भारतीय प्रौद्योगिकी संस्थान
(भारतीय खनि विद्यापीठ)
धनबाद

IIT ISM

INDIAN INSTITUTE OF TECHNOLOGY
(INDIAN SCHOOL OF MINES)
DHANBAD

GPC510 - Well logging

Semester - Winter 2024; Lecture - 8

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TEACHING OUTLINE

Week 4

Tutorial 10 – Water saturation, Archie's equation

Tutorial 11 – Capillary pressure, water saturation

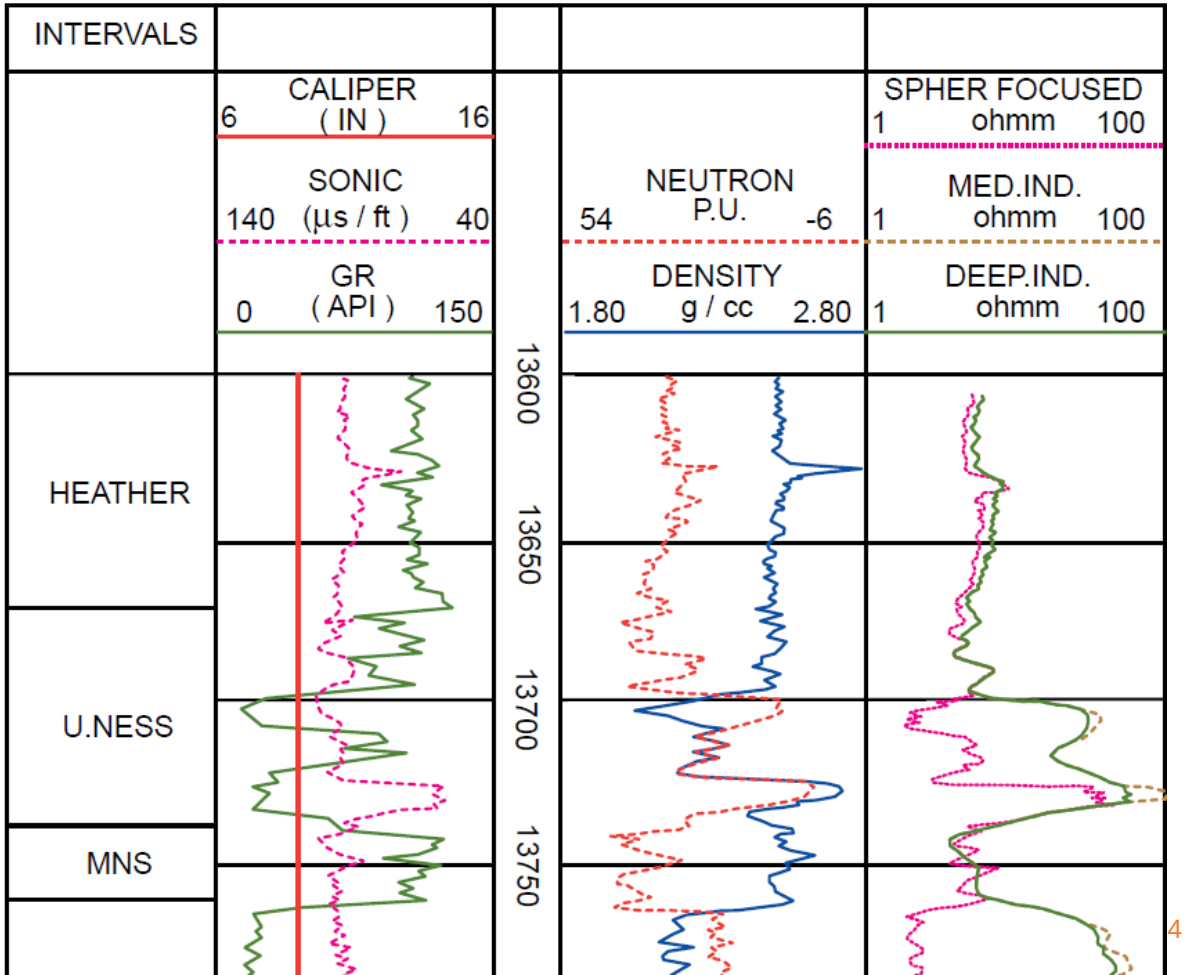
Tutorial 12 – Logging tools, natural gamma ray measurement

