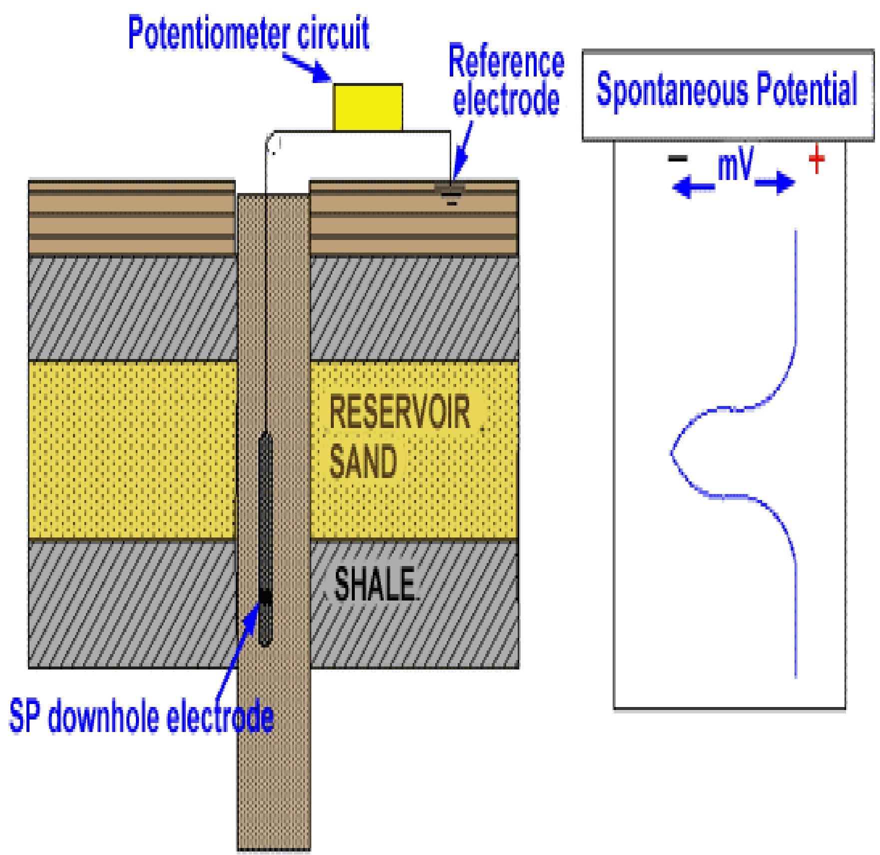
Spontaneous potential (SP –Log)

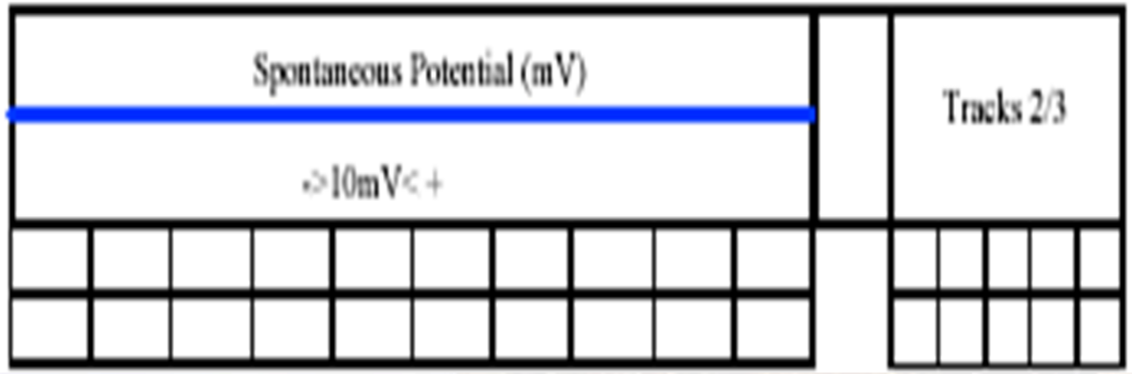
Spontaneous potential (SP –Log)

- Spontaneous Potential is one of the earliest logs used and still in use. It is one of the electrical log types.
- The SP is a measure and record of direct current (DC) voltage differences between the naturally occurring potential of a moveable electrode in the well bore, and the potential of a fixed electrode located at the surface.
- The SP log is recorded on the left hand track of the log in track #1
- It is measured in millivolts (mv).
- The scale on the log shows a number of mV per division for example 20 mV/division. This gives a total for the track of 200 mV.
- The scale across the track is variable and depends on the conditions in the well.
- The scale is set during logging to have the SP curve in the track over the zone of interest and as much of the rest of the log as possible.



❖ **<u>Uses of Spontaneous potential (SP –Log)</u>**

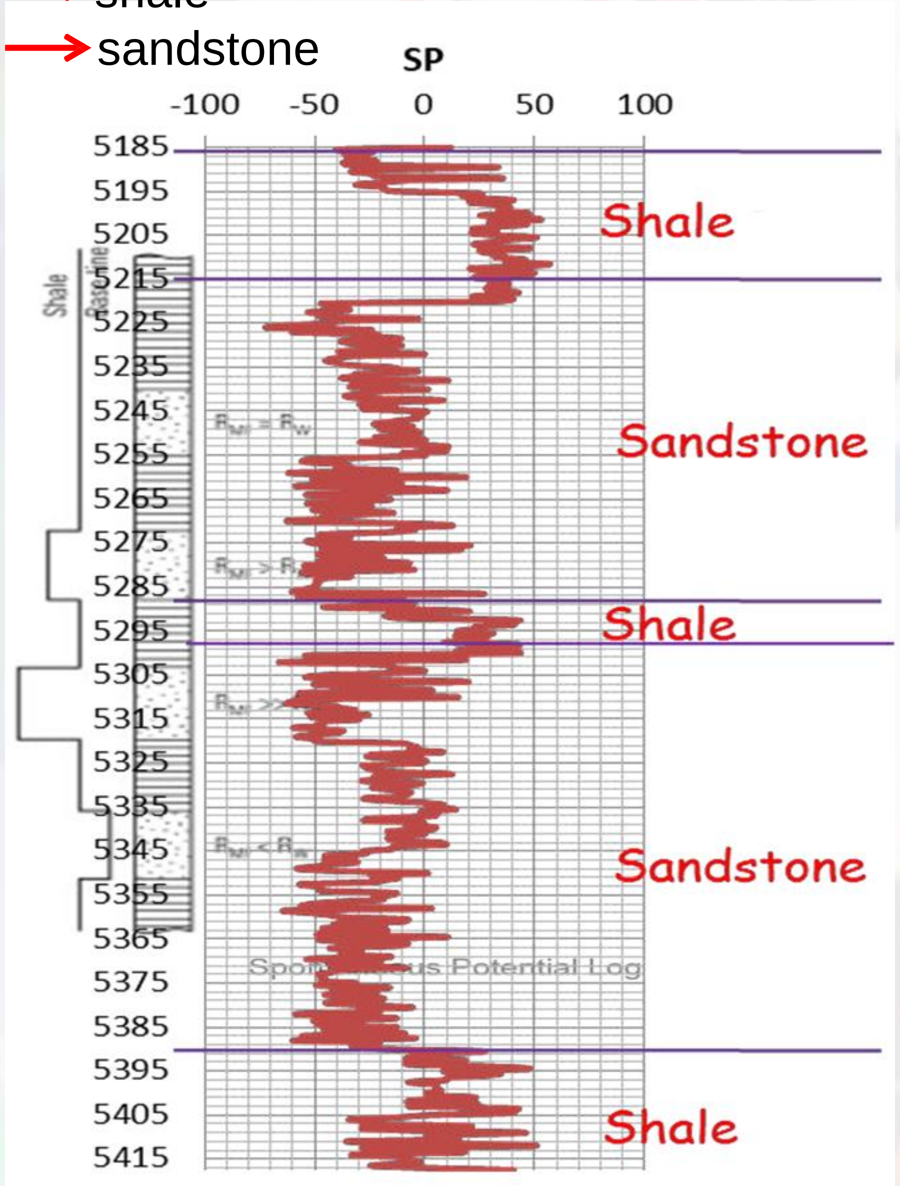
1. The SP log is used to identify impermeable zones such as shale, and permeable zones such as sand,
2. Detect boundaries of permeable beds,
3. Determination formation water resistivity (Rw).
4. Given an indication of shaliness (maximum deflection is clean sand; minimum is shale)
5. Calculation the volume of shale in permeable beds.
6. Aids in lithology identification



