Logging

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Well logging

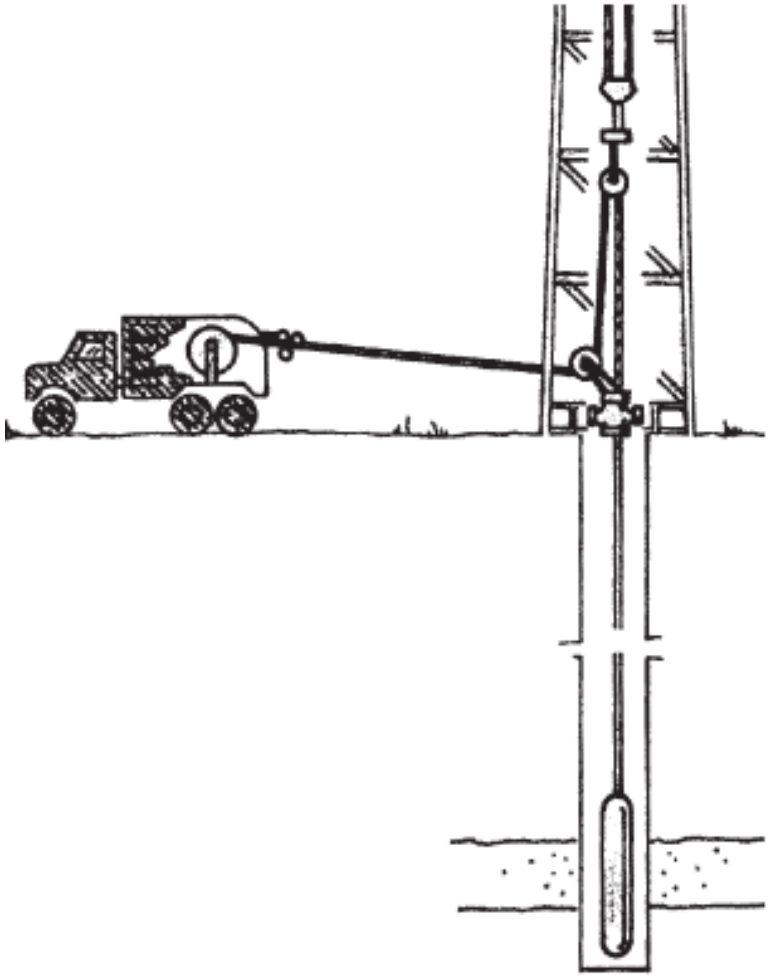
(measure of physical properties)

- After the well was drilled a sonde with measuring instruments is lowered into the well on a cabel.
- It is slowly withdrawn up the hole, continuous measurements of certain **physical properties of the rocks are transmitted electrically to surface**, where they are digitally recorded.

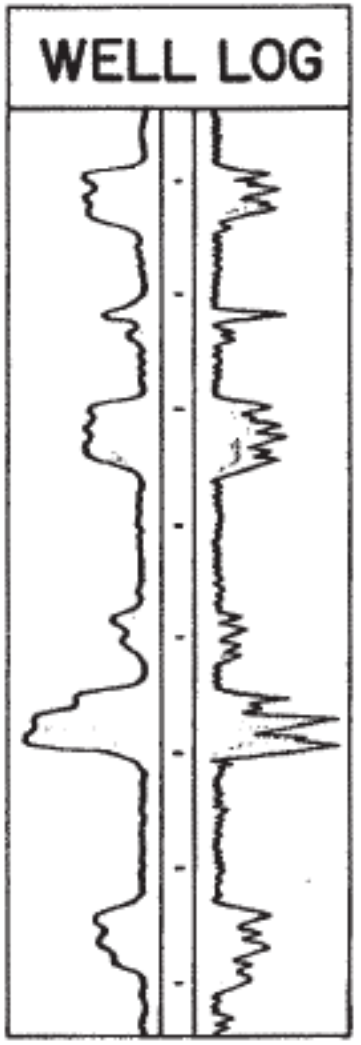


<u>Logs give information on</u>

-Lithology
-Porosity
-CH saturation
-Dips of layers



Well logging with a logging tool run down a well on a wireline. Hyne 2012



A wireline well log
Hyne 2012

Logs are used

- for stratigraphic **correlation** (one well with the other)
- Identification of **sedimentary facies** (only for siliciclastic sediments)
- To determine **porosity**
- To determine water and oil **saturation** (if relevant)
- **Correlating sequences** in sedimentary basin
- **Evaluating the properties** of reservoir rocks and their fluid content for production purposes.
- Image logs: **stratification, faults**
- Dip log: **dips of layers**

What kind of logs do we have?

- Gamma Ray (GR)
- Spontaneous Potential (SP)

Distinguish permeable and impermeable zones

- Resistivity (RD, RS, LLD, LLS, MLL)

HC saturation

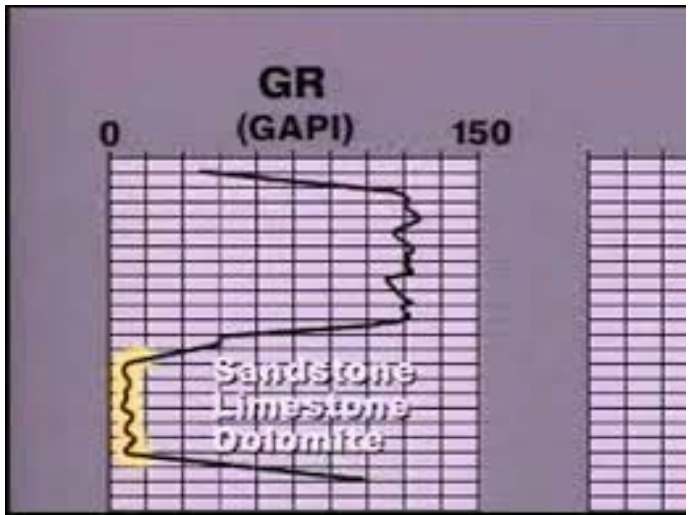
- Density (ρ)
- Acoustic (Δt)
- Neutron porosity (Φ_N)

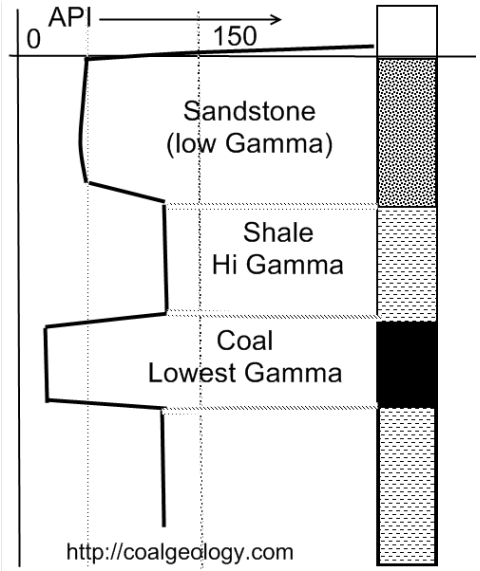
Porosity

- Caliper

Gamma-ray (GR) log

- Measures the natural radioactivity of the rocks (U, Th, ^{40}K).
- Shales contain more radioactive minerals than sandstones and shales.
- Sand and lime „kick” to the left, clay right.
- Resolution: 0,5m.



