

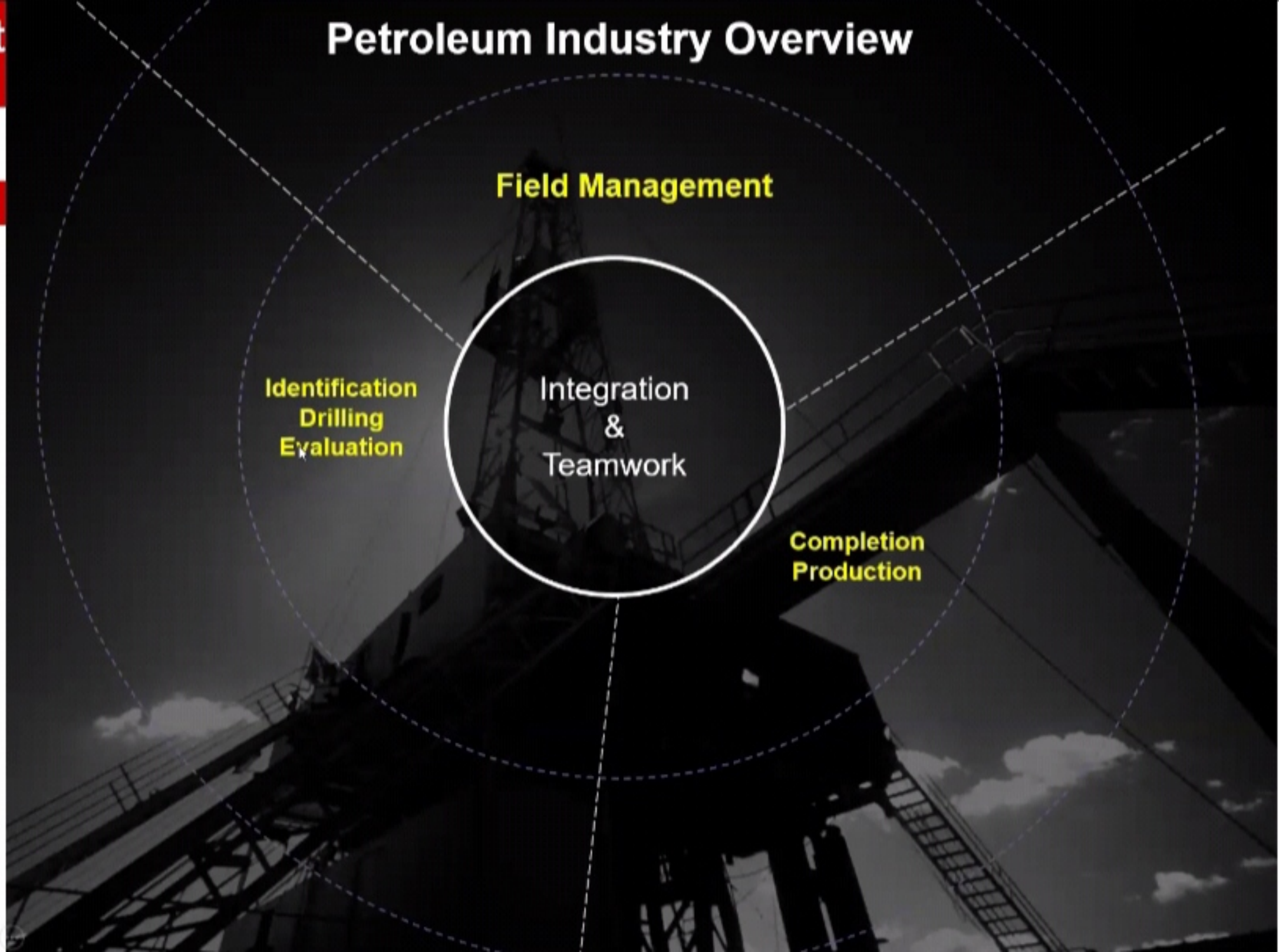
# Introduction

To Well Logging

## Introduction to Well Logging

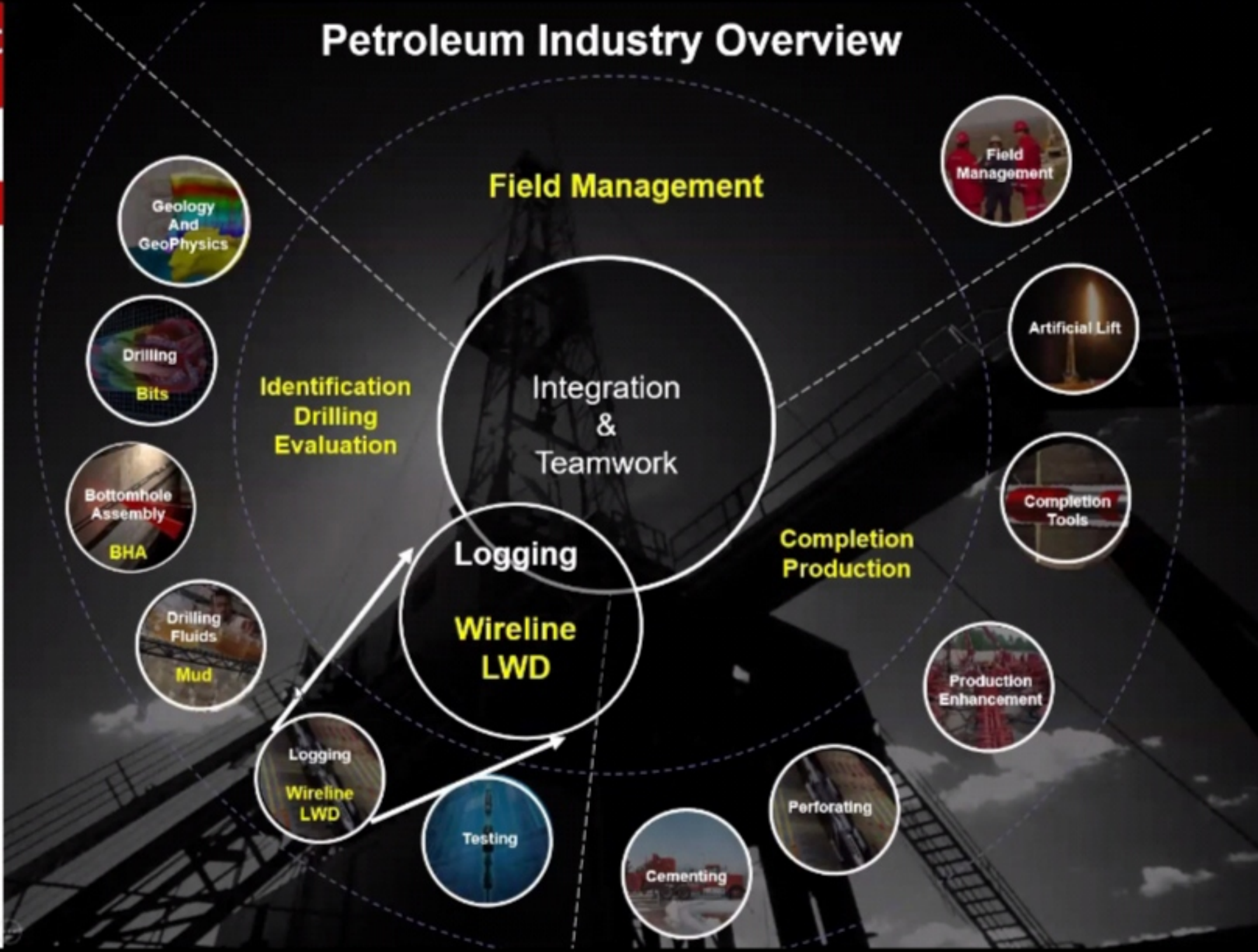
### Wireline and LWD Evaluation Tools

# Petroleum Industry Overview





# Petroleum Industry Overview





# Introduction

To Well Logging

## Logging for Evaluation

Wireline Logging



logging while drilling (LWD) instrument string assembly

The JOIDES Resolution is at the first site for Expedition 372 and the instruments for Logging While Drilling (LWD) are being connected together in what will eventually be an 85m long instrument "string"

Play 3)

0:00 / 1:01

Logging While Drilling



# Introduction

To Well Logging

## Logging for Evaluation

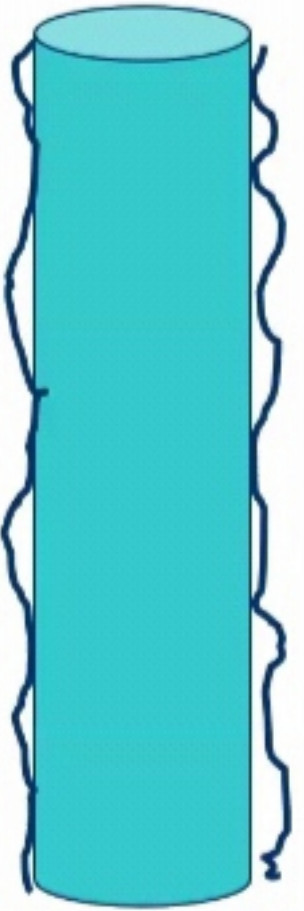
Wireline Logging



# Introduction

To Well Logging

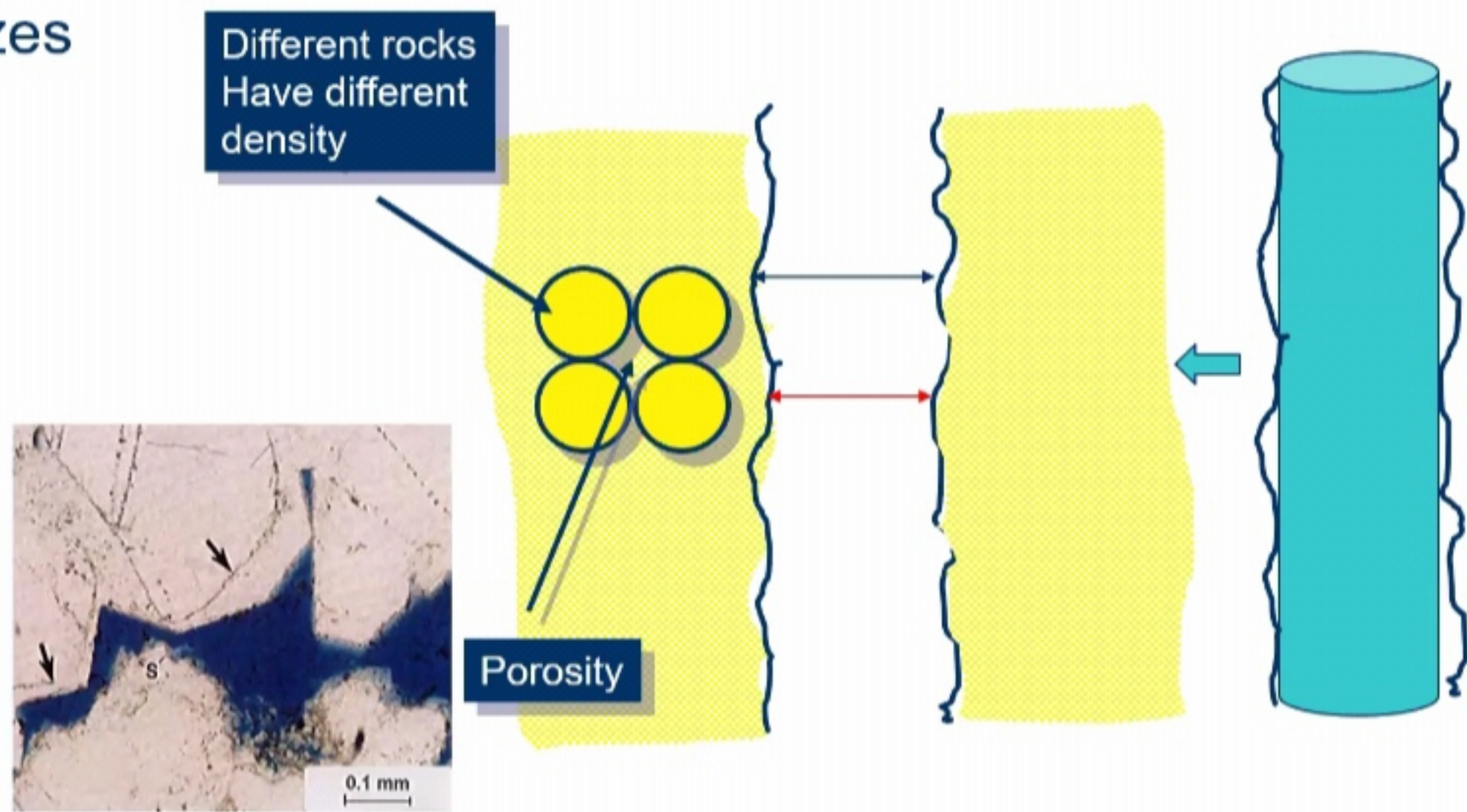
## What do we measure?





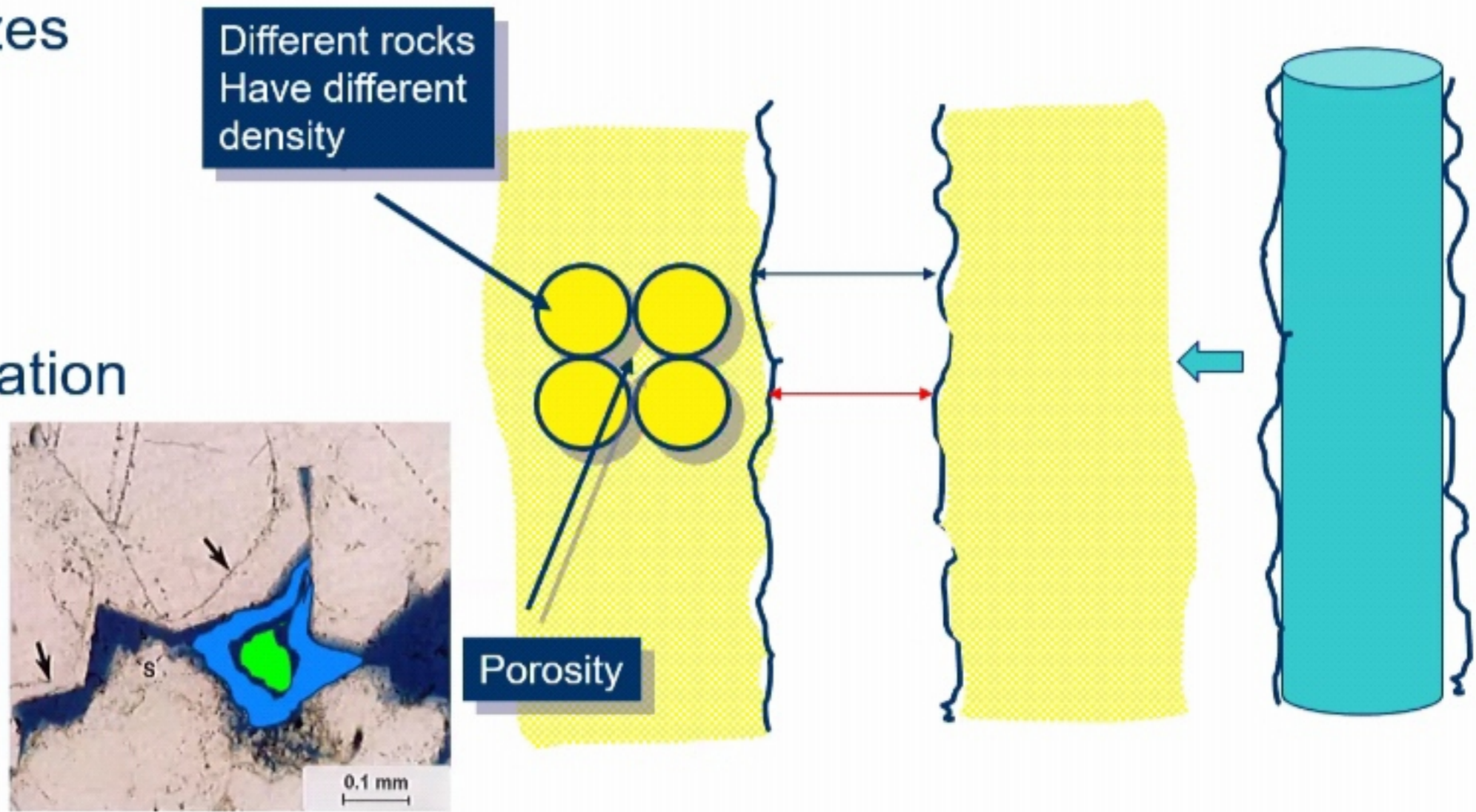
## What do we measure?

- Borehole sizes
- Porosity



## What do we measure?

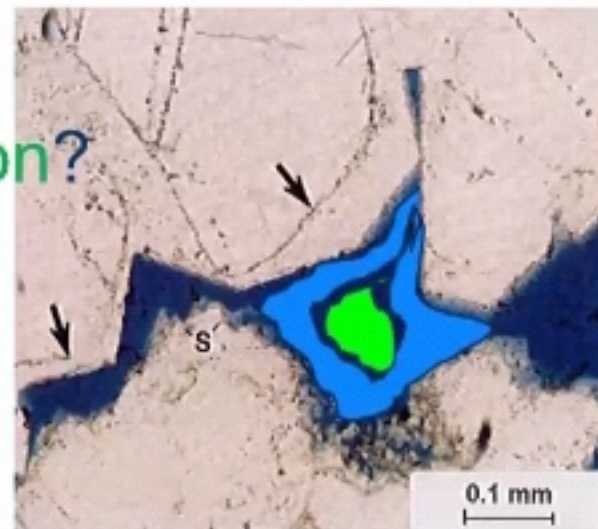
- Borehole sizes
- Porosity
- Density
  - Lithology
- Fluids Saturation





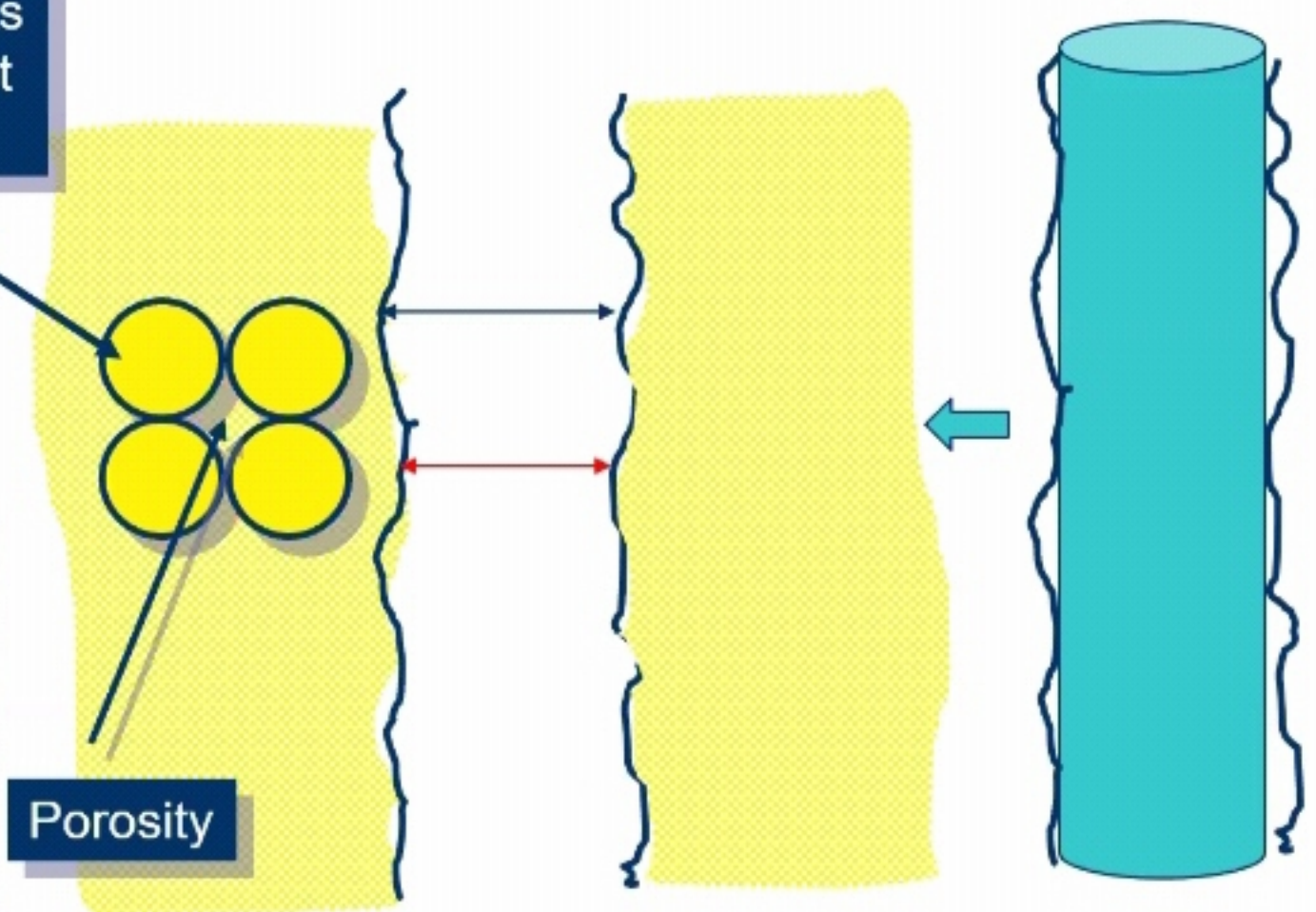
## What do we measure?