- In shaly sections, the maximum SP response to the right can be used to define a "Shale Line".
- Deflections of the SP log from this line indicates zones of permeable lithologies with interstitial fluids containing salinities differing from the drilling fluid.
- SP logs are good indicators of lithology where sandstones are permeable and water saturated.
- However, if the lithologies are filled with fresh water, the SP can become suppressed or even reversed.
- Also, they are poor in areas where the permeabilities are very low, sandstones are tightly cemented or the interval is completely bitumen saturated (i.e., oil sands).

Behavior of SP- Log in front of Shale and standalone , generally :

- High SP → shale
- Low SP → sandstone



❖ Limitations of SP Log

- The SP cannot be recorded in air or oil-base muds, since there is no conductive fluid in the borehole.
- Conductive mud is essential for generation of a spontaneous potential.
- In salt-mud, SP tends to be straight line (less salinity contrast).
- If bed is too thin, the full SP will not develop. Chart exist to correct for this effect, but only significant for bed thickness < 20ft.
- Hydrocarbon and shale in the formation reduce SP development.

Calculation of Shale Volume from SP Log

- Volume of shale is used in the evaluation of shaly sand reservoirs and as mapping parameter for both sandstone and carbonate faces analysis.
- The SP log can be used to calculate the volume of shale in a permeable zone by the following formula:

$$V_{sh} = 1 - \frac{PSP}{SSP}$$

- Or by using the follow equation:

$$V_{Shale} = \frac{PSP - SSP}{SP_{Shale} - SSP}$$

- Where:

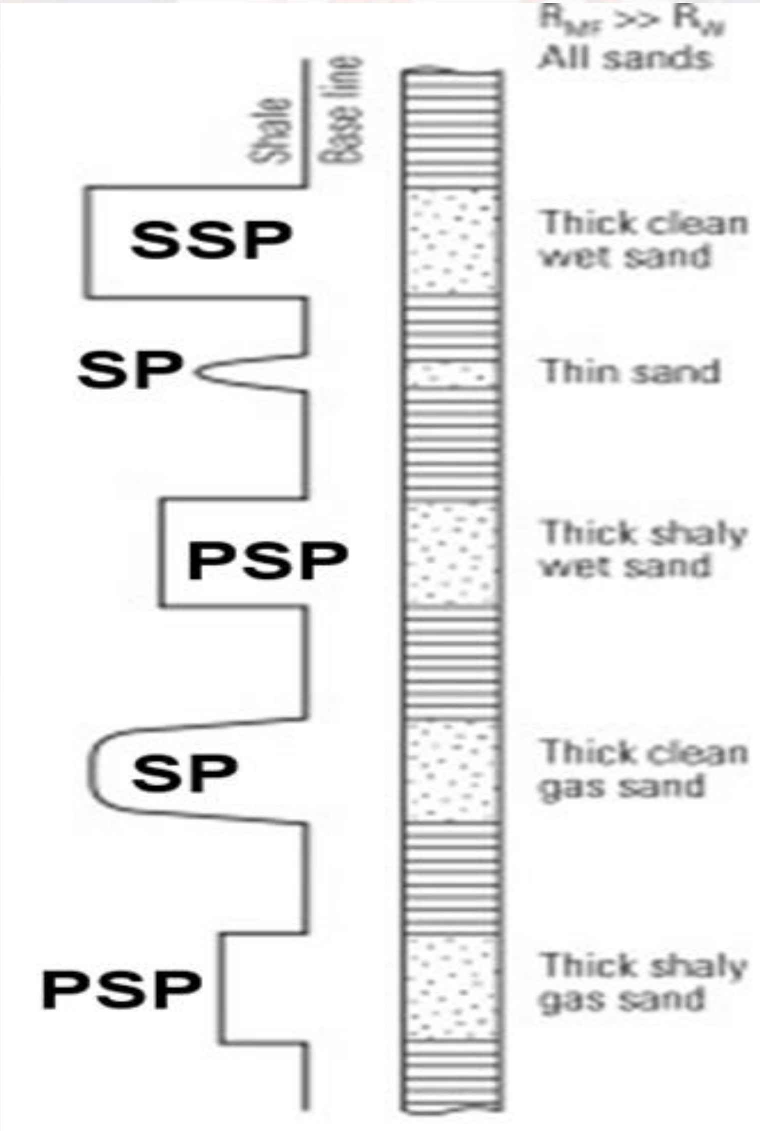
$Vshale$ =volume of shale

PSP =pseudostatic spontaneous potential (maximum SP of shaly formation)

SSP= Static spontaneous potential of a nearby thick clean sand bed.

PS =pseudo-static spontaneous potential (maximum SP of the Shaly formation)

SP_{shale} =value of SP in a shale bed (usually is 0)

