भारतीय प्रौद्योगिकी संस्थान (भारतीय खनि विद्यापीठ) धनबाद

IIT ISM

INDIAN INSTITUTE OF TECHNOLOGY (INDIAN SCHOOL OF MINES) DHANBAD

GPC510 - Well logging

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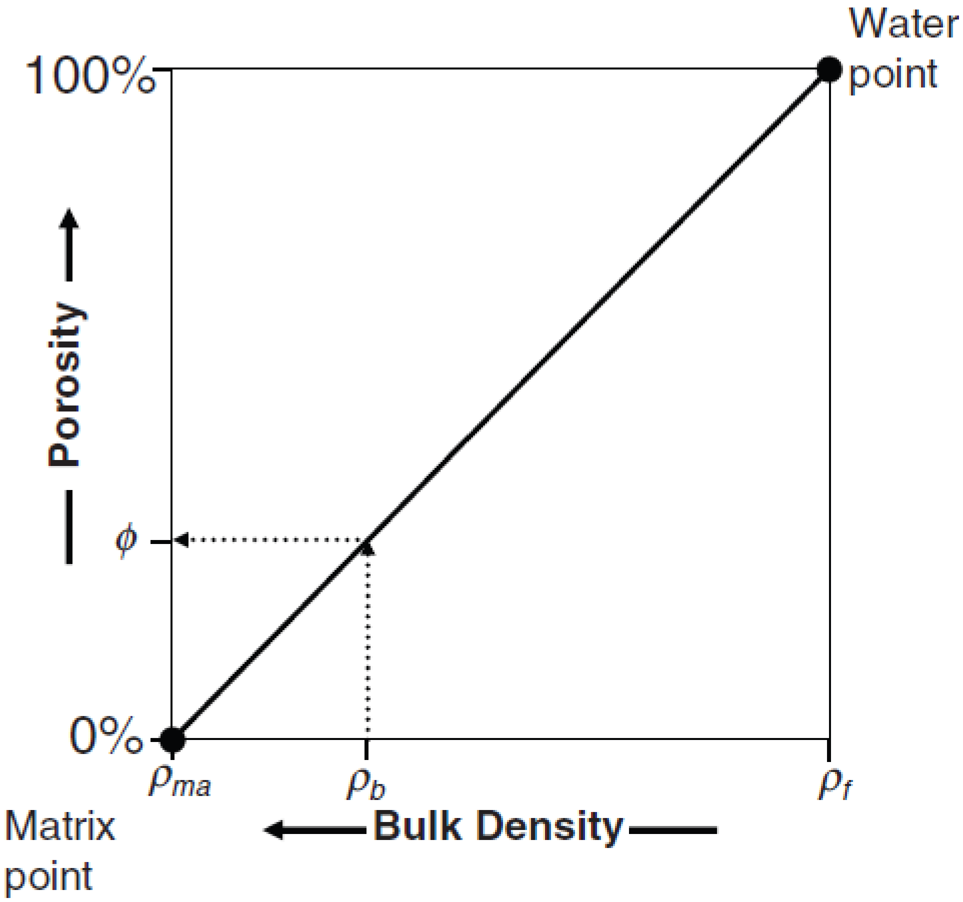
AGENDA

