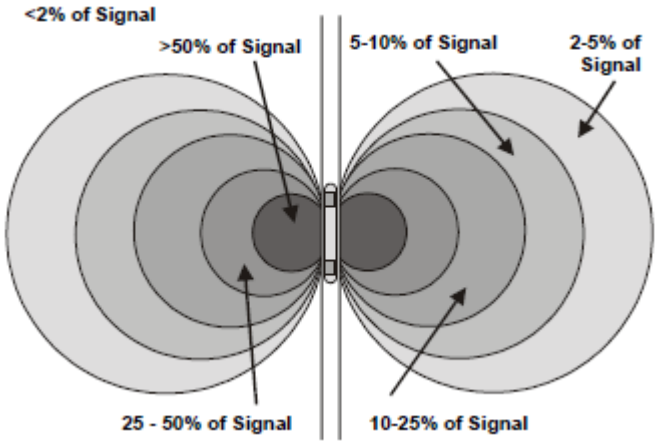
SENSITIVITY OF INDUCTION TOOL

- 6FF40 - 6 coils system
- The extra coils are used to focus the signal, i.e., to enhance the response from the virgin formation at the expense of the invaded zone.
- The response can be estimated by considering each transmitter-receiver coil pair in turn, and adding their responses algebraically, taking into account polarity and position relative to the measure point
- Focusing achieves several improvements in signal response:

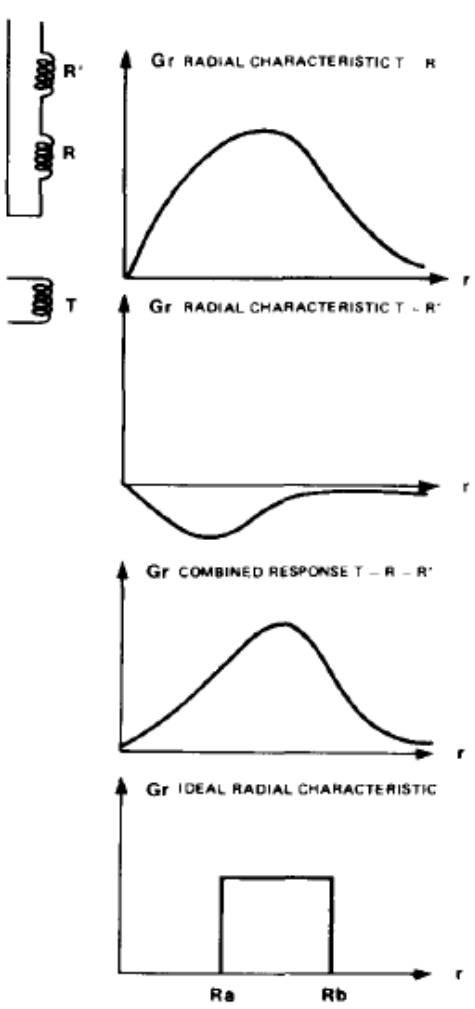
(1) better vertical resolution by stronger suppression of the adjacent bed signals;

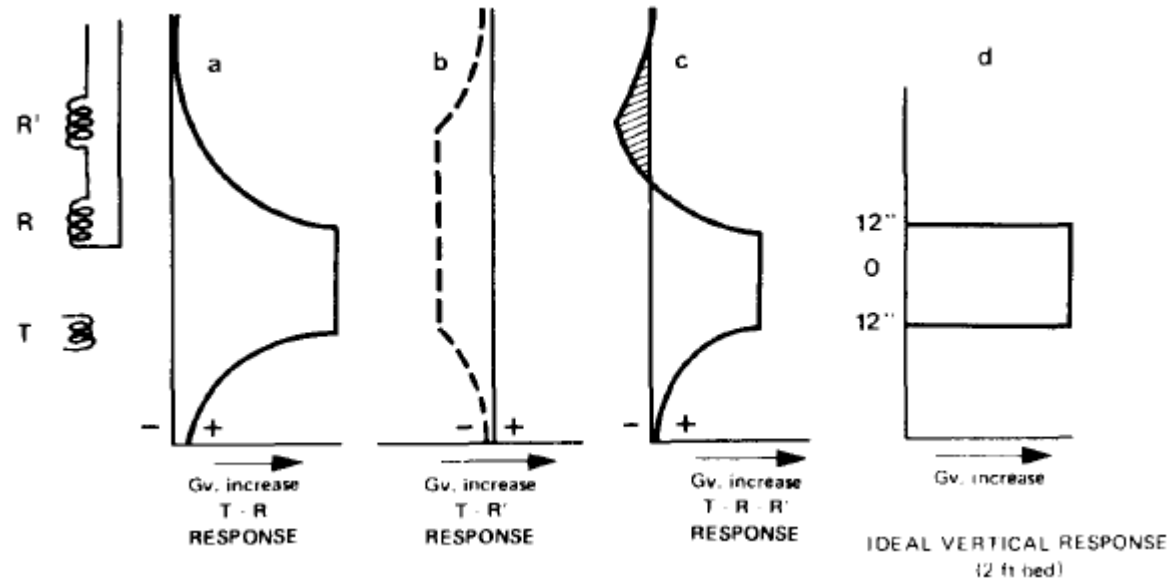
(2) smaller borehole effect, and deeper investigation, by suppression of the unwanted signals (hole and invaded zone);

