LEARNING OBJECTIVES

By the end of this lesson, you will be able to:

✓ Describe the basic physics of the Gamma Ray (GR) logging tool
✓ Outline the calibration standard used for GR logs and explain the GR API Units
✓ Identify the three most common radioactive elements found in sedimentary rock and explain the purpose of the Spectral GR tool
✓ Explain how the GR log is used to discriminate between reservoir and non-reservoir rock
✓ Recognize the typical GR log response in five or more common formations
**Gamma Ray Logging Tools:**

- Passive detectors respond to natural gamma radiation in the subsurface
- Do not have a radioactive source
- Harmless equipment

**NET/GROSS – Gamma Ray**

To measure the natural gamma rays emitted from the formation, the Gamma Ray (GR) tool is lowered in the borehole.

The Gamma Ray tool consists of a detector and associated electronics to measure the gamma radiation originating in the volume of formation near the tool.
Spectral Gamma Ray (SGR)

Also known as the Natural Gamma Ray Tool (NGT)

The simplest tool is the **Gamma Ray tool** that measures total gamma rays

**Two Types of Gamma Ray Tools:**

1. **Gamma Ray tool**
2. **Spectral Gamma Ray (SGR)**
   Also known as the Natural Gamma Ray Tool (NGT)

**Radiation found in Sedimentary Rocks**

- **Potassium** (K)
- **Thorium** (Th)
- **Uranium** (U)

**API GAMMA RAY STANDARD**

This standard is made up of radioactive cement containing fixed amounts of radioactive elements.

Three most commonly occurring radioactive elements in sedimentary rocks are:

- **13 ppm** (116.81 mg/m³) Uranium
- **24 ppm** (227.73 mg/m³) Thorium
- **4% Potassium**

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GAMMA RAY APPLICATIONS

Correlation
- Well to Well correlation
- Depth matching between separate trips in the well
- Positioning of open-hole sampling tools
- Providing the depth control needed for cased hole perforation
  - Note: gamma rays do pass through steel

General lithology indicator
- Discriminate between reservoir and non-reservoir
- Used to determine Net to Gross ratios
- Qualitative “shaliness” evaluation of the reservoir rock
- Gamma Ray data can be empirically calibrated to estimate percent shale in a shaly sand interval

GR RESPONSE TO LITHOLOGY

The Gamma Ray log is a good “first-pass” indicator of lithology
- The Gamma Ray log records total abundance of the radioactive isotopes of Potassium (K), Thorium (Th) and Uranium (U)
- K, Th and U are usually concentrated in shales and less in sandstones and carbonates (owing to differences in mineralogy) with some notable exceptions

Common GR readings, in API units*, are:
- Limestones, anhydrites, 15-20 API
- Dolomites and “clean” (quartz-rich) sandstones, 20-30 API
- Shales, average 100 API, but can vary from 75 to 300 API
- Other lithologies: coal, salt (halite, NaCl) and gypsum usually low readings (<20 API), volcanic ash and beds of potash salts (sylvaite, KCl) give high readings (>75)

* 1 API unit = 1/200th of the response generated by a calculated standard that has 2 times the average radioactivity of shale with 6 ppm (58.4 mg/m3) U, 12 ppm (113.87 mg/m3) Th and 2% K
GR RESPONSES (TYPICAL) IN TRACK 1

NET/GROSS – GR INTERPRETATION IN A SAND SHALE SEQUENCE
NET/GROSS – GR INTERPRETATION IN A SAND SHALE SEQUENCE

But... Is this the same as “Net Pay”?

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Only if the “net reservoir” is saturated with movable hydrocarbons!

NET/GROSS, NET RESERVOIR

Well A
Net
Gross
N/G = 0.5

Cross-section
Sand

Well B
N/G = ?
N/G = 0.3

Porosity

Water Saturation
SPECTRAL GAMMA RAY APPLICATIONS

The spectral Gamma Ray, also called the Natural Gamma Ray tool or NGT, has the following applications:

- Assist in mineralogy identification
- May improve Vshale determination
- Improved clay mineral identification
- Fracture detection
- Aid in difficult well to well or core-to-log correlations
- Highlights potential source rock
- Detection of unconformities
- Identification of scale build-up

GR SPECTRA CAN BE USEFUL

[Graph showing Gamma Ray spectra for Potassium, Uranium, and Thorium series]
NET/GROSS – GAMMA RAY

Apparent shale caused by high uranium streak in Northern California well

Del Rio: Typical shale. High potassium content associated with illite.

Buda: Limestone. Very low radioactivity (<20 API).

Eagleford: Shale and source rock. High uranium content associated with high TOC (Total Organic Carbon).
GAMMA RAY SUMMARY

- Relatively simple passive measurement of naturally occurring radioactivity
- Primary sand/shale discriminator because shales are more radioactive than most reservoir rocks.
- Primary well-to-well and logging run-to-logging run correlation tool
- $V_{shale}$ indicator via transform
- Spectral version helps with fracture detection, mineral identification, clay typing, and infiltration of fluids carrying dissolved radioactive minerals (production scale)
- Gamma ray, like all radioactive measurements, are statistical and log quality is affected by logging speed
- High pressure, high temperature (HPHT) versions of tools available

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