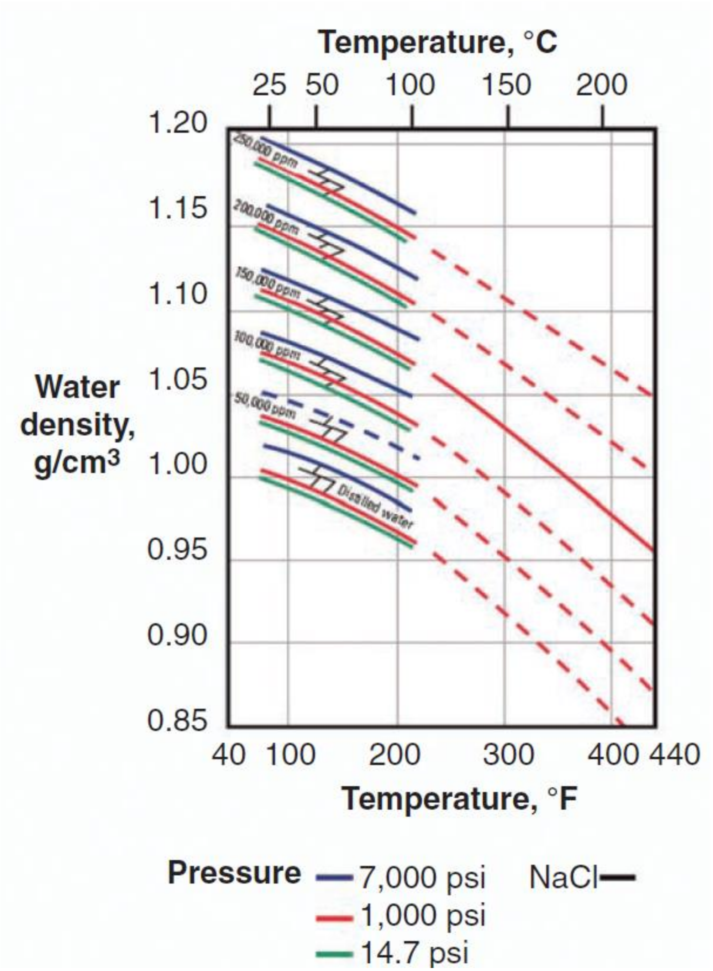
- Influencing factors on density log measurement
- Quality control
- Photoelectric effect (PE) log

DENSITY-POROSITY PLOT

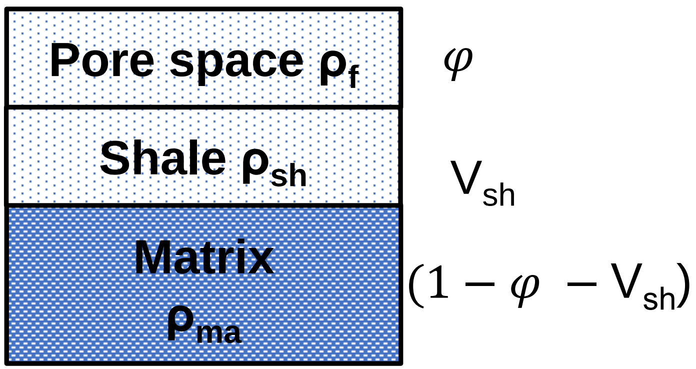


WATER EFFECT

- Porosity derivation assume clean matrix with water filled pore space
- Porosity estimation will be affected when the lithology is mixed, gas or hydrocarbon is present in the flushed zone or the pad loose contact with the wall in washed out zone
- Since the tool records density response close to the borehole wall where the mud filtrate flushed away most of the original fluids, the choice of ρ_f is dictated by mud-filtrate therefore linked with pressure , temperature and salinity



SHALE EFFECT



Rock = Solid matrix + Fluid filled pores;

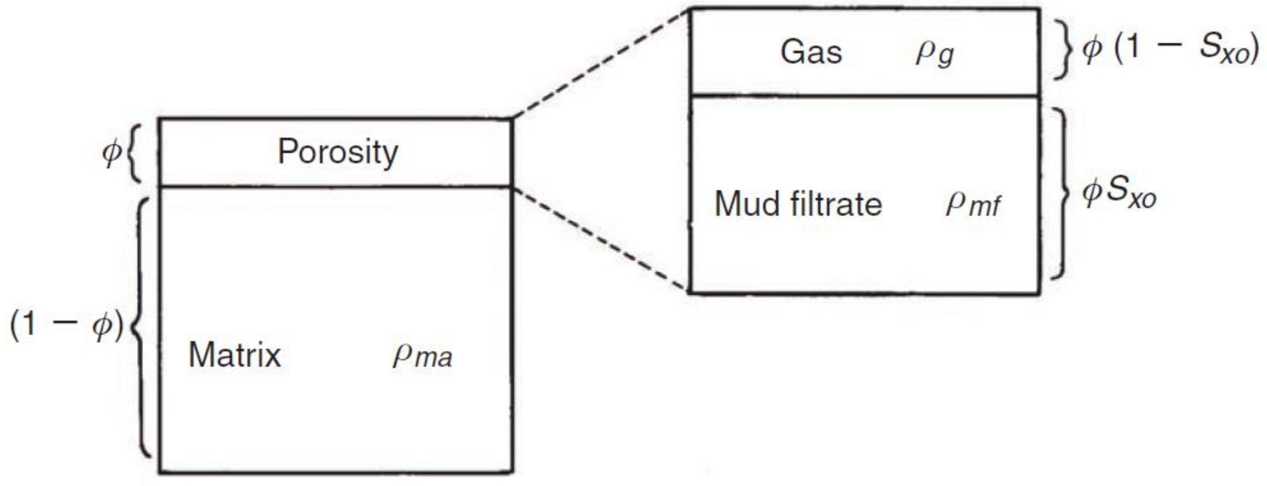
$$\varphi = \frac{(\rho_{ma} - \rho_b) - Vsh(\rho_{ma} - \rho_{sh})}{\rho_{ma} - \rho_f}$$

