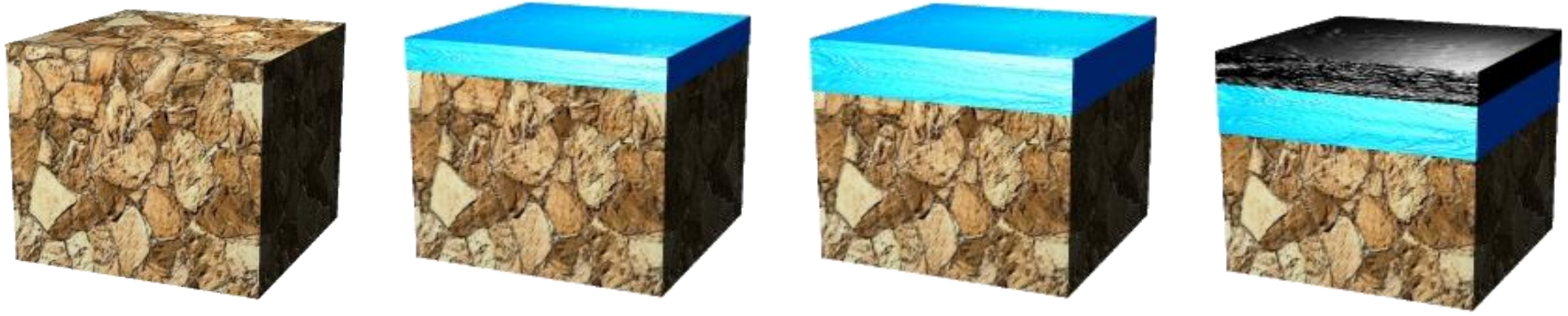
Density

Bulk Density: Applications

- The bulk density measurement is used to help determine:
  - Porosity
  - Lithology (in combination with the neutron tool)
  - Gas identification (in combination with the neutron tool)
  - Mechanical properties (in combination with the sonic tool)

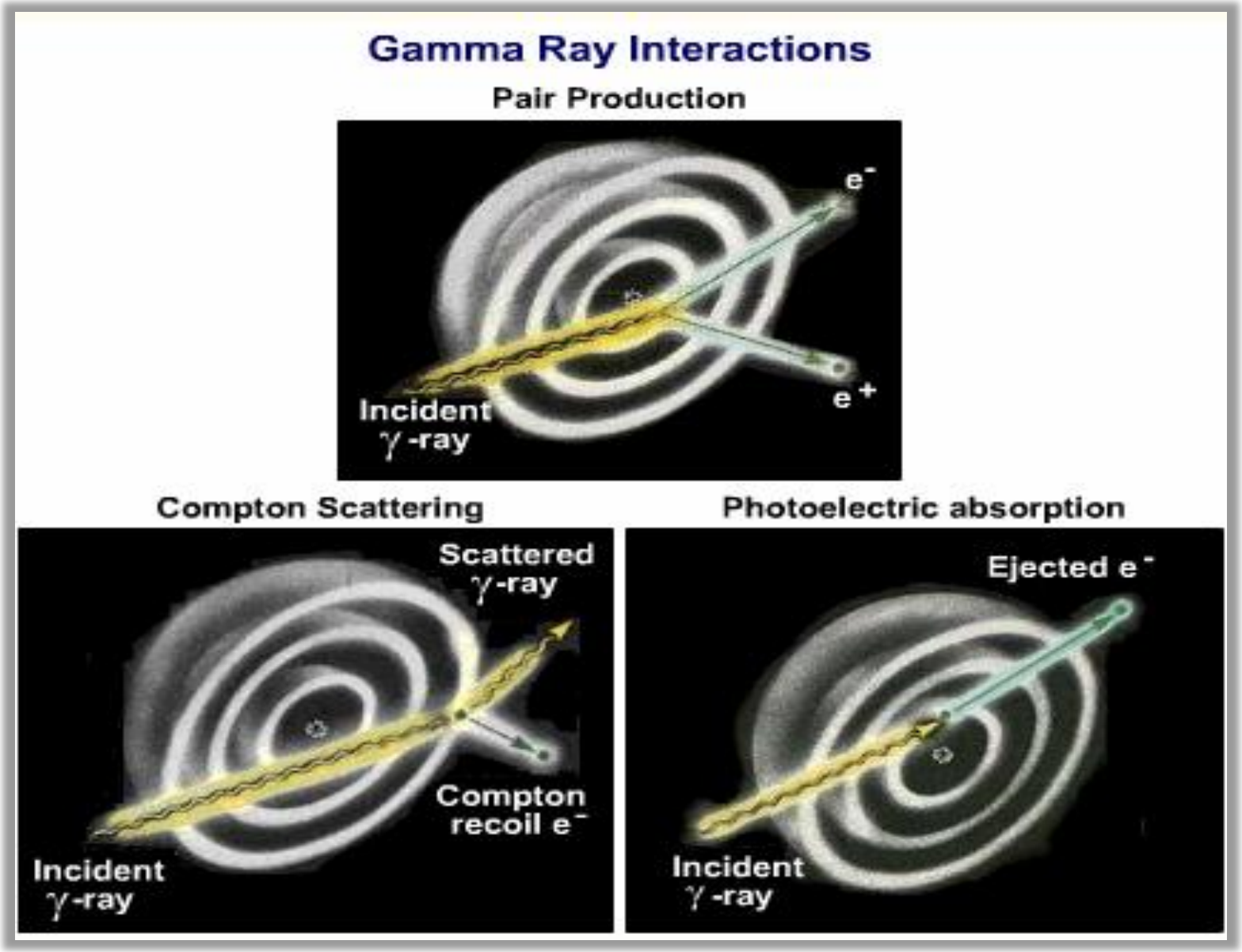
What is Density?