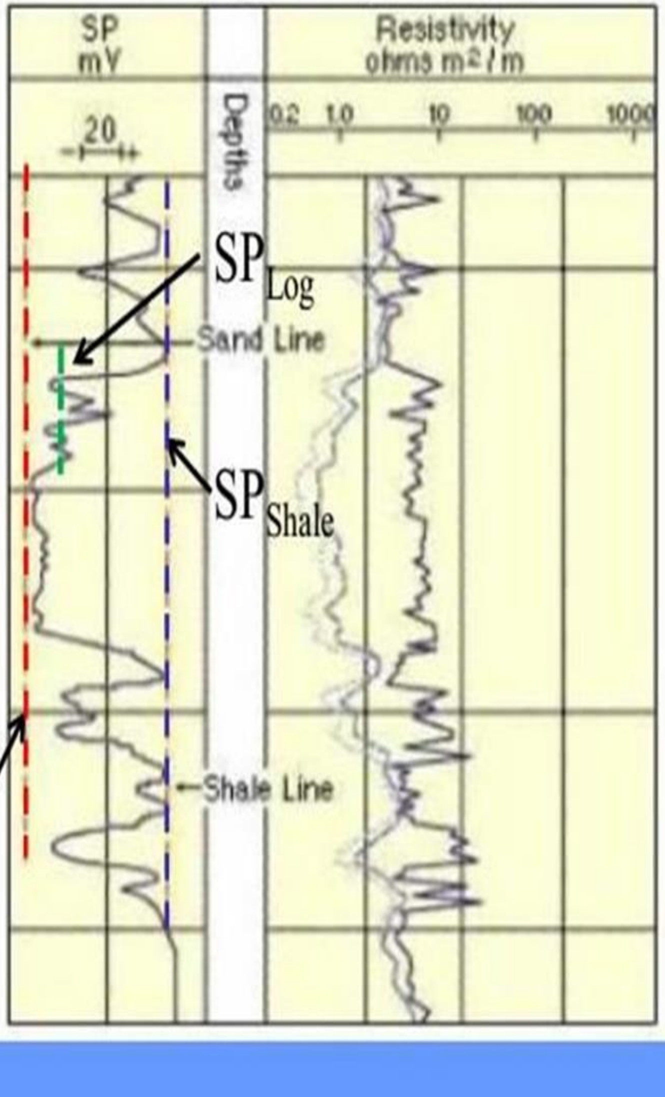


$$(V_{sh})_{SP} = \frac{SP - SP_{clean}}{SP_{Shale} - SP_{clean}} \Rightarrow V_{sh} = 1 - \frac{PSP}{SSP}$$

SP Log Interpretation

$$V_{sh} = \frac{SP - SP_{cl}}{SP_{sh} - SP_{cl}}$$

- V_{sh} : Shale volume
- SP : SP Log reading
- SP_{sh} : SP Log reading in Shale zone
- SP_{cl} : SP Log reading in clean Sand zone



$$V_{sh} = 1 - \frac{PSP}{SSP}$$

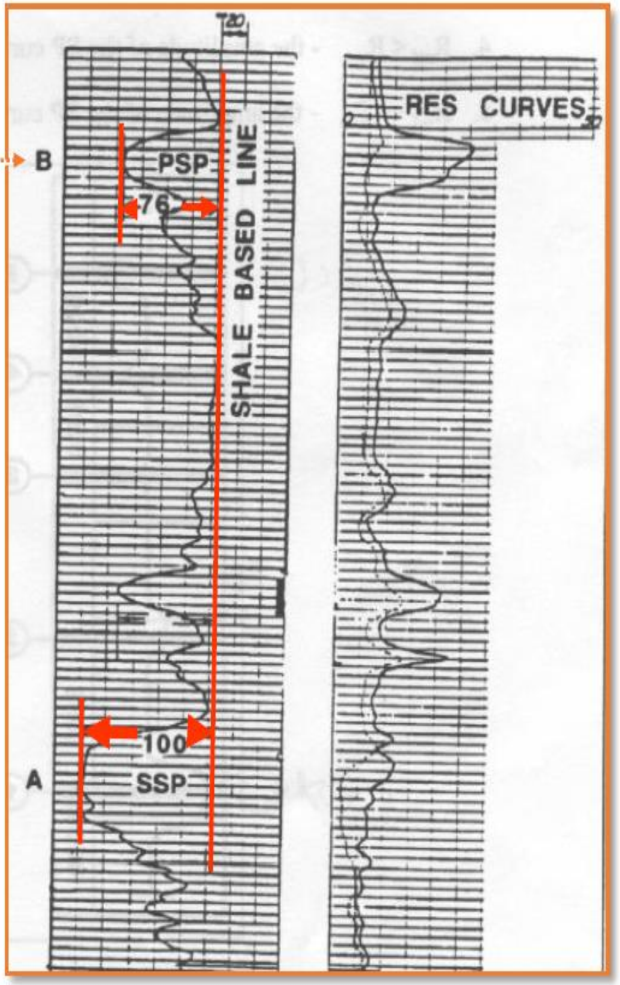
$SSP = 100\ mV$

$PSP = 76\ mV$

$$V_{sh} = 1 - \frac{76}{100} = 0.24$$

$$V_{sh} = 24\ \%$$

SSP and PSP are measured from shale baseline



Determination of formation water resistivity.

❖ SP logs have been used widely for determining formation-water resistivity (*Rw) in oil* wells

$$SP = K \log \frac{R_m}{R_w}$$

Where
SP = log deflection in mV,
K = lithological factor or temperature dependent coefficient. Can be estimated from

K = 60 + 0.133T,

T = borehole temperature, in degrees Fahrenheit

Rm = resistivity of borehole fluid, in Ohm-m,

Rw = resistivity of formation water, in ohm-m.

❖SP deflection is read from a log at a thick sand bed.

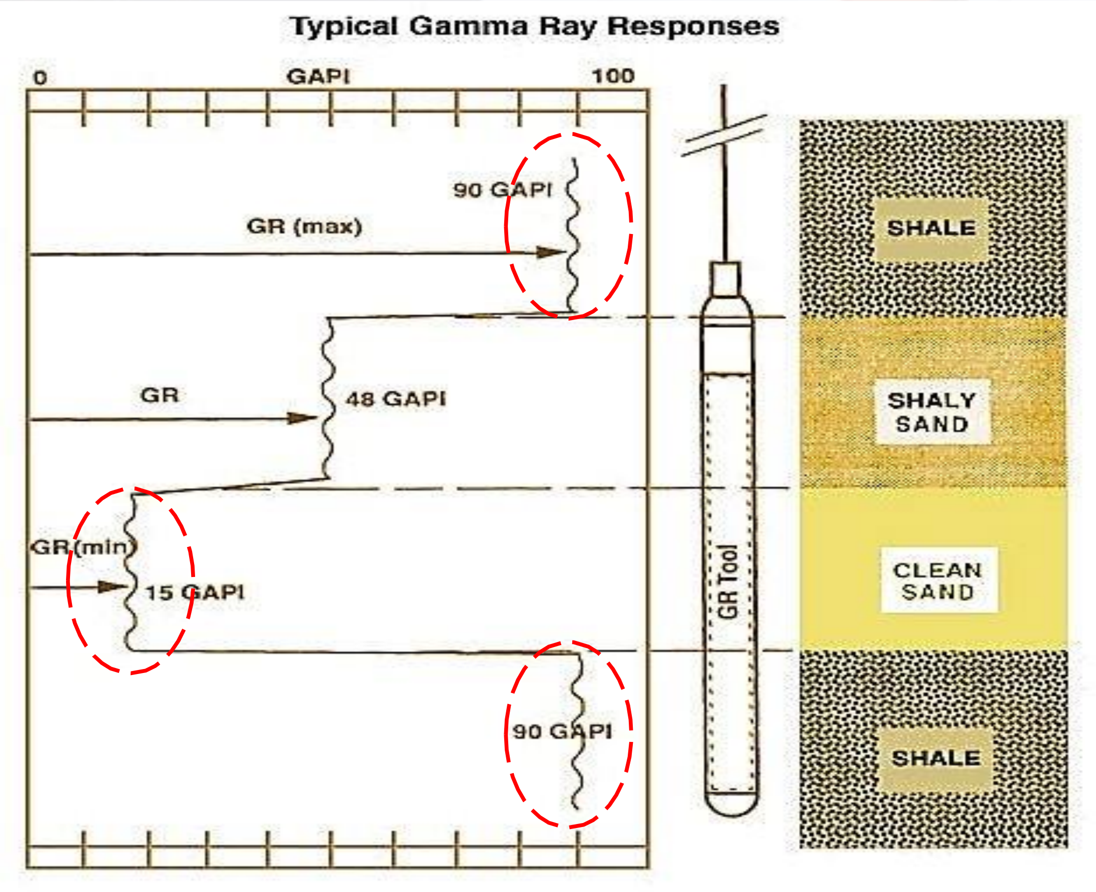
❖*Rm is measured with a fluid-conductivity log.*