$$\varphi = \varphi_D - V_{sh}(\varphi_{Dsh})$$

Where V_{sh} and φ_{Dsh} represents volume of shale and apparent density porosity of shale respectively.

GAS EFFECT

- Porosity can be overestimated on the density log if gas is present in the formation as the density of gas is very low
- If the formation is gas bearing, then this may be a problem, because significant amount of gas is always left in the invaded zone
- To accurately quantify gas effect on density tool response, both gas saturation and effective density of gas (ρ_g) are known



GAS EFFECT

$$\rho_b = \rho_{ma}(1-\varphi) + \rho_{mf}\varphi S_{xo} + \rho_g\varphi(1-S_{xo})$$

$$\varphi = \frac{\rho_{ma} - \rho_b}{(\rho_{ma} - \rho_g) - S_{xo}(\rho_{mf} - \rho_g)}$$

By assuming $\rho_{mf} >> \rho_g$ and $\rho_{ma} >> \rho_g$, $\varphi \approx \frac{\rho_{ma}-\rho_b}{\rho_{ma}-\rho_{mf}*S_{xo}}$

- Following estimation of S_{xo} value, porosity can be calculated as

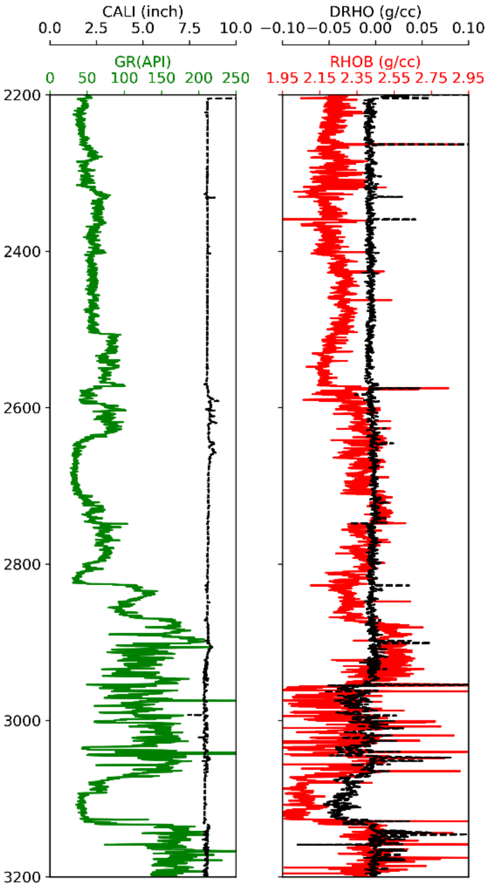
$$\varphi = \frac{(\rho_{ma}-\rho_b) + (\rho_{mf} - \rho_g)(\frac{R_{mf}}{R_{xo}})^{1/2}}{(\rho_{ma} - \rho_g)}$$

- This can be demonstrated for a sandstone rock with main mineral being quartz with a matrix density of 2.65 g/cm3 and a bulk density of 2.3 g/cm3. if the fluid content is incorrectly judged to be oil instead of gas, then the porosity will change from about 13% to 19%, an overestimation of around 6%