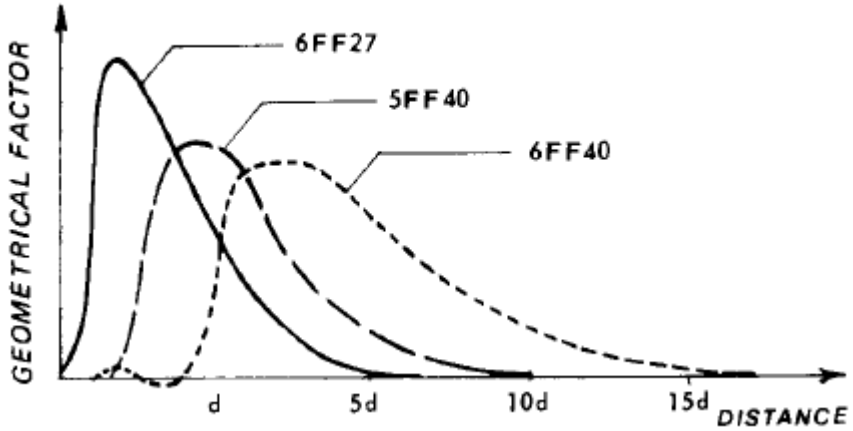
(3) reduced X-signal component.



INDUCTION LOGGING – GEOMETRICAL FACTOR







SKIN EFFECTS

- The *skin effect* is a problem that occurs with very conductive formations which results in the reduction of the signal. This is automatically corrected for during the logging run.
- Skin effect is the result of the interactions between the current loops
- These loops are responsible for reduction of electromagnetic field reaching the deeper formation via:

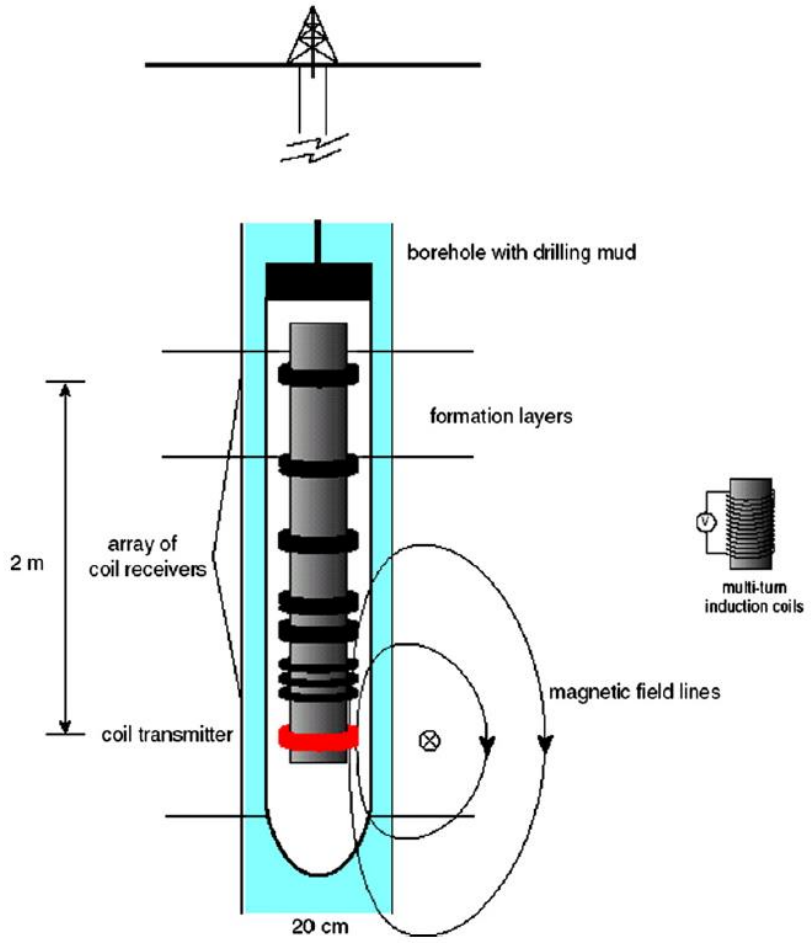
a) Energy is dissipated by current flow in the loops, diminishing the energy available for transmission to the remoter formation

b) Out of phase EM fields generated by Foucalt (Eddy) current nearer the tool destructively interfere with the emitter field propagating farther out

- As a consequence, a reduction in receiver coil signal therefore a reduction of conductivity of the formation

ARRAY INDUCTION TOOL (AIT)