- Borehole sizes
- Porosity
- Density
  - Lithology
- Fluids Saturation
  - Water?
  - Hydrocarbon?



Different rocks  
Have different  
density

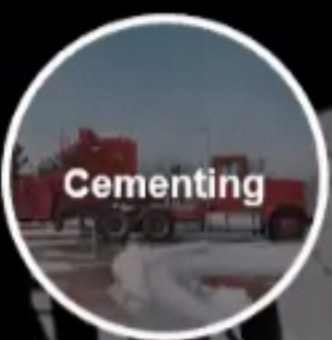
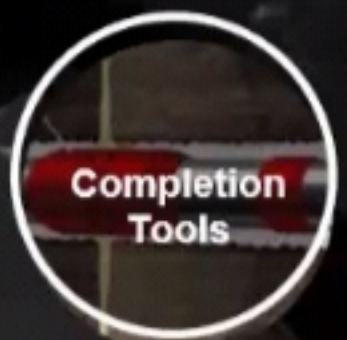
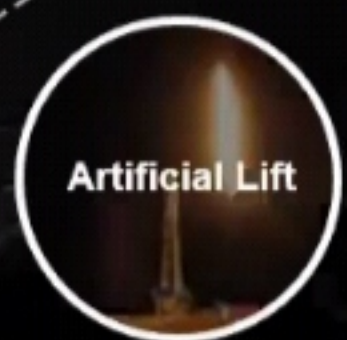
Porosity





# Petroleum Industry Overview


## Field Management



## Identification Drilling Evaluation

Integration  
&  
Teamwork

Production  
Enhancement

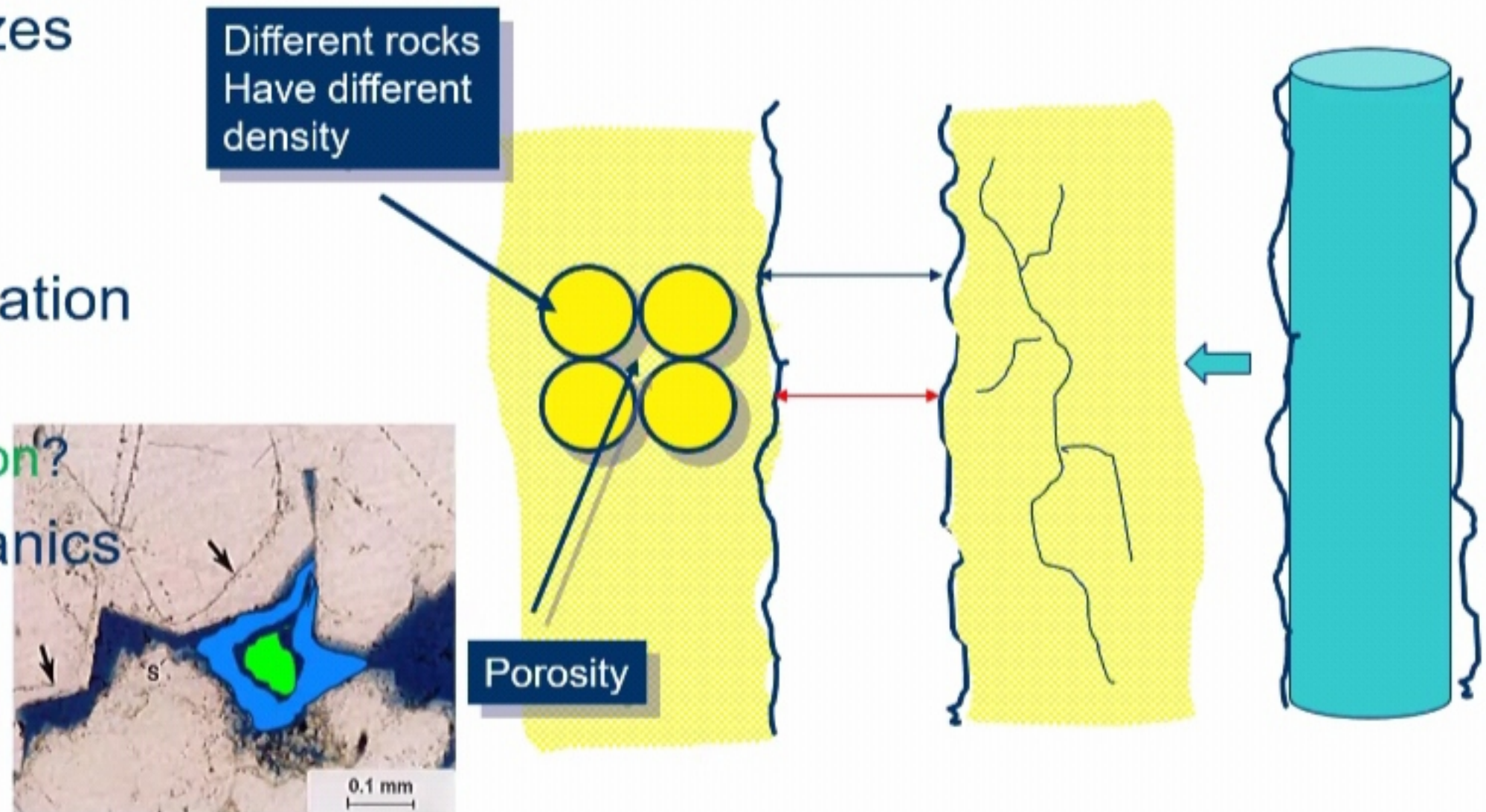


## Completion Production



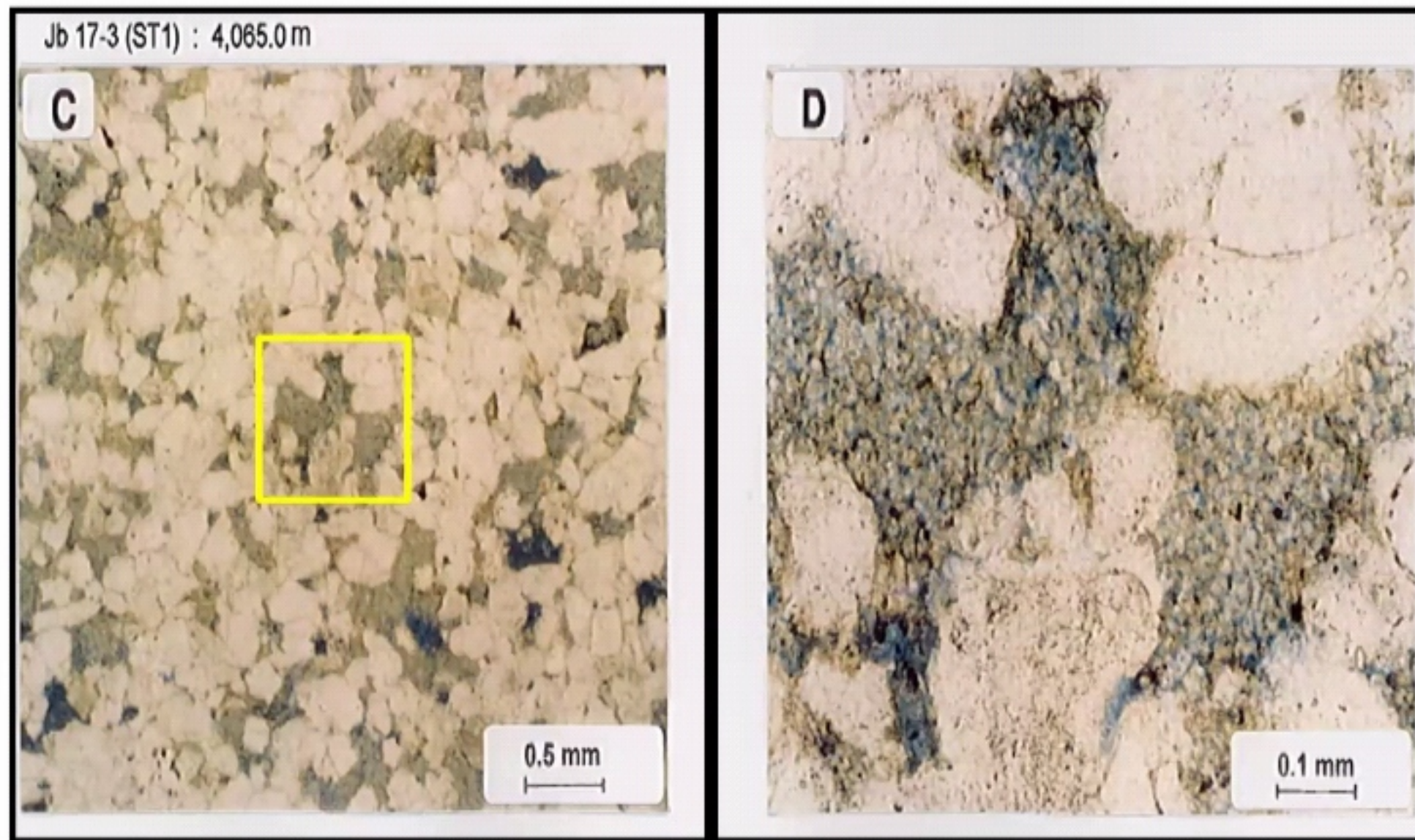
## What do we measure?

- Borehole sizes
- Porosity
- Density
- Fluids Saturation
  - Water?
  - Hydrocarbon?
- Rock mechanics