- A typical correction factor is **x 0.8**

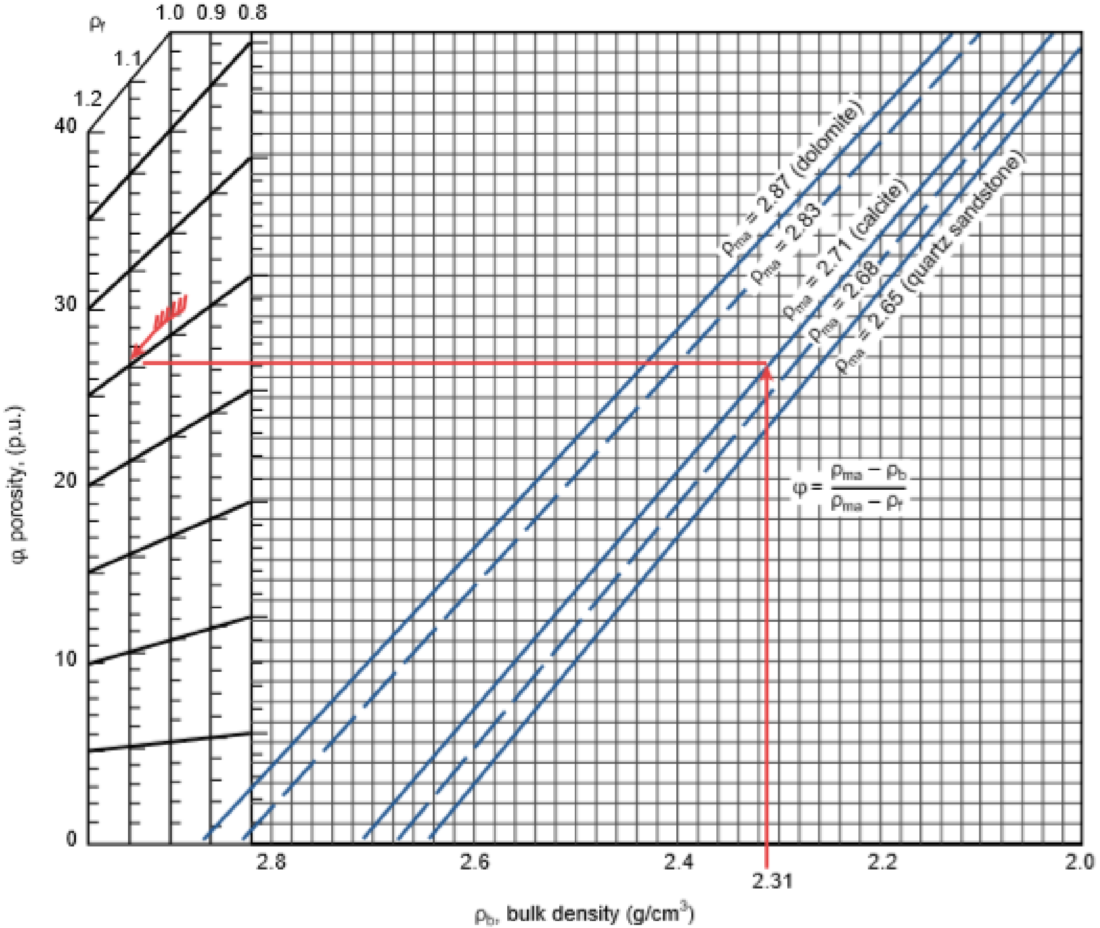
QUALITY CONTROL

- Correction log of density (DRHO) is an important QC
- DRHO within limits of ± 0.10 g/cm^3 is acceptable
- Required for generating acoustic impedance log ($AI = \rho_b * V_p$)



(Mandal, 2020)

DENSITY TO POROSITY CONVERSION



Example ρ_b = 2.31 g/cm^3 in limestone lithology
ρ_{ma} = 2.71 g/cm^3
ρ_f = 1.1 g/cm^3 (salt mud)
Porosity = ? pu
pu – porosity unit

(Schlumberger)