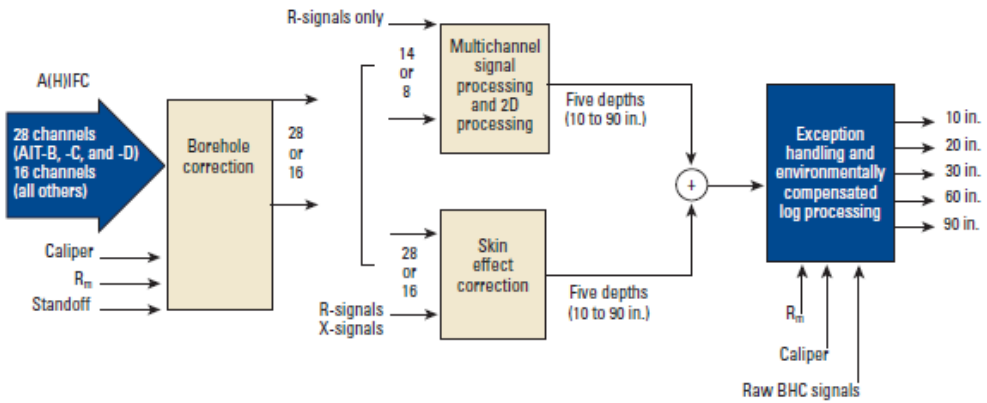
- AIT provides five resistivity curves with radially focused depth of investigation of 10, 20, 30, 60 and 90 inches
- Wireline array induction tools use an array induction coil that operates at multiple frequencies. Software focusing of the received signals generates a series of resistivity logs with different depths of investigation.
- Quantitative 2D imaging of formation resistivity is possible because of the large number of measurements made. The images represent bedding and invasion features clearly and quantitatively.