2650 Kg/m^3 > 2485 Kg/m^3 > 2320 Kg/m^3 > 2145 Kg/m^3

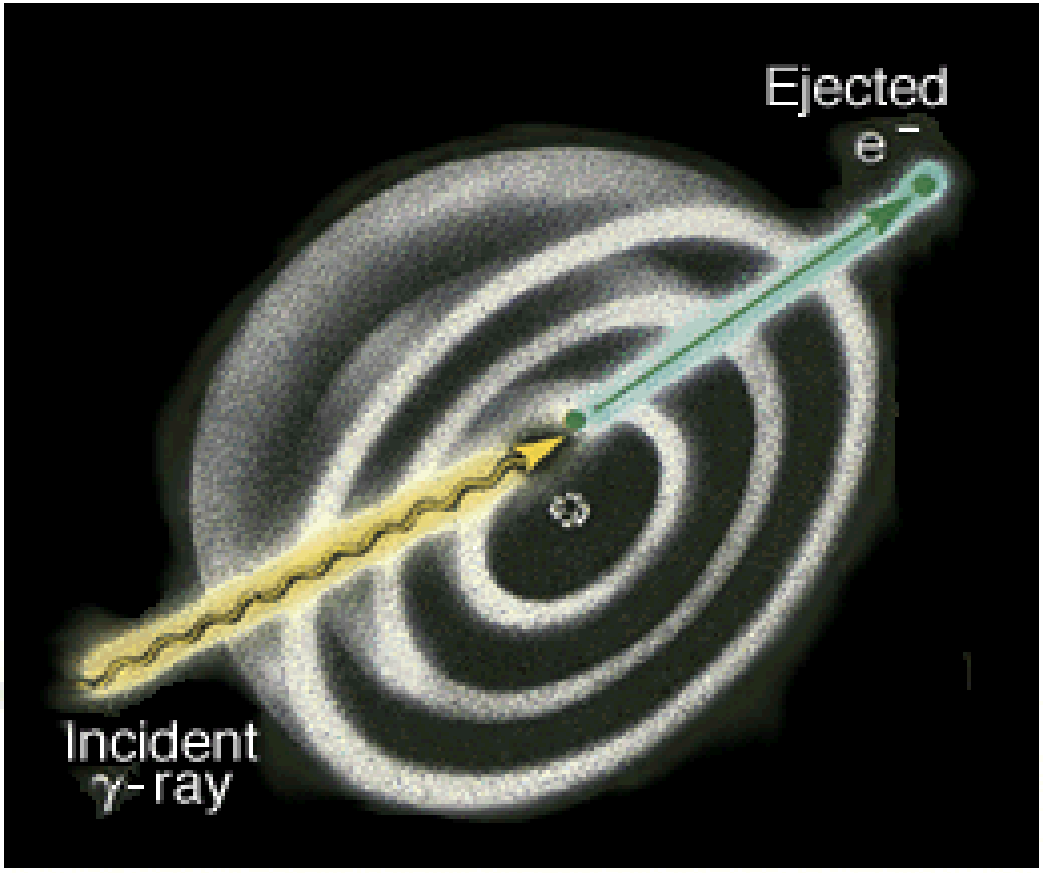
Density $\propto 1/\phi$

Gamma Ray Interactions



Photoelectric Absorption

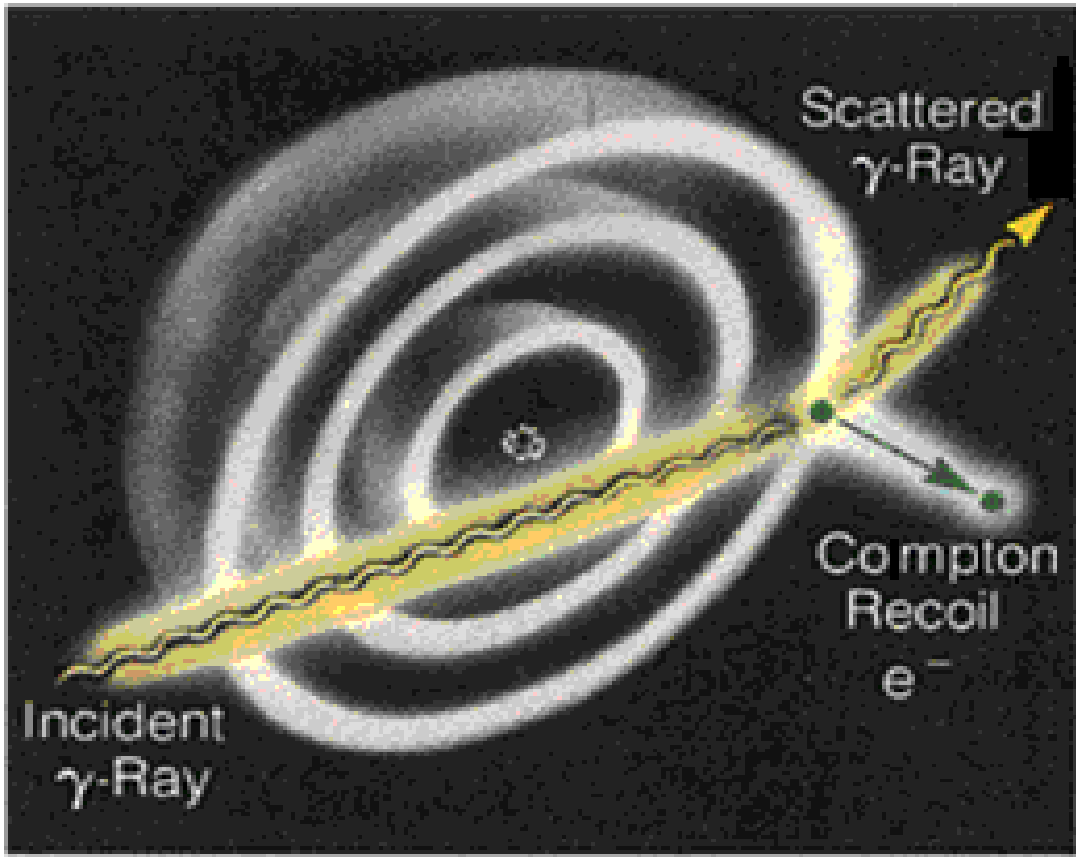
- SourSource: Low energy Event
- GR -ray is absorbed
- Electron ejected