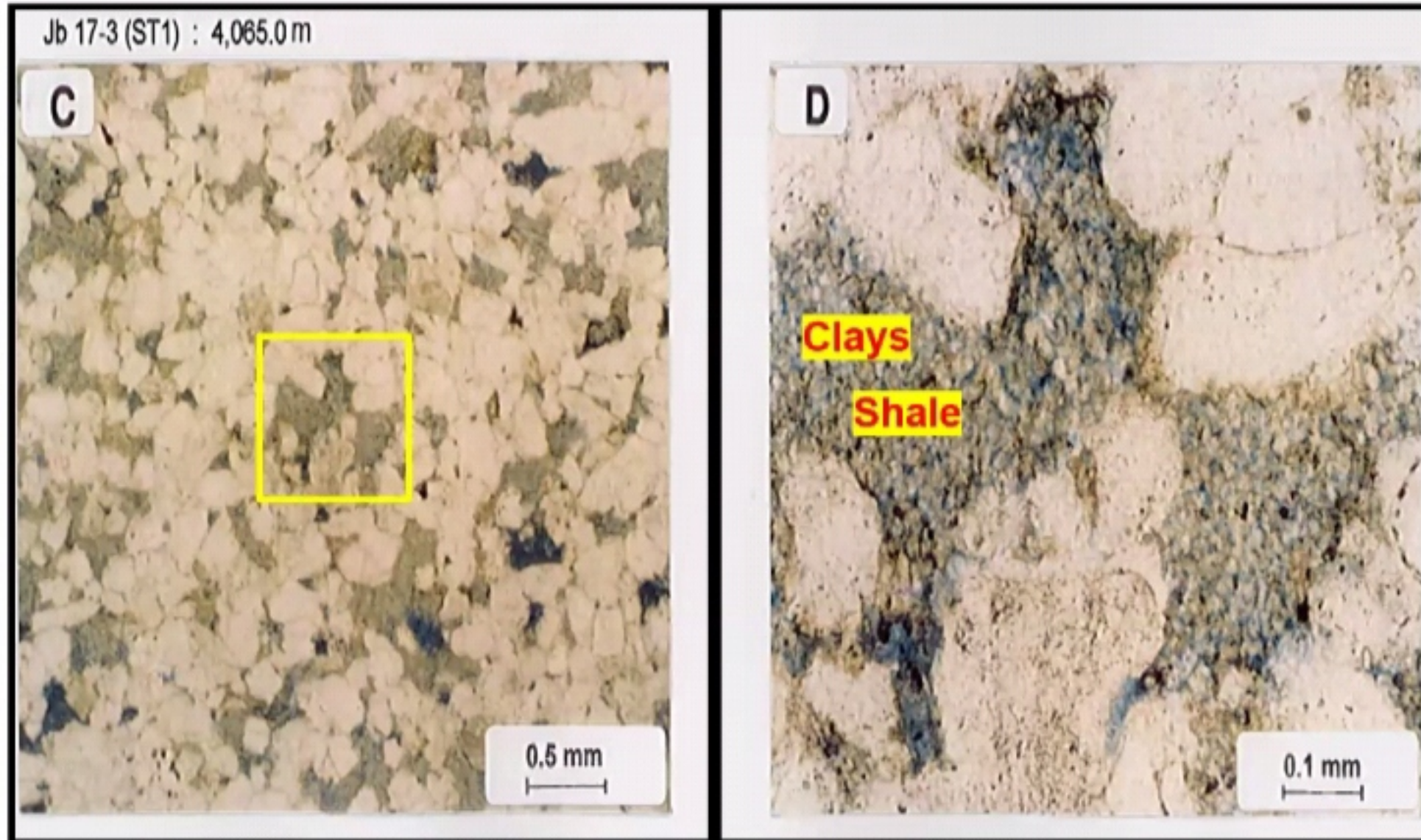
## Clays / Shale





Porosity = **Close to none**

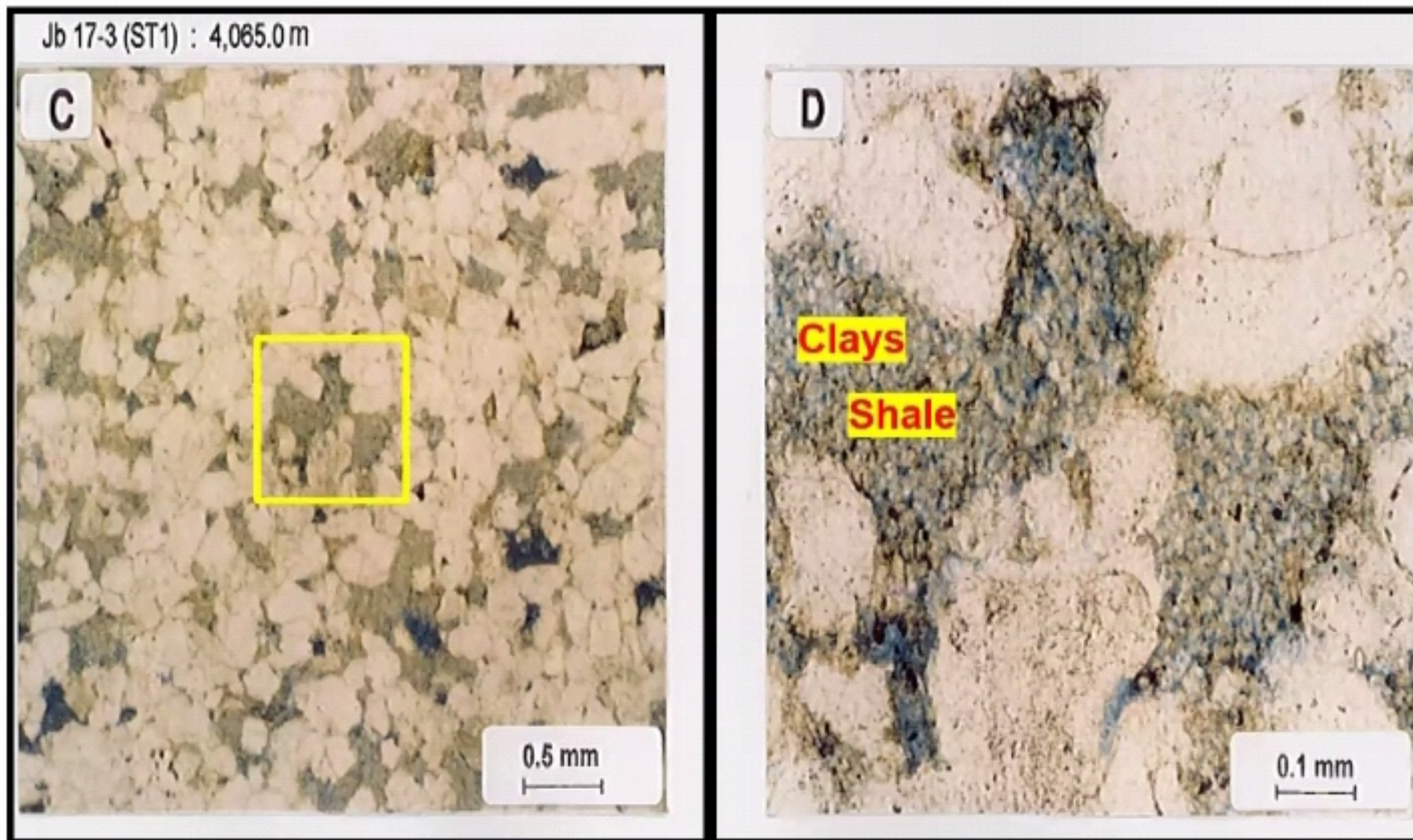
## Clays / Shale





Porosity = **Close to none**

## Clays / Shale - Very Harming to Reservoirs

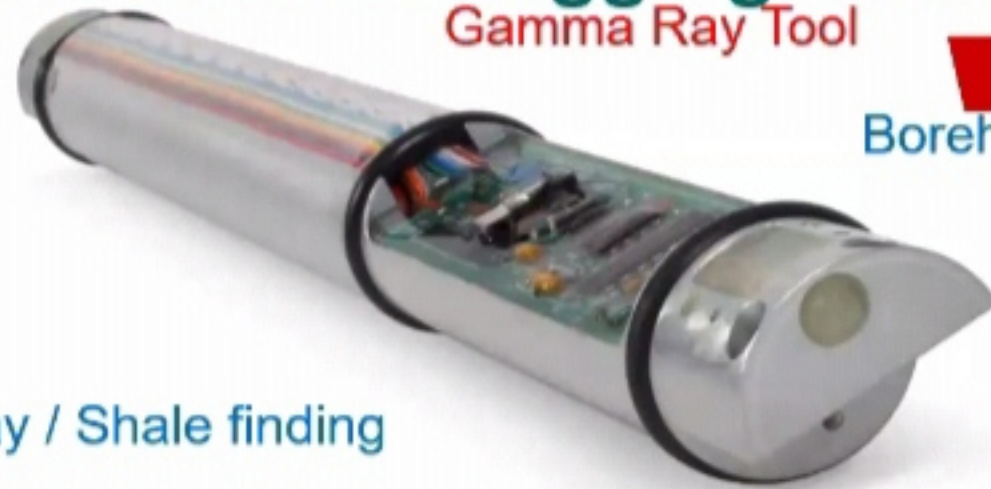




# Introduction

To Well Logging

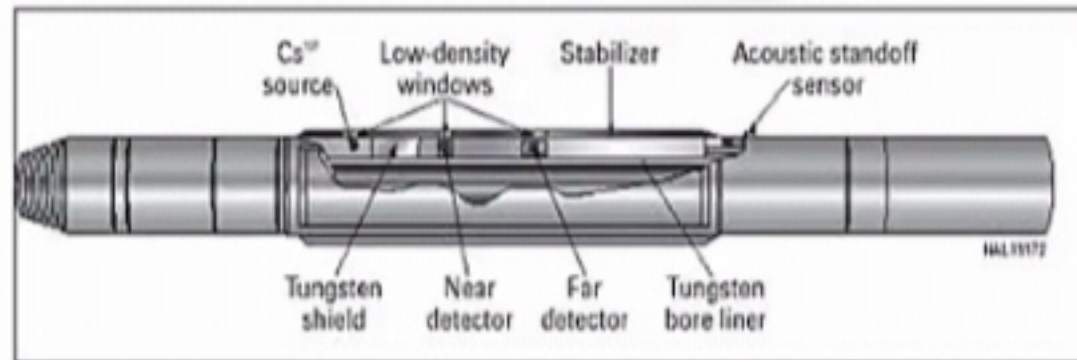
## Basic Wireline/LWD Logging Tools



Gamma Ray Tool

Clay / Shale finding

Density Tool



Caliper Tool

Borehole Diameter

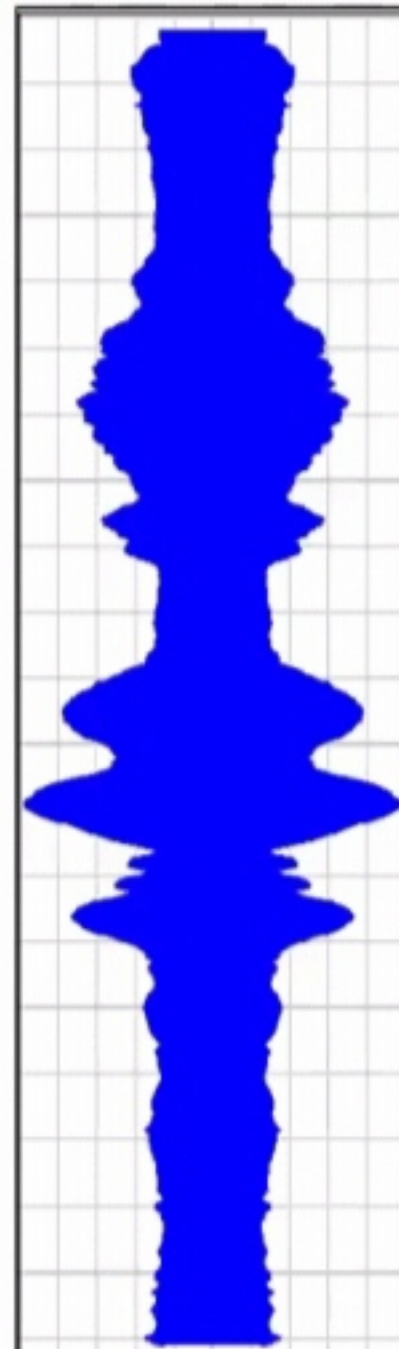


Reservoir Porosity

Neutron Porosity Tool



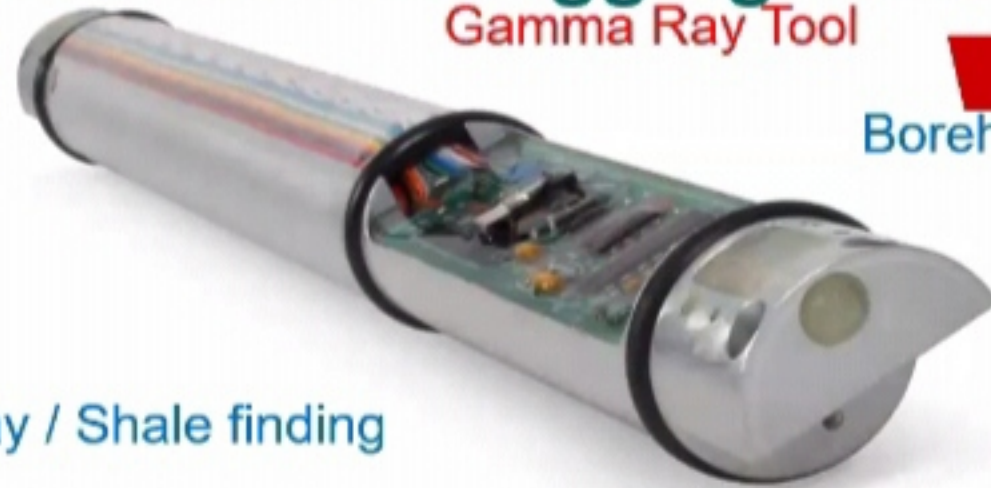
Rock Lithology



# Introduction

To Well Logging

## Basic Wireline/LWD Logging Tools

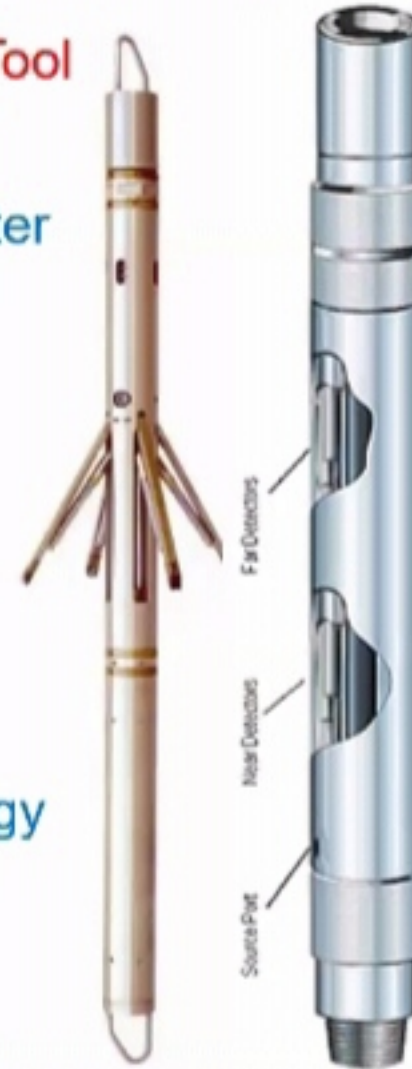


Gamma Ray Tool

Clay / Shale finding

Borehole Diameter

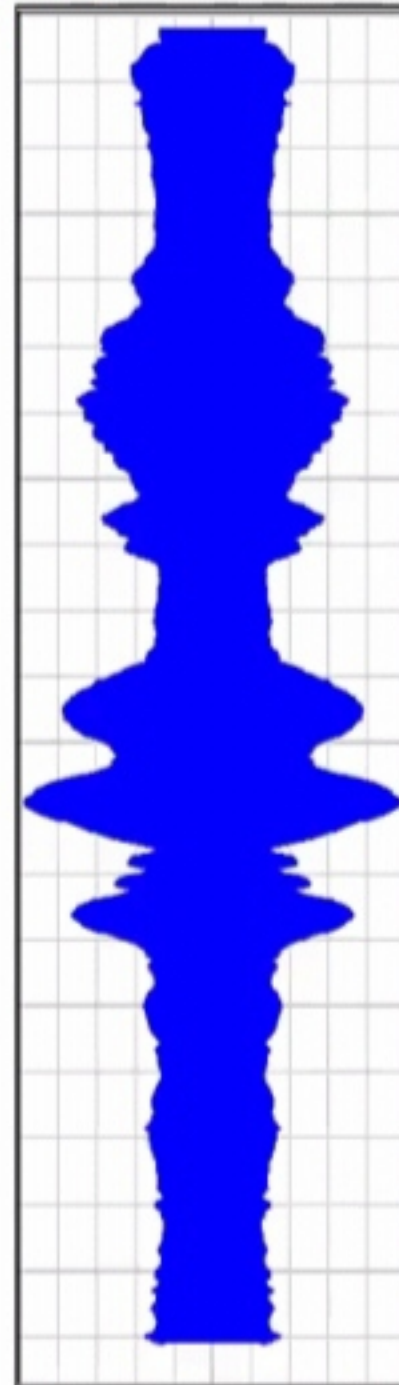
Caliper Tool



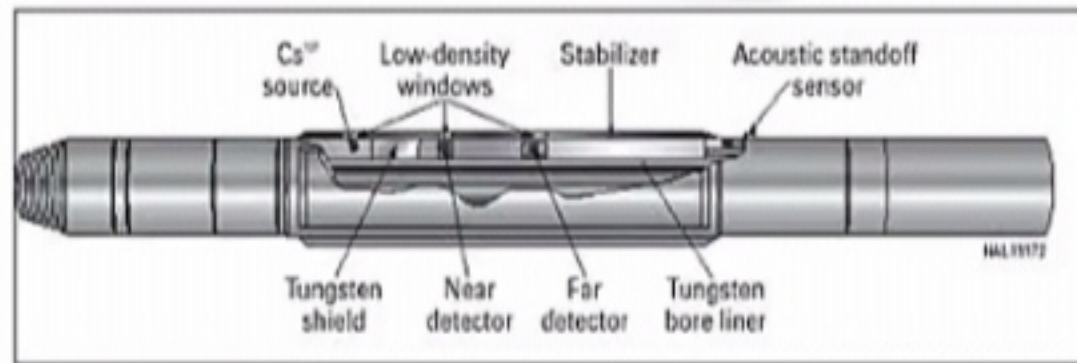
Reservoir Porosity

Neutron Porosity Tool

Far Detectors  
Near Detectors  
Source Port

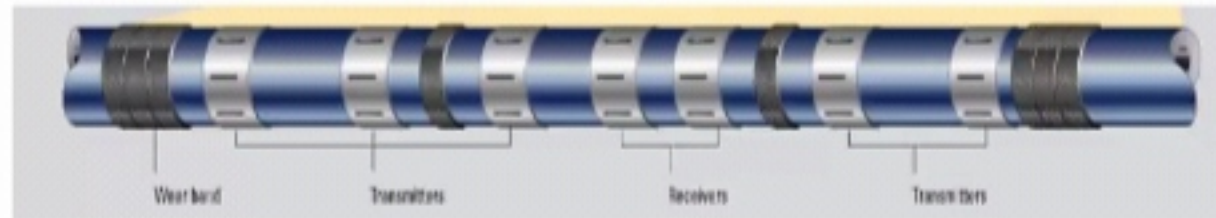


Density Tool



Rock Lithology

Resistivity Tool



Fluids Saturation

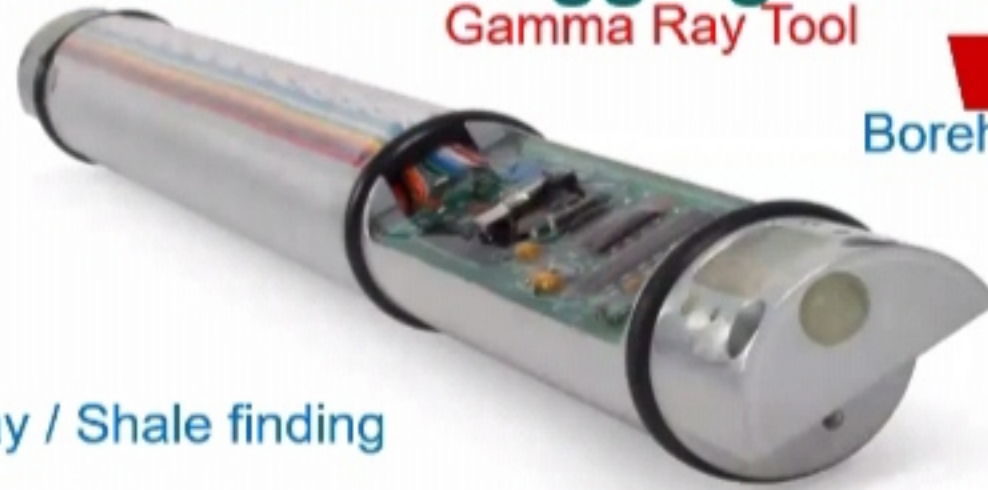
Rock Mechanical Properties



# Introduction

To Well Logging

## Basic Wireline/LWD Logging Tools

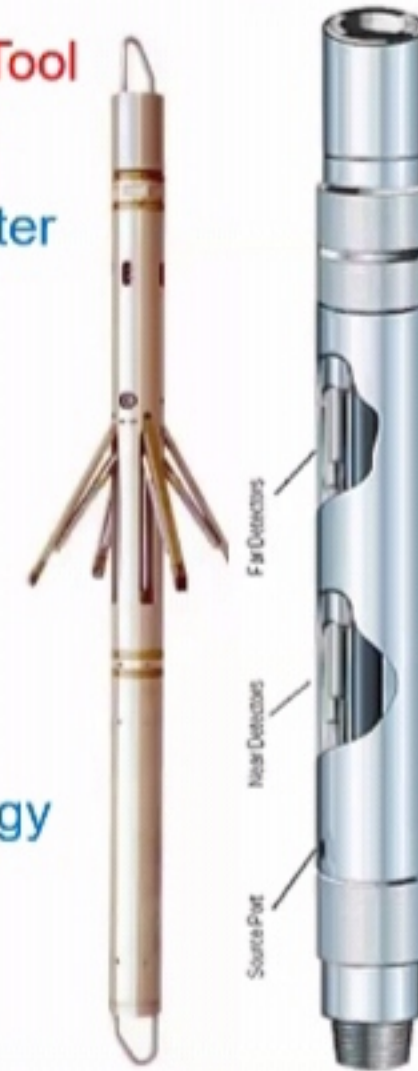


Gamma Ray Tool

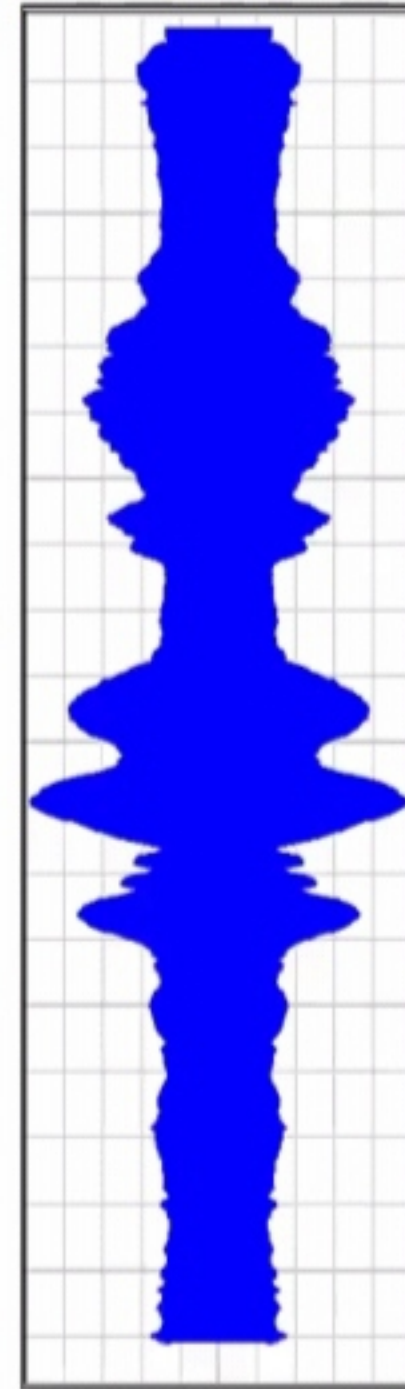
Clay / Shale finding

Borehole Diameter

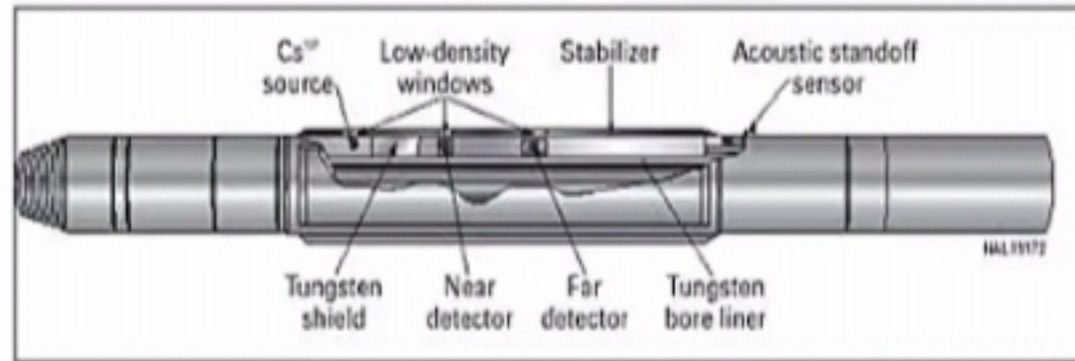
Caliper Tool



Reservoir Porosity  
Neutron Porosity  
Tool

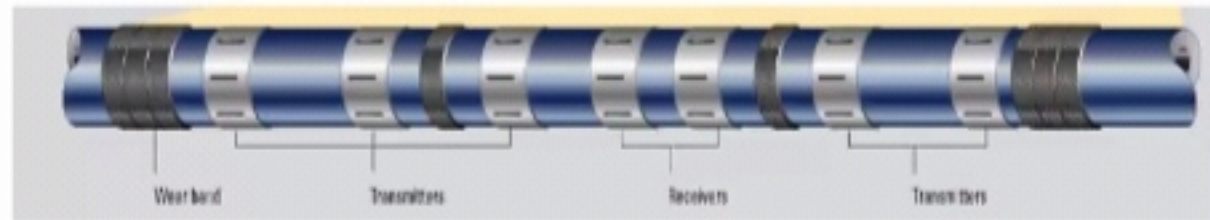


Density Tool



Rock Lithology

Resistivity Tool



Fluids Saturation

Sonic Tool



Rock Mechanical Properties



# Introduction

To Well Logging

**How does each tool work?**



**How does each tool work? What does each tool measure?**

**Review Your Physics Courses**

Petro-Physics ↵



## Caliper Tools for Borehole size

- Why
  - Washout while drilling
  - Washout after drilling
  - Clays swelling
  - Rock deterioration

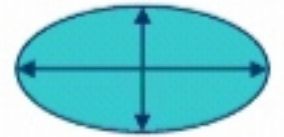
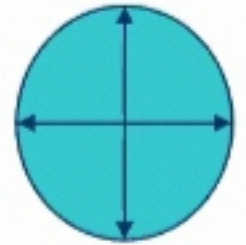


## Caliper Tools for Borehole size

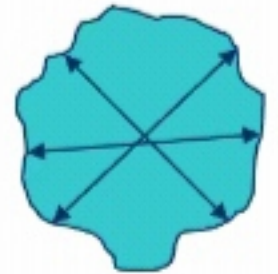


- Why
  - Washout while drilling
  - Washout after drilling
  - Clays swelling
  - Rock deterioration

- 2 arms caliper
- 4 arms caliper
- 6 arms caliper



↳

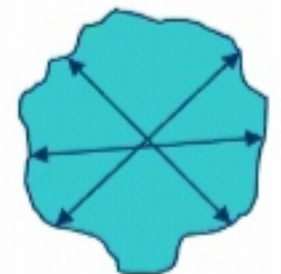
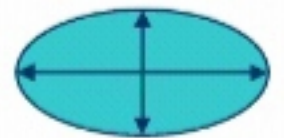
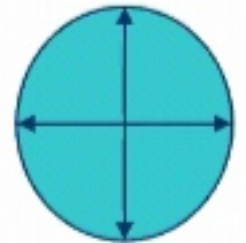