❖*Temperature obtained* from a log, or estimated from bottom-hole temperature if available

Gamma Ray Log (GR –Log)

Gamma ray log (GR 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.
- GR log can be run in both open and cased hole
- Appear in the left track on a standard log.
- Measured in API units.
- Linear scale (0 – 150 API)
- Usually recorded with Caliper log
- The natural gamma ray log can be run in almost any logging situation including cased wells, or in open holes drilled with air or Gas mud, Water based mud (salt mud or fresh mud) and Oil based mud



Applications :

A.cased hole Application : including depth control in all operation during well completion and workover

B.Open hole Application :
Correlation; Lithology identification (sand and shale count); Depth control

- In **sedimentary rocks** radioactive elements tend to concentrate in clays, which in turn concentrate in shales.
- **Sandstone, limestone, dolomite** have low radioactivity. **Black shales and marine shales** exhibit highest radioactivity.
- Thus: radioactivity can be used to distinguish shale from non-shale formations and to estimate shale content.
- Qualitative lithology log

❖ Uses of Gamma ray log (GR–Log)

- Gamma Ray (GR) logs can be used for identifying lithologies and for correlating zones.
- GR logs can be used not only for correlation, but also for the determination of shale volume.
- Identify mineral deposits of potasium, uranium, and coal.
- Estimate bed boundaries & formation thickness.
- Perforating depth control in cased hole

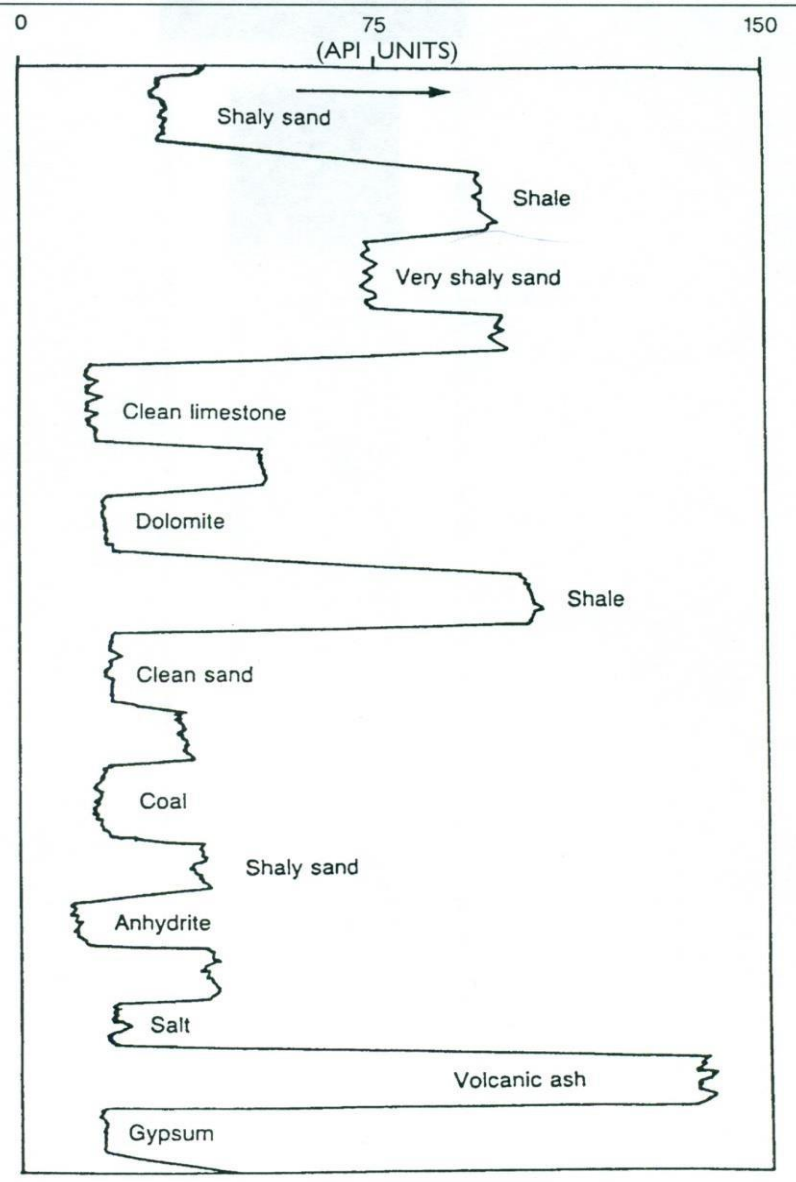


Figure C25: Relative GR response for various rocks/formations

Shale Volume Calculation

- Because shale is more radioactive than sand or carbonate, gamma ray logs can be used to calculate volume of shale in porous reservoir.
- The volume of shale expressed as decimal fraction or percentage is called $Vshale$.
- Calculation of the gamma ray index I_{GR} is the first step needed to determine the volume of shale from a gamma ray.
- GR has a linear and non linear relationship based on:

Shale distribution type ; Age of shale (tertiary or older); Local area

- The non linear responses are based on geographic areas or formation age. All non linear relationships produce a shale volume value lower than that from a linear equation.
- For a first order estimation of shale volume, the linear response $Vsh = I_{GR}$ should be used.