AGENDA

- Key logging tools
- Natural Gamma ray measurement

KEY MEASUREMENT TOOLS

- Caliper – borehole diameter
- Gamma ray – radioactive response
- Density – rock density
- Neutron – evaluation of porosity
- Sonic – acoustic wave travel time
- Resistivity – resistivity of rock



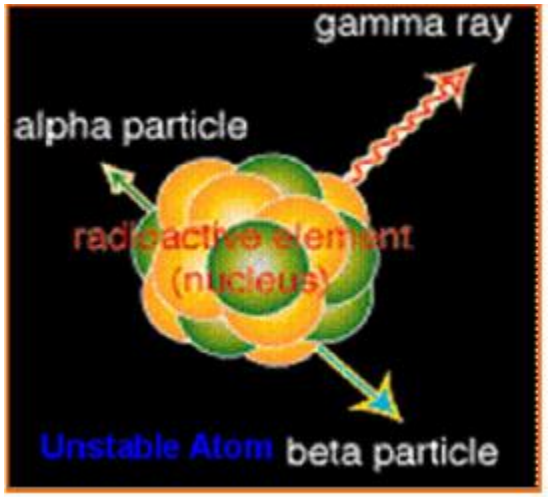
GAMMA RAY (GR) LOG

Natural gamma radiation is one form of spontaneous radiation emitted by certain unstable atomic nuclei. The main applications of the tool is as follow:

- Determination of reservoir thickness
- Identify rock type / lithology (sandstone, shale, limestone, dolomite, base metal, gold exploration etc)
- Multi-well stratigraphic correlation (spatial variation)
- Volume of shale estimation

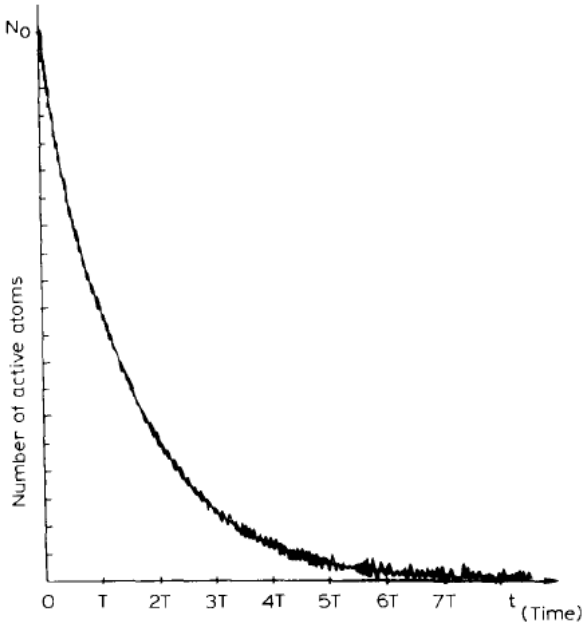
GAMMA RADIATION

- Gamma rays are electromagnetic radiation (high frequency range between 10^{19} to 10^{21} Hz) emitted from an atomic nucleus during radioactive decay
- Gamma ray emission corresponds to change from one state to lower energy state with release of a photon of energy hv. The energy difference between two states related to wavelength as $E = hv = \frac{hc}{\lambda}$ [c = the velocity of light, h = Plank's constant , 6.626 x 10^{-34} joule s
- Energy of the gamma rays are expressed in multiple of electron-volts (eV) , KeV or MeV



RADIOACTIVE DECAY

- Decay of radioactive atom consists of emission of different radiations and heat helping to reach lower state then finally reaching to a stable state, statistical driven process.
- Decay is defined in terms of half-life $T_{1/2}$ where decay constant λ_d is linked with $T_{1/2}$ as $T_{1/2}\lambda_d = 0.693$
- Half-life can be defined in years, days, hours, minutes, etc