## Caliper Tools for Borehole size



- Why
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  - Washout after drilling
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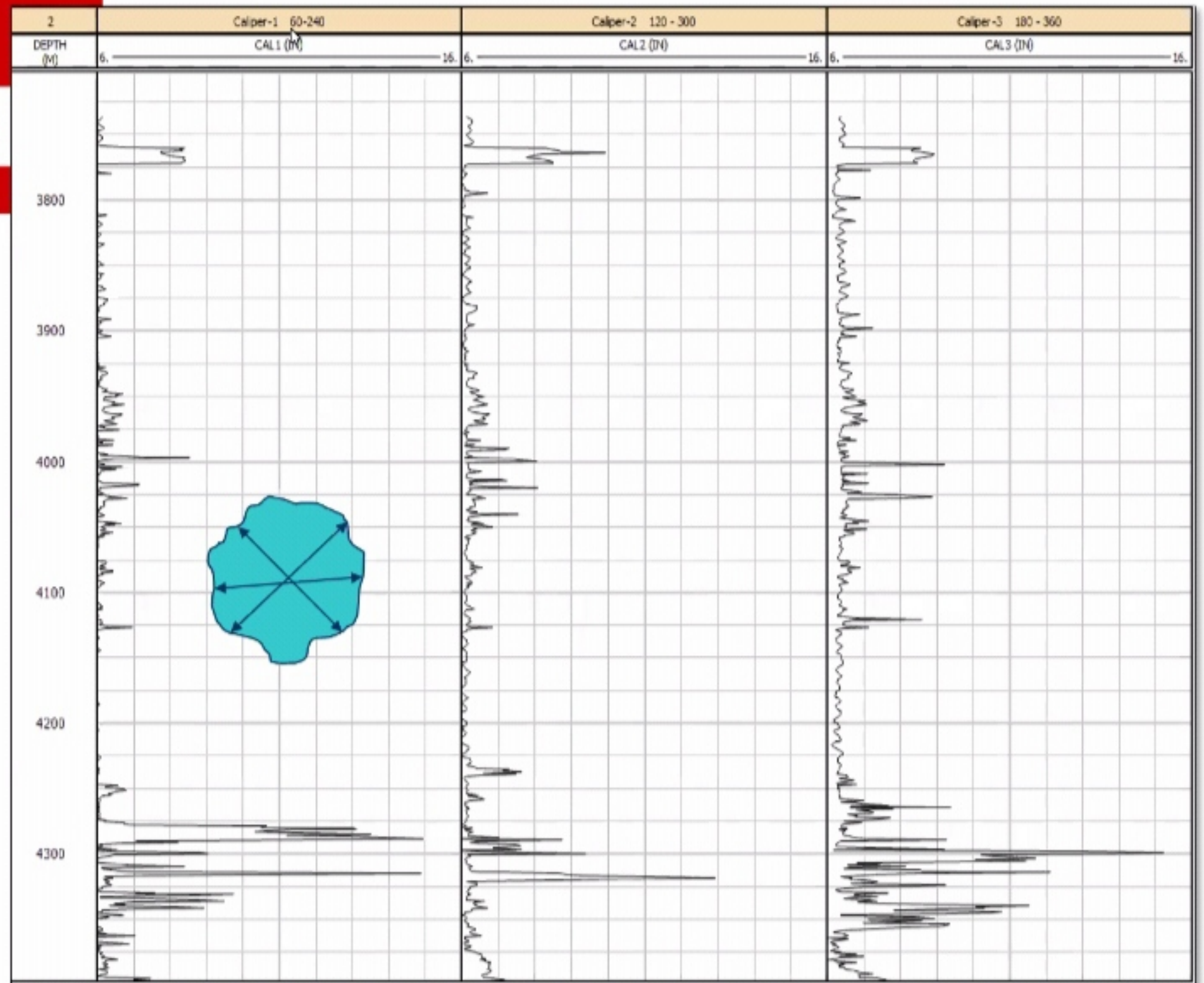




# Introduction

To Well Logging

## 6 arms caliper



## Clay Zones Evaluation

### Physics:

- ✓ Clays are Radioactive
- ✓ They contain radioactive elements
  - ✓ Potassium K
  - ✓ Thorium Th



## Clay Zones Evaluation

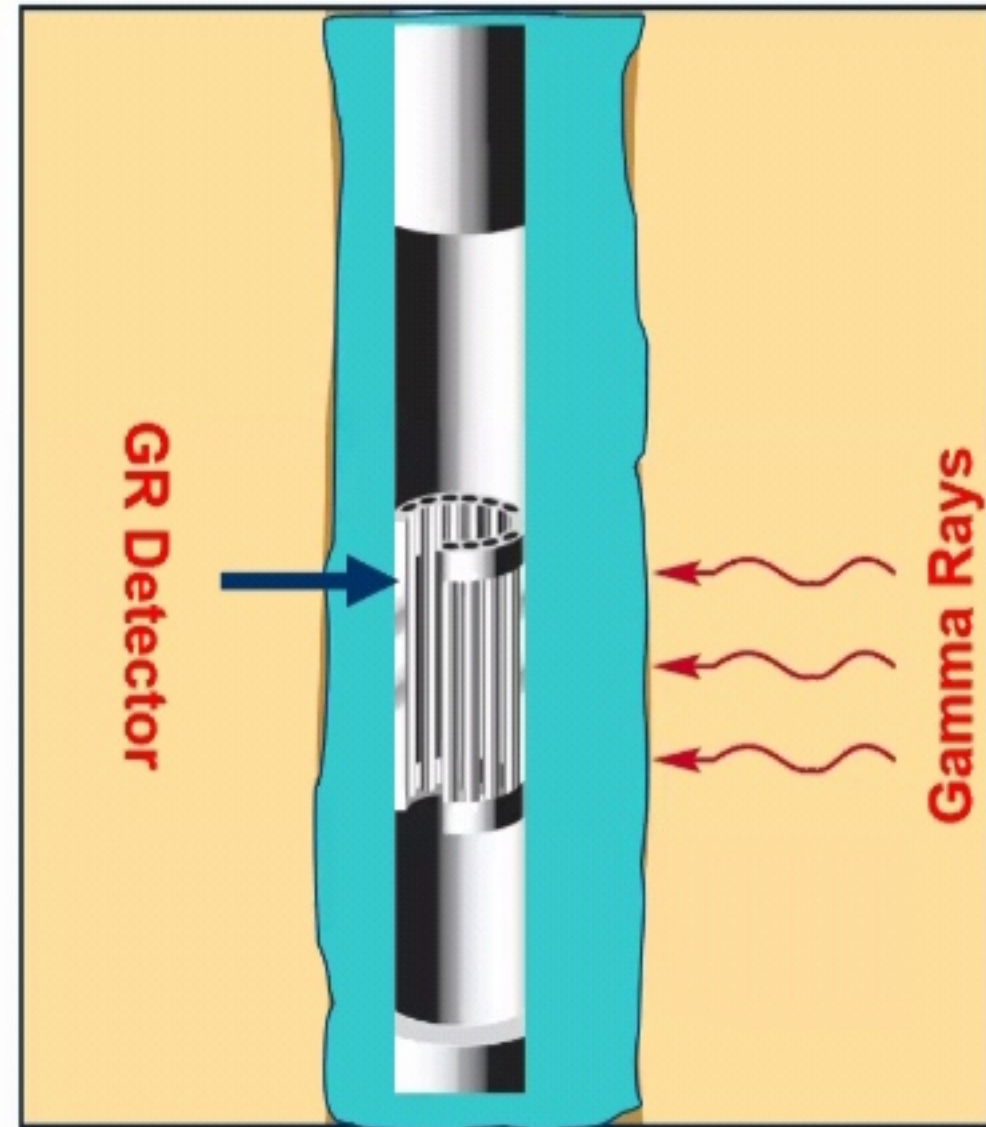
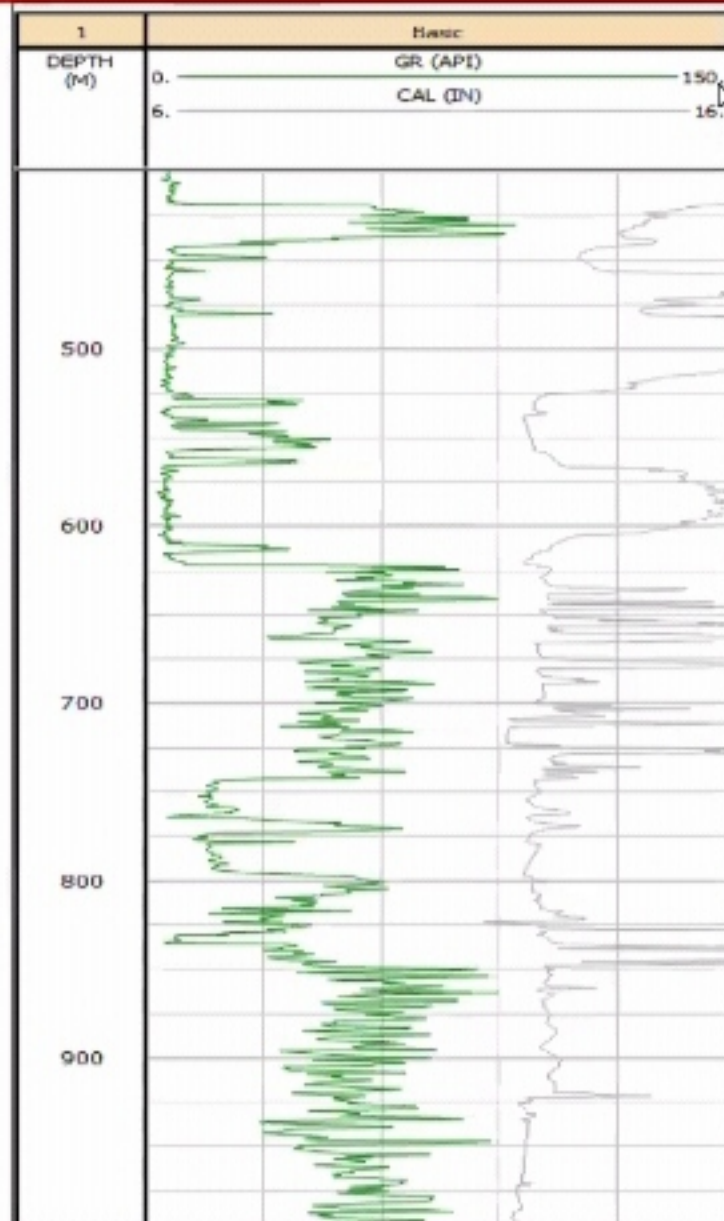
### Physics:

- ✓ Clays are Radioactive
- ✓ They contain radioactive elements
  - ✓ Potassium K
  - ✓ Thorium Th
- ✓ They emit gamma rays

### Detection:

- ✓ measure the gamma rays

### Gamma Ray Tool For Clays





## Composition of fluids in pores

- Water
- Oil or gas

## Composition of fluids in pores

- Water
  - H<sub>2</sub>O
  - Hydrogen and Oxygen
- Oil or gas
  - Hydro-Carbon
  - Hydrogen and Carbon
- Both water and Hydrocarbon have a common atom

Hydrogen



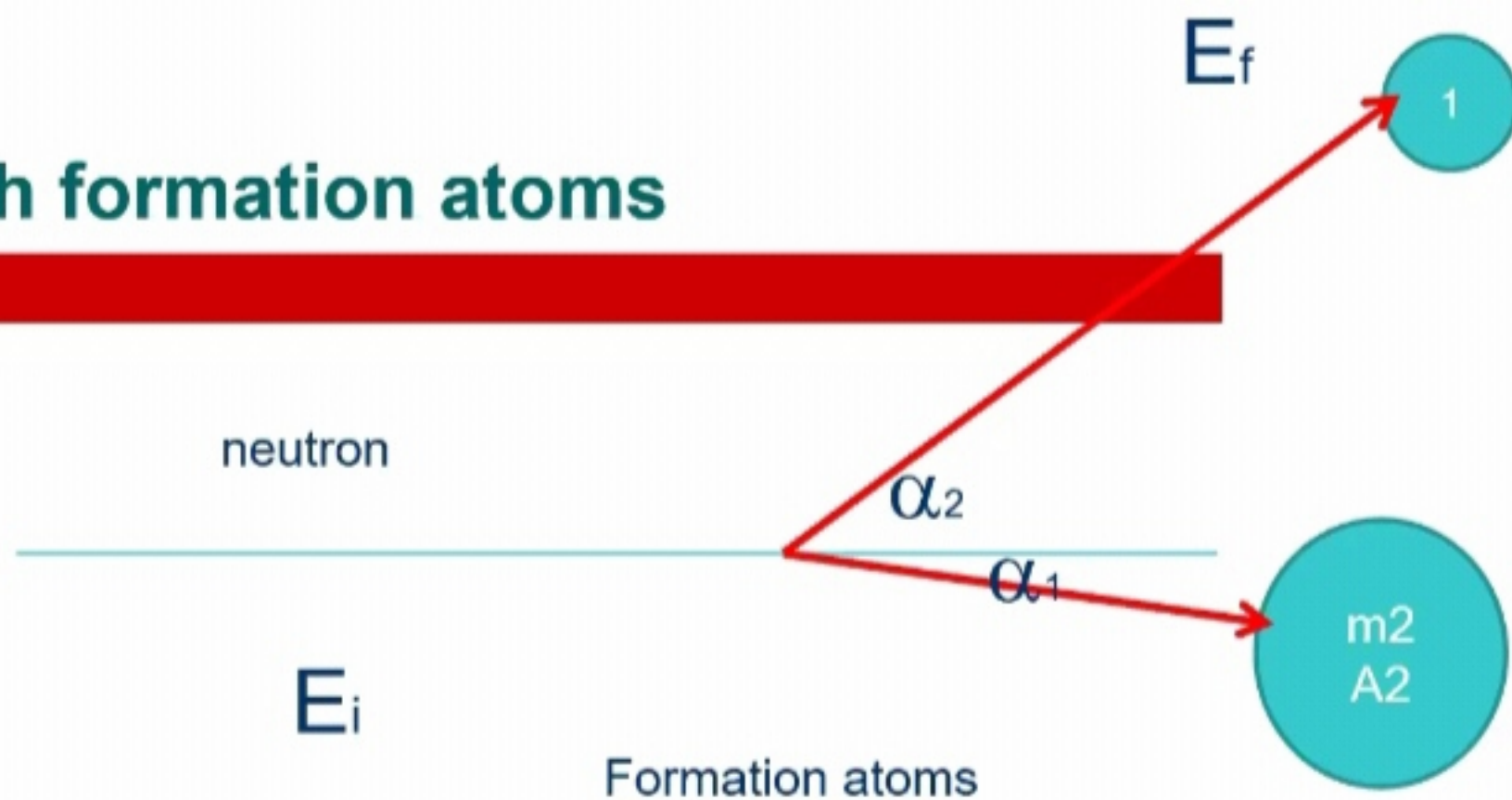
## Composition of fluids in pores

- Water
  - H<sub>2</sub>O
  - Hydrogen and Oxygen
- Oil or gas
  - Hydro-Carbon
  - Hydrogen and Carbon
- Both water and Hydrocarbon have a common atom

Hydrogen

- If you measure Hydrogen atoms, this can be translated to Porosity

## Neutron collides with formation atoms

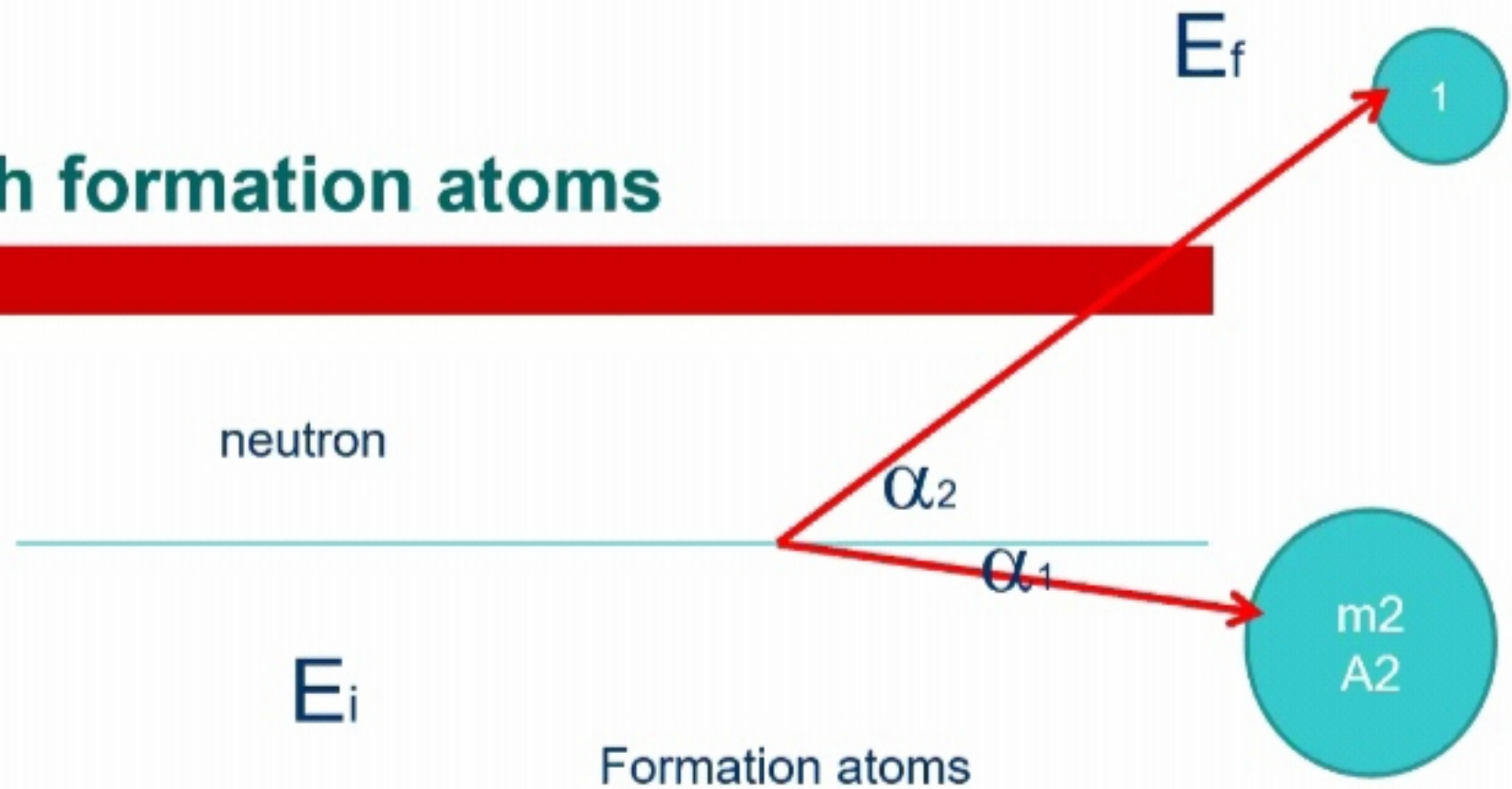


Lowest Final Energy

$$E_f = \left( \frac{A_2 - 1}{A_2 + 1} \right)^2 E_i$$



## Neutron collides with formation atoms



Lowest Final Energy 
$$E_f = \left( \frac{A_2 - 1}{A_2 + 1} \right)^2 E_i$$

Lowest Final Energy if it collides with **Hydrogen** 
$$E_f = \left( \frac{1 - 1}{1 + 1} \right) E_i \quad E_f = 0$$

## Porosity Measurements **The Neutron Tool**

### Physics:

- ✓ Use a neutron source
- ✓ Let the neutrons collide with atoms

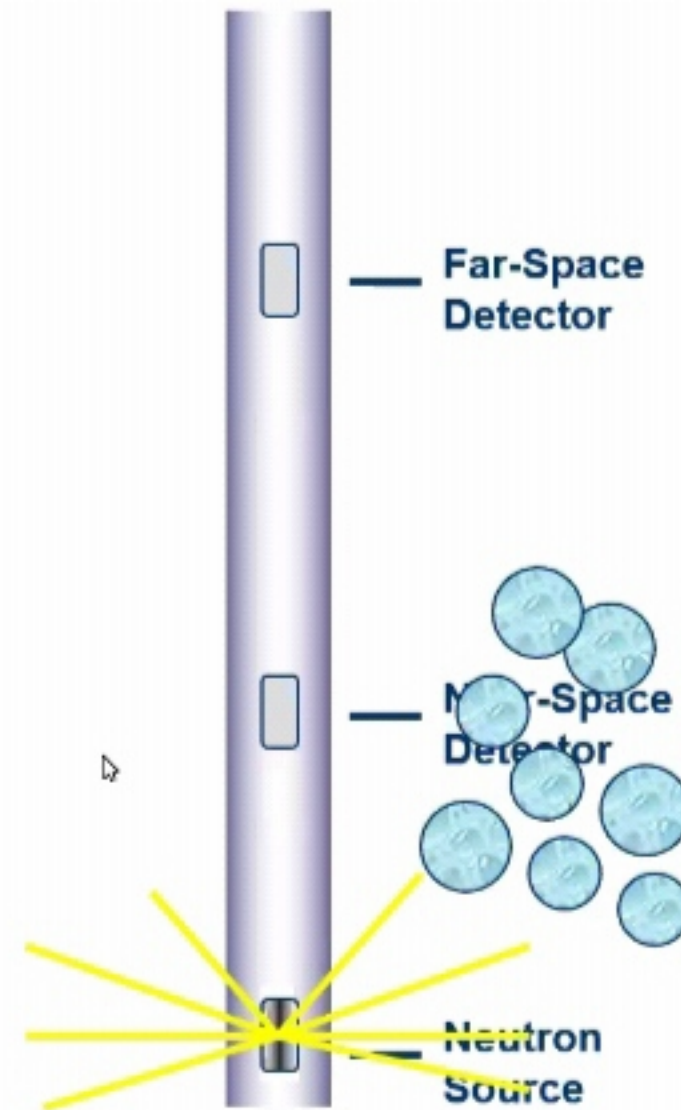
### Detection:

- ✓ Count the number of neutrons coming back



## The Neutron Tool

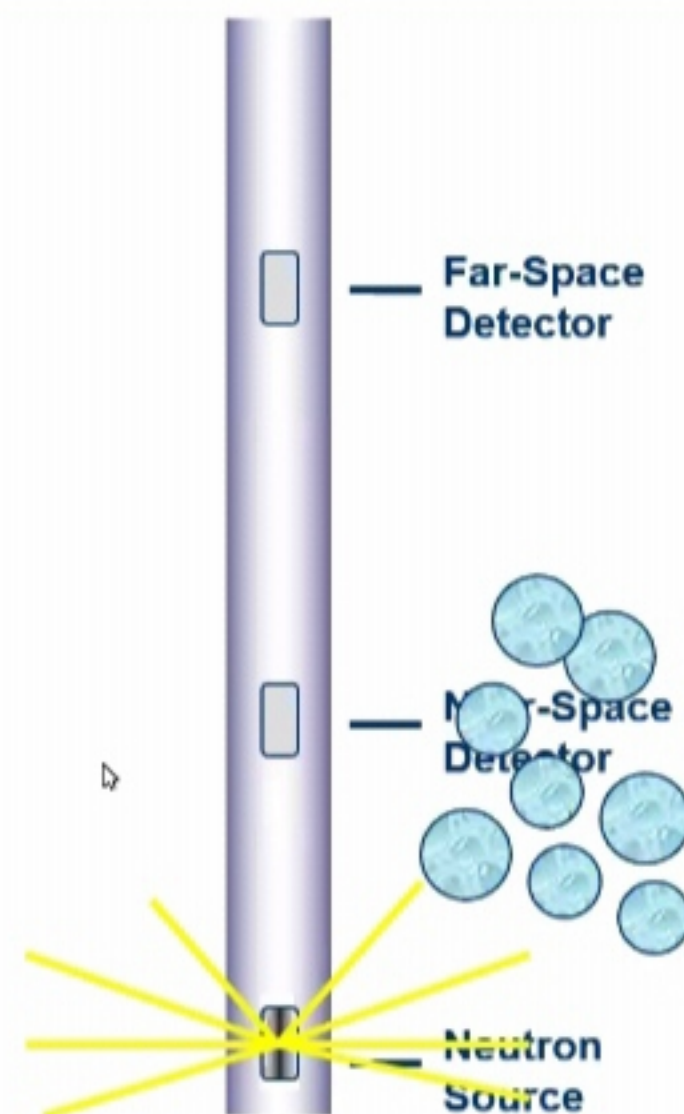
- ❑ Uses a neutron source
- ❑ Usually (AmBe)
- ❑ Uses neutron detectors



The source emits **very high energy neutrons** into the formation

## The Neutron Tool

- ❑ Uses a neutron source
- ❑ Usually (AmBe)
- ❑ Uses neutron detectors



The source emits **very high energy neutrons** into the formation

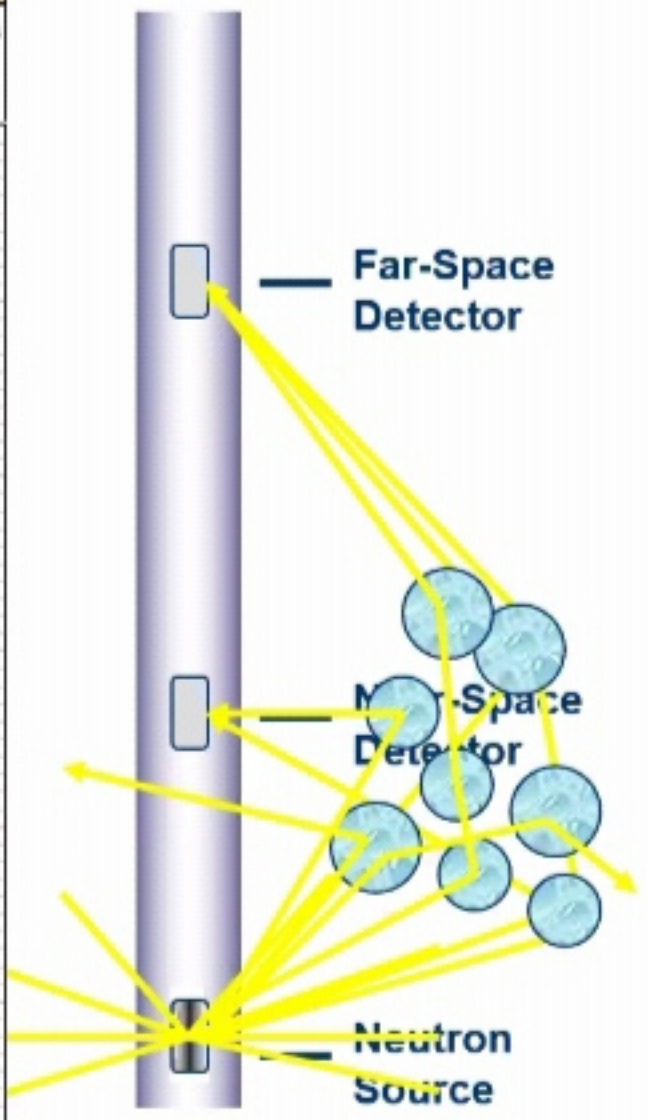
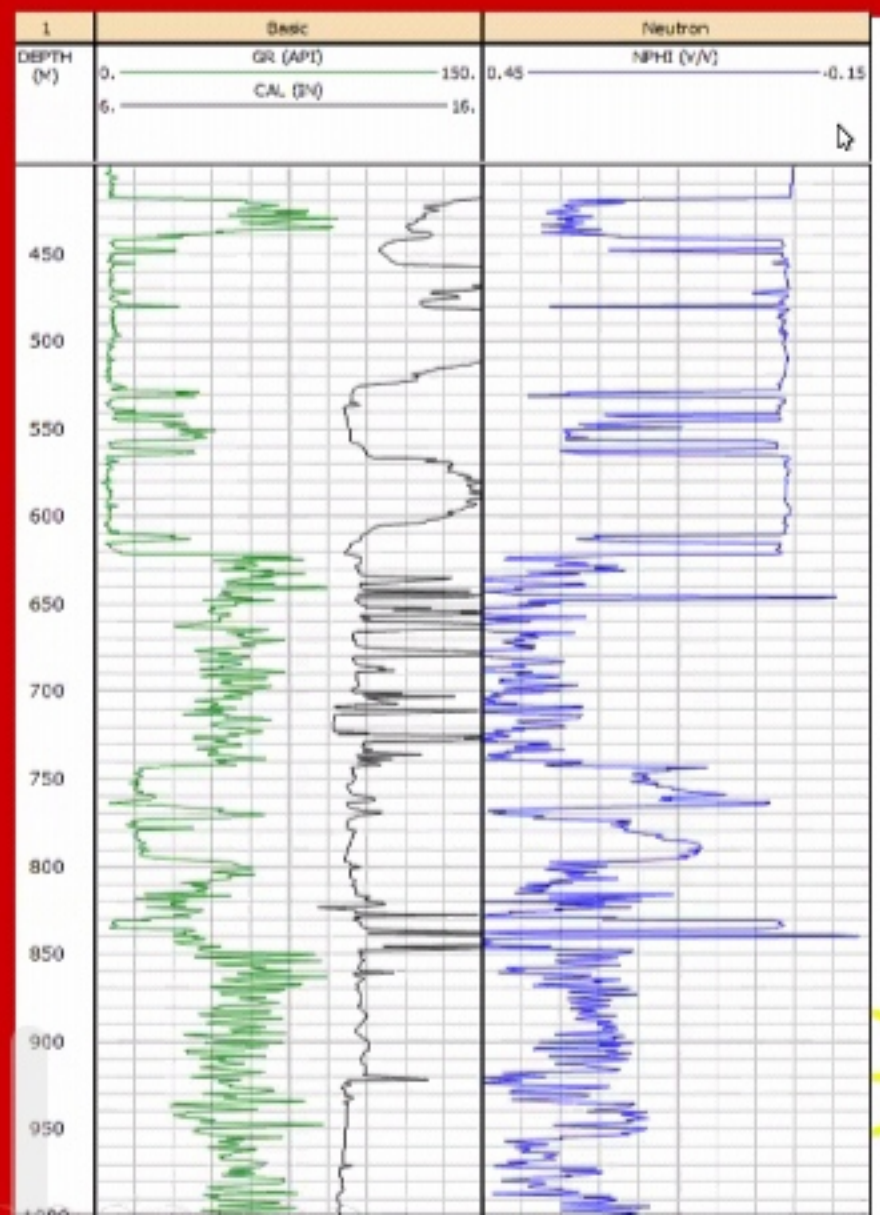


# Introduction

## To Well Logging

### The Neutron Tool

- ❑ Uses a neutron source
- ❑ Usually (AmBe)
- ❑ Uses neutron detectors



The source emits **very high energy neutrons** into the formation

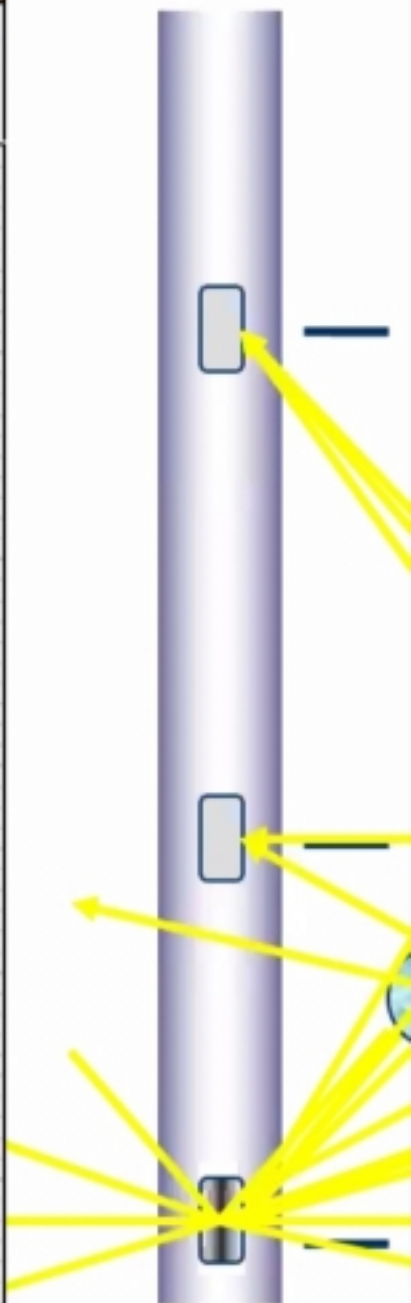
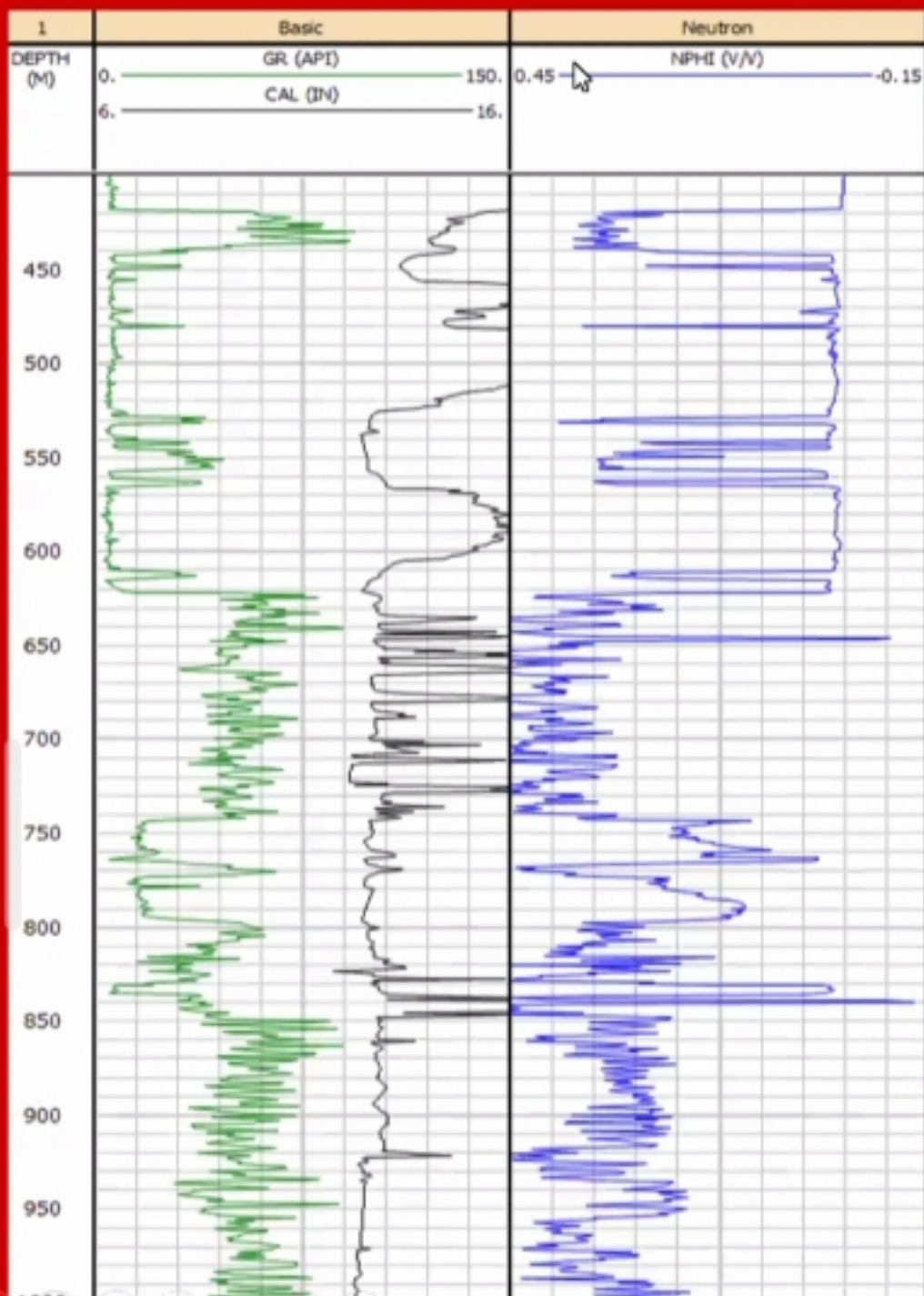
As neutrons collide with hydrogen and other elements, they lose energy



# Introduction

To Well Logging

## The Neutron Tool



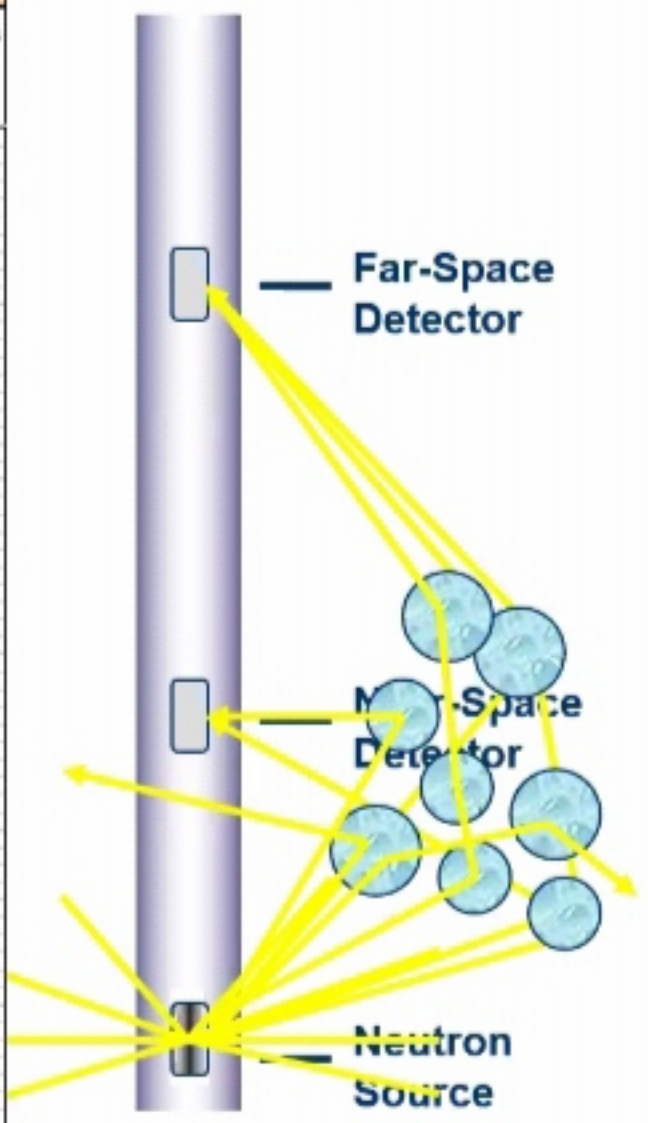
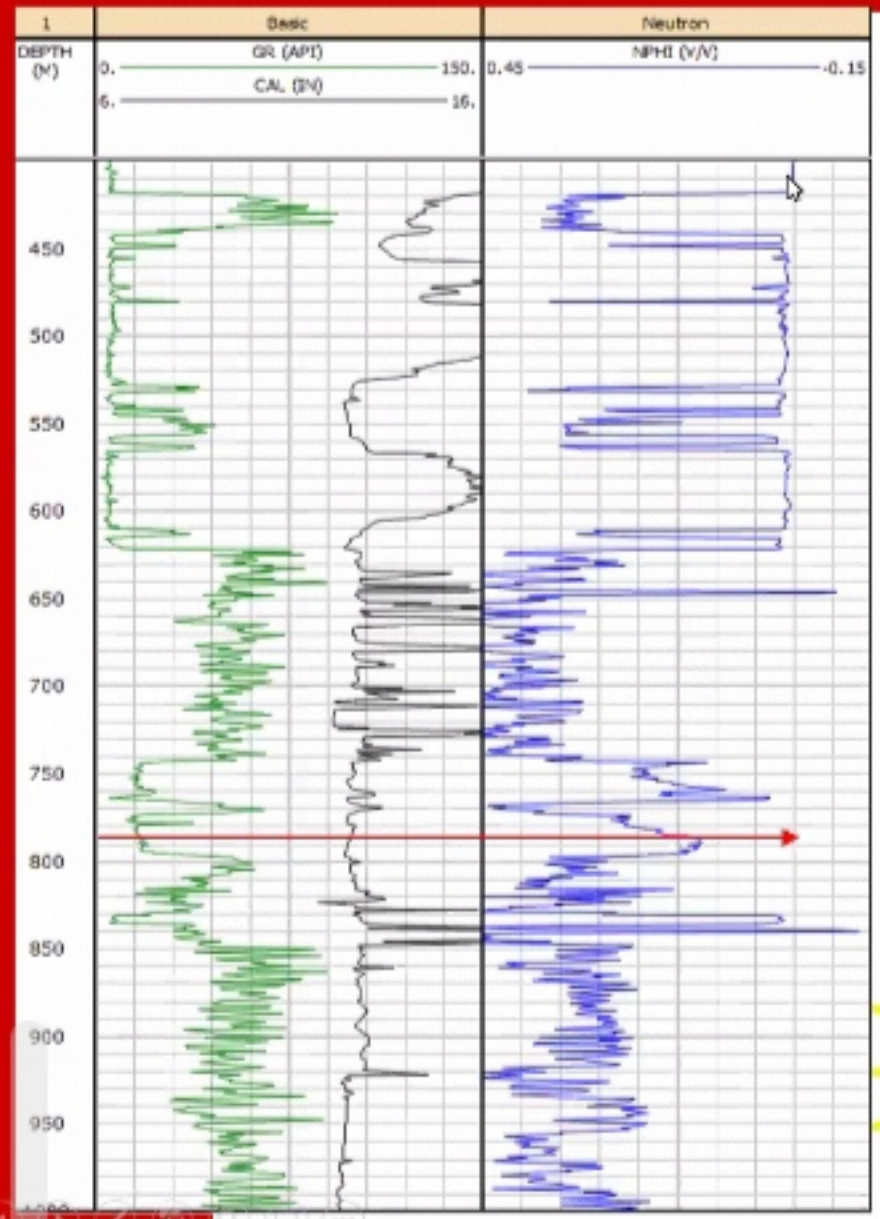