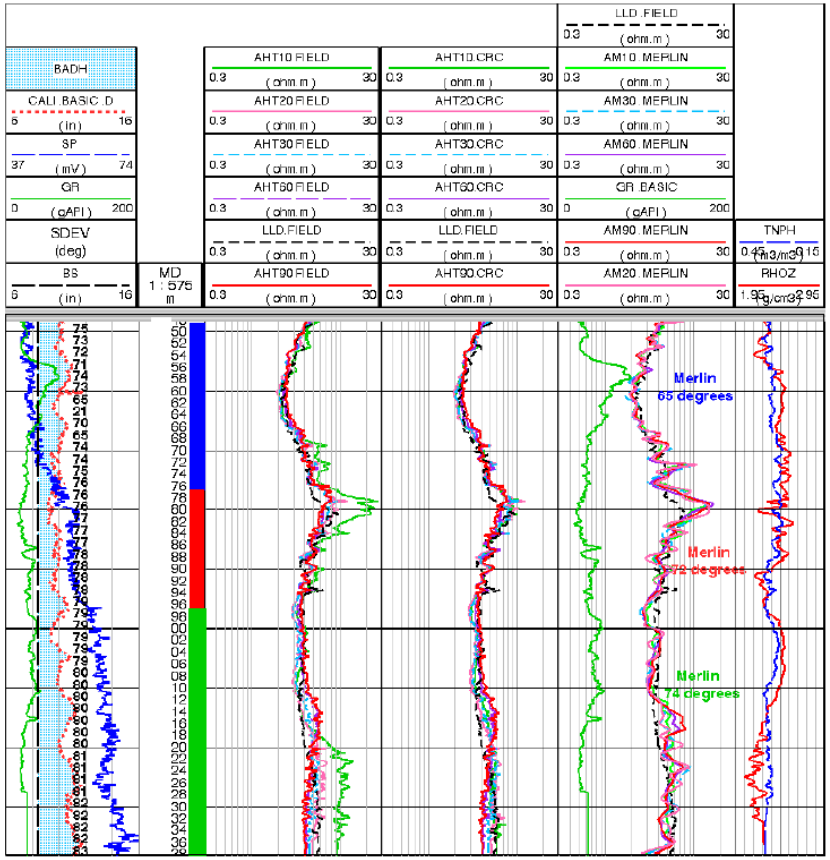


Alpak et al., 2008

AIT PROCESSING

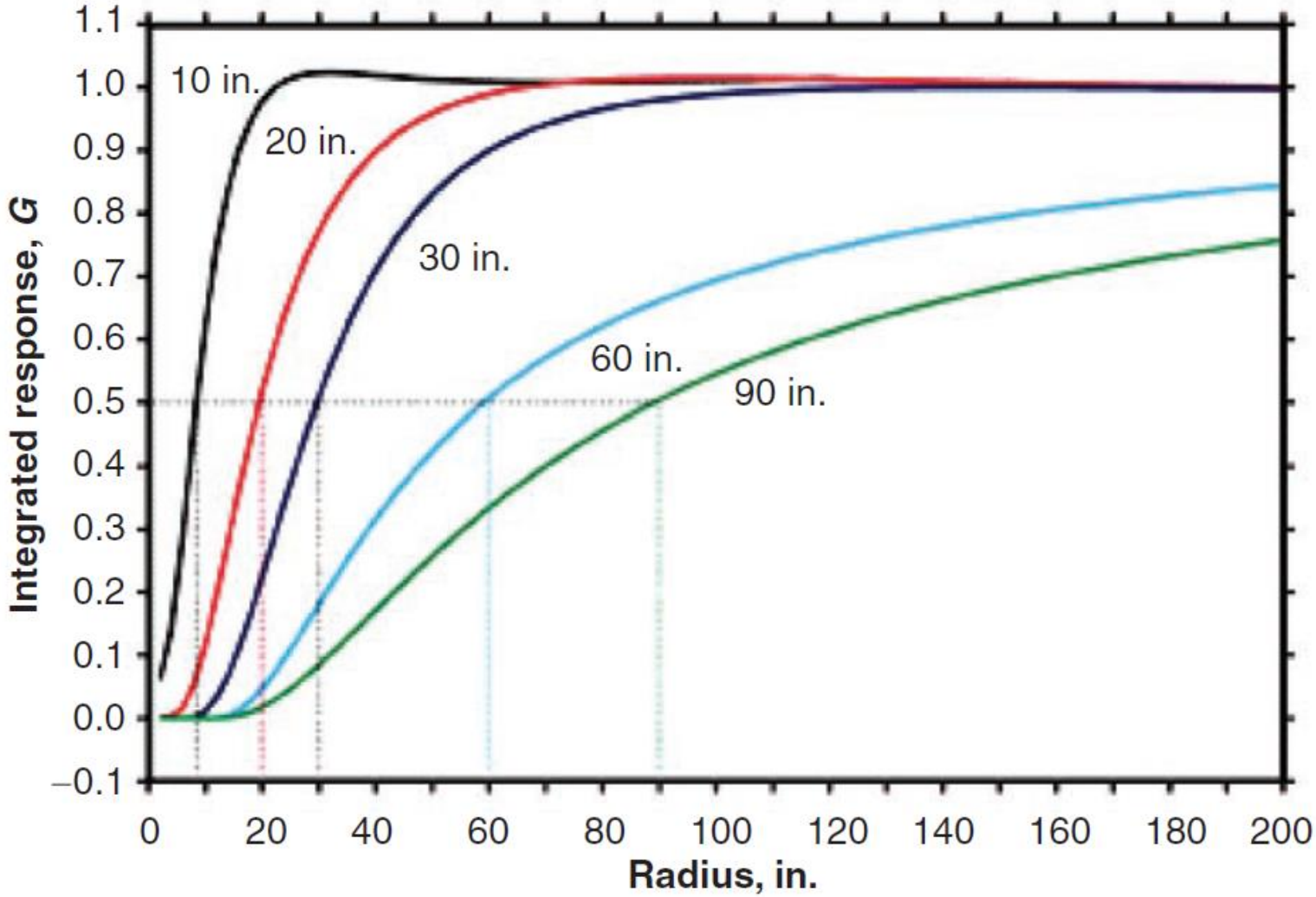
- For a deviated well or the dipping beds in vertical well, a specific processing is required