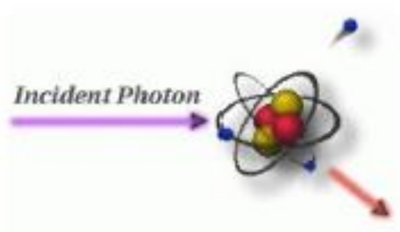
SUMMARY

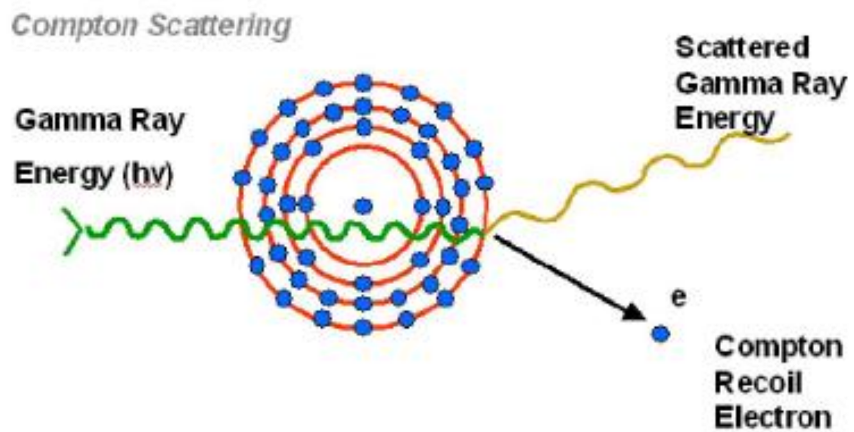
- Direct measurement: Bulk Density (ρ_b)
- Unit: g/cm3
- Indirect measurement:
  1. Total porosity
  2. Lithology Identification
  3. Fluid estimation
  4. Acoustic impedance (with sonic log)
  5. Mineral identification
- Equation: $\varphi = \frac{\rho_{ma} - \rho_b}{\rho_{ma} - \rho_{fl}}$