# Introduction

## To Well Logging

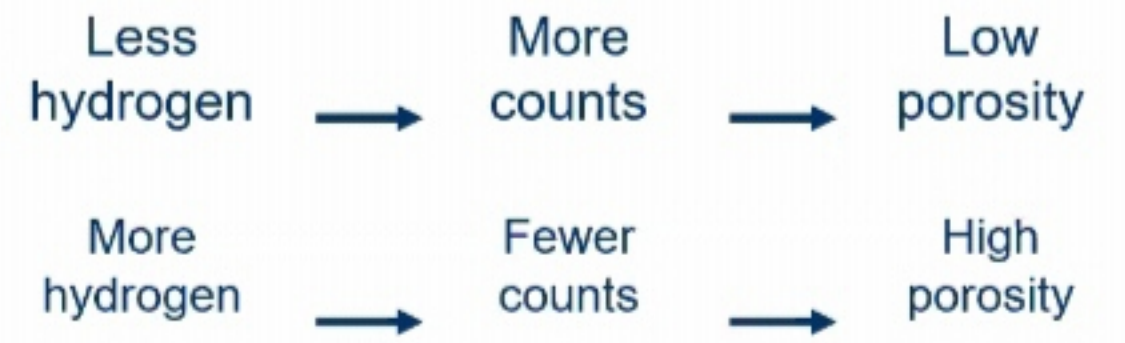
# The Neutron Tool

- ❑ Uses a neutron source
- ❑ Usually (AmBe)
- ❑ Uses neutron detectors



The source emits **very high energy neutrons** into the formation

As neutrons collide with hydrogen and other elements, they lose energy



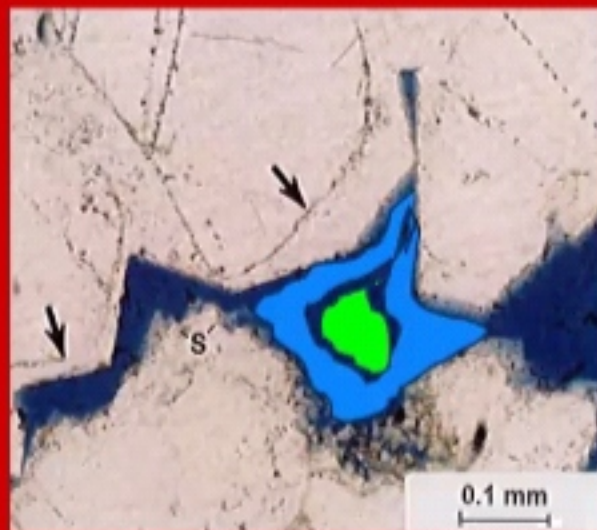
## Fluids Saturation



## Fluids Saturation Hydrocarbon or Water?

Physics:

- ✓ Water is conductive
- ✓ Oil / gas are resistive

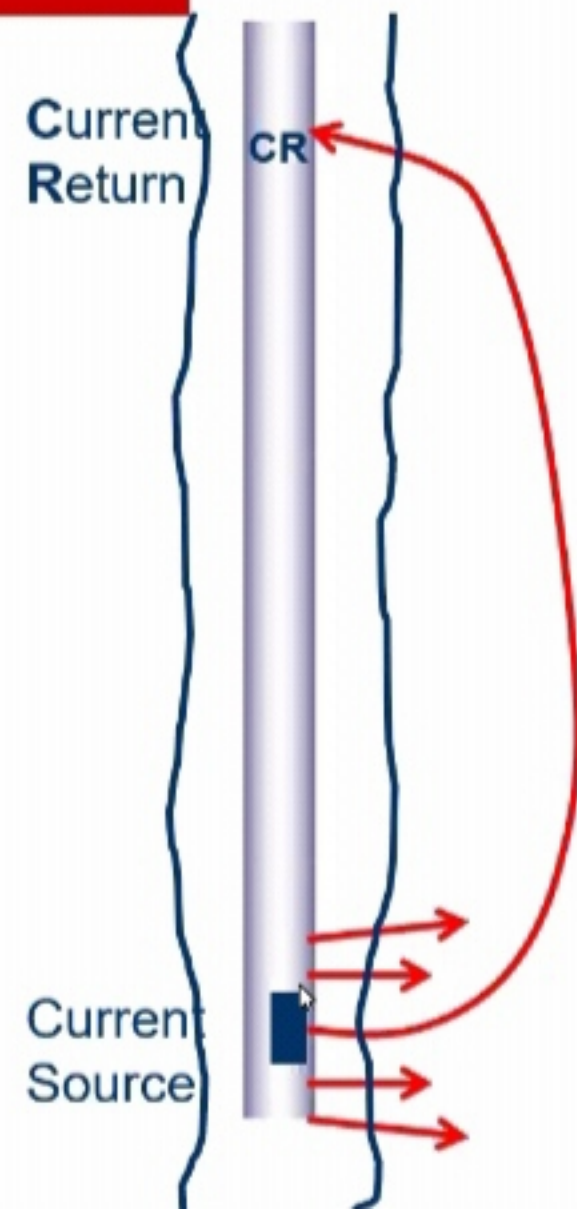


### Rock Resistivity

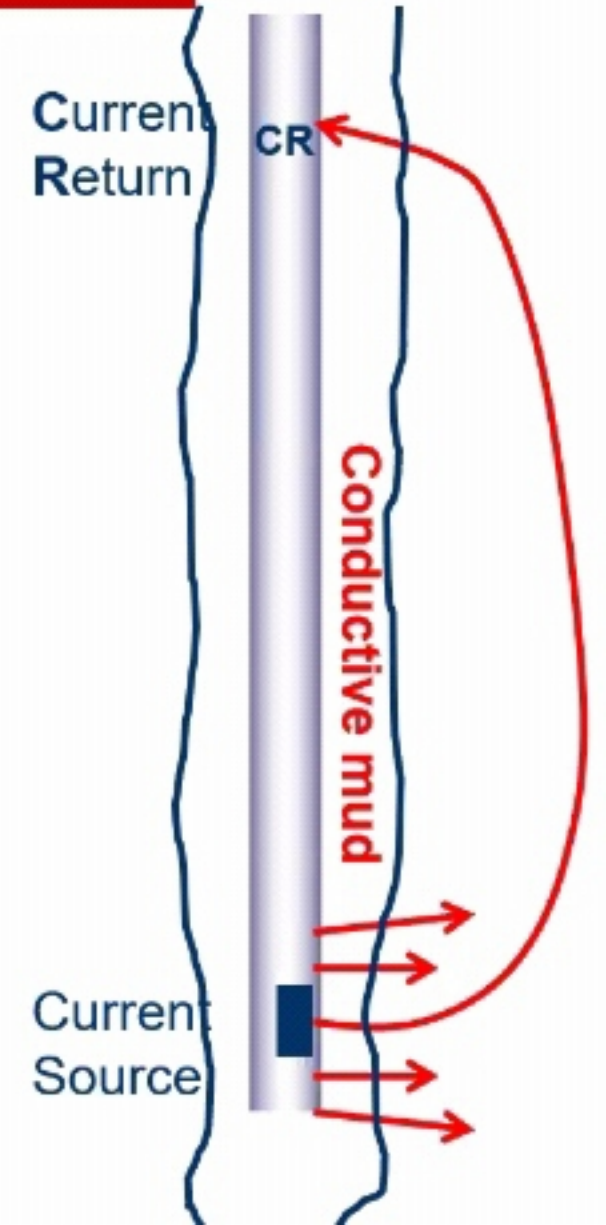




## Resistivity Tools

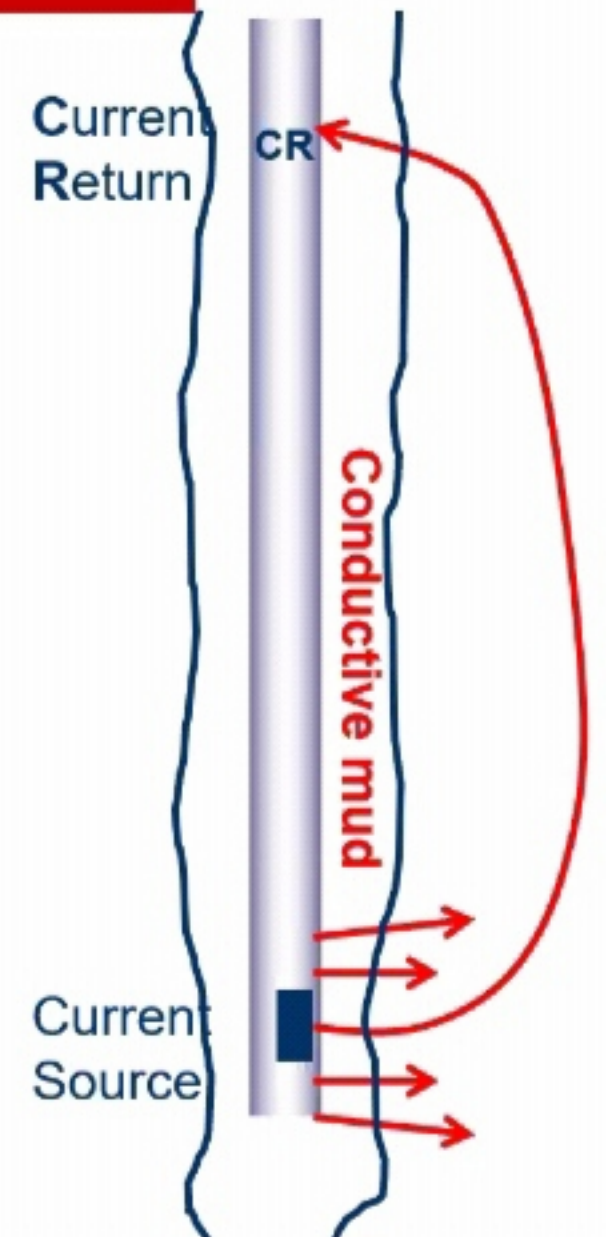
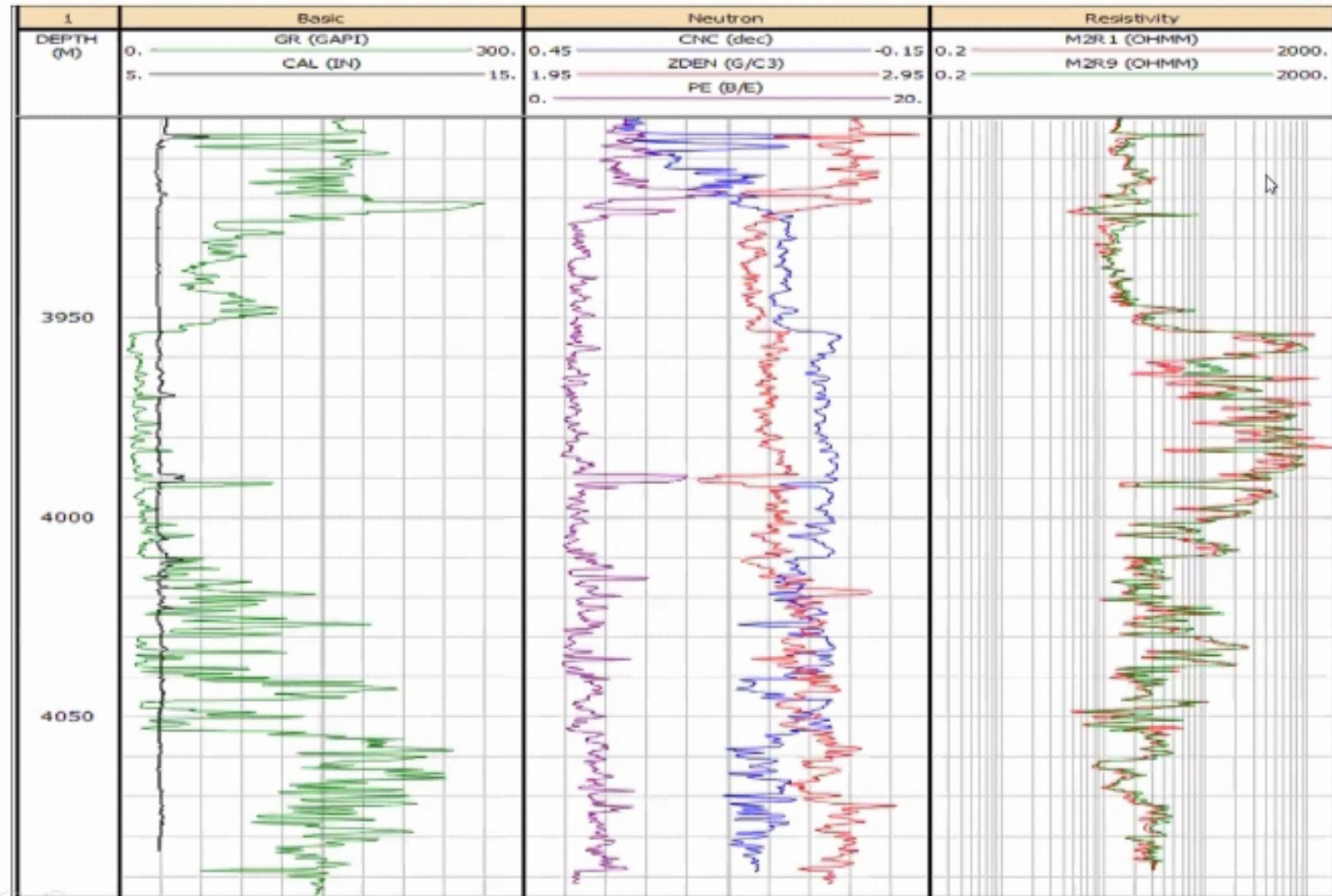


## Resistivity Tools - Lateral Resistivity Tools



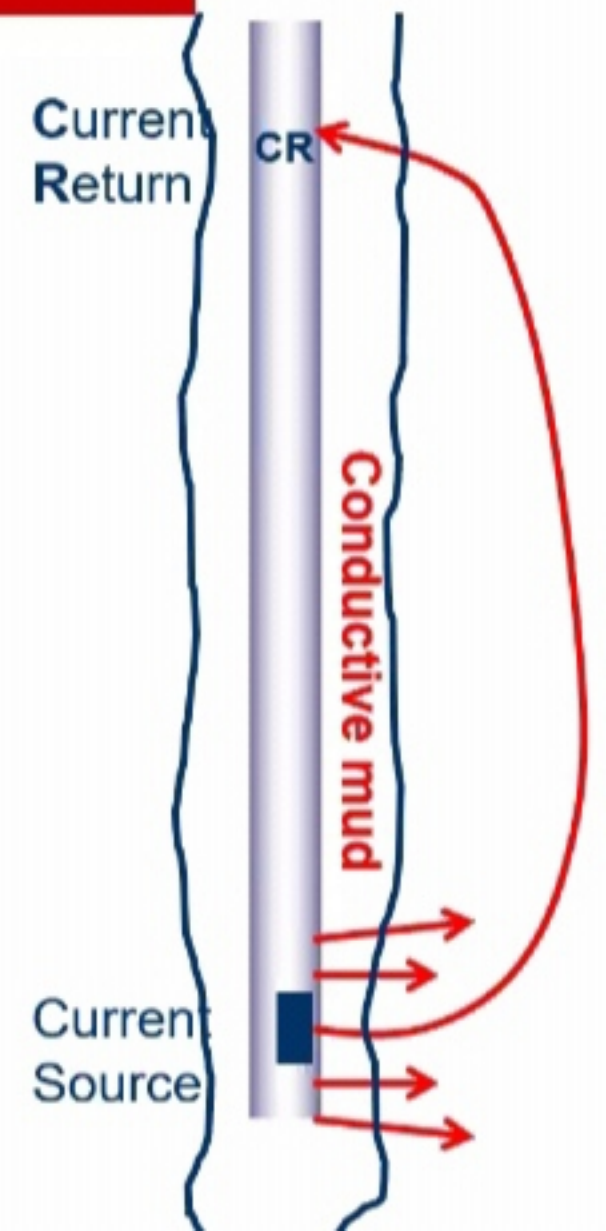
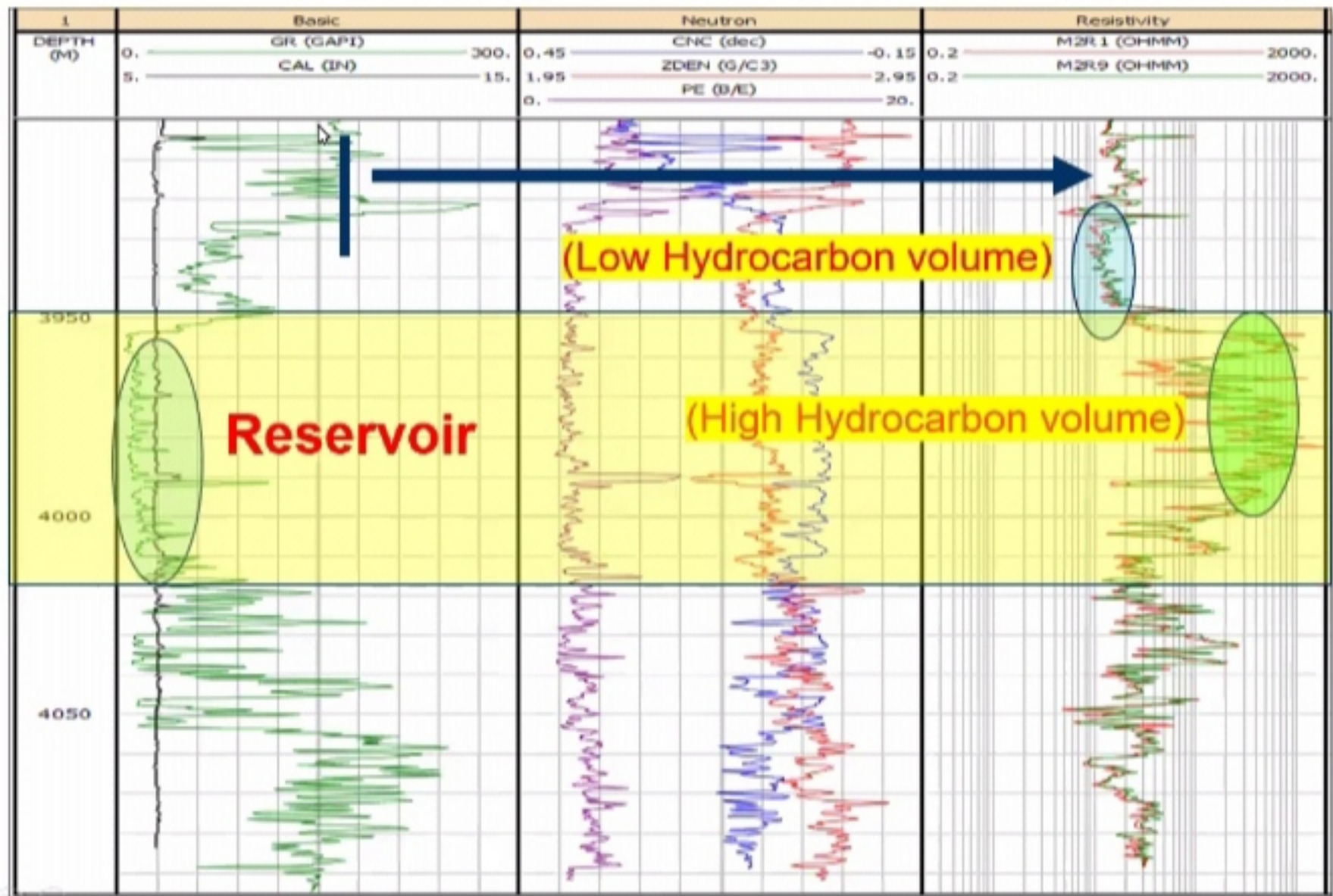