$$I_{GR} = \frac{GR_{log} - GR_{min}}{GR_{max} - GR_{min}}$$

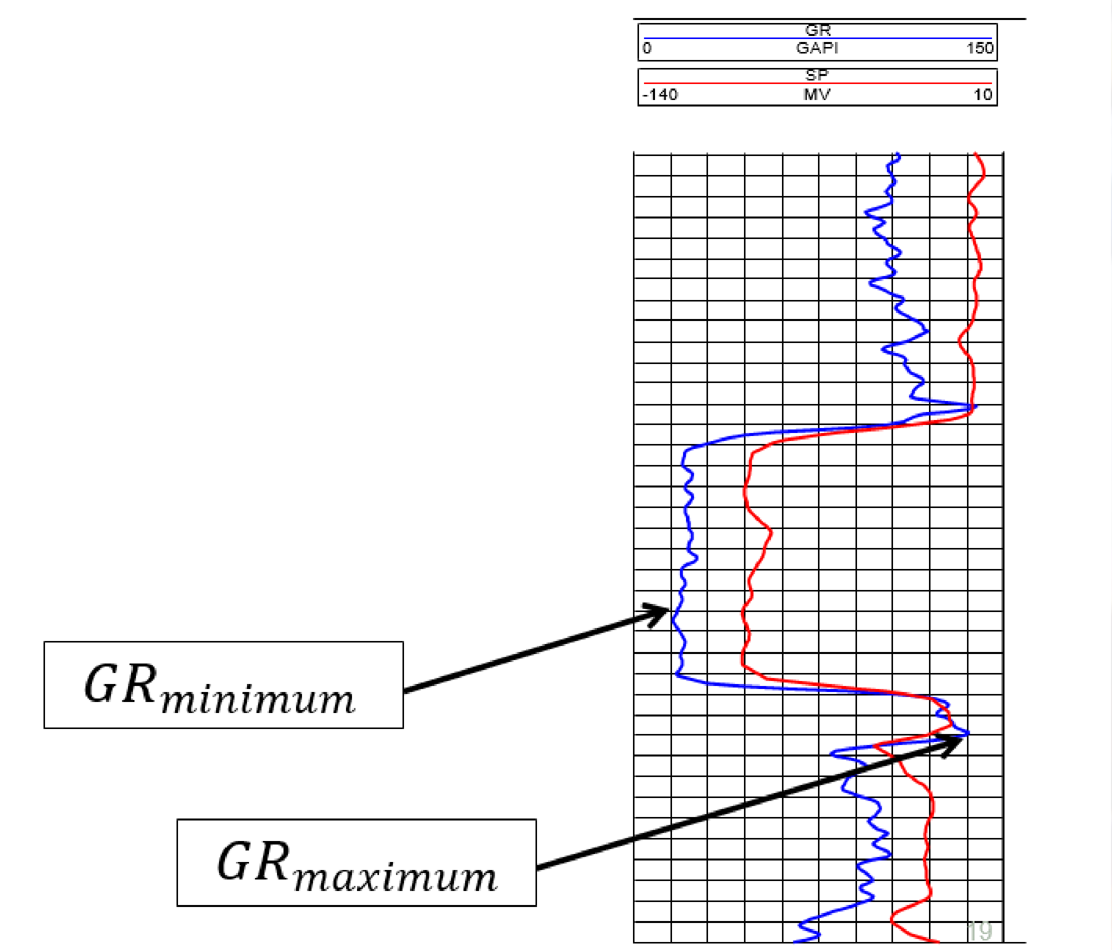
<u>Where:</u>

I_{GR} = Gamma ray index

GR_{log} = Gamma ray reading of formation

GR_{max} = minimum gamma ray (clean sand or carbonate)

GR_{min} = maximum gamma ray (shale).



- For very hard compacted formation at depth of 8,000 ft or more, gamma ray index is considered equal to shale volume: Vsh= IGR

$$I_{GR} = \frac{GR_{log} - GR_{min}}{GR_{max.} - GR_{min}}$$

- For tertiary sediment rocks; unconsolidated at depth of less than 4,000 ft, the shale volume is:

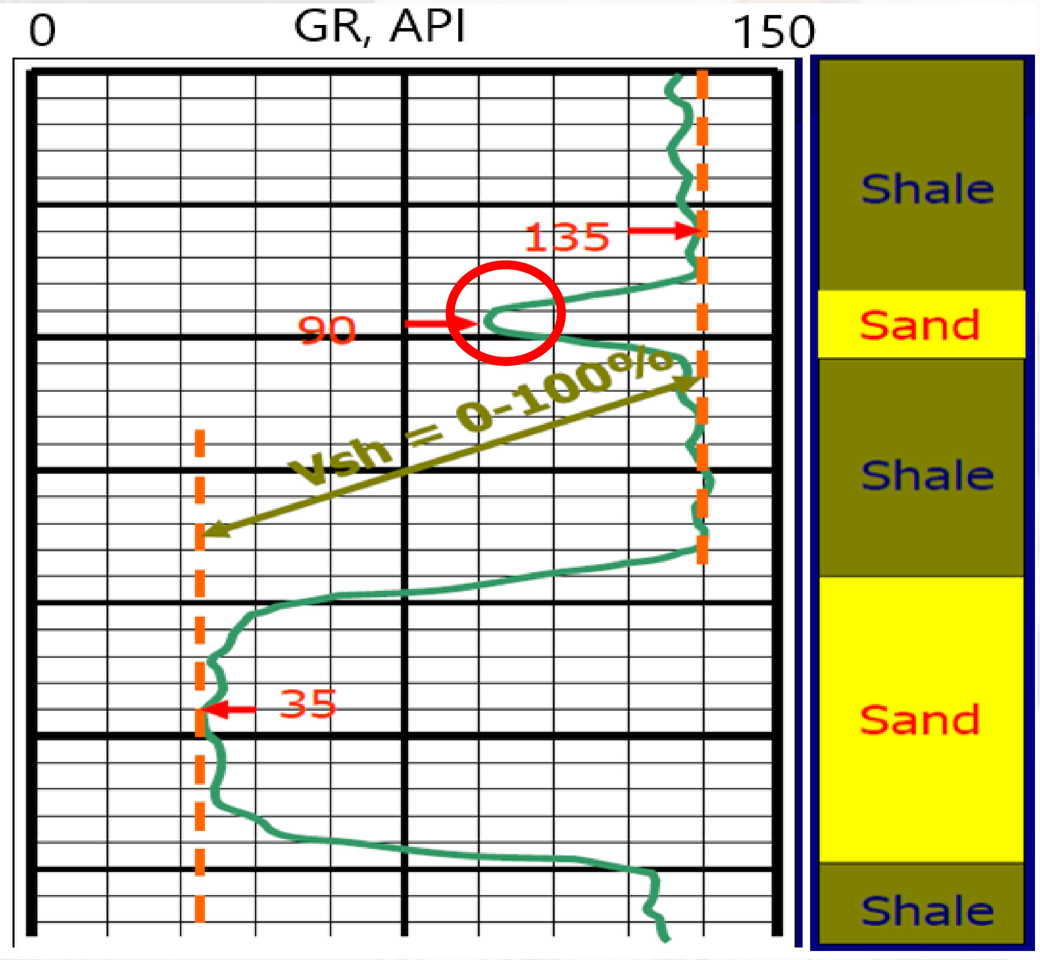
$$Vsh = 0.083 \times (2^{3.7 \times IGR} - 1)$$

- For Order rocks; consolidated at depth of 4,000-8,000 ft, the shale volume is :

$$Vsh = 0.33 \times (2^{2 \times IGR} - 1)$$

Example

Calculate Vsh at the depth of interesting (red circle) .



