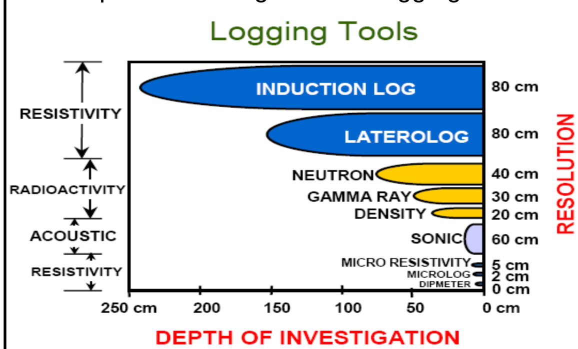
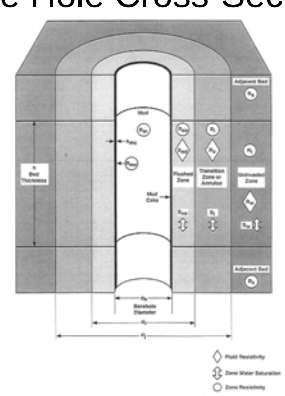
Well Log Applications

- depth to lithological boundaries
- lithology identification
- minerals grade/quality
- inter-borehole correlation
- structure mapping
- dip determination
- rock strength
- in-situ stress orientation
- fracture frequency
- porosity
- fluid salinity

Depth Of Investigation Of Logging Tools

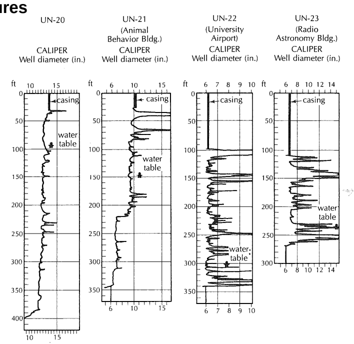


Bore Hole Cross-Section

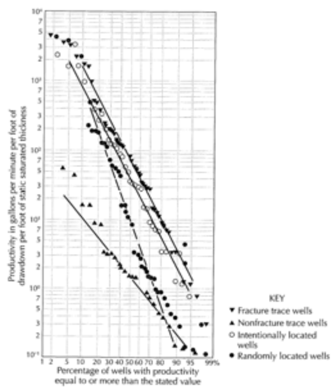


Caliper log use to measure the borehole size.

Through this log we can determine the caving size, wash outs, and fractures



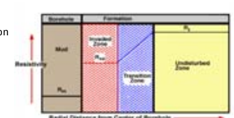
Fractures and Fluid Flow



Resistivity Log

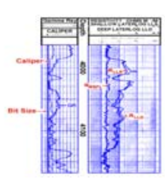
- **Basics about the Resistivity:**

- Resistivity measures the electric properties of the formation
- Resistivity is the inverse of conductivity,
- The ability to conduct electric current depends upon:
  - The **Volume** of water,
  - The **Temperature** of the formation,
  - The **Salinity** of the formation



The Resistivity Log:
Resistivity logs measure the ability of rocks to conduct electrical current and are scaled in units of ohm-meters.
The Usage:
Resistivity logs are electric logs which are used to:

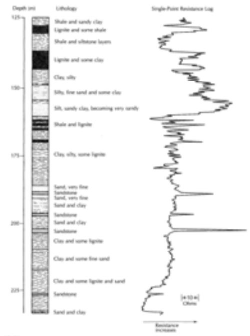
Determine Hydrocarbon versus Water-bearing zones,
Indicate Permeable zones,
Determine Resisitivity Porosity.



Single-Point-Resistance Log - electrical resistance between the borehole and an electrical ground at land surface. In general, resistance increases with grain size and decreases with borehole diameter, density of water-bearing fractures, and increasing dissolved-solids concentration of borehole fluid.

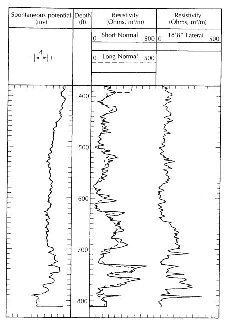
A fluid-filled borehole is required for single-point-resistance logs, and they are run only for the saturated part of the formation below the casing.