- Used for PEF logging
- ce: Low energy Event
- GR -ray is absorbed
- Electron ejected
- Used for PEF logging

Compton Scattering

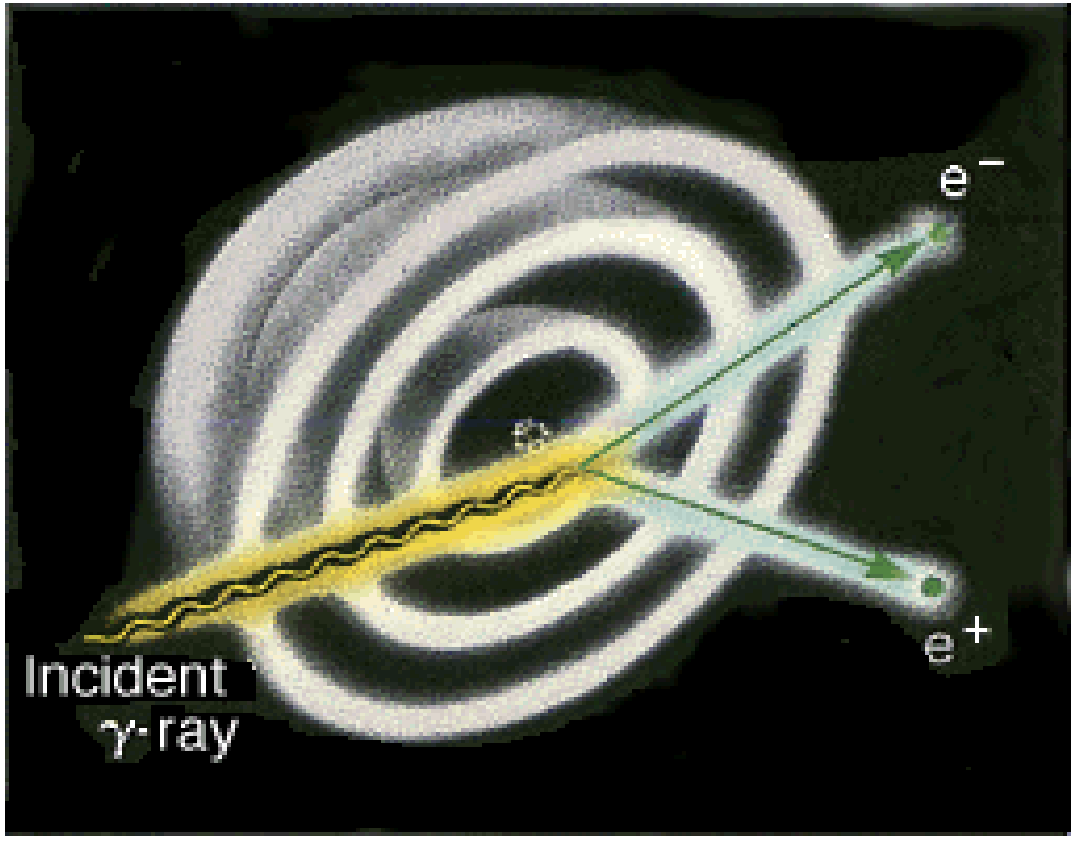
- Source: High energy Event
- GR -ray is scattered
- Electron recoil
- Used for density logging