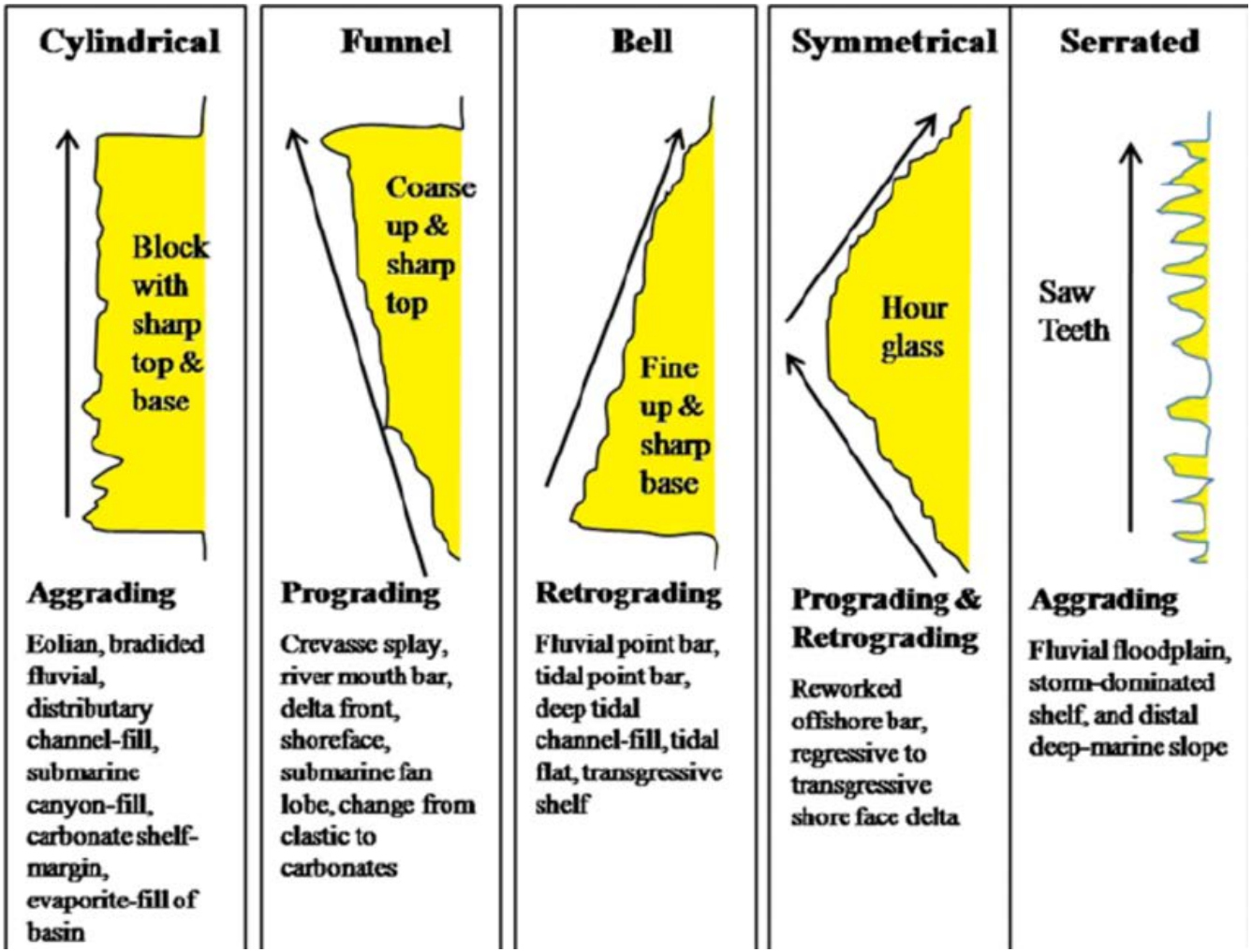


Gamma Ray

- Measure natural gamma radiation
- Unit [API, gAPI]

	Lithology	GR values [gAPI]
Source rocks	Organic-rich shale	100-250
	Shale	80-150
Reservoir rocks	Sandstone (quartz)	15-30
	Limestone, Dolomite	10-30
	Evaporitic minerals	8-15

Gamma ray refers to depositional environment



Resistivity log

- An electric current is sent out from the sonde into the rocks and is picked up through another sonde.
- The voltage drop is measured and resistivity calculated.
- An electric current passes easily through a porous rock filled with salty water, than through one containing fresh water, and more readily through one filled with oil than one with gas.

Poor conductors

- Dry rocks (exceptions: some sulphides, graphite, chlorite)
- Oil and gas

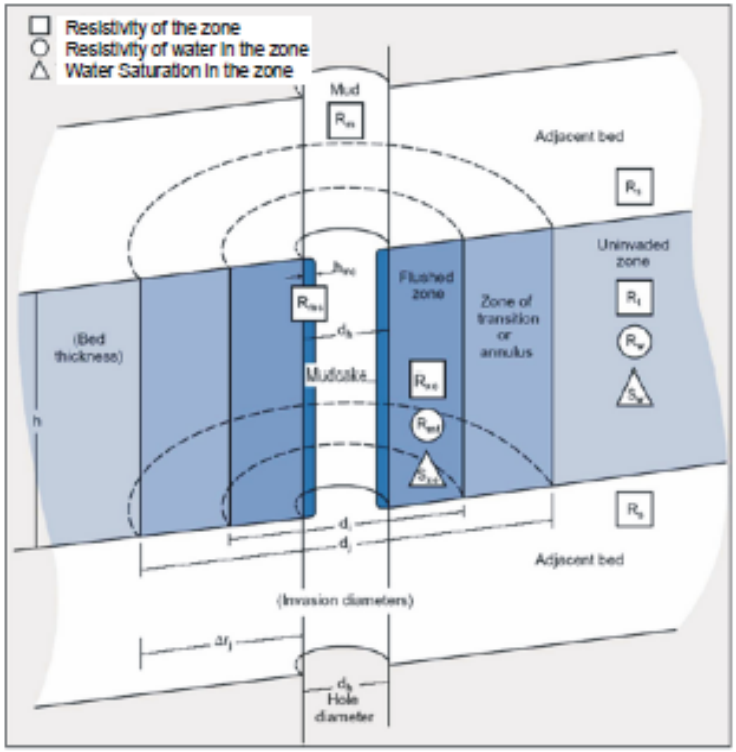
Electrical conductivity of rocks is mainly controlled:

- Salinity
- Amount of water

Uses:

- Indicate HC vs. Water-bearing zones
- Indicate permeable zones
- Determine resistivity porosity