Serra, 1985

NATURAL RADIOACTIVITY IN ROCKS

- Three main radioisotopes [Potassium ^{40}K, Uranium ^{238}U, Thorium ^{232}Th] are the main source of decay and substantial amount of gamma emission
- Source mineral of potassium are alkali potassic feldspar and micas plus a large number of minerals of minor importance
- Shale, certain carbonates, coal, igneous rocks [granite, rhyolite],

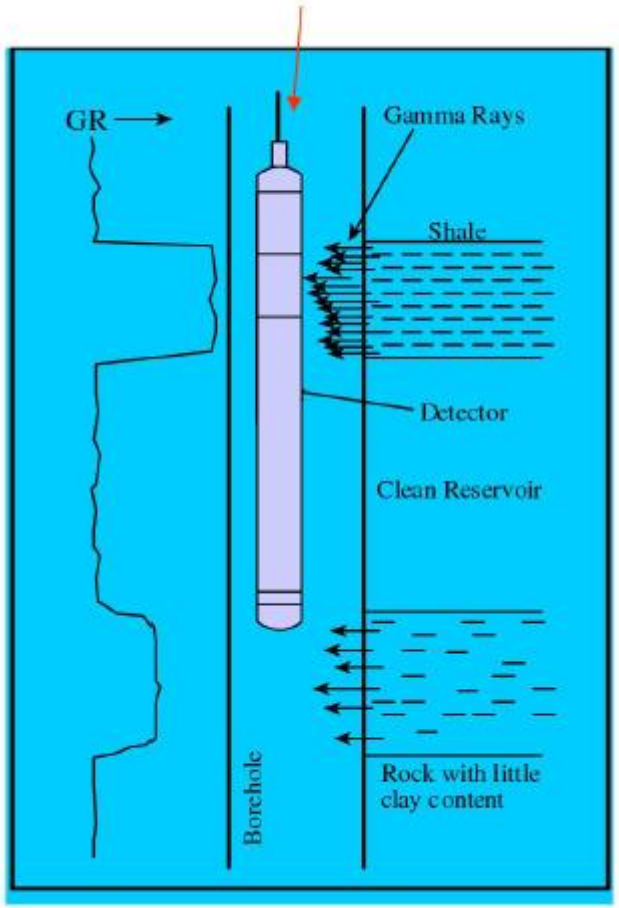
Main radioactive elements

Element	Isotope	Percentage of the total element %	Emissions			Half life (year)	Relative abundance in Earth's crust (ppm)
			α	β	γ		
Primeval natural gamma-ray emitters							
Potassium	^{40}K	0.0118		1	1	1.3×10^9	2.5 [c]
Uranium [d]	^{235}U	0.72	8 [d]	5 [d]	[a]	7.1×10^8	0.02
Secondary gamma-ray emitters by their daughters							
Uranium series	^{238}U	99.27	8 [d]	6 [d]	[b]	4.5×10^9	3
Thorium series	^{232}Th		7 [d]	5 [d]	[b]	1.4×10^{10}	12

[a] Gamma ray emitter by itself and its daughters. [b] For more detail see Fig. 6-4. [c] From Krauskopf (1967): Introduction to Geochemistry. McGraw Hill, New York. [d] From Adams and Gasparini (1970).

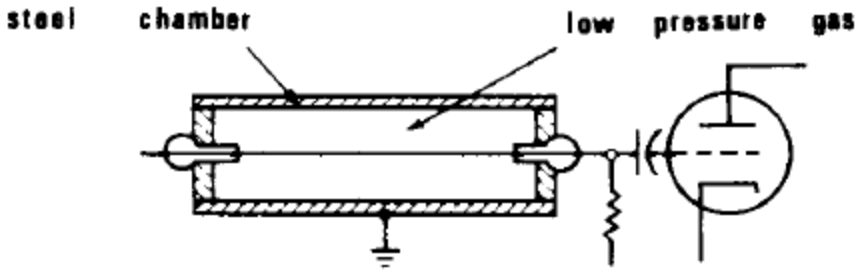
MEASUREMENT TOOL PRINCIPAL

- Gamma ray tools consist of a gamma ray detector and the associated electronics for passing the gamma ray count rate to the surface
- The tool records the count rate of the gamma emissions from rock formations adjacent to the borehole
- Gamma emissions are coming from natural radioisotope contained in rock matrix
- The standard GR tool measures total radioactivity
- Clean formations have minimal amount of natural radioactivity
- Units of measurement is API