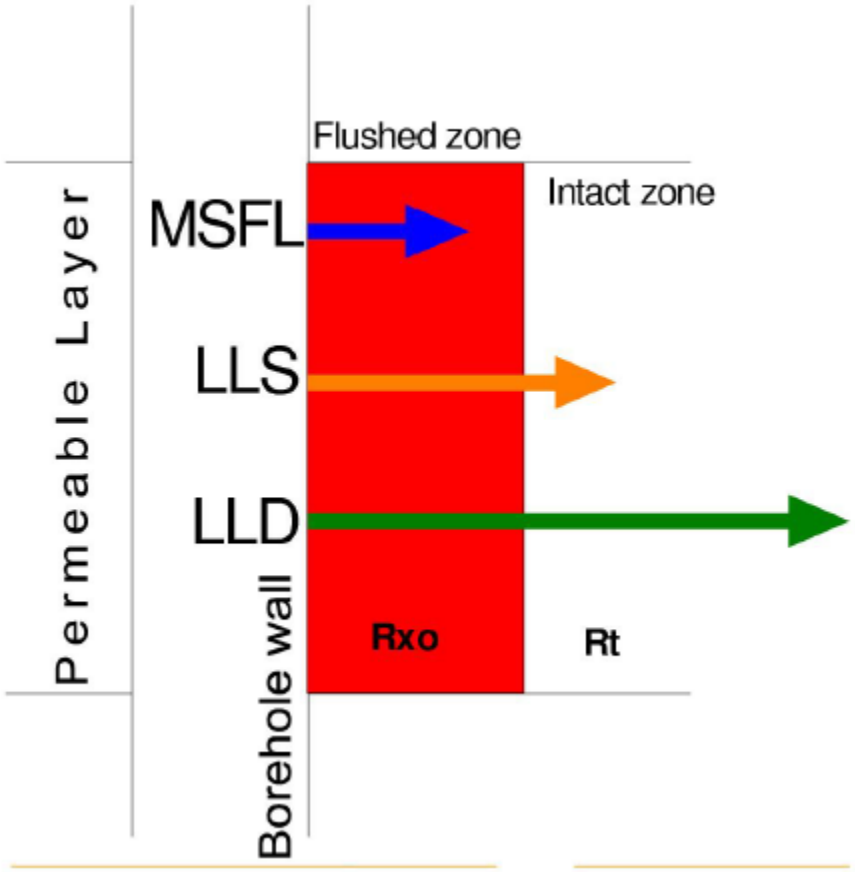
Chadah et al., 2007

RADIAL GEOMETRIC FACTOR

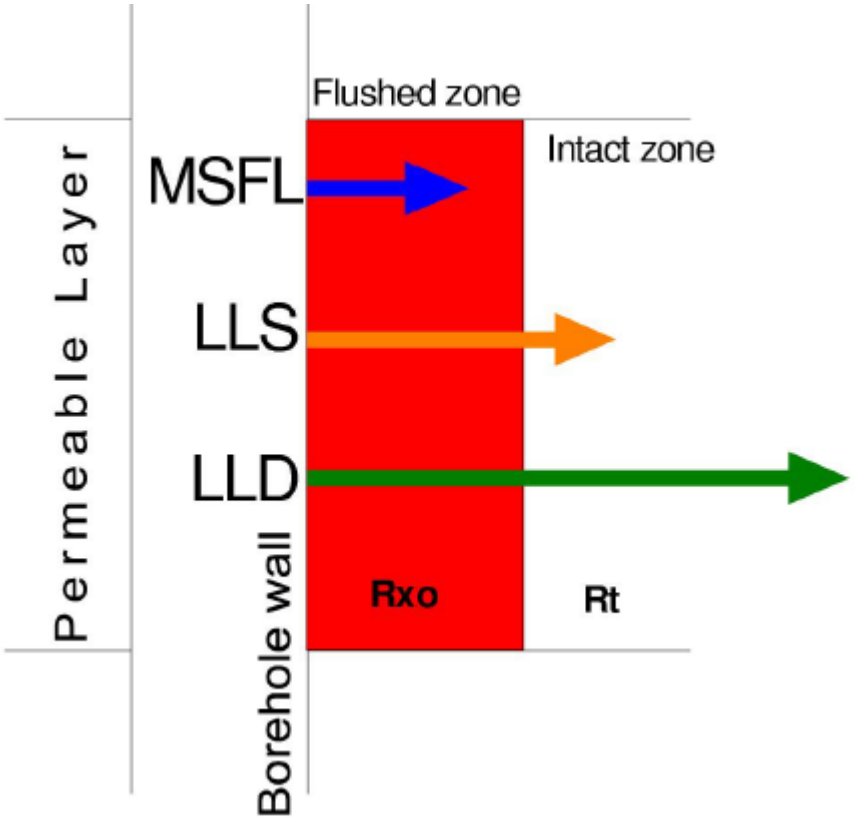


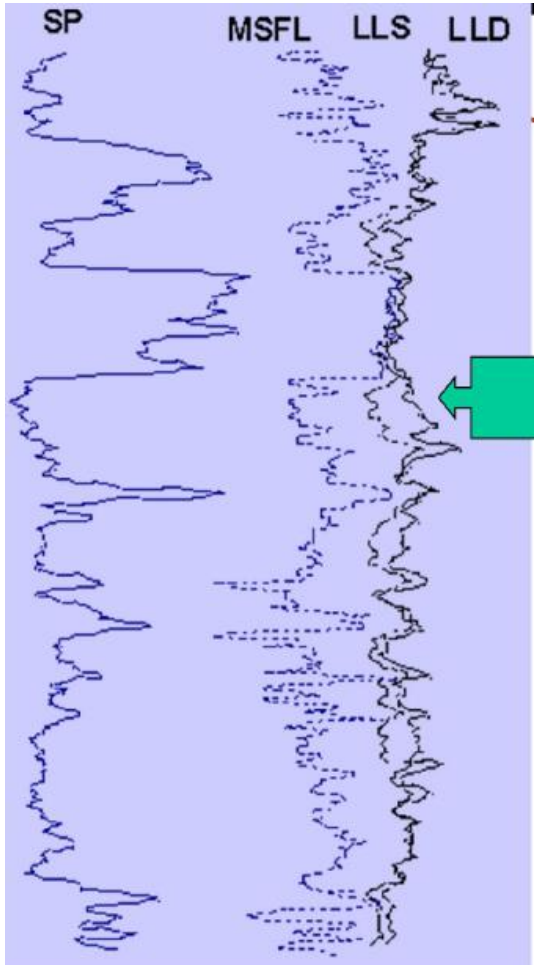
TRUE FORMATION RESISTIVITY

- The resistivity measured by a suite of resistivity logs with different depth of investigation from mud/mud cake to a combination of true resistivity and invaded zone