Invasion: fluids from the wellbore enter into permeable formations



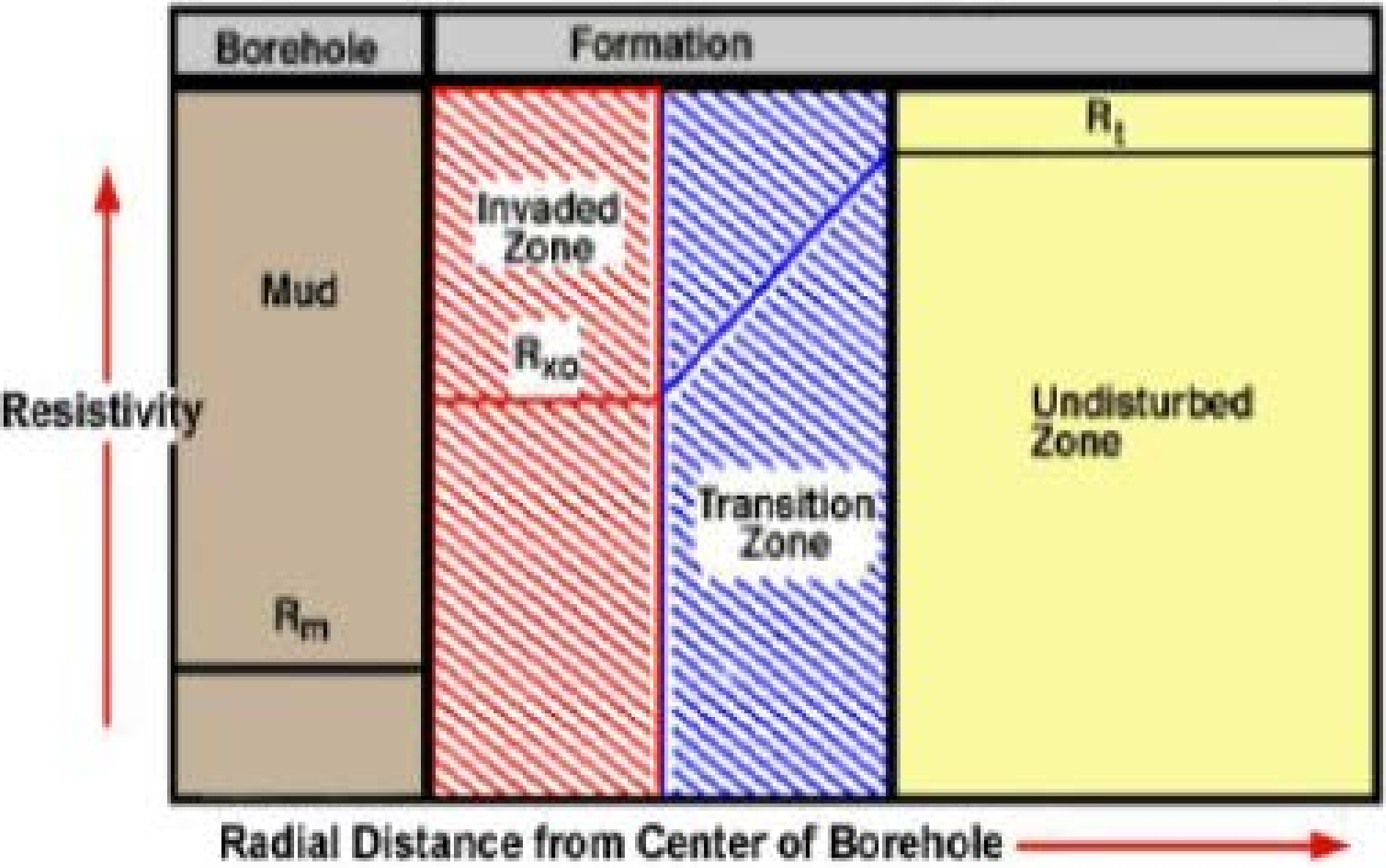
Short-spaced devices gather data from very near the wellbore.
Long-spaced devices gather data from deep in the formation.

Information on resistivities of
- drilling mud (R_m),
- mud filtrate (R_{mf})
- mud cake (R_{mc})

are given on the header of the log and are used in calculations.

Sachsenhofer 2017.

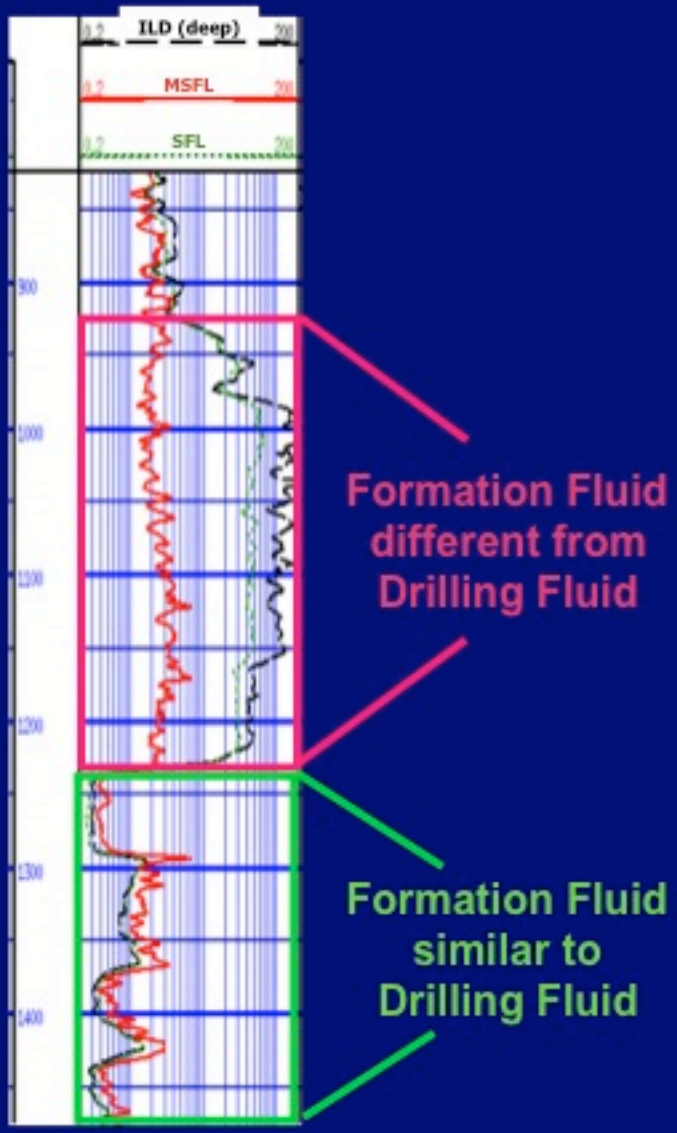
- During drilling permeable rocks adjacent to the well are flushed with drilling mud.
- Some of the large solid particles form the mud are plastered against the well walls to form the mud cake, and some of the drilling mud liquid along with finer solid particles (mud filtrate) is forced into the rock.
- The area adjacent to the wellbore that is flushed with mud filtrate (*invaded zone*) goes from 0 to 254 cm back from the wellbore, depending on the porosity and permeability of the rock.