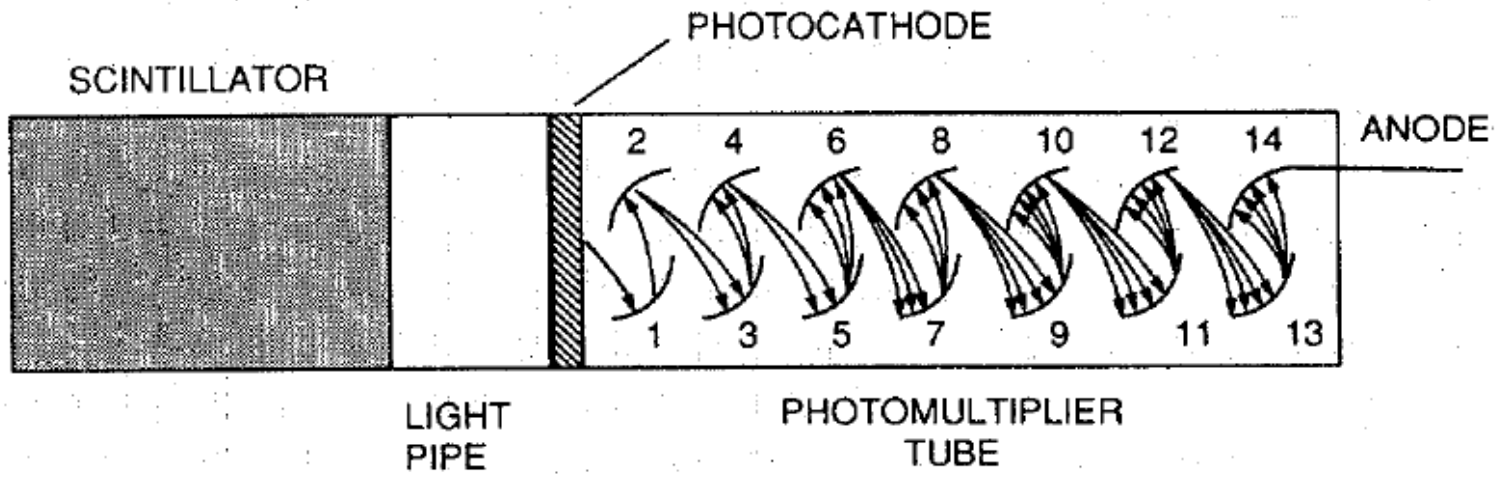
MEASUREMENT TOOL

- Few systems are available to measure total gamma radiation (i) Geiger-Mueller counters (ii) Ionization chambers (iii) **Scintillation counters**



- A metal chamber with a central wire maintained at a positive potential relative to the cylindrical chamber wall. The chamber contains gas (argon, helium, or neon) at a low pressure.
- Incident gamma rays cause the ejection of electrons from the detector wall into the gas. As the ejected electron is drawn towards the highly charged central wire, other collisions occur between each electron and gas atoms, thus producing additional electrons which in turn cause additional ionization by collision.