PRINCIPLES

Compton Scattering

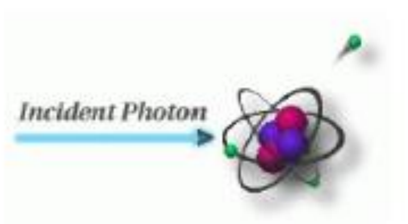
Depends on electron density

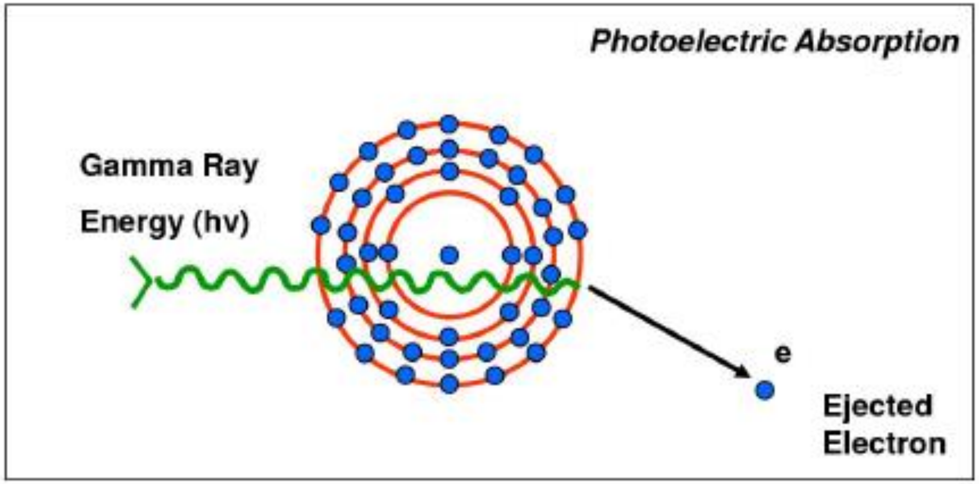




Photoelectric absorption

Depends on atomic number



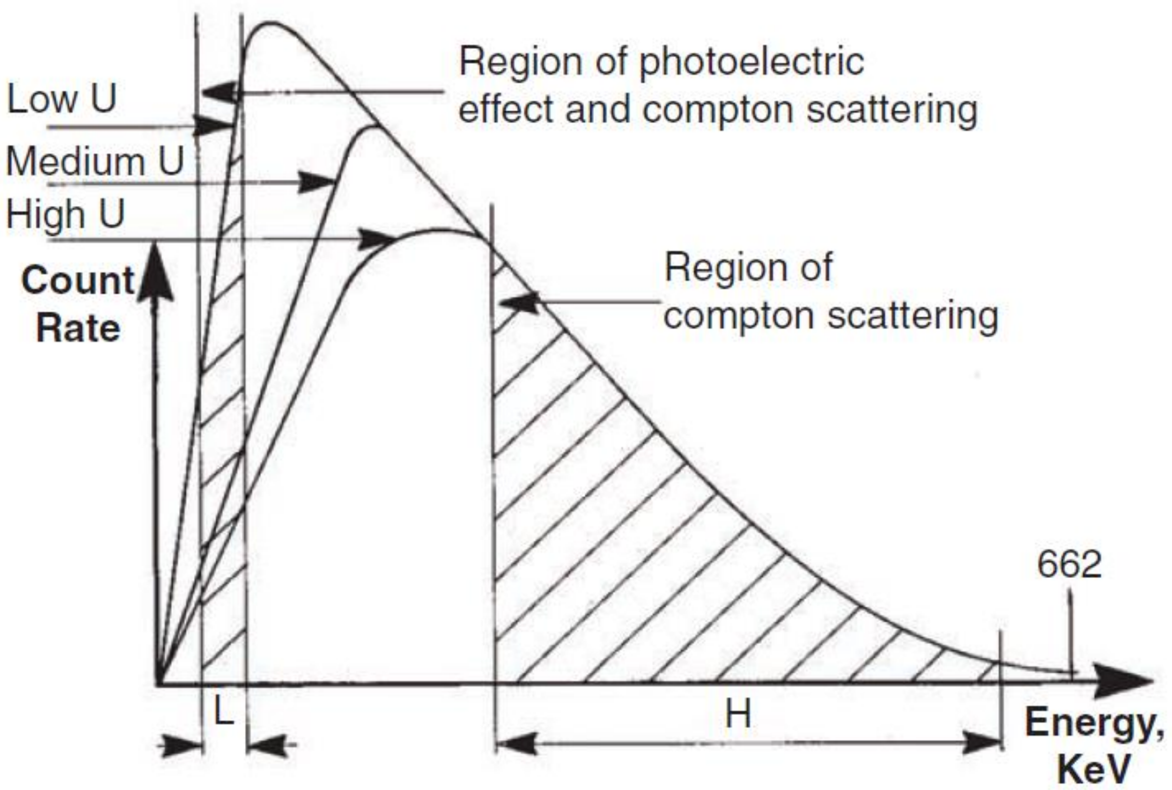


PHOTOELECTRIC EFFECT

- The photoelectric effect occurs when a gamma ray collides with an electron and absorbed in the process. Therefore, all energy transferred to the electron.
- The probability of this reaction depends upon incident gamma ray energy and the type of atom
- The litho-density tool measures photoelectric absorption index (P_e) along with bulk density
- P_e values increases with the increase of atomic number as