Borehole
Formation
Mud
R_m
Invaded Zone
R_{xo}
Transition Zone
R_t
Undisturbed Zone
Resistivity
Radial Distance from Center of Borehole

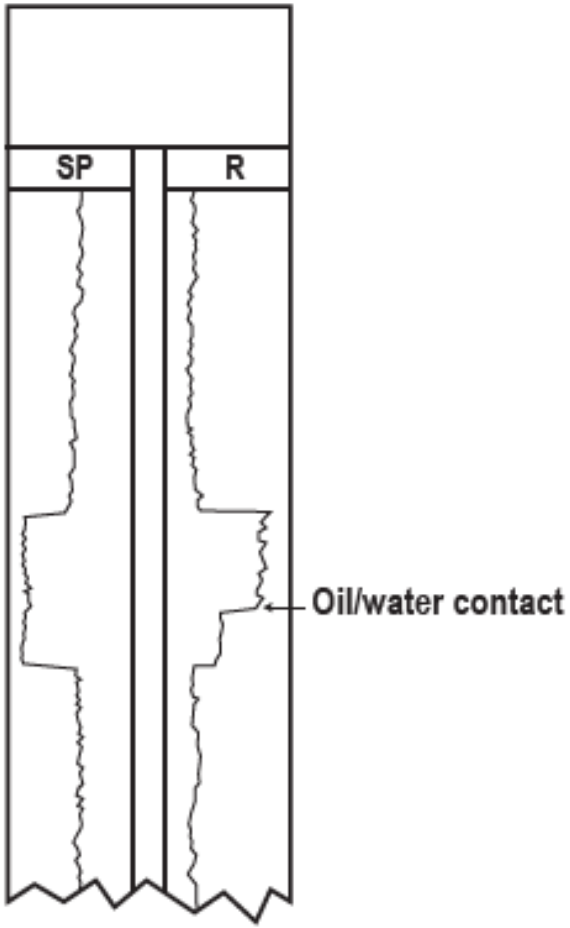
Resistivity Logs

- **High deep resistivity means:**
  - Hydrocarbons
  - Tight streaks (low porosity)
- **Low deep resistivity means:**
  - Shale
  - Wet sand
- **Separation between resistivities means:**
  - The formation fluid is different from the drilling fluid
  - The formation is permeable to the drilling fluid

Deep, Medium, and Shallow refers to how far into the formation the resistivity is reading (4 ft, 2 ft, few in)



Oil/water contact on the resistivity log

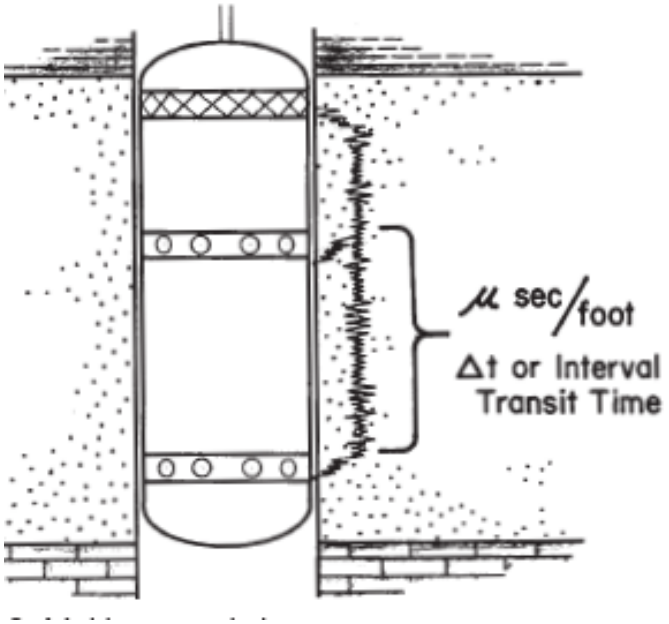


An oil-water contact on a resistivity curve
Hyne 2012.

- If there is no change in porosity, an oil-water or gas-water contact appears as a kick on the resistivity curve.
- Oil and gas cannot be differentiated on a resistivity log (R log).

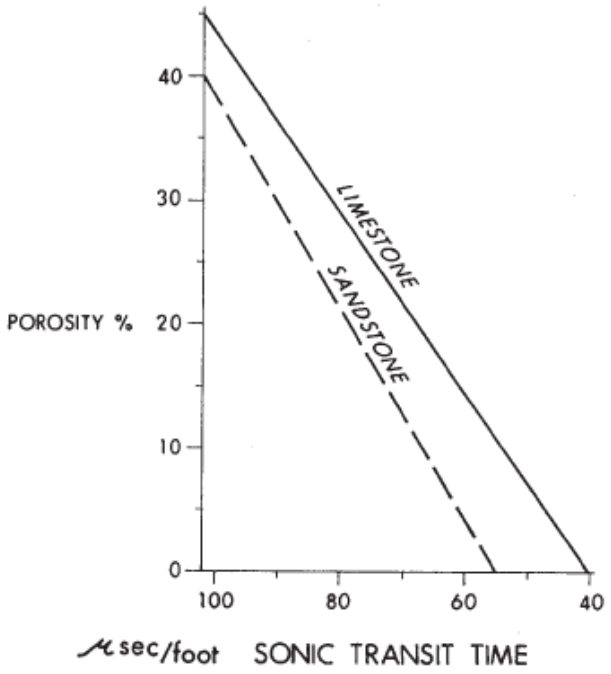
Sonic (Acoustic log)
(Porosity logs: Sonic, Density, Neutron)

- **Sonic log: provide information on lithology and porosity, control on seismic velocities.**
- Records the speed of sound through the rock layers.
- Sound from an emitter at one end of the sonde travels through the borehole wall and is picked up
- by a reciever at the other end.
- Lithology: sound travels faster through one rock, than other.
- Porosity: sound waves take longer to pass through e.g. a porous sandstone than a non-porous one.



Hyne 2012.

- Porosity: sound waves take longer to pass through e.g. a porous sandstone than a non-porous one. The more gas or liquid the rock contains the slower its sonic velocity will be.
- If the composition of the rock is known, the porosity of the rock can be computed from the interval transit time of the rock
- Sonic porosity doesn't contain fracture porosity.



The relationship between interval transit time and porosity. Hyne 2012.

Neutron

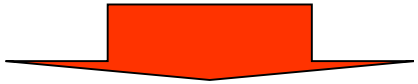
(Porosity logs: Sonic, Density, Neutron)

- A stream of neutrons is sent out into the well bore from a sonde.
- They react with the hydrogen in the rock generating gamma-rays, which are then measured in the sonde.
- Because hydrogen is concentrated in fluid filled pores, radiation is a function of porosity.
- Gas effect: when the pores are filled with gas rather than oil or water, neutron porosity will be lowered.

Density log (gamma-gamma)

(Porosity logs: Sonic, Density, Neutron)

The tool emits gamma radiation and records the amount of gamma radiation returning from the formation.