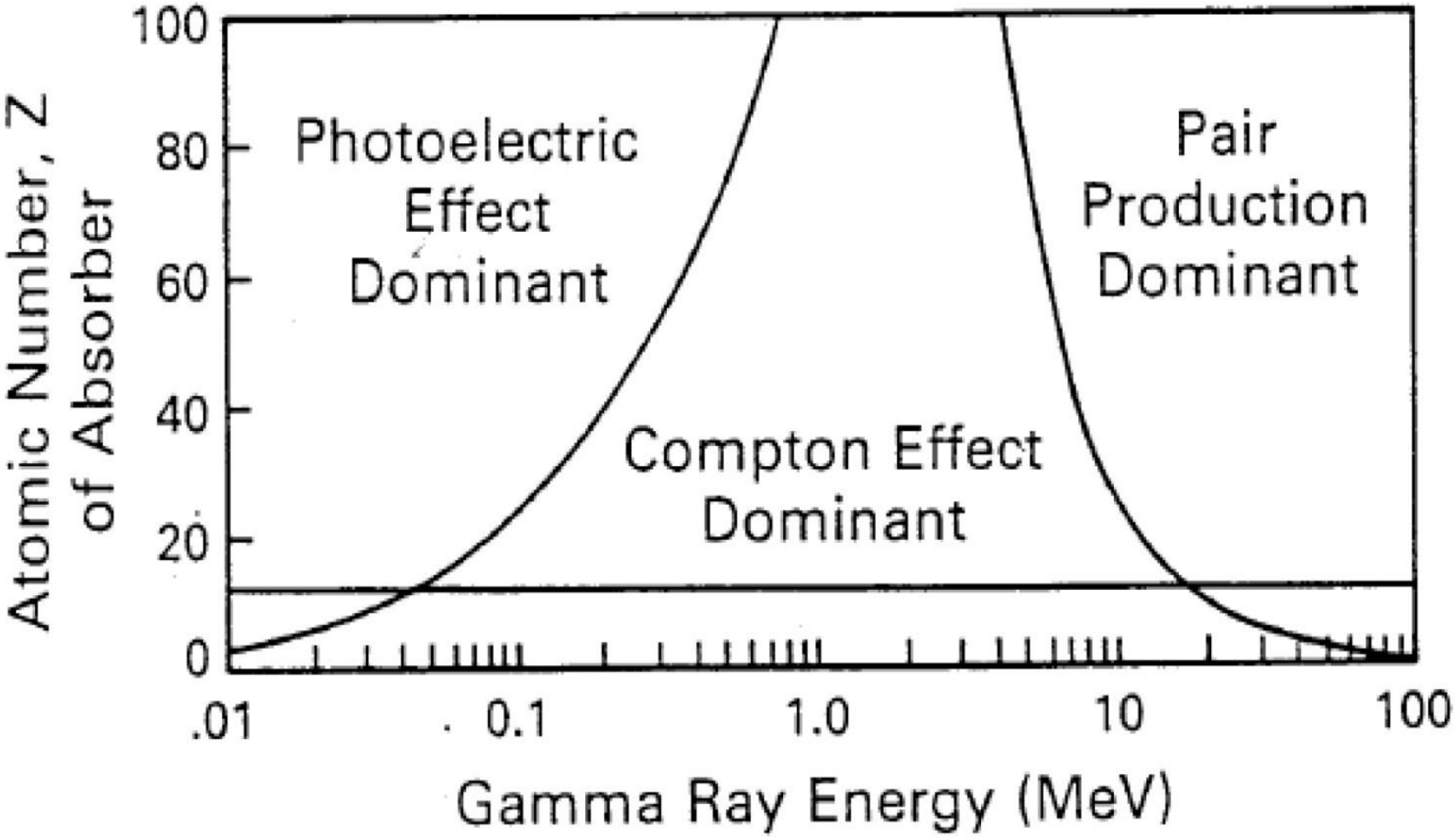
Compton Scattering occurs between about 75 keV – 10 MeV

Pair Production

- Source: Very high energy Event
- GR -ray is absorbed
- Electron & Positron produced
- Not used for logging



GR Energy


Atomic Number, Z of Absorber
100
80
60
40
20
0
Photoelectric Effect Dominant
Compton Effect Dominant
Pair Production Dominant
.01
0.1
1.0
10
100
Gamma Ray Energy (MeV)

Formation Density Measurement

- Electron density is converted to bulk density

Atomic weight (A)

- the mass of an atom (Protons + Neutrons)

Atomic number (Z)

- the number of electrons in a neutral atom

$$\rho_e = \rho_b * (2\,Z / A)$$

Most cases, $2\,Z / A = 1$

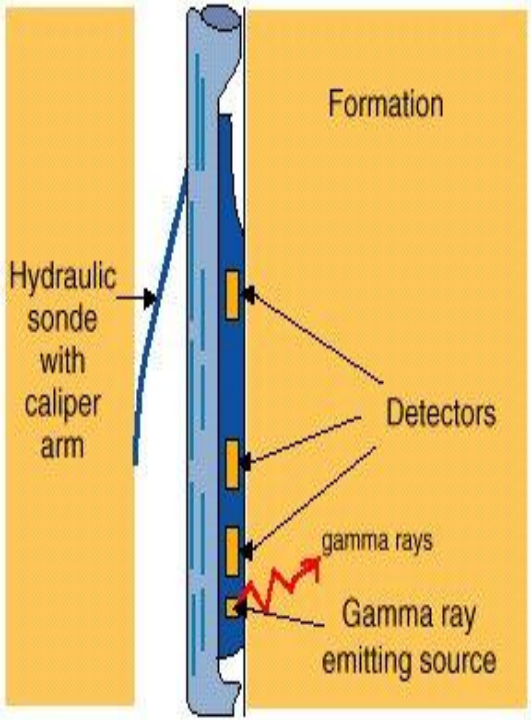
$$\rho_e = \rho_b$$

Bulk Density: measurement theory

- The number of gamma rays returning to the detector depends on the number of electrons present, the electron density, ρe.
- The electron density can be related to the bulk density of the minerals by a simple equation.