RESISTIVITY LOG INTERPRETATION





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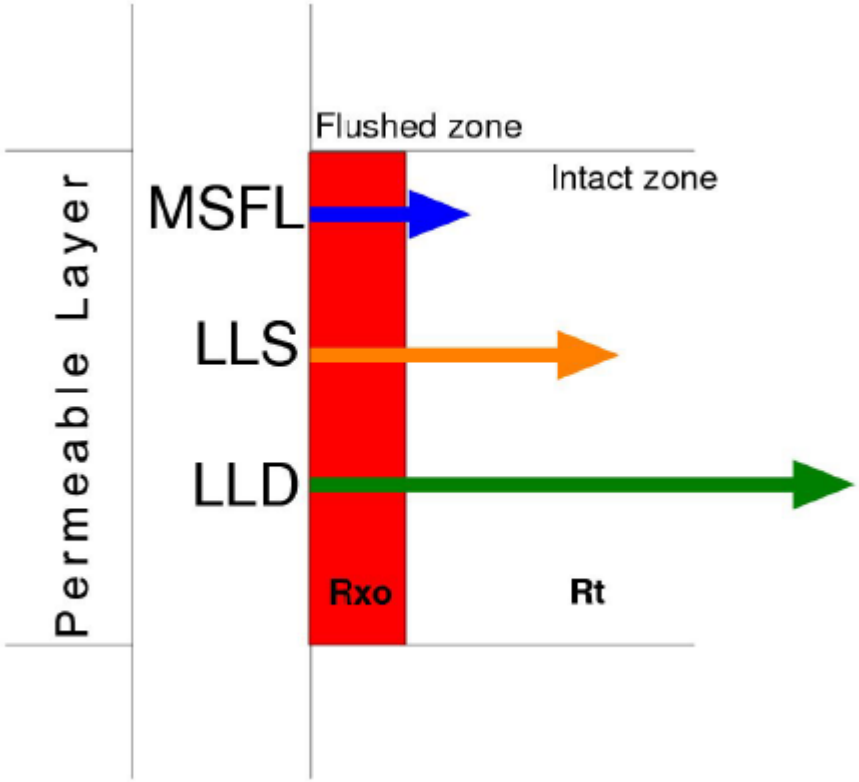