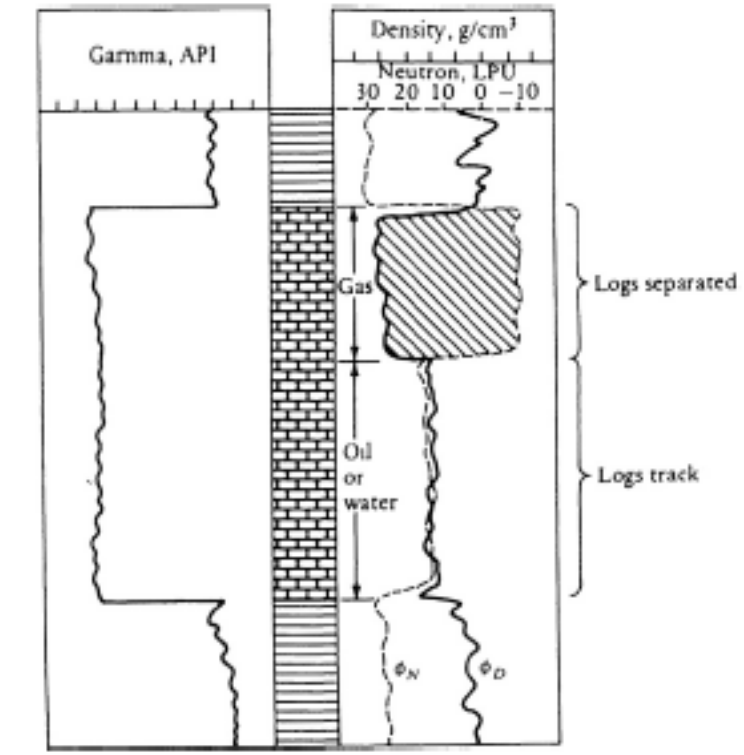


It is related to the electrondensity of the atoms in the formation.

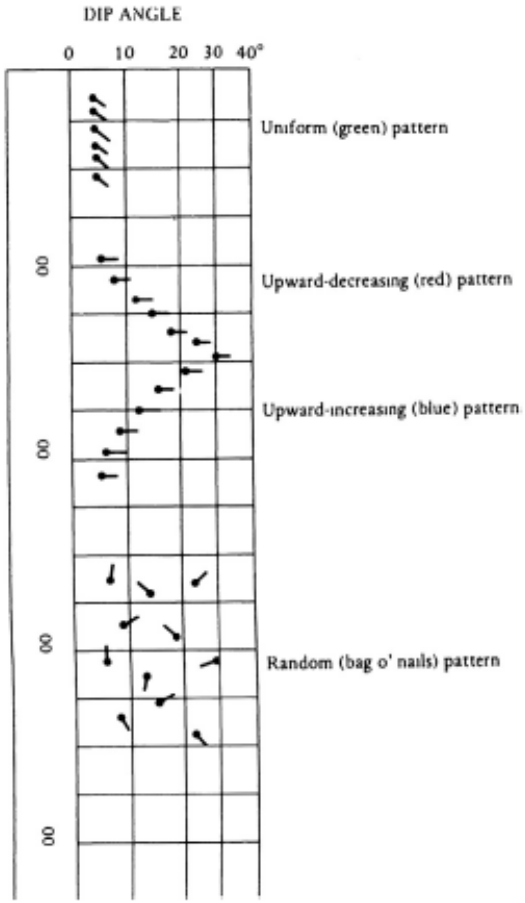
Is a function of lithology (rock matrix), porosity, density of fluids. .

Neutron/density log cross over

- In gas zones the neutron log indicates too low porosity and the density log, too high porosity.
- Separation between the log traces indicates the presence of gas.



Dip Meter Log



- Measures the direction of dip of beds adjacent to the borehole.
- Conventional dip meter tadpole plot showing the four common dip motifs.
- The head of the tadpole shows the amount of dip. The tail of the tadpole points in the direction of dip.