- Solution:

1) Pick a clean GR response (GRmin), here GR min = 35 API

2) Pick a shale GR response (GRmax), here GR max = 135 API

3) Scale between (i.e. the GR log reading at the depth of interest), here GR log = 90 API

Then $V_{sh} = \frac{GR_{log} - GR_{min}}{GR_{max.} - GR_{min}} = \frac{90 - 35}{135 - 35}$ so Vsh = 55%

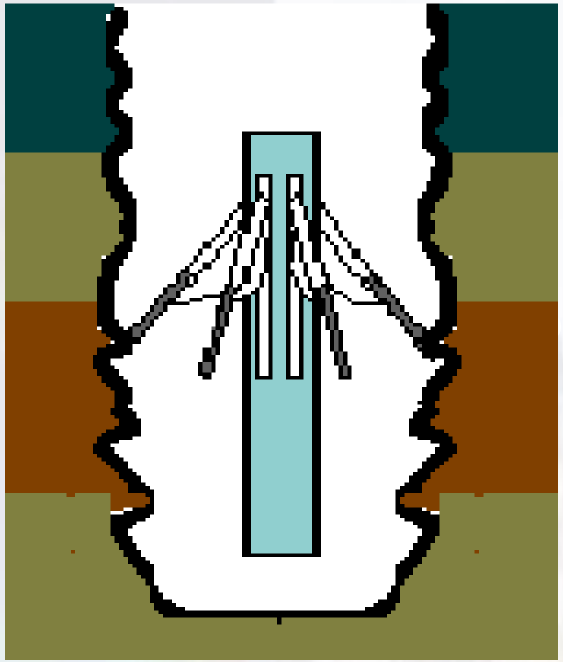
Caliper Log (CAL –Log)

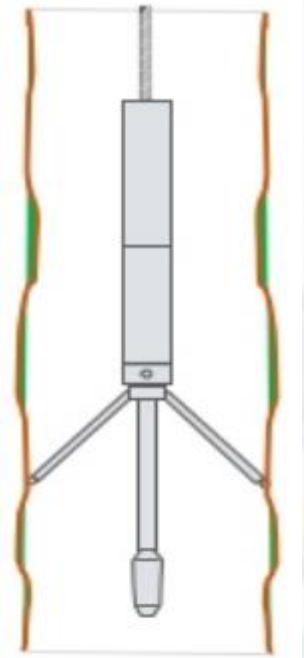
Caliper Log (CAL)

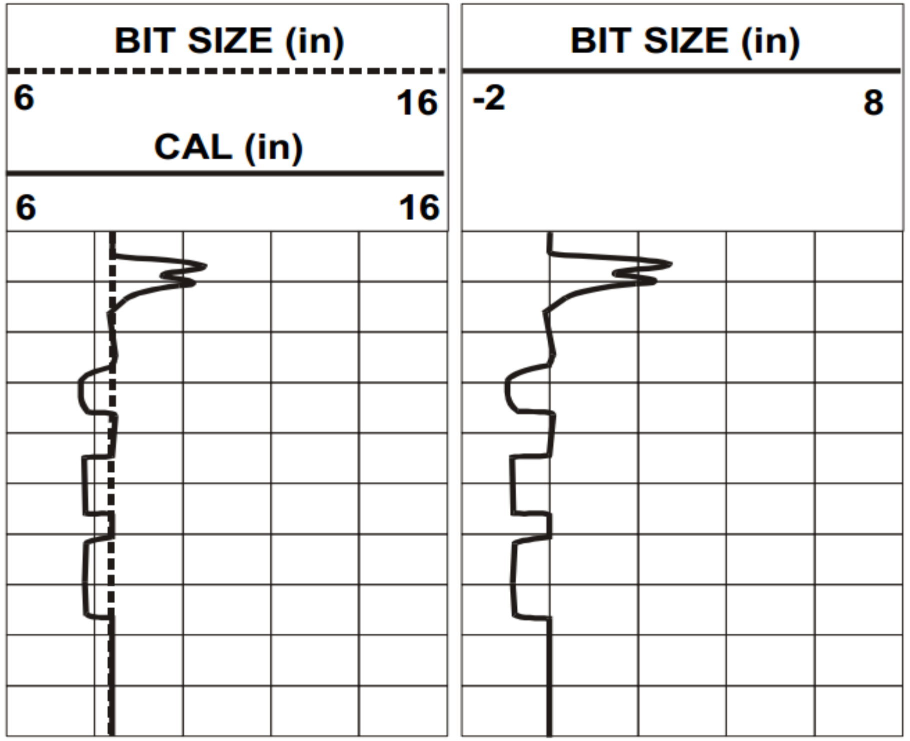
- A **caliper log** is a **well logging** tool that provides a continuous measurement of the size and shape of a **borehole** along its depth. The measurements that are recorded can be an important indicator of caving.
- This log use by cementing engineer to calculate the volume of cement .
- Can be used in both soft and hard formations, run in uncased wells.
- The caliper logs are plotted in track 1 with the drilling bit size for comparison, or as a differential caliper reading, where the reading represents the caliper value minus the drill bit diameter. The scale is generally given in inches, which is standard for measuring bit sizes. (as shown in figure)

❖ **Applications of Caliper logs**

1. Evaluate the borehole environment for logging measurements
2. Identification of mud cake deposition, evidence of formation permeability
3. Estimate hole volume to determine cement volume requirements
4. Determine competent formations to set packers
5. Provide position data for dipmeter interpretation