Single-point-resistance logs sometimes help to identify the location of water-bearing zones because a fluid-filled fracture is less resistive than solid rock.

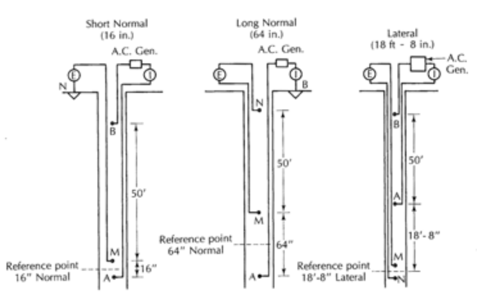


A log of the resistivity of the formation, expressed in ohm-m.

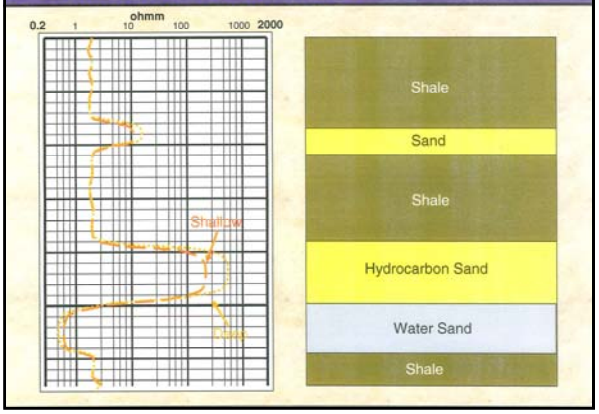
The resistivity can take a wide range of values, and, therefore, for convenience is usually presented on a logarithmic scale from, for example, 0.2 to 2000 ohm-m. The resistivity log is fundamental in formation evaluation because hydrocarbons do not conduct electricity while all formation waters do. Therefore a large difference exists between the resistivity of rocks filled with hydrocarbons and those filled with formation water. Clay minerals and a few other minerals, such as pyrite, also conduct electricity, and reduce the difference.

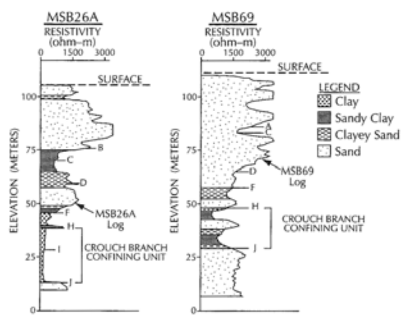


Resistivity Log



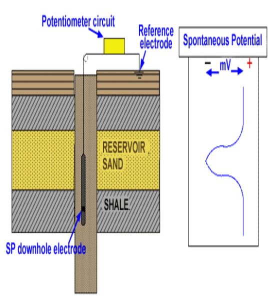
Basic Resistivity Logging Response



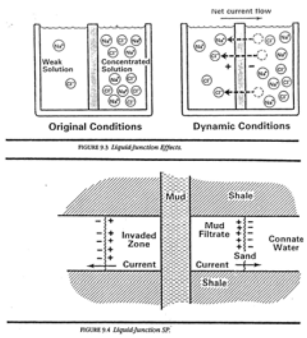


Spontaneous Potential Log (SP)

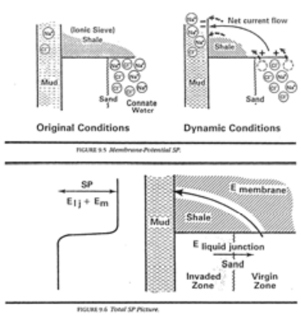
- The spontaneous potential (SP) curve records the naturally occurring electrical potential (voltage) produced by the interaction of formation connate water, conductive drilling fluid, and shale
- The SP curve reflects a difference in the electrical potential between a movable electrode in the borehole and a fixed reference electrode at the surface
- Though the SP is used primarily as a lithology indicator and as a correlation tool, it has other uses as well:
  - permeability indicator,
  - shale volume indicator
  - porosity indicator, and
  - measurement of Rw (hence formation water salinity).