### Resistivity Tools - Lateral Resistivity Tools





## Resistivity Tools - Lateral Resistivity Tools

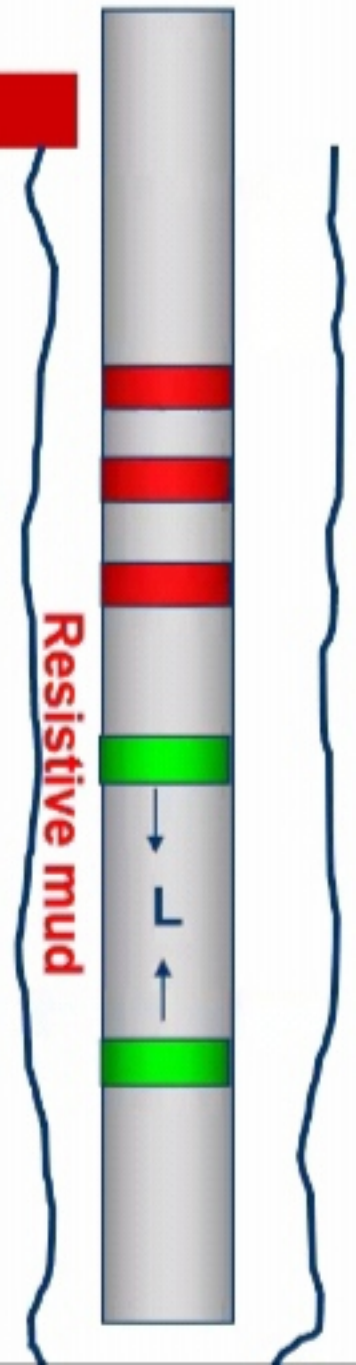


## Never Forget this .....

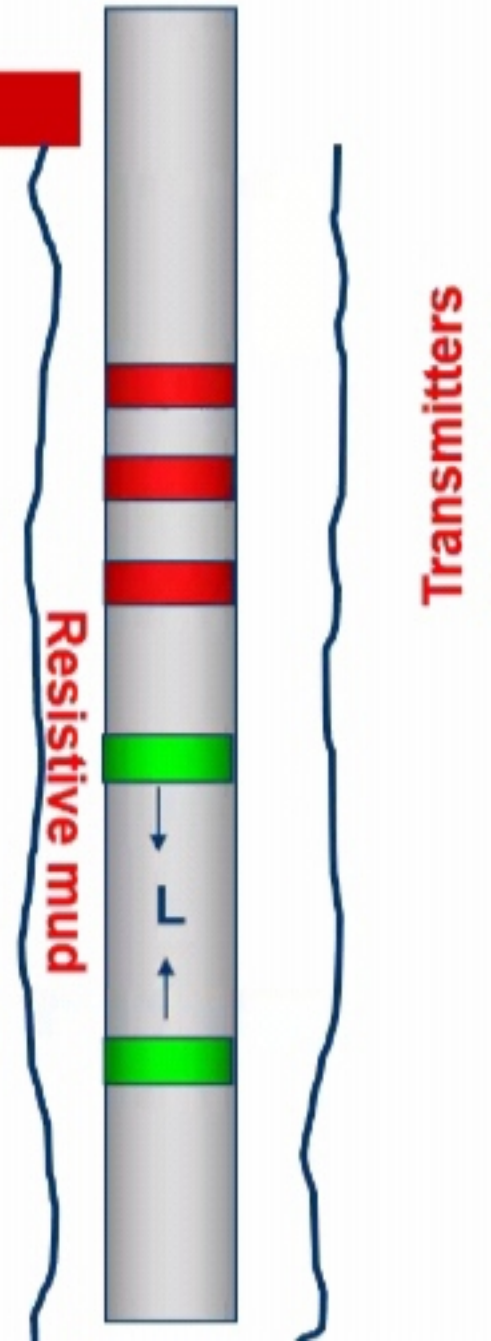
- **NONE** Reservoir properties on LOGS
  - High Gamma Ray
  - Low Resistivity



## Resistivity Tools in Resistive Mud

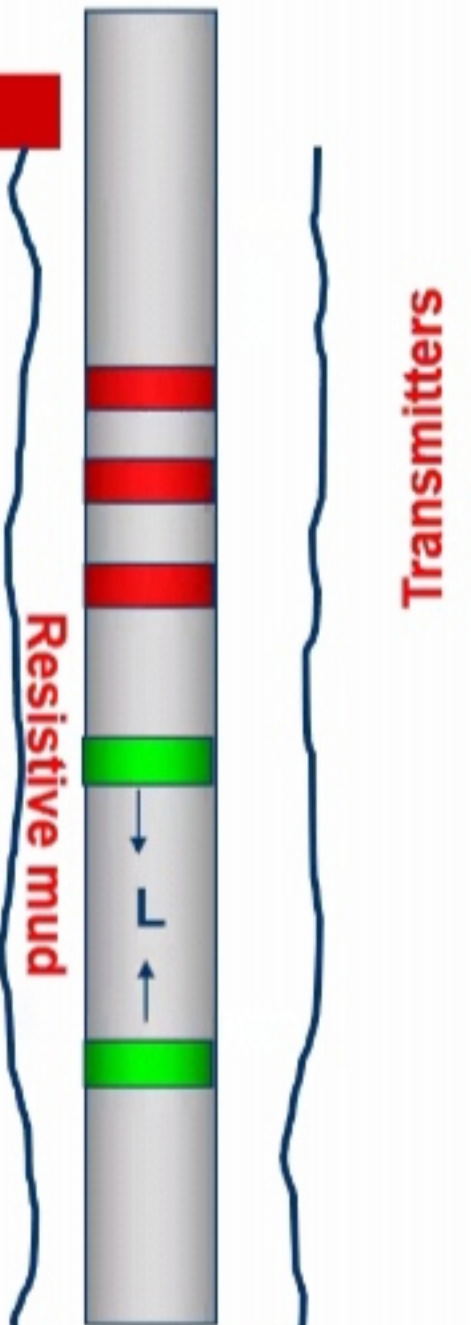
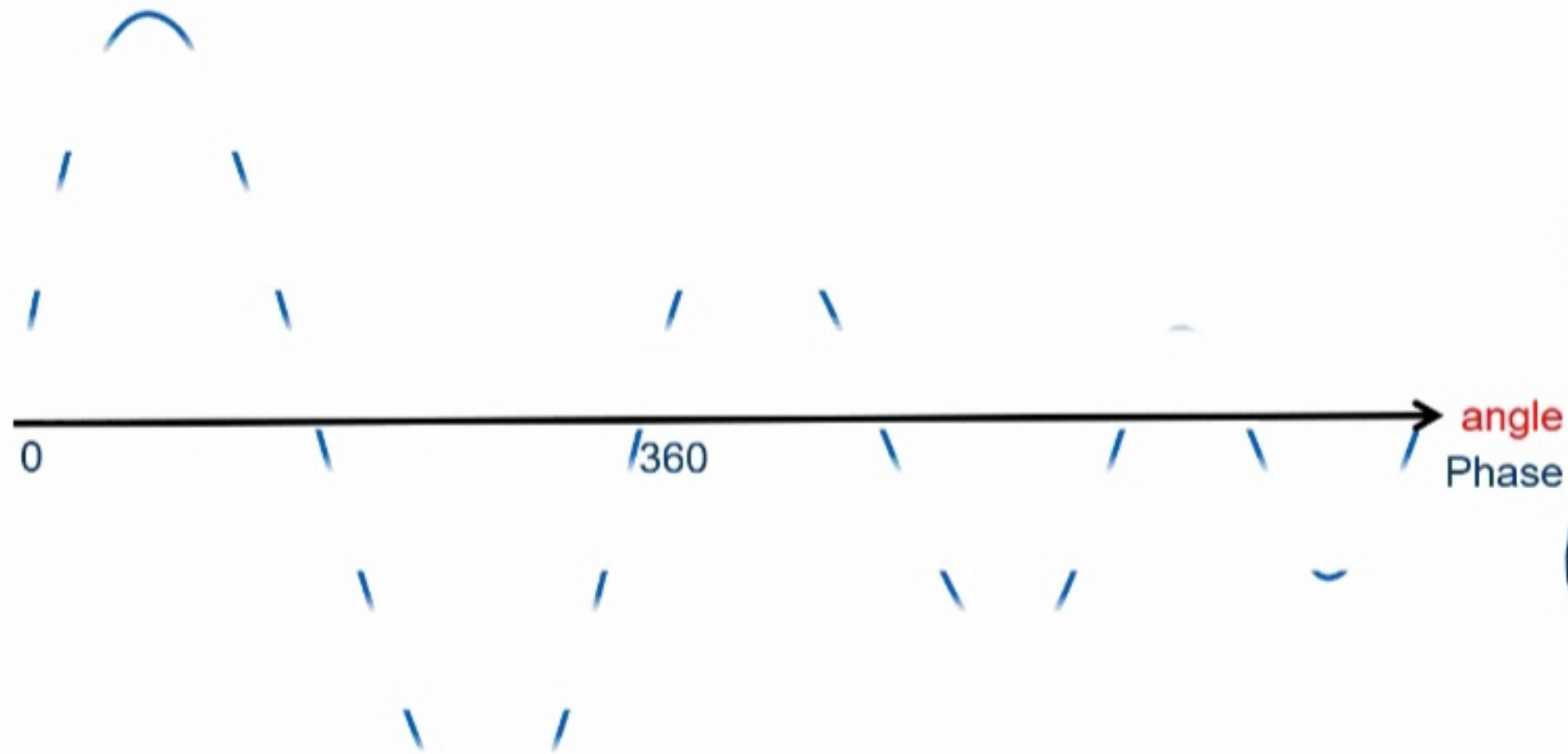


## Resistivity Tools in Resistive Mud

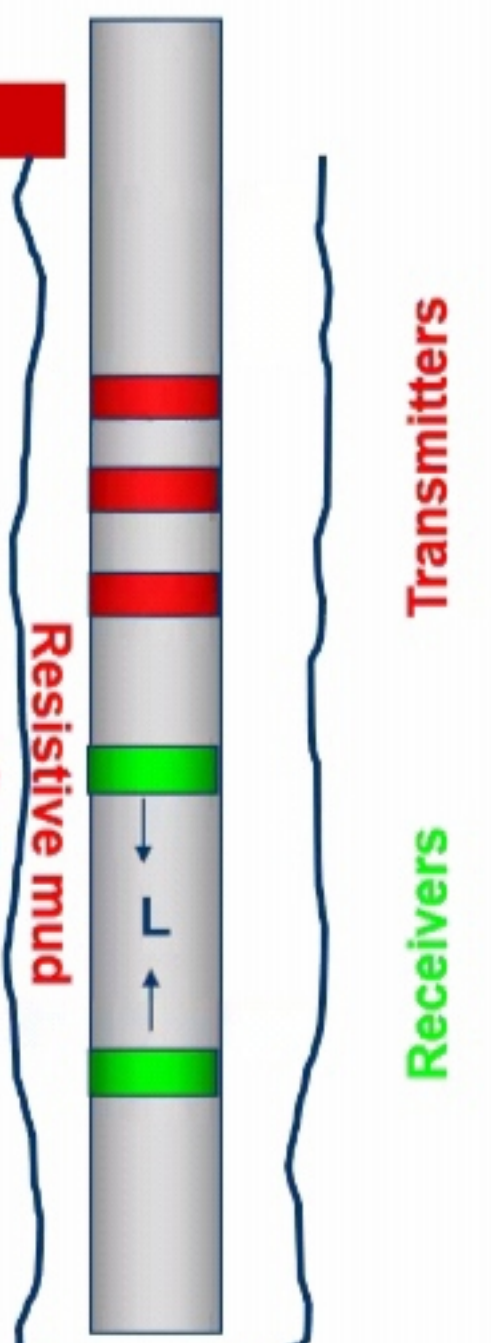
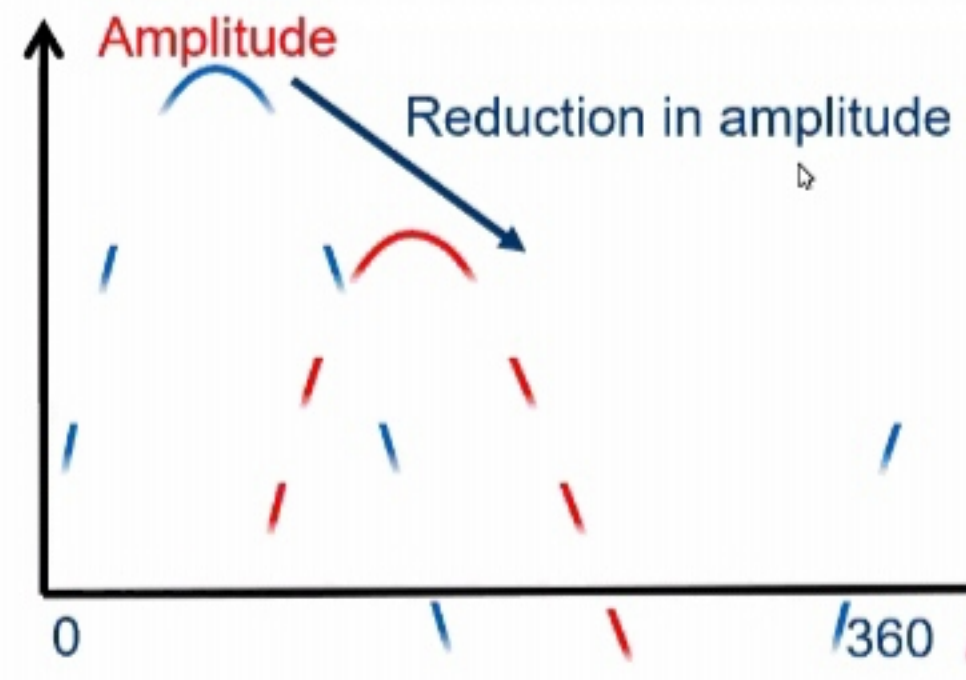




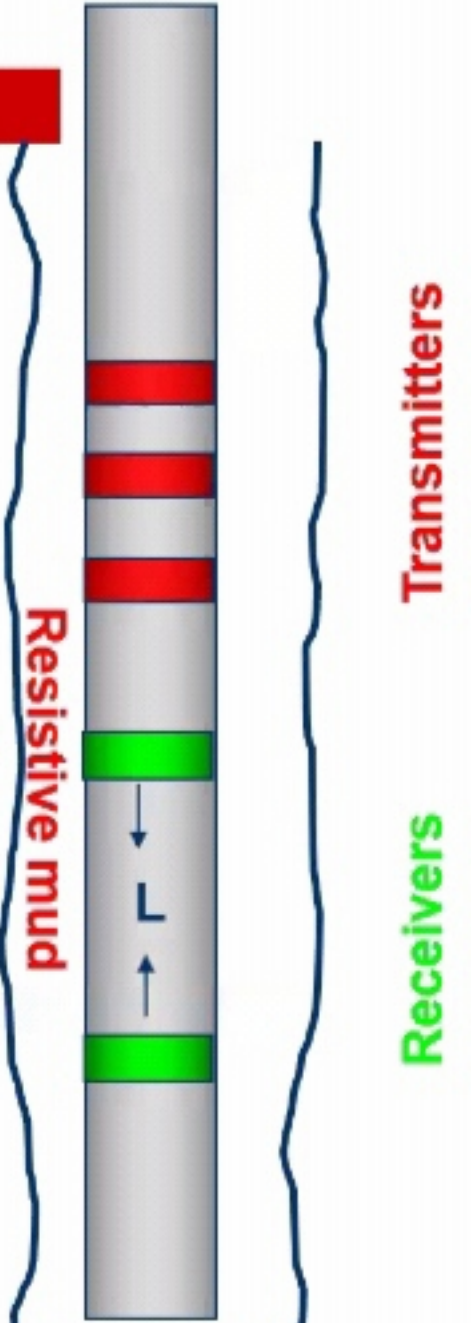
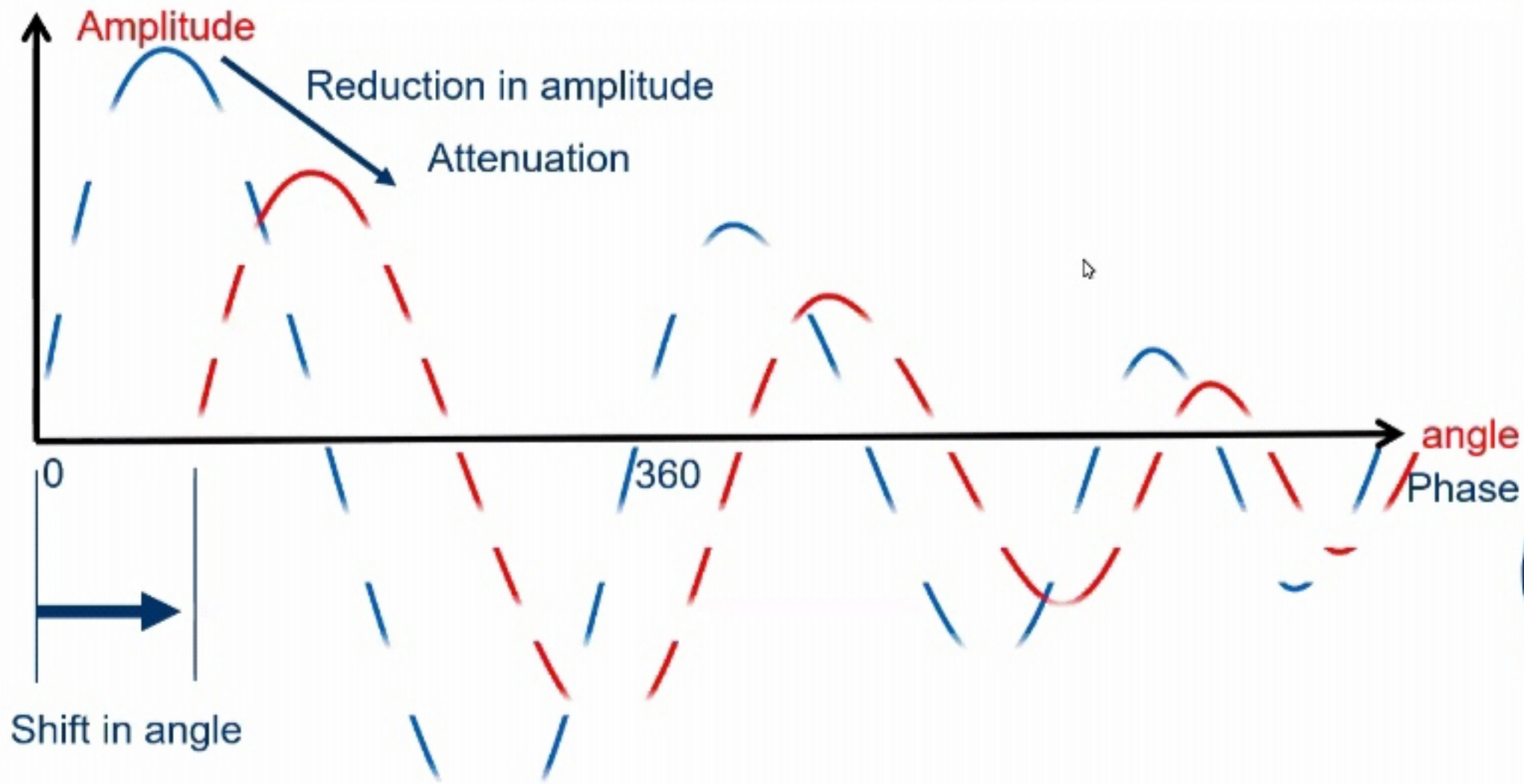
## Resistivity Tools in Resistive Mud