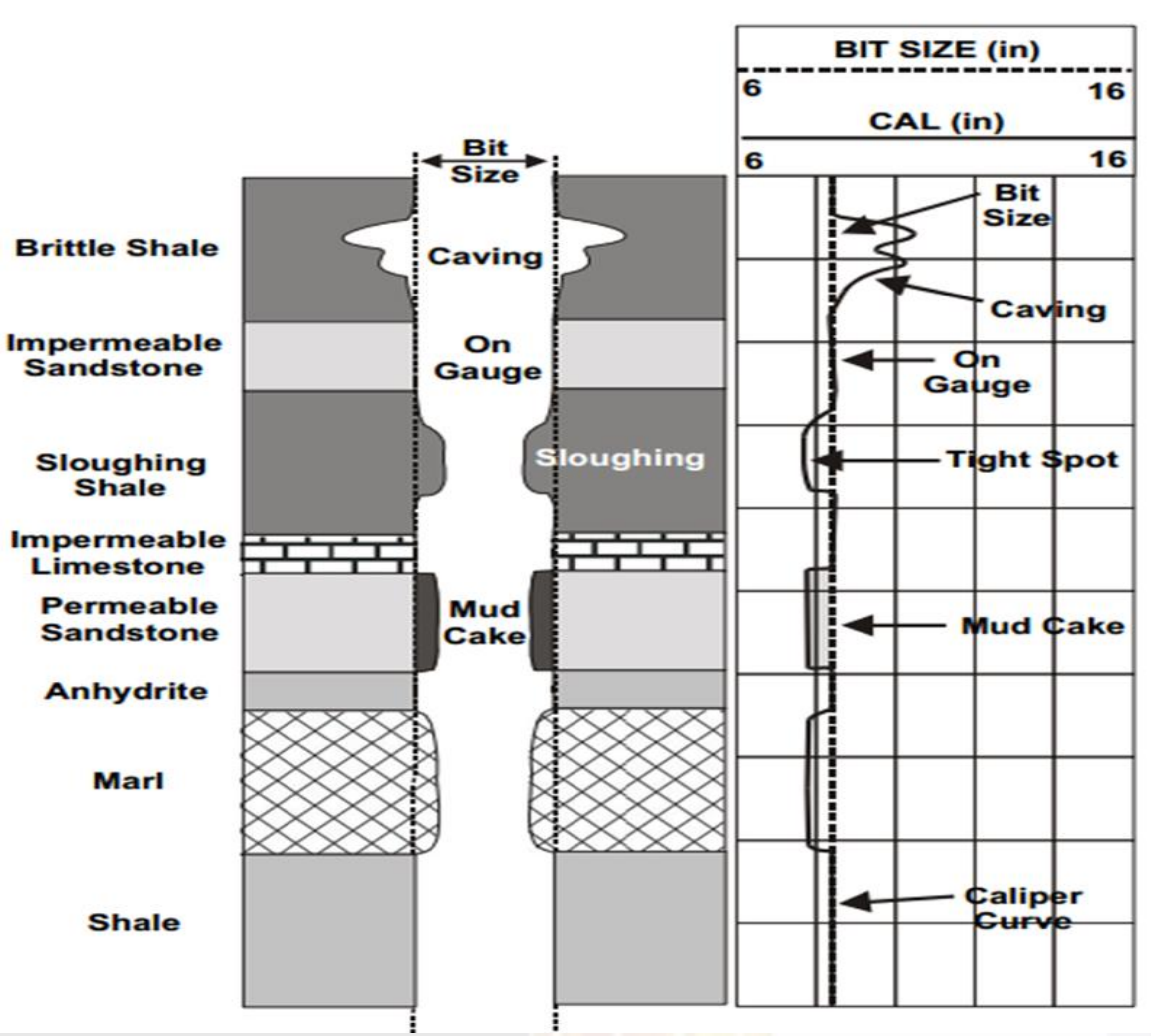






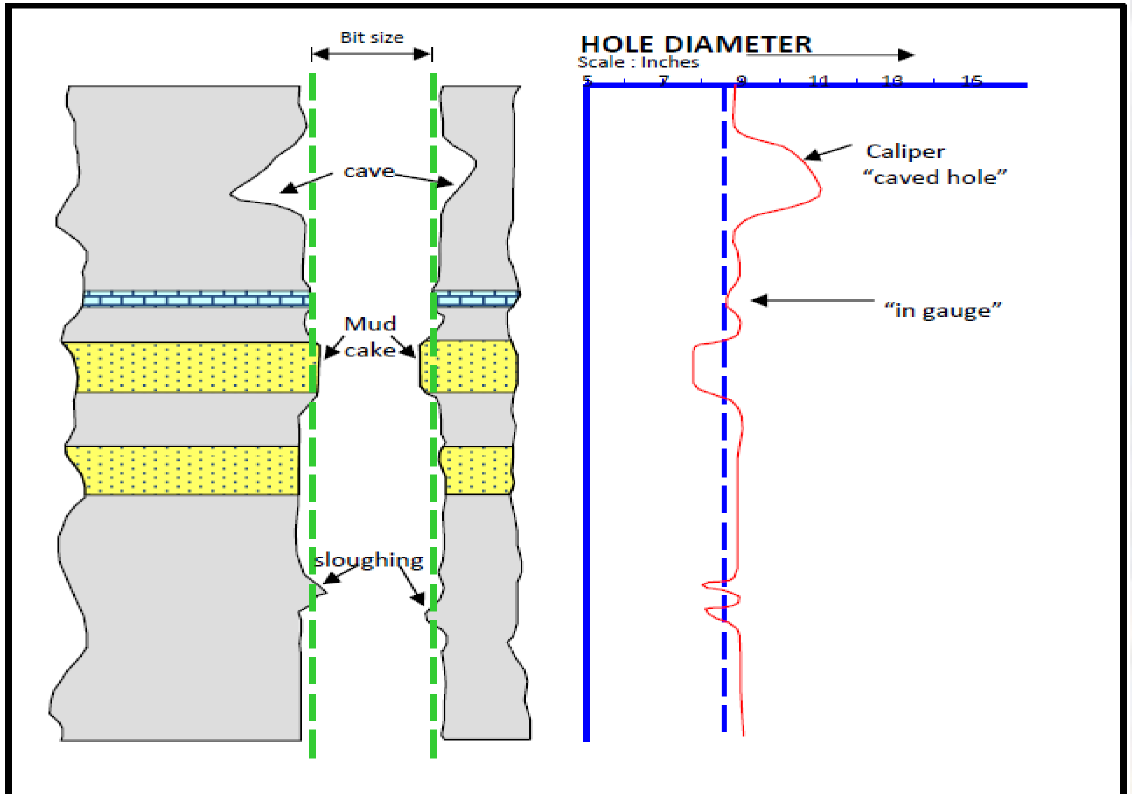
○ Simple Caliper Interpretation

- Figure shows a schematic hole with caliper information. Note that when a hole is the same diameter as the bit-size it is called *on gauge*.



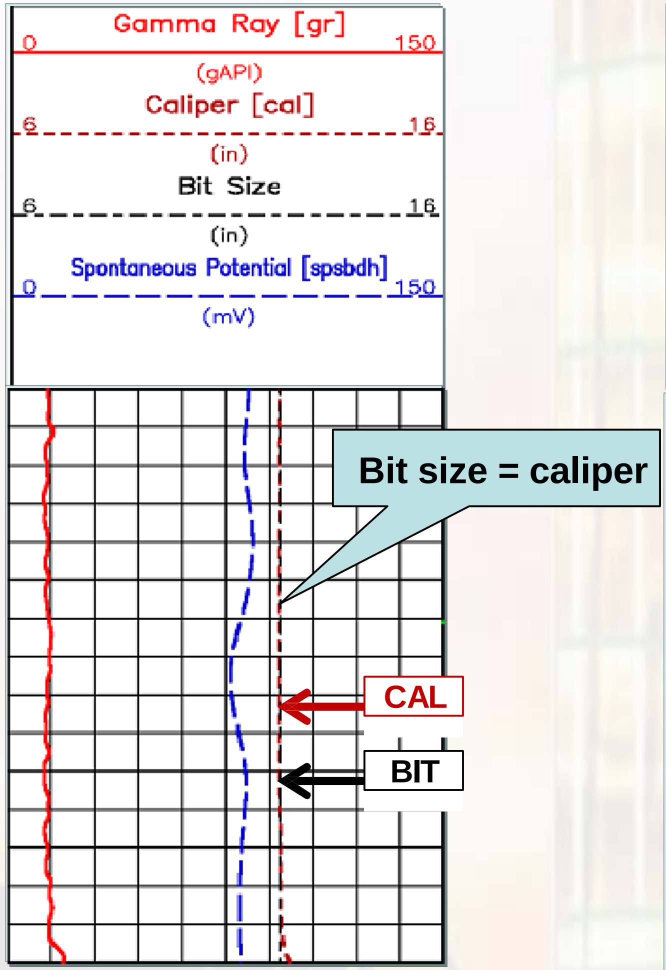
○ Borehole size & shape

- **In gauge**: borehole diameter is equal to drilling bit size.
- **Borehole reduction**: mud cake buildup
- **Borehole enlargement:**
  - – Swelling and sloughing of shales
  - – Collapse of poorly cemented rocks
  - – Dissolution of salts, evaporates.