$$P_e = (0.1\ x\ Z_{eff})^{3.6}$$

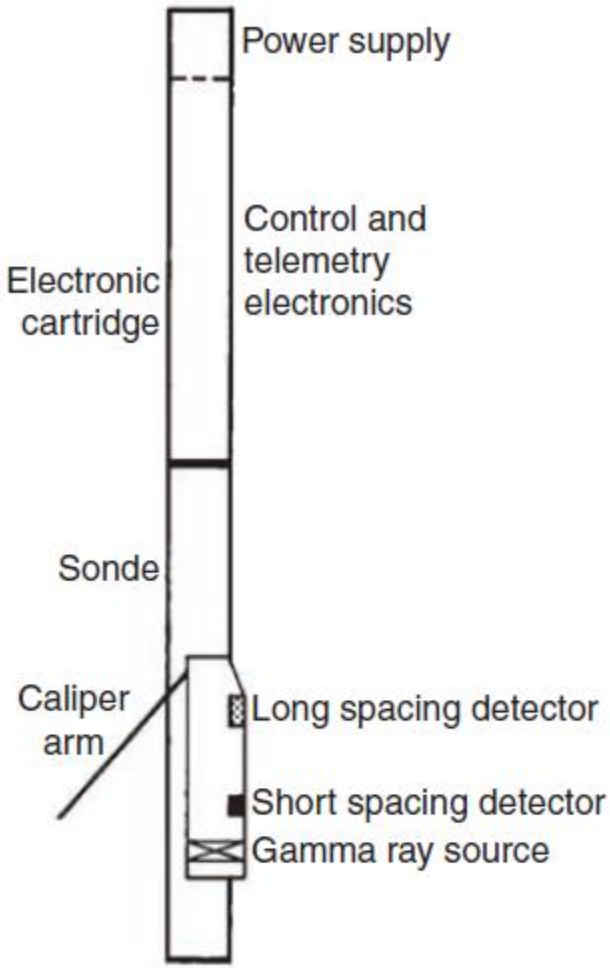
GAMMA-RAY SPECTRUM & PE VALUES

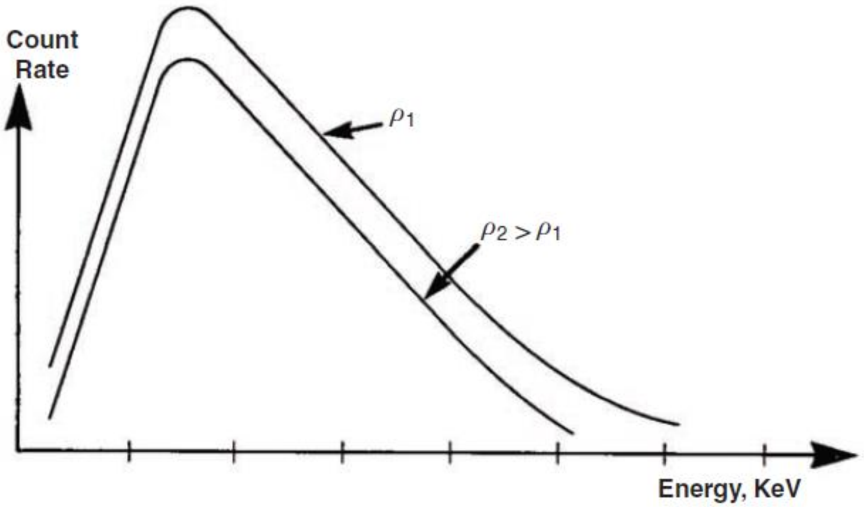


Gamma-ray response variation with constant density but different photoelectric capture cross-section