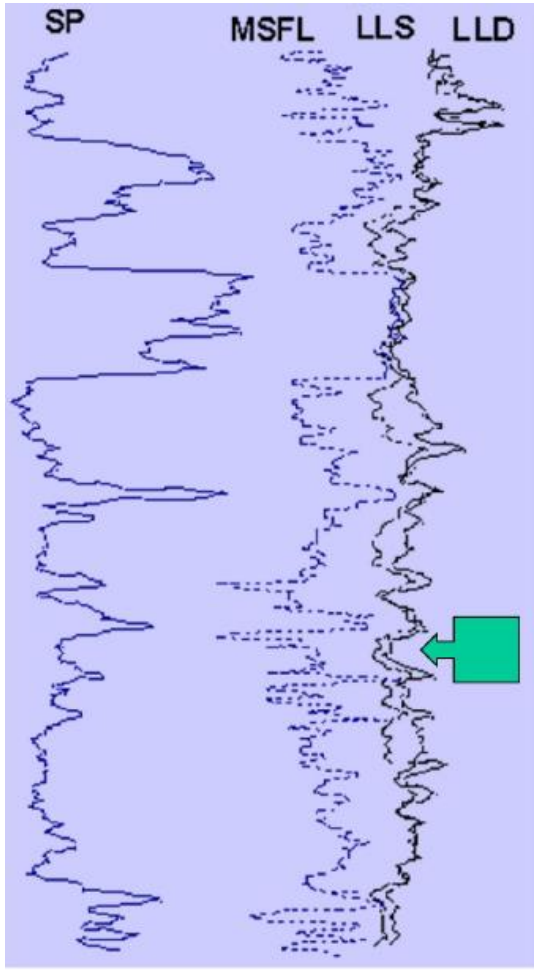

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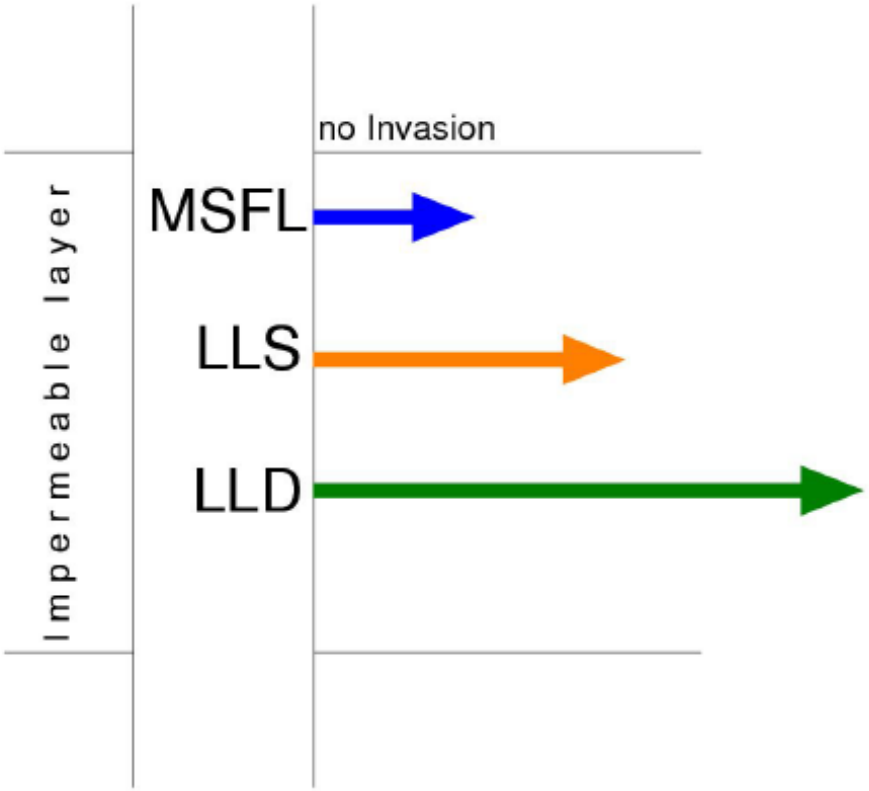
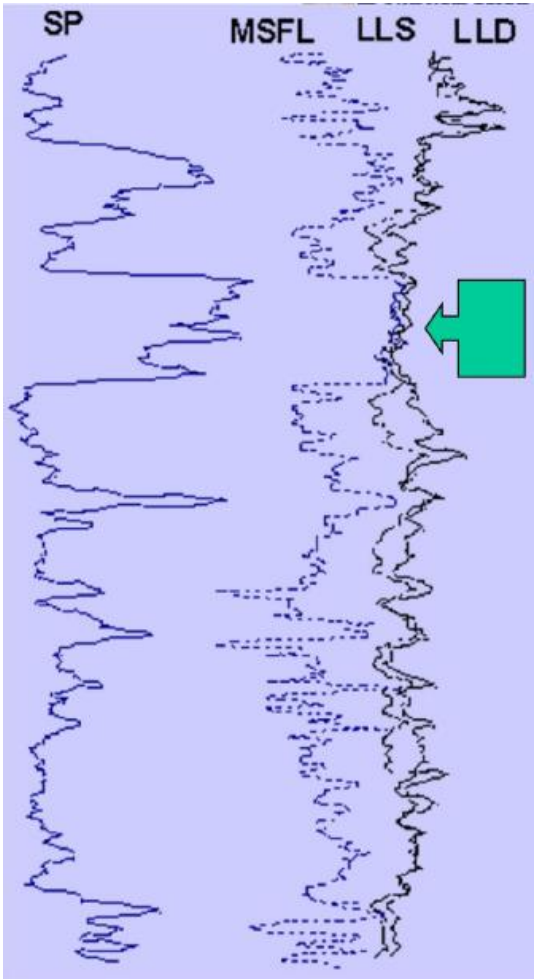