Dipmeter

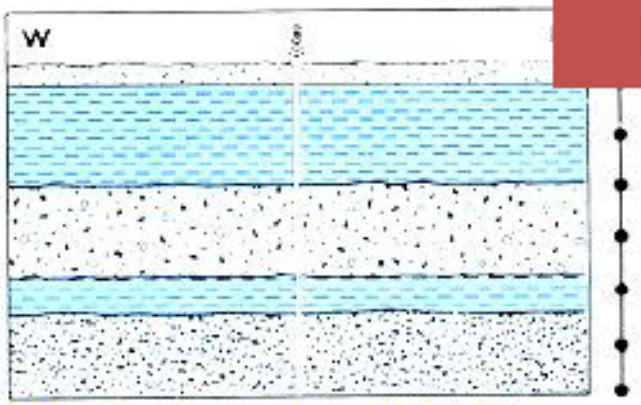


Figure 1 - No dip, horizontal bedding

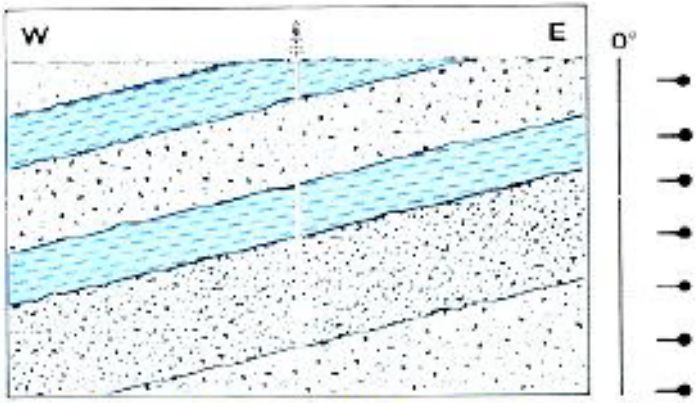


Figure 2 - Constant dip, tilted bedding

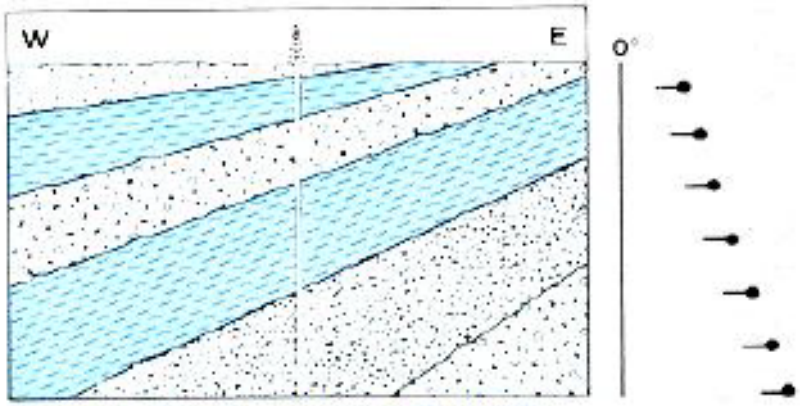


Figure 3 - Dip increasing with depth, downdip thickening

Dipmeter

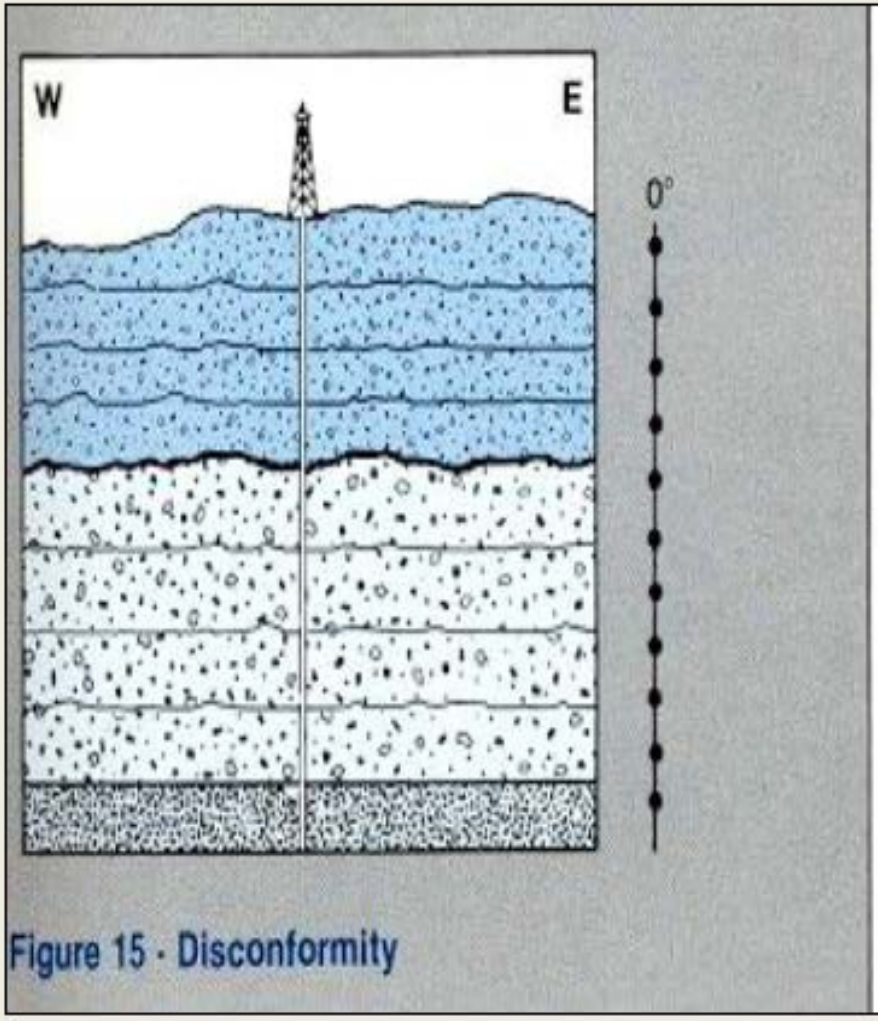


Figure 15 - Disconformity

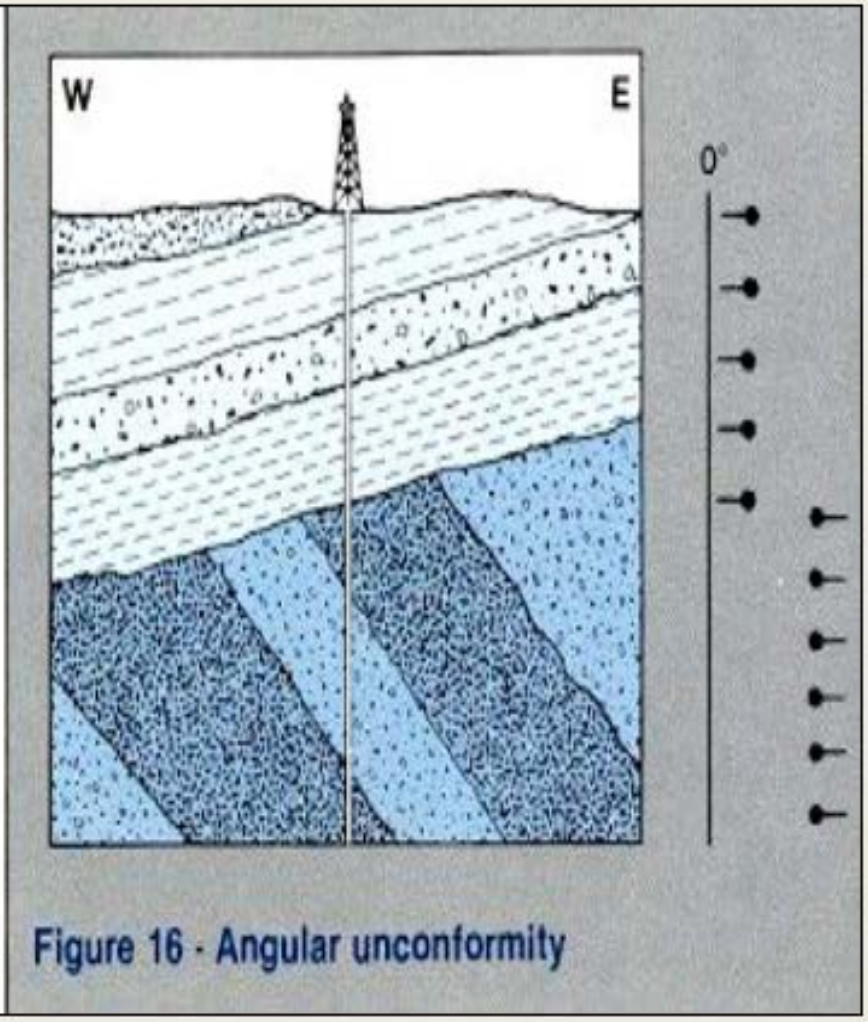