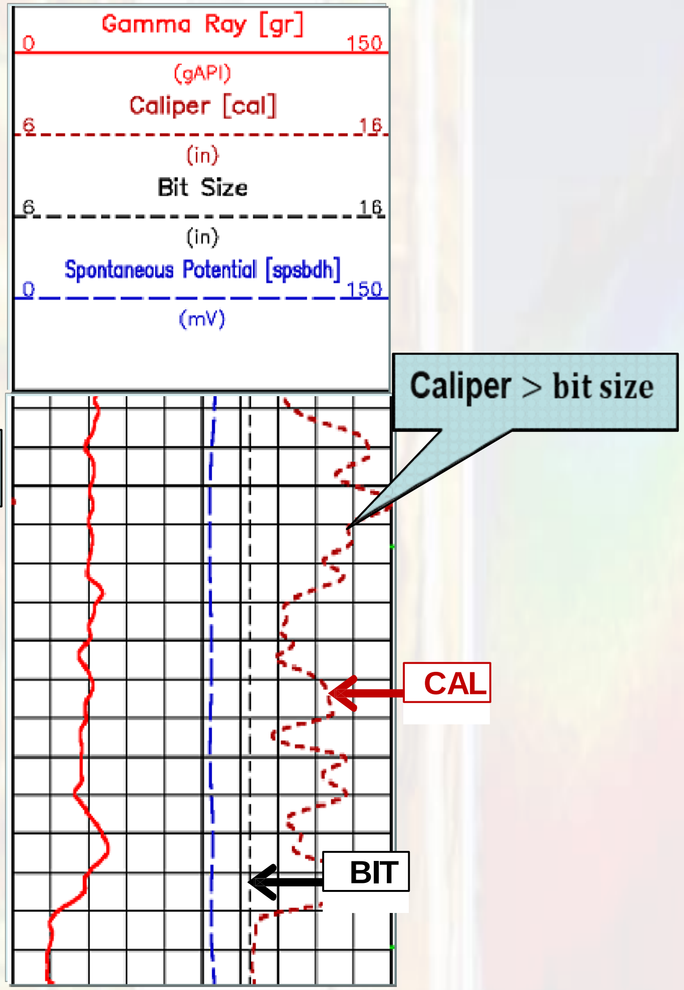


The caliper log showing hole diameter: some typical responses.

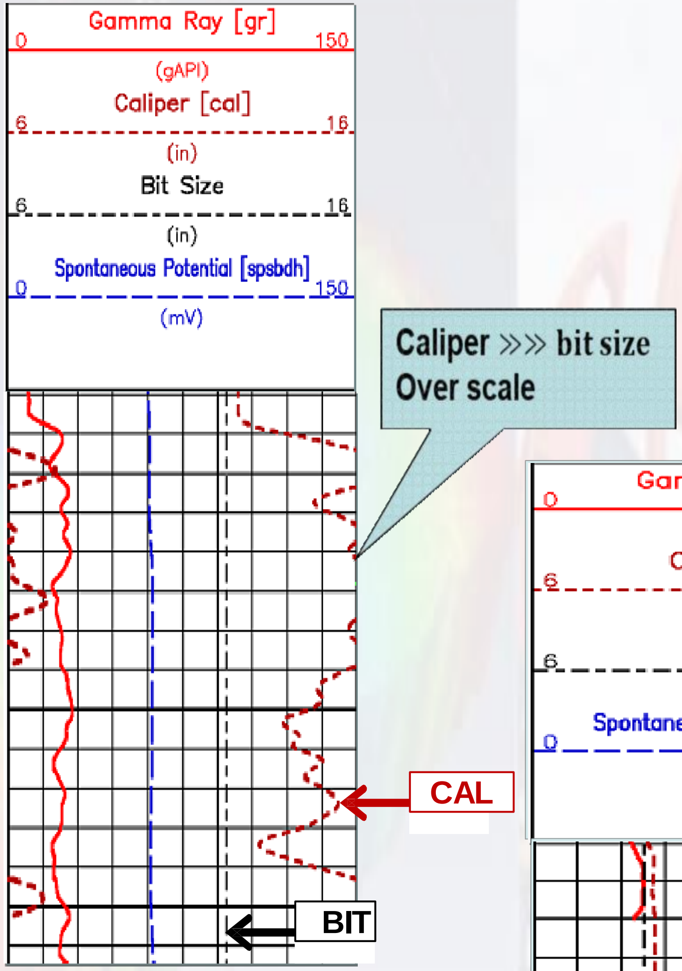
Caliper Log-in vertical wells (four cases)



1.Normal case

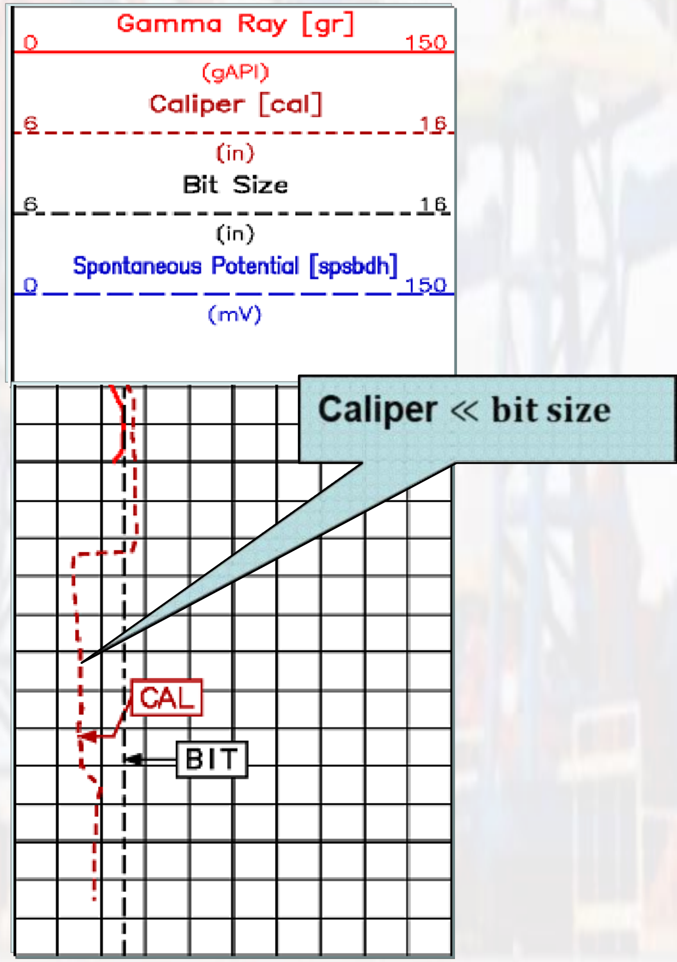


2.caving



3.Wash out

4.Tight spot



Caliper log calculation

- Mud cake thickness (hmc) can be estimated from the caliper by dividing the decrease in hole size by two (the caliper giving the hole diameter) i.e. if diameter of hole (d_h) < diameter of bit (d_{bit})

  then :

$$\boldsymbol{h_{mc} = (d_{bit} - d_h)/2}$$

where *h* stands for the hole, in inches.

- Measurement of borehole volume, ***Vh = (dh²/2)+1.2%*** , in litres per metre.
- Measurement of required cement volume,

Vcement = 0.5 *(dh² – dcasing²)+ 1% , in liters per meter.