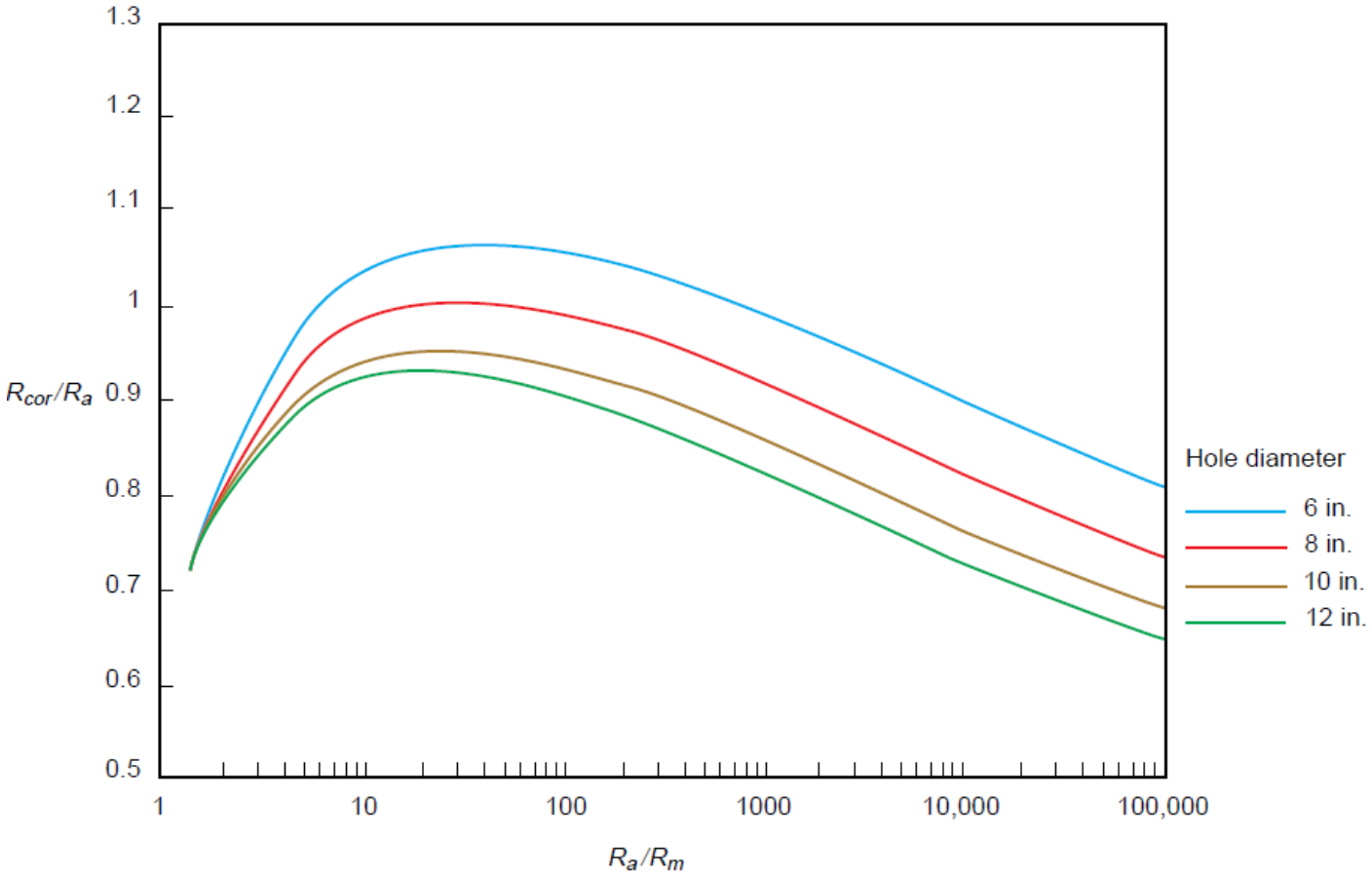
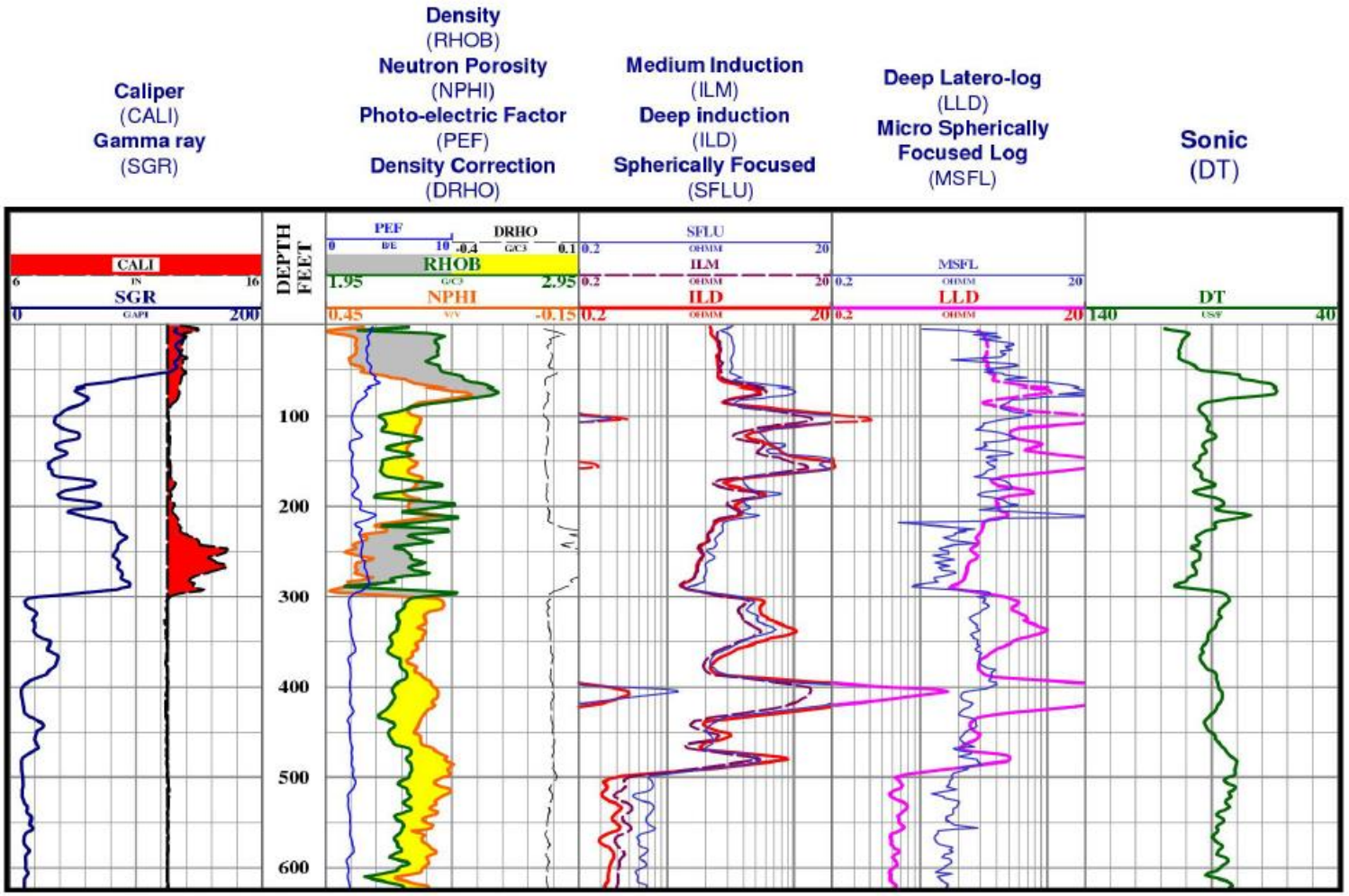




ENVIRONMENTAL CORRECTIONS



RESISTIVITY LOGS DISPLAY



END OF LECTURE