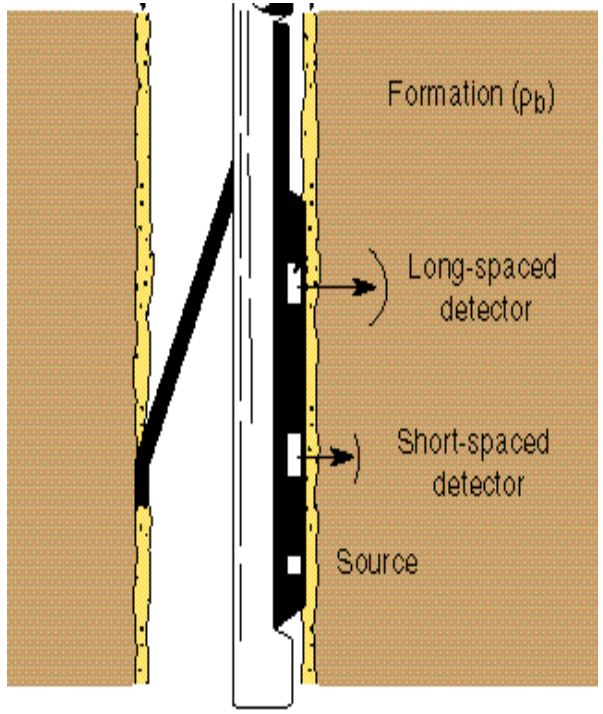
$\rho e = \rho(2Z/A)$

The Density Tools use a chemical gamma ray source and two or three gamma ray detectors.