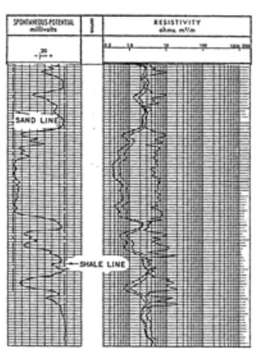
Spontaneous Potential - Response 1



Spontaneous Potential - Response 2



Spontaneous Potential - The Shale Line



What might A, B, and C represent?

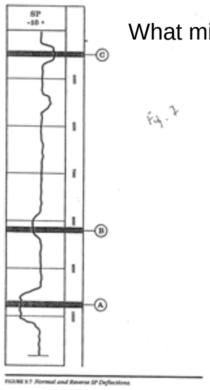
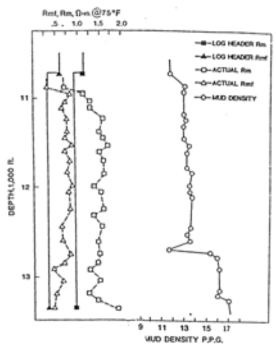
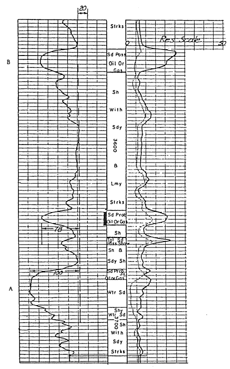


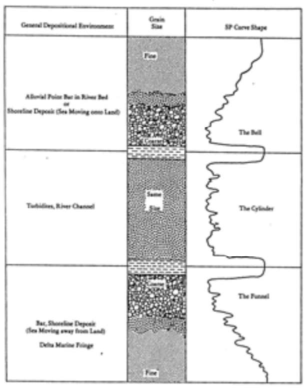
FIGURE 5.7 Normal and Reverse SP Deflections.

Spontaneous Potential - QC

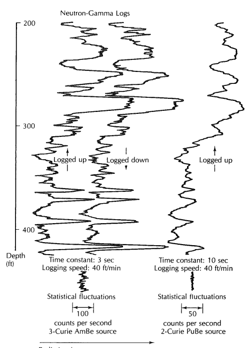


Spontaneous Potential and Resistivity





Radioactive Logging Speed



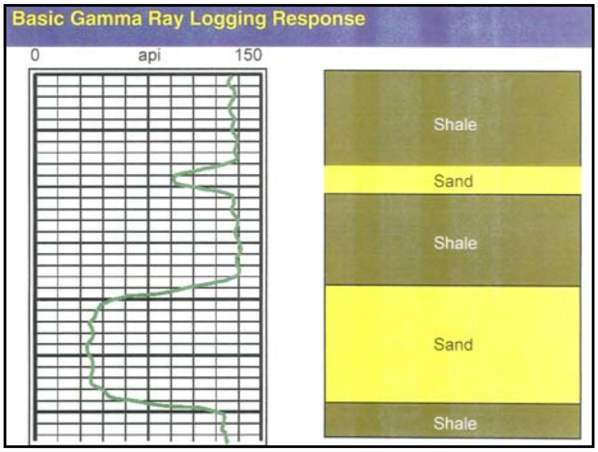
Gamma-Ray Log

A well log of the natural formation radioactivity level.

In sediments the log mainly reflects clay content because clay contains the radioisotopes of potassium, uranium, and thorium. Potassium feldspars, volcanic ash, granite wash, and some salt deposits containing potassium (potash for example) may also give significant gamma-ray readings. The log often functions as a substitute for the SP for correlation purposes in nonconductive borehole fluids in open holes, for thick carbonate intervals, and to correlate cased-hole logs with open-hole logs.