Figure 16 - Angular unconformity

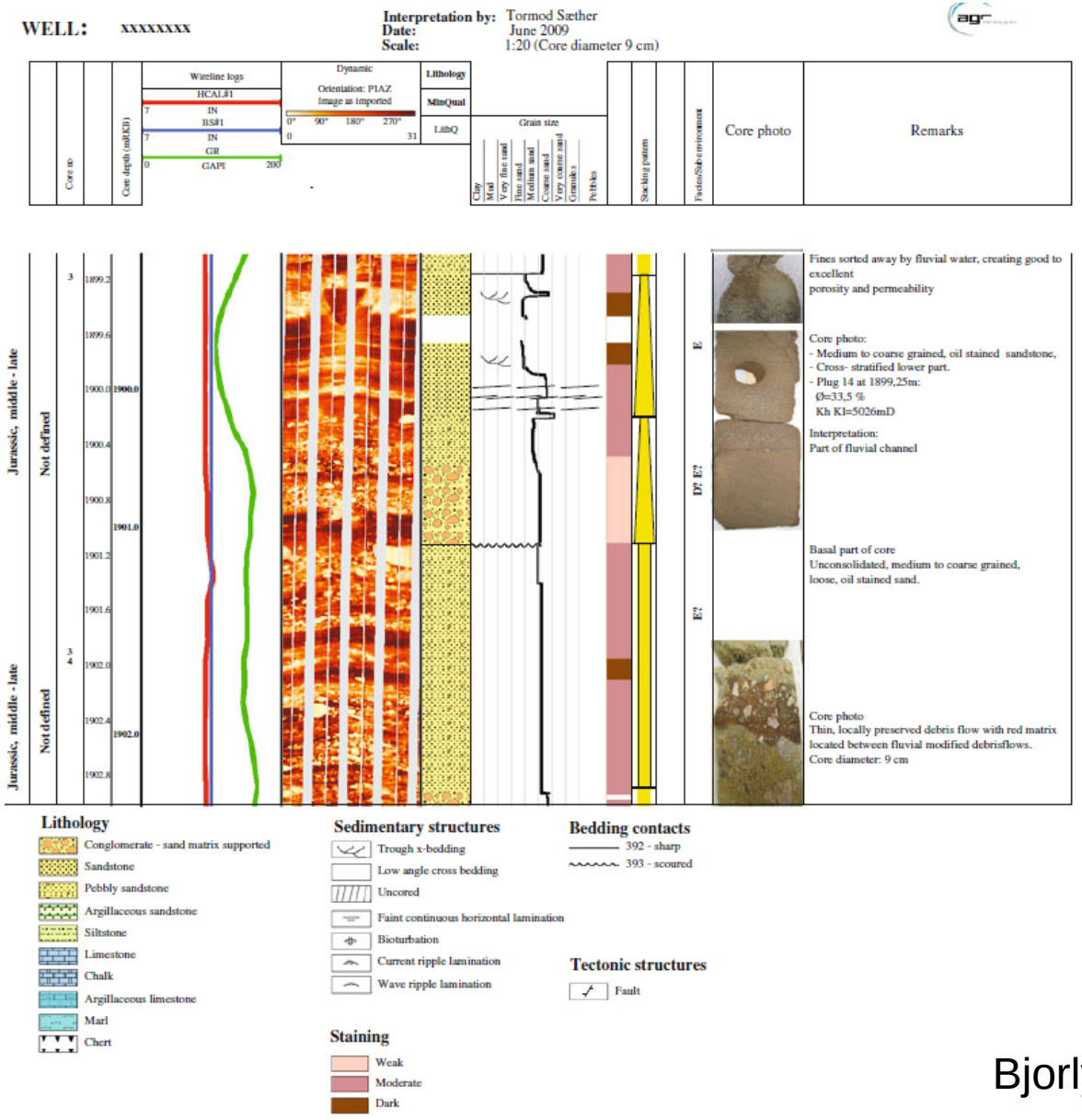
Image Logs

Bore hole images are pictures of the rocks from inside the well. Video cameras

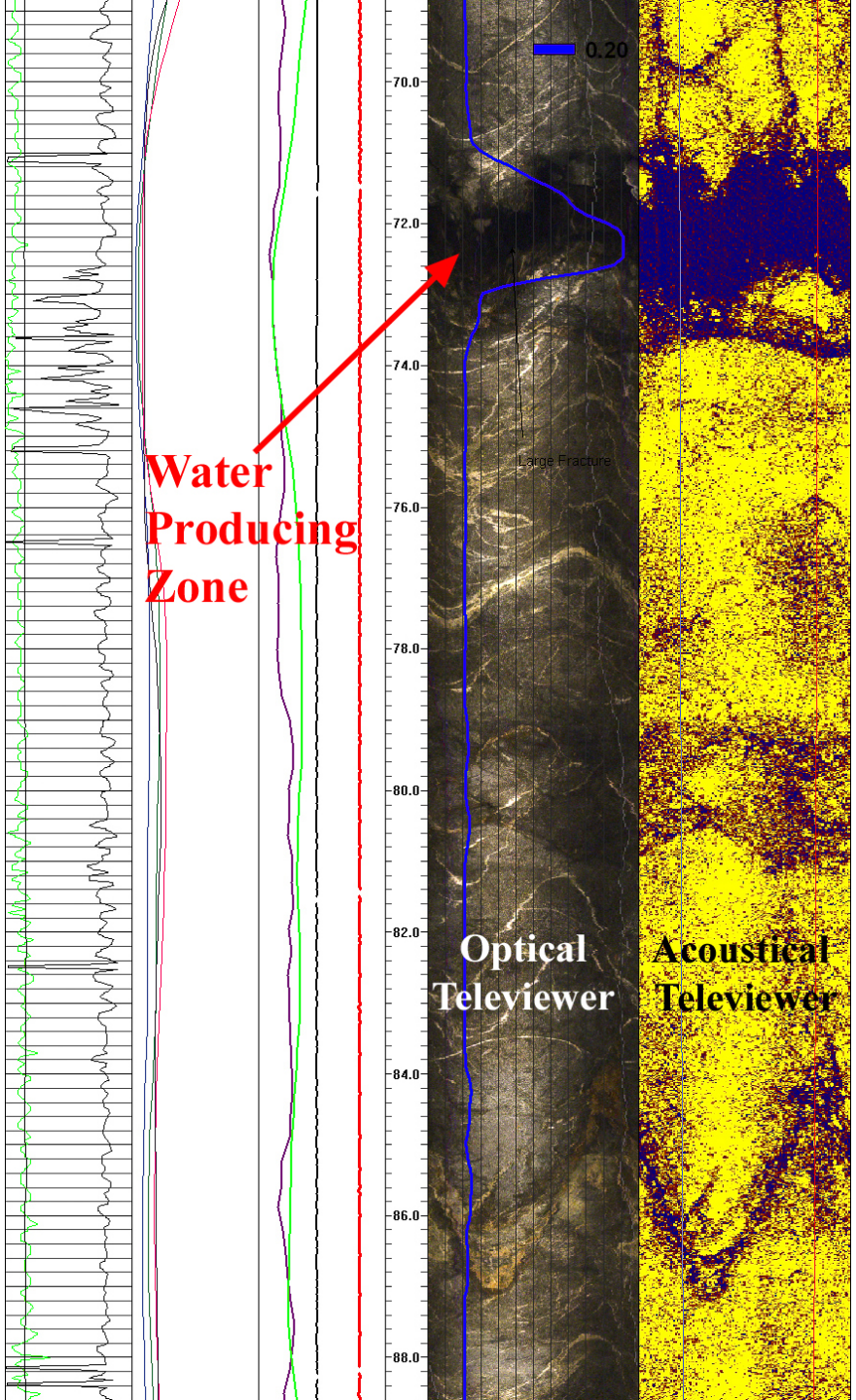
may record the **lamination** and **bedding**, and because they are oriented, **palaeocurrent** direction may be inferred. This method may be very useful recording