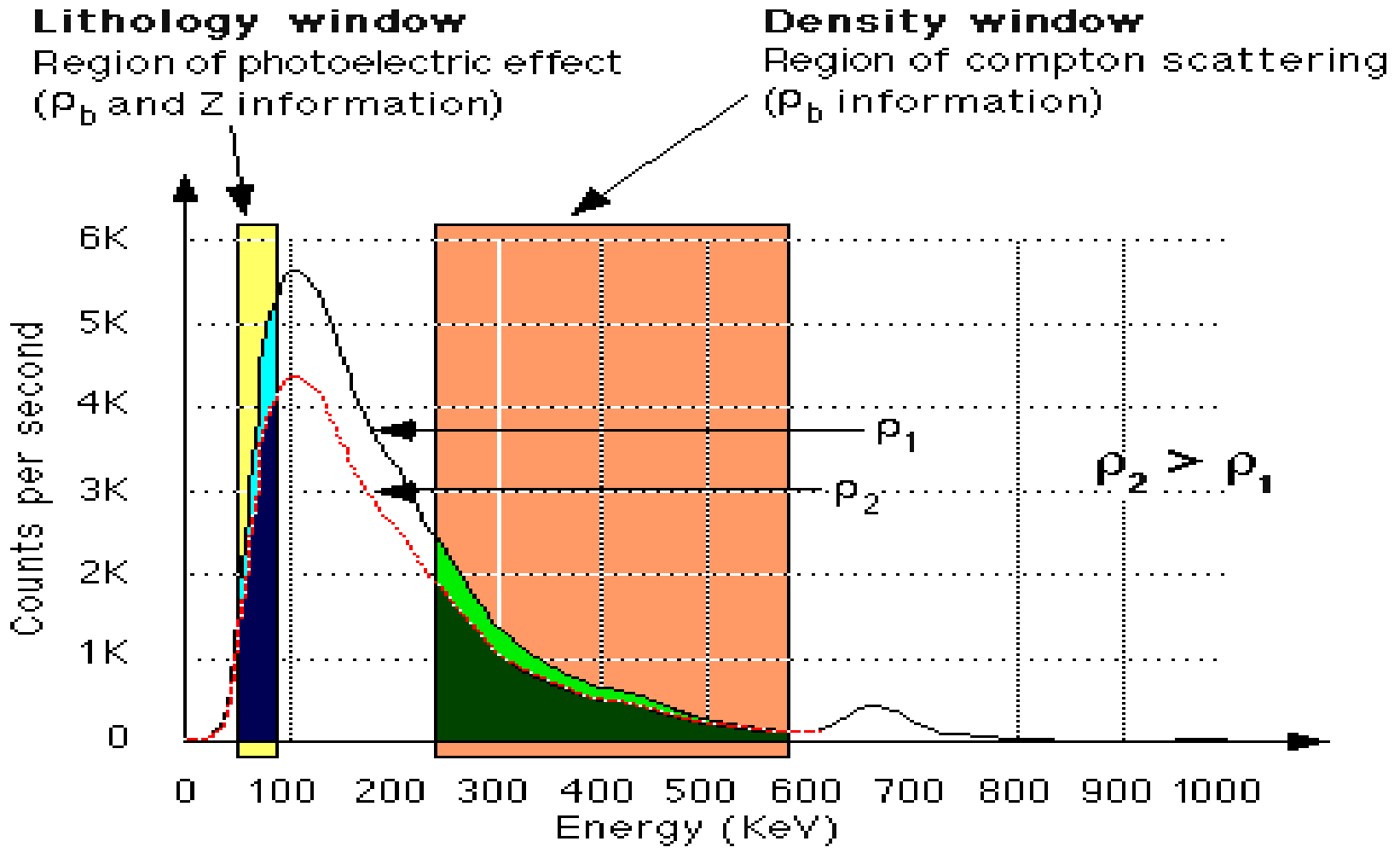


TLD

LDT & LWD



Bulk Density: measurement theory

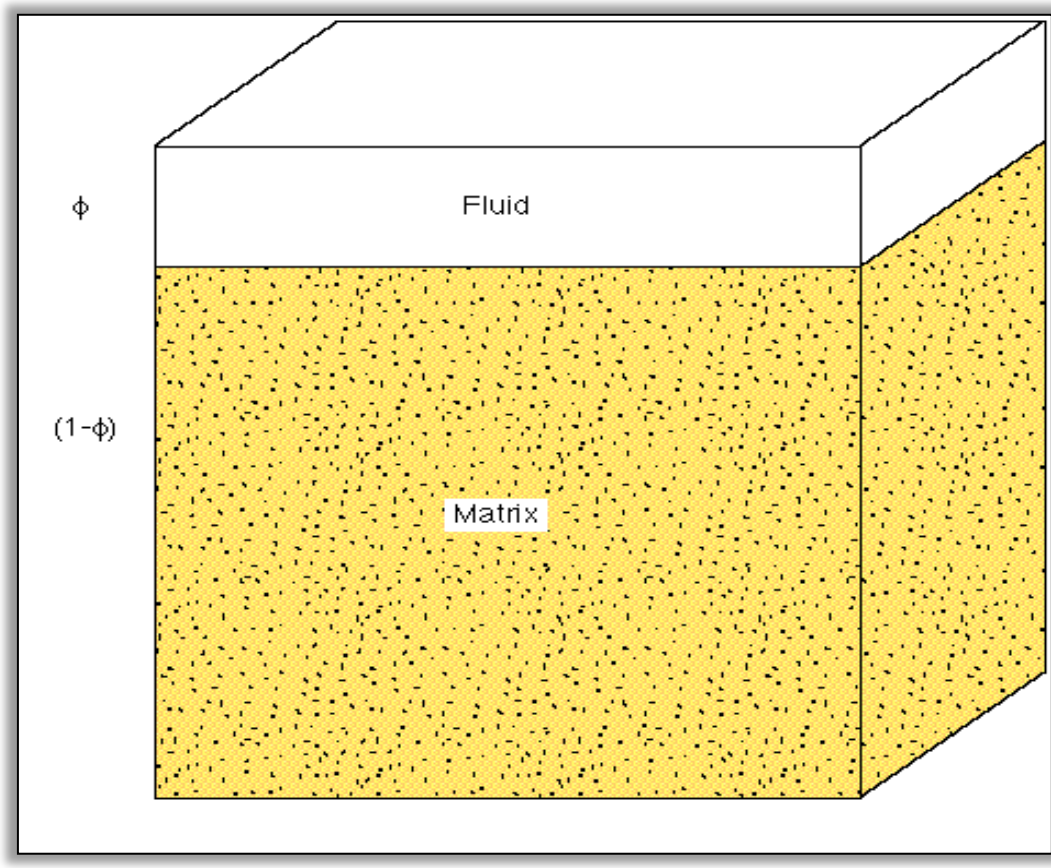


Porosity