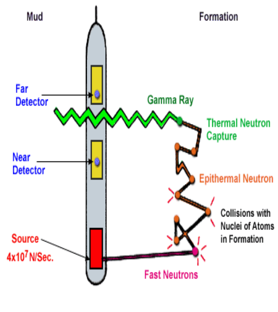
GAMMA RAY LOG

- Gamma Rays are high-energy electromagnetic waves which are emitted by atomic nuclei as a form of radiation
- Gamma ray log is measurement of natural radioactivity in formation verses depth.
- It measures the radiation emitting from naturally occurring U, Th, and K.
- It is also known as shale log.
- GR log reflects shale or clay content.
- Clean formations have low radioactivity level.
- Correlation between wells,
- Determination of bed boundaries,
- Evaluation of shale content within a formation,
- Mineral analysis,
- Depth control for log tie-ins, side-wall coring, or perforating.
- Particularly useful for defining shale beds when the sp is featureless
- GR log can be run in both open and cased hole



Neutron Logging

- The Neutron Log is primarily used to evaluate formation porosity, but the fact that it is really just a hydrogen detector should always be kept in mind
- It is used to detect gas in certain situations, exploiting the lower hydrogen density, or hydrogen index
- The Neutron Log can be summarized as the continuous measurement of the induced radiation produced by the bombardment of that formation with a neutron source contained in the logging tool which sources emit fast neutrons that are eventually slowed by collisions with hydrogen atoms until they are captured (think of a billiard ball metaphor where the similar size of the particles is a factor). The capture results in the emission of a secondary gamma ray; some tools, especially older ones, detect the capture gamma ray (neutron-gamma log). Other tools detect intermediate (epithermal) neutrons or slow (thermal) neutrons (both referred to as neutron-neutron logs). Modern neutron tools most commonly count thermal neutrons with an He-3 type detector.

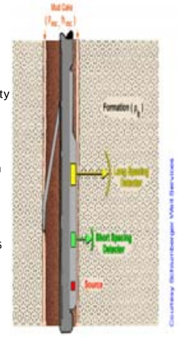


The Density (Gamma-Gamma) Log

- The formation density log is a porosity log that measures ***electron density*** of a formation
- Dense formations absorb many gamma rays, while low-density formations absorb fewer. Thus, high-count rates at the detectors indicate low-density formations, whereas low count rates at the detectors indicate high-density formations.
- Therefore, scattered gamma rays reaching the detector is an indication of formation Density.

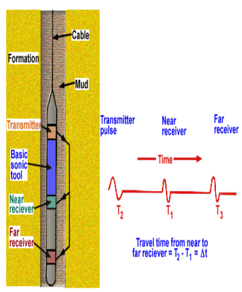
Scale and units:

The most frequently used scales are a range of 2.0 to 3.0 gm/cc or 1.95 to 2.95 gm/cc across two tracks.



Acoustic Log

- **Acoustic tools measure the speed of sound waves in subsurface formations.** While the acoustic log can be used to determine porosity in consolidated formations, it is also valuable in other applications, such as:
- Indicating lithology (using the ratio of compressional velocity over shear velocity),
- Determining integrated travel time (an important tool for seismic/wellbore correlation),
- Correlation with other wells
- Detecting fractures and evaluating secondary porosity,
- Evaluating cement bonds between casing, and formation,
- Detecting over-pressure,
- Determining mechanical properties (in combination with the density log), and
- Determining acoustic impedance (in combination with the density log).



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Temperature: Volumetrics, Maturation, Fluid Flow

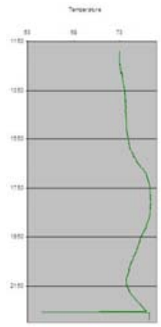
Data Type	Utility	Availability	Comment
Production/Drillstem Test (DST)	High	Rare	Down-hole gauge
Static Test			
Bottom-hole Temperature (BHT)	Medium	Abundant	Biased
Temperature Log		Rare	'Problem' wells
Heat Flow			Data-poor areas
Average Thermal Gradient	Low	Common	Large error
Aqueous Geothermometry		Rare	Inaccurate
Repeat Formation Test (RFT)		Common	Biased
Mud Circulation Temperature		Rare	Not applicable

Table 1. Subsurface temperature data types can be ranked according to their utility for determining true formation temperature and their availability to the practicing geologist.