## Resistivity Tools in Resistive Mud



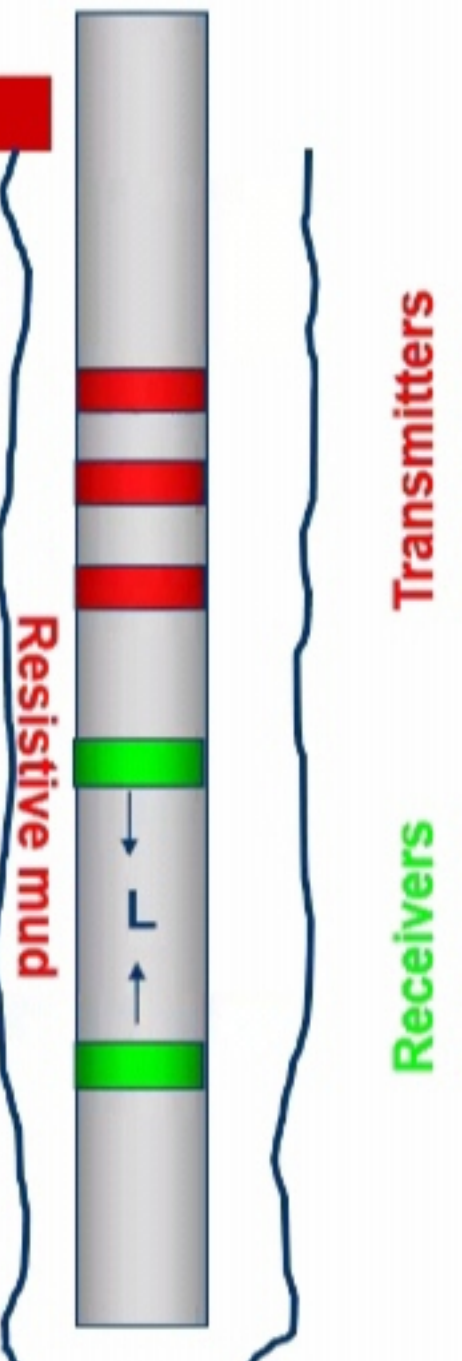
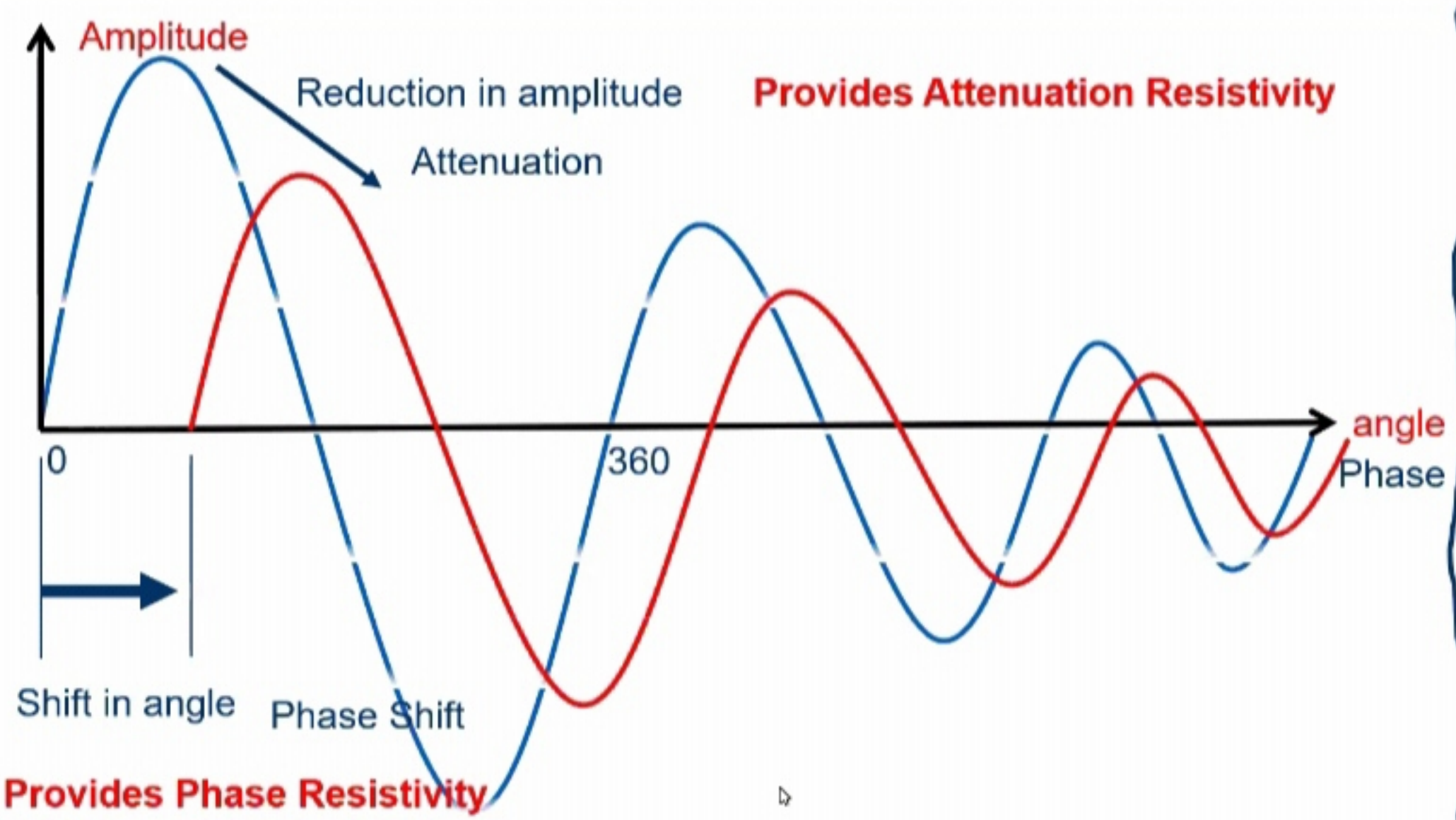
## Resistivity Tools in Resistive Mud



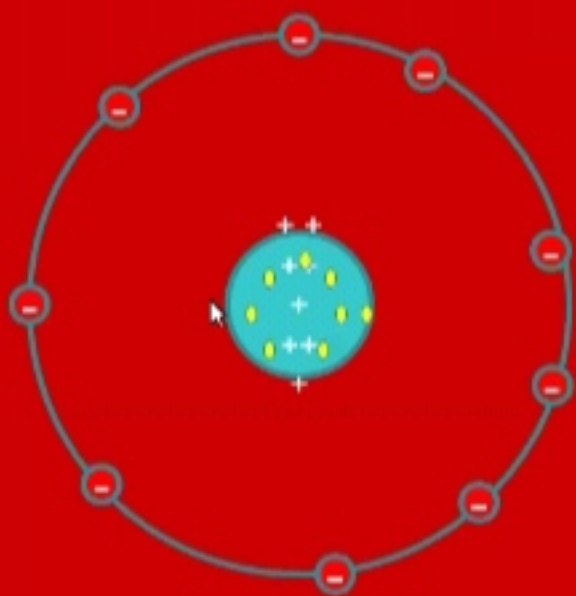


## Density Measurement

## Resistivity Tools in Resistive Mud



## Density Measurement



Physics:

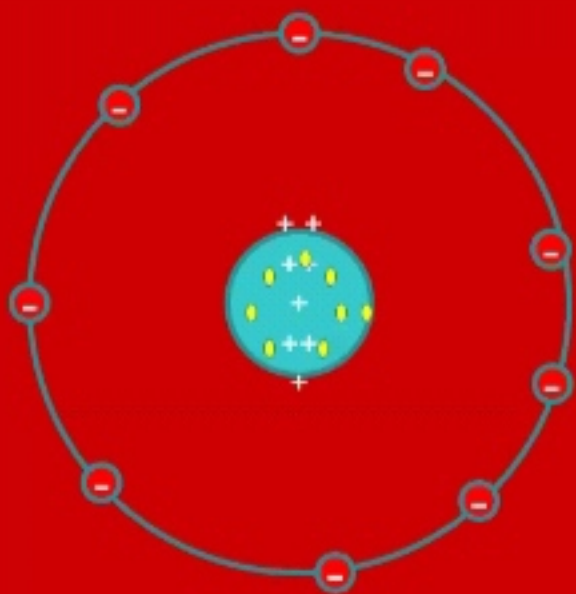
- ✓ What is density?

$$\rho = \frac{M}{V} \quad \longrightarrow \quad \rho = \frac{M}{1} = M$$

- ✓ Measuring mass will relate to density
- ✓ Mass of atoms relate to neutrons and protons in the nucleus



## Density Measurement



Physics:

- ✓ What is density?

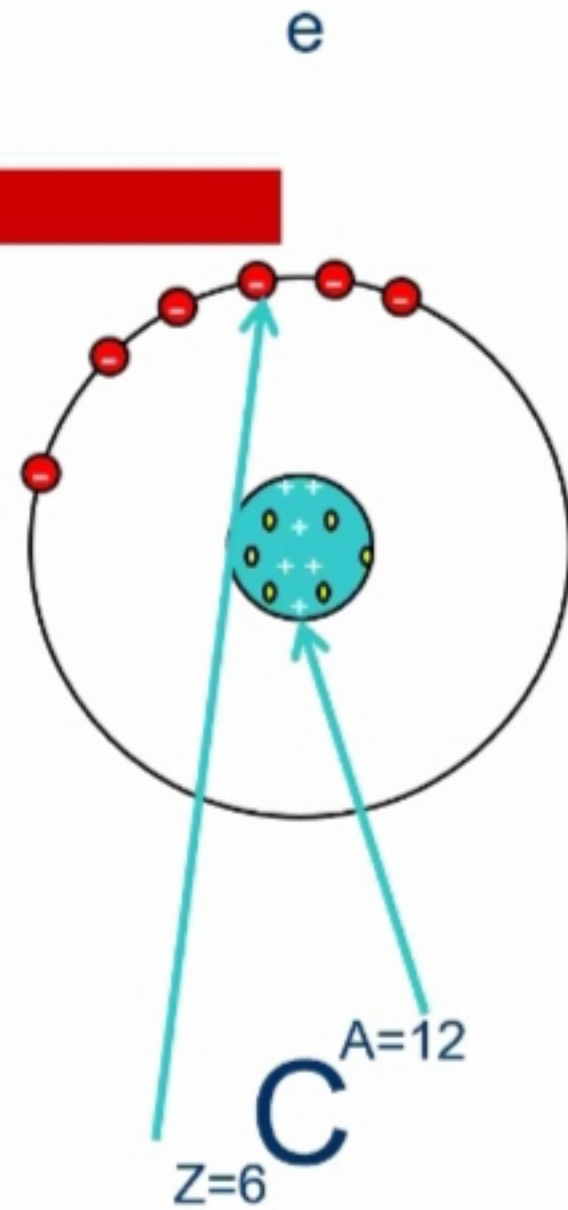
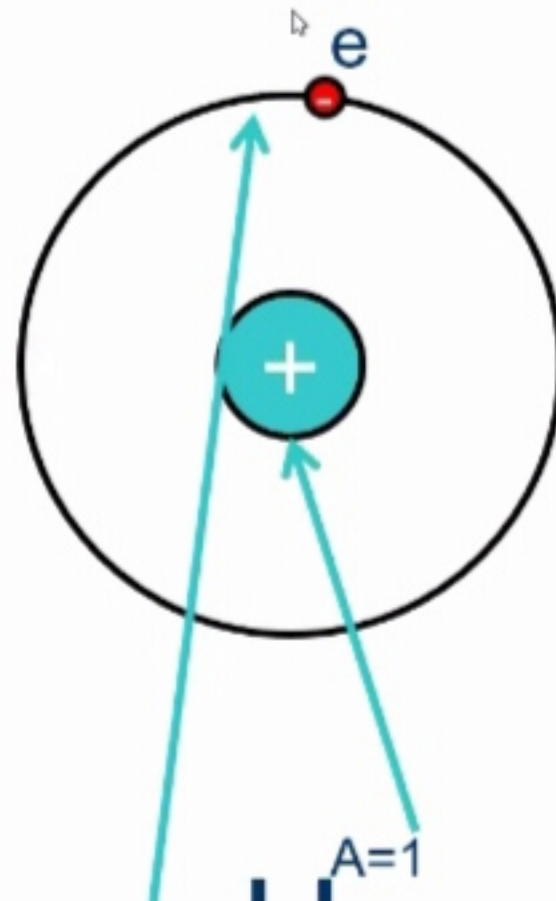
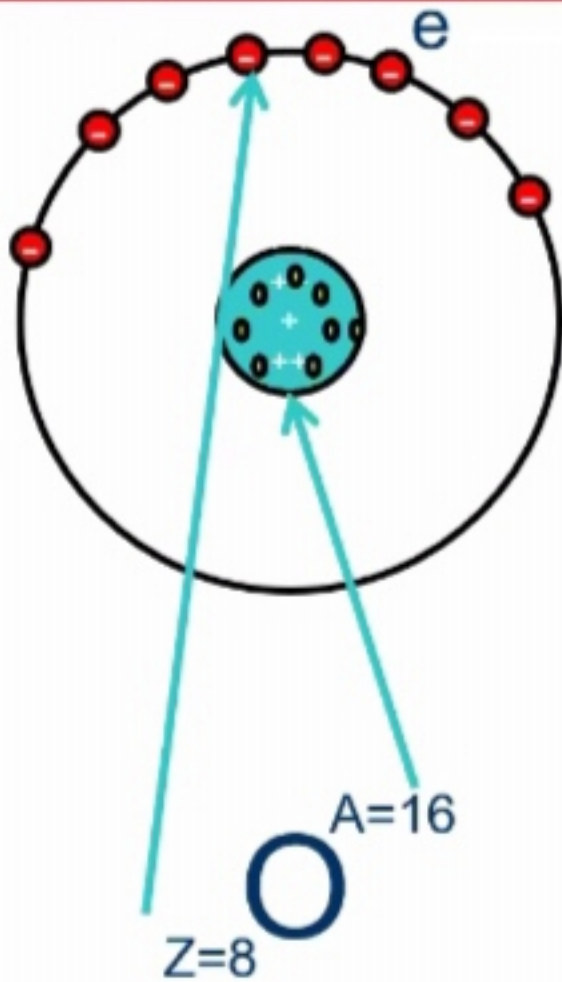
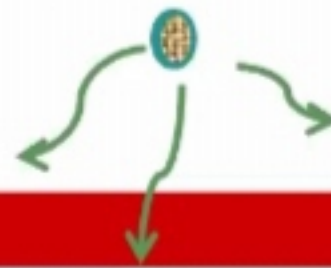
$$\rho = \frac{M}{V} \quad \longrightarrow \quad \rho = \frac{M}{1} = M$$

- ✓ Measuring mass will relate to density
- ✓ Mass of atoms relate to neutrons and protons in the nucleus
- ✓ In our rocks ( non-radioactive)
  - ✓ # electrons = # protons = # neutrons

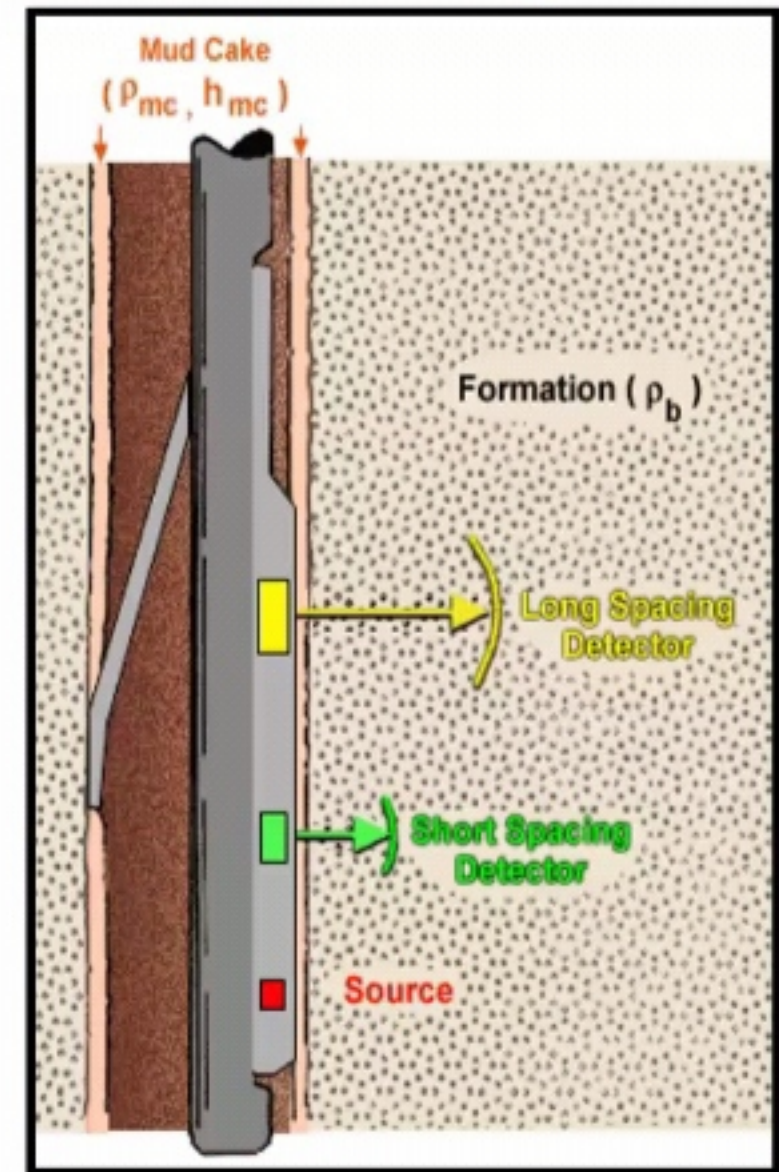
# Introduction

To Rock Evaluation

Low Energy Gamma Ray,  $\gamma$ , source



## Density Tool

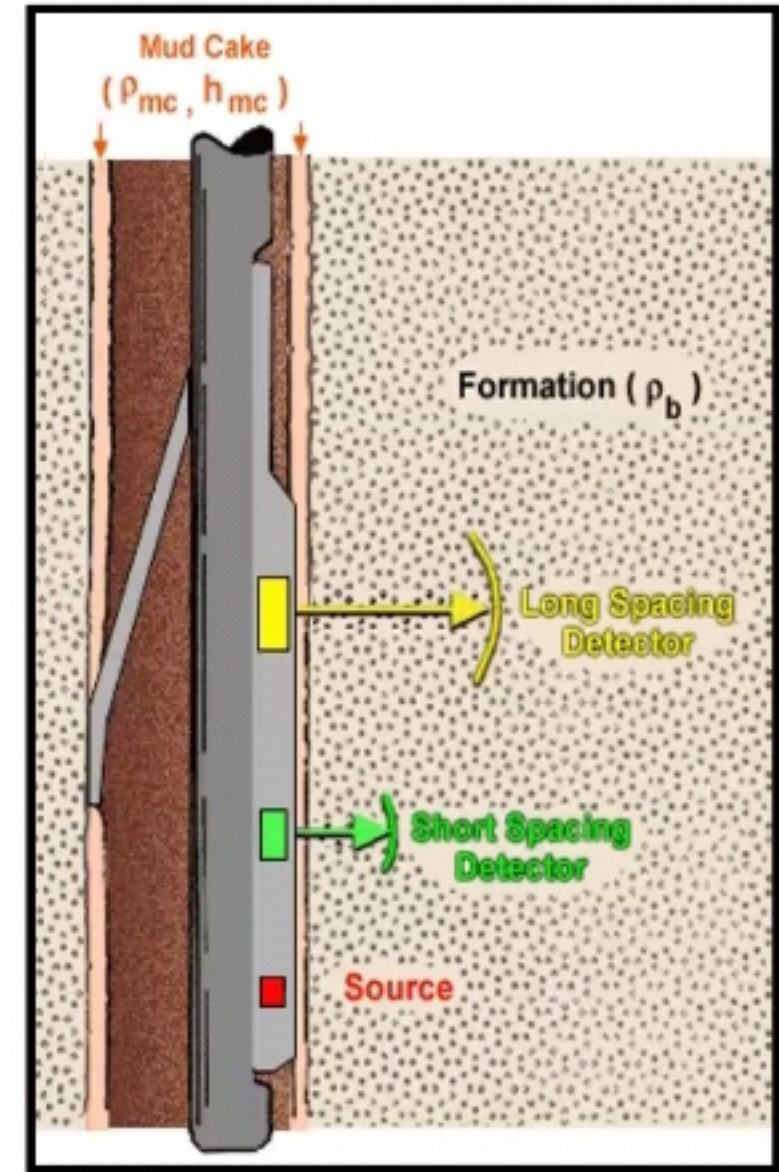