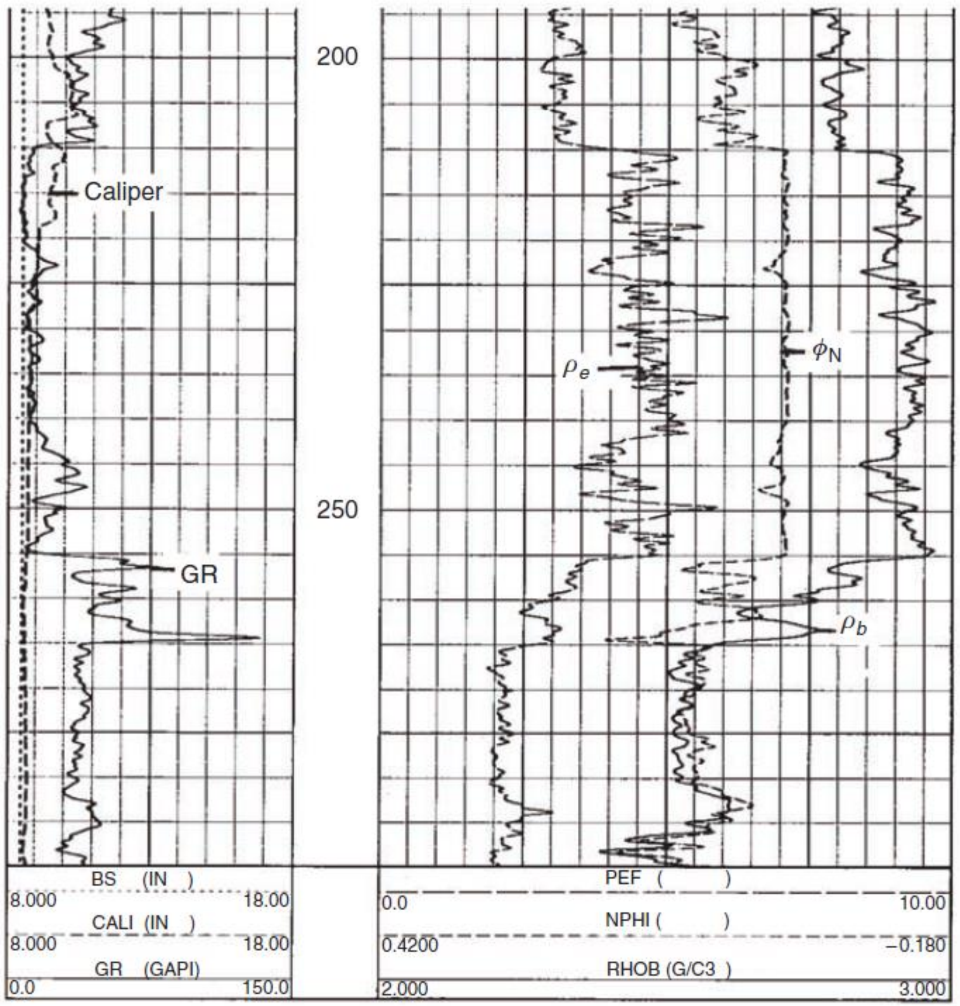
Bateman, 2012

LITHO-DENSITY TOOL



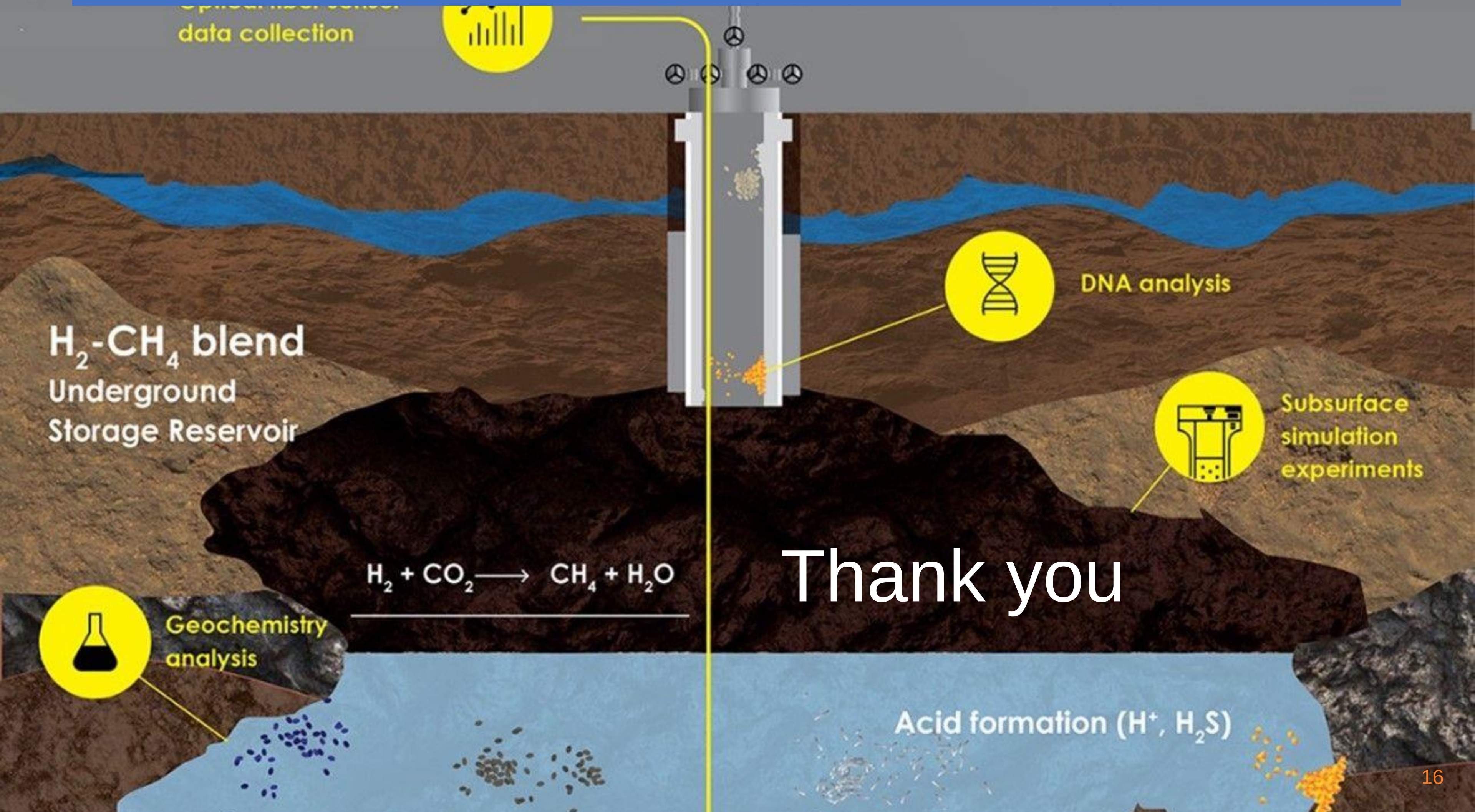


LITHOLOGY IDENTIFICATION



Material	P_e
Sandstone	1.81
Limestone	5.08
Dolomite	3.14
Salt	4.65
Anhydrite	5.05

END OF LECTURE



Thank you