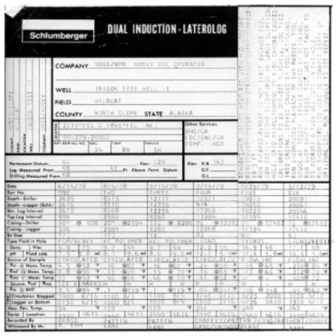
Temperature Logging

A record of the temperature gradient in a well. The temperature log is interpreted by looking for anomalies, or departures, from the reference gradient. This reference might be the geothermal gradient, a log recorded before production started or a log recorded with the well shut-in. Most anomalies are related to the entry of fluids into the borehole or fluid exit into the formation. Since the temperature is affected by material outside the casing, a temperature log is sensitive to not only the borehole but also the formation and the casing-formation annulus.

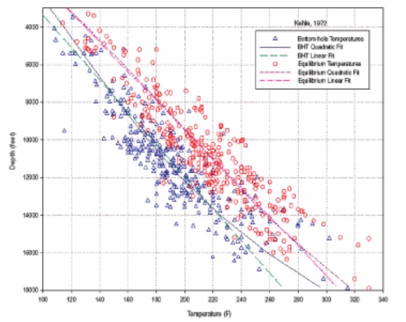
Temperature logs have many applications, with the most common being to identify zones producing or taking fluid, to evaluate a cement or hydraulic fracture treatment, and to locate lost circulation zones and casing leaks. Since temperature takes time to dissipate, a temperature log tends to reflect the behavior of a well over a longer time period than other measurements.



Bottom Hole Temperatures



Bottom Hole Temperatures: Corrected by Depth (AAPG)

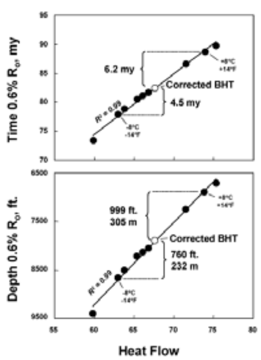


Corrected Bottom Hole Temperature: Horner Plot

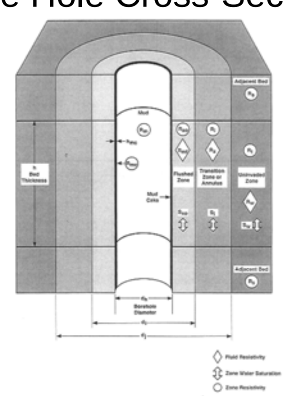
Log Tool	Circulation		Recorded Logger-on-bottom	Interpreted Logger-on-bottom	Time Since Circ., hr.	Temp., °F/°C
	Time, hr.	Stopped				
DIL	16	1100 8/3	1000 8/4	2200 8/3	23 (11)	139/59
FDC			0530 8/4	0530 8/4	18.5 (18.5)	144/62
BHC			1230 8/5	0030 8/5	49.5 (25.5)	149/65

Table 3. Summary data for logging run #2 from compensated formation density (FDC), dual induction-laterolog (DIL), and borehole compensated sonic logs (BHC) at ~8260 ft. (~2518 m) in the Inigok-1 well, North Slope, Alaska. Values in parentheses are based on re-interpreted logger-on-bottom times as discussed in the text.

Corrected Bottom Hole Temperatures



Bore Hole Cross-Section

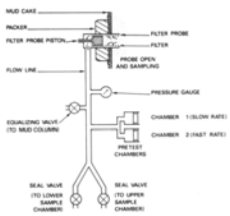


DST – Drill Stem Test

A procedure to determine the productive capacity, pressure, permeability or extent (or a combination of these) of a hydrocarbon reservoir. While several different proprietary hardware sets are available to accomplish this, the common idea is to isolate the zone of interest with temporary packers. Next, one or more valves are opened to produce the reservoir fluids through the drillpipe and allow the well to flow for a time. Finally, the operator kills the well, closes the valves, removes the packers and trips the tools out of the hole. Depending on the requirements and goals for the test, it may be of short (one hour or less) or long (several days or weeks) duration and there might be more than one flow period and pressure buildup period.

Repeat Formation Tester (RFT)

The repeat formation tester (RFT) is operated by an electrically driven hydraulic system so that it can be set and retracted as often as necessary to pressure test all zones of interest on one trip in the well. Two separate fluid tests can also be taken on one trip. Formation pressures are recorded at the surface in both digital and analog form.



RFT Pretest
and Sampling Principle
(Courtesy of Schlumberger)