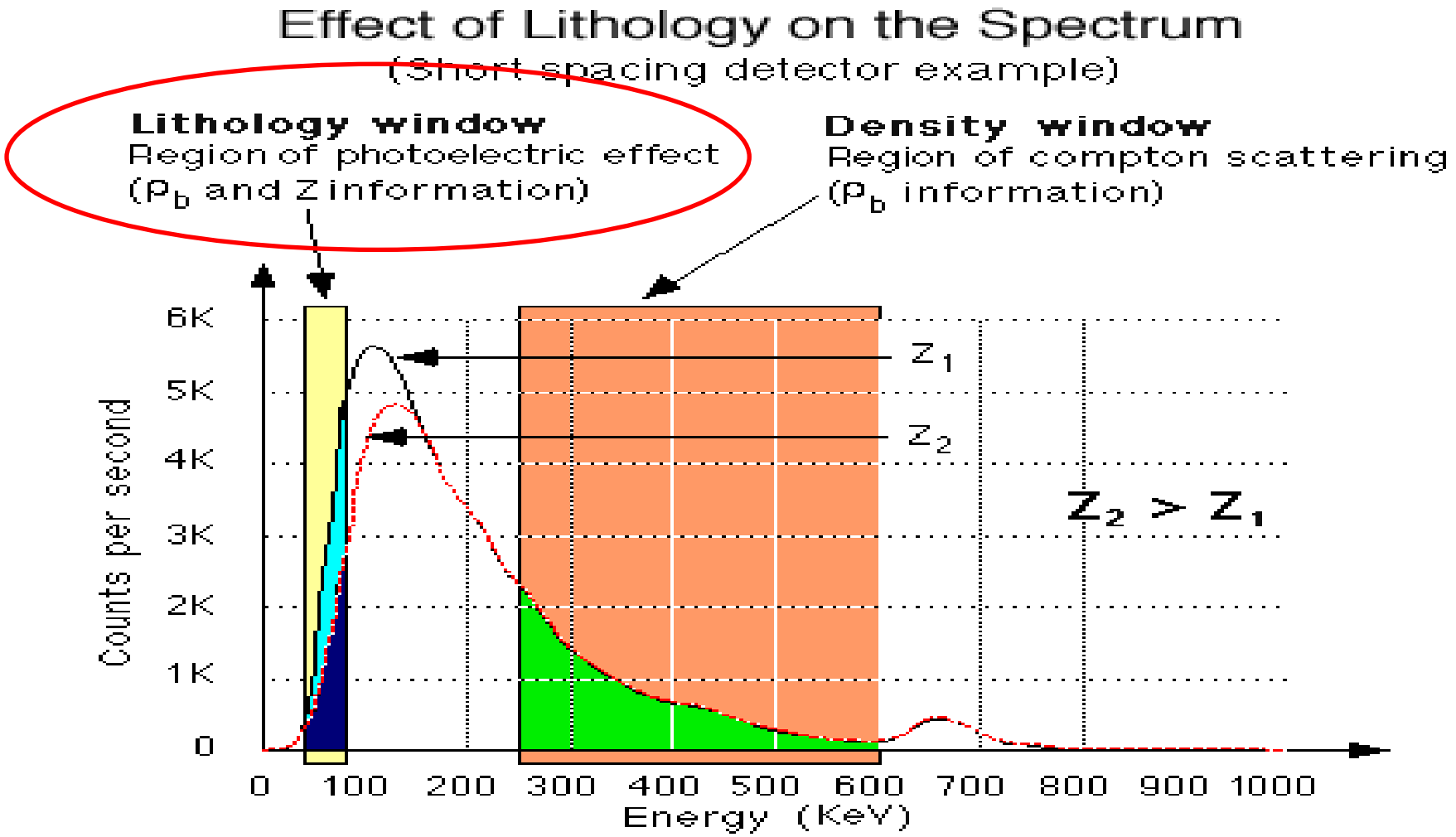
$$\rho_b = \rho_{ma}(1-\phi) + \rho_f \phi$$

ρ_b = bulk density (tool)
ρ_{ma} = matrix density (parameter)
ρ_f = fluid denity (parameter)