GR DETECTOR - SCINTILLATOR

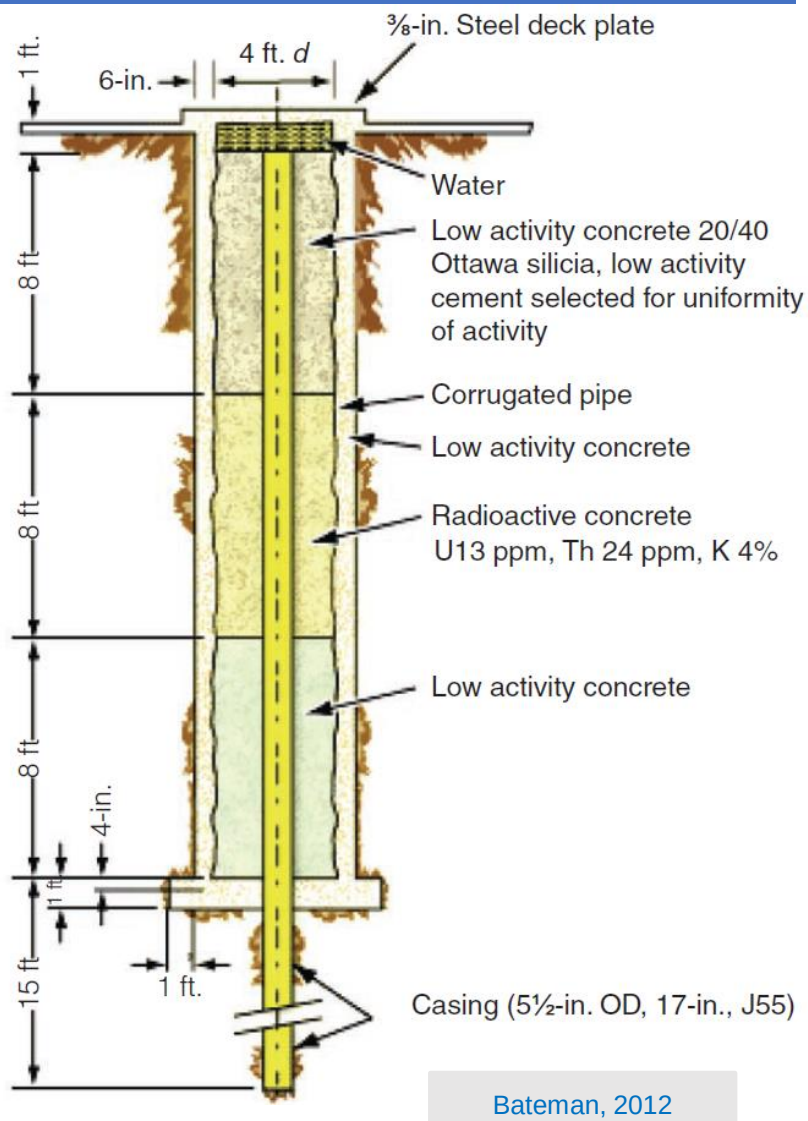


- The Scintillator material can be organic (plastics, liquids) or inorganic (Sodium iodide - NaI, Lithium iodide - LiI).
- When gamma rays interact with scintillator material, ionized (excited) atoms relax to a lower-energy state and emit photons of light. But this is not enough to make photomultiplier tube sensitive. Small impurities are added to enhance the emission of the visible photons. An example is thallium-doped NaI(TI).
- The output signal produced at anode is proportional to the energy deposited by the gamma ray in the scintillation medium

Smith and Lucas

TOOL CALIBRATION

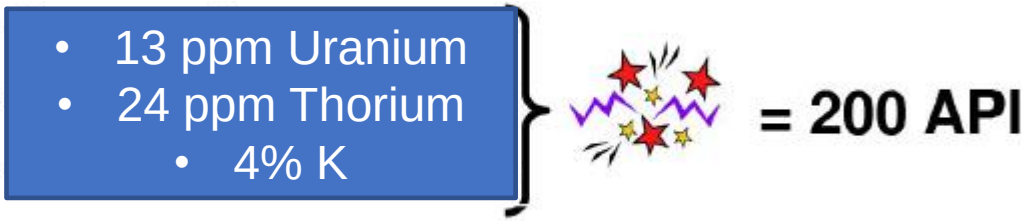
- Gamma ray unit is expressed in AP/ GAPI (American Petroleum Institute), of an artificial test pit Houston, Texas
- A cylinder 4 ft in diameter and 24 ft long contains a central 8-ft section consisting of cement mixed with 13 ppm uranium, 24 ppm thorium, and 4% potassium sandwiched by 8-ft sections of pure Portland cement on either side. This 24-ft sandwich is cased with 5.-in. J55 casing



Bateman, 2012

TOOL CALIBRATION

- Essentially API is defined as 1/200 of the deflection measured between high and low radioactivity zones in the test pit



- At the wellsite, the tool is checked and adjusted with a GR jig, a clamp on arms which locates small amount GR source of known strength at a fixed distance from the tool

END OF LECTURE