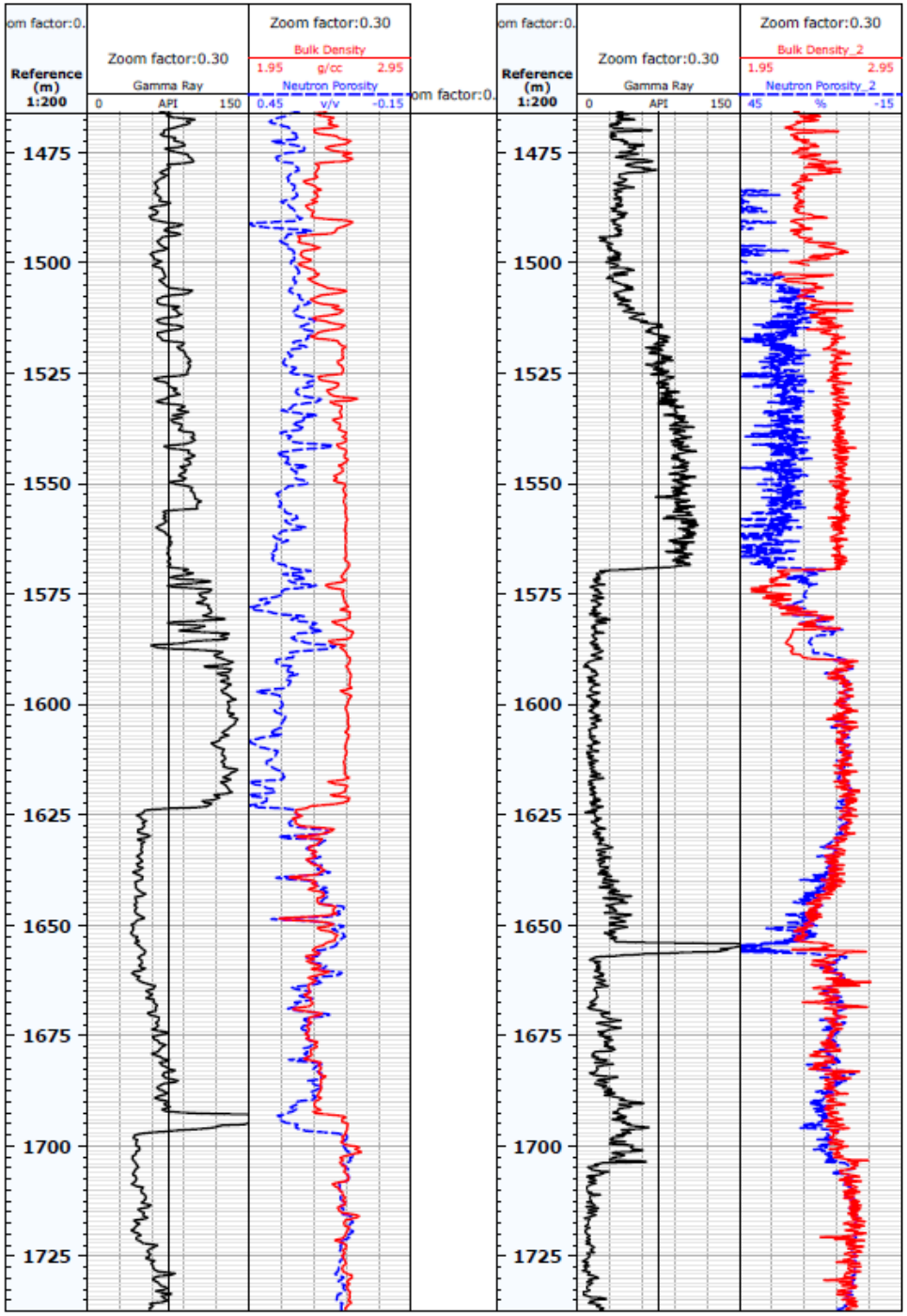
fractures and large **pores** (vugs).

Image logs with core description



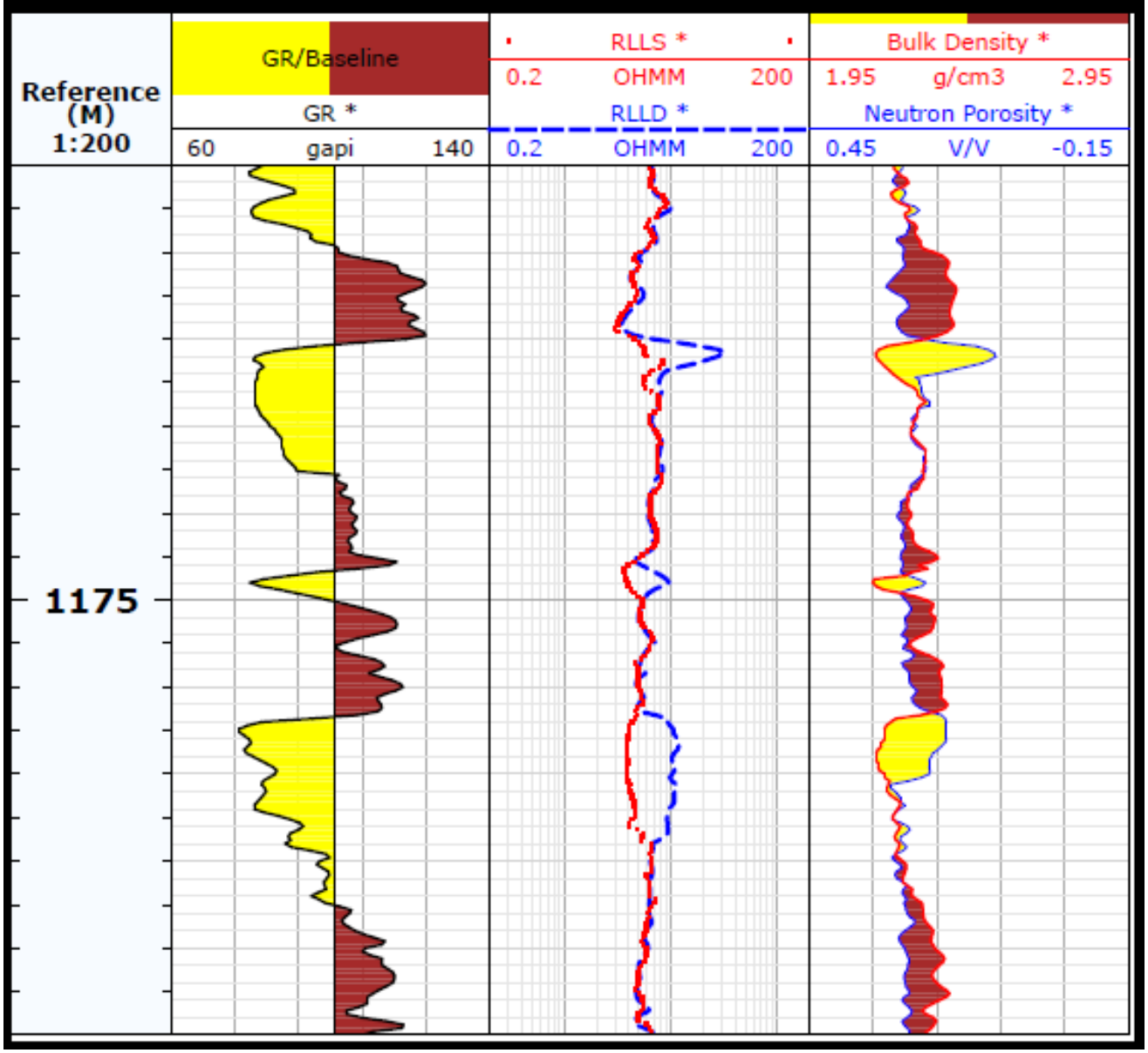
Bjorlykke 2010


0.20
70.0
72.0
74.0
76.0
78.0
80.0
82.0
84.0
86.0
88.0
Large Fracture
Water
Producing
Zone
Optical
Televiewer
Acoustical
Televiewer



Exercise 1

- With the help of the logs correlate the succession of the two wells.


Reference
(M)
1:200
GR/Baseline
GR *
60
gapi
140
RLLS *
0.2
OHMM
200
RLLD *
0.2
OHMM
200
Bulk Density *
1.95
g/cm3
2.95
Neutron Porosity *
0.45
V/V
-0.15
1175

Exercise 2.