$$\Phi_D = \frac{\rho_{ma} - \rho_B}{\rho_{ma} - \rho_f}$$



PEF: Lithology measurmwnt

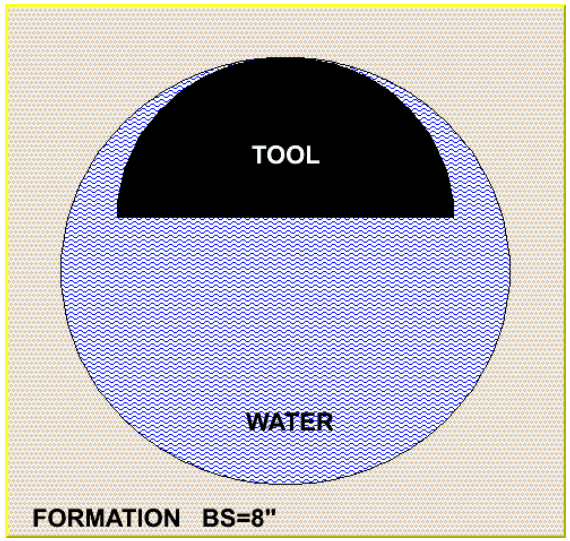


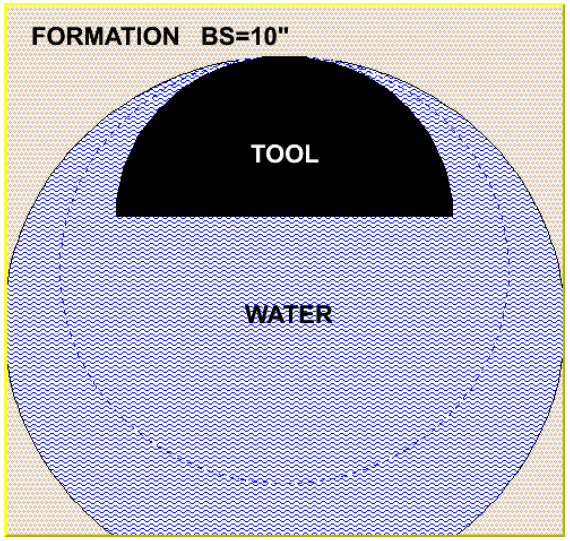
Density & PEF typical values

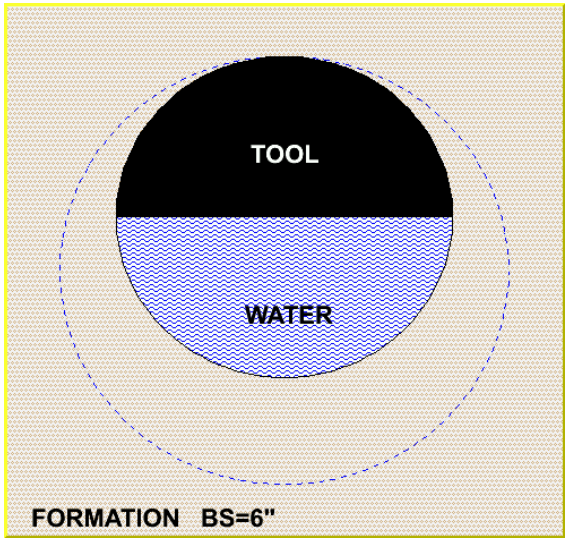
Formation	Density gm/cc	PEF
Sandstone	2.65	1.8
Limestone	2.71	5.1
Dolomite	2.81	3.1
Anhydrite	2.98	5.1
Salt	2.03	4.6
Shale	2.1 – 2.8	1.8 – 6.3

Density: Environmental Corrections

- **Hole size**
- Mud Weight
- Barite

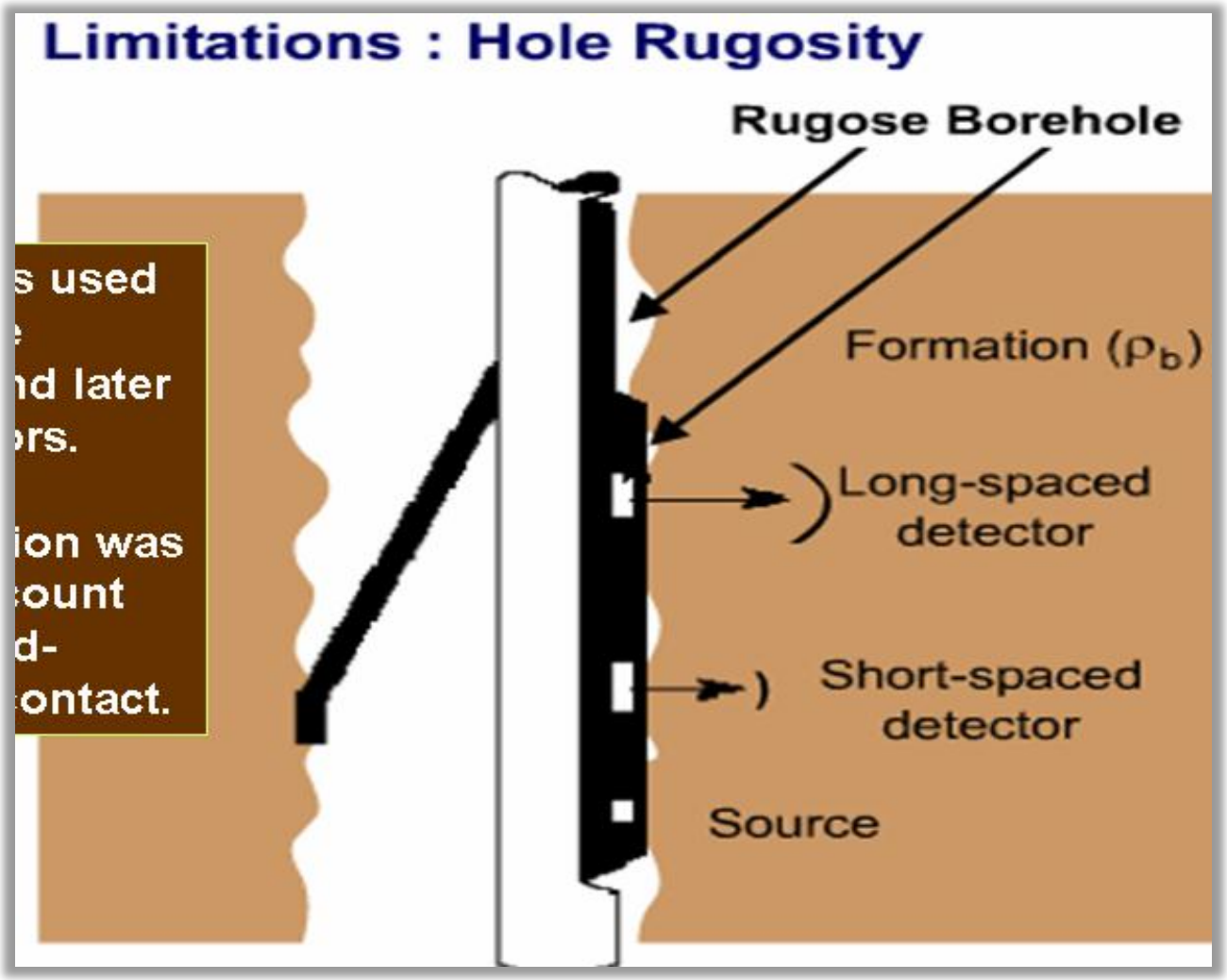






Density: Log Quality Control – hole conditions

- Hole Rugoses affect Density reading



Density: LQC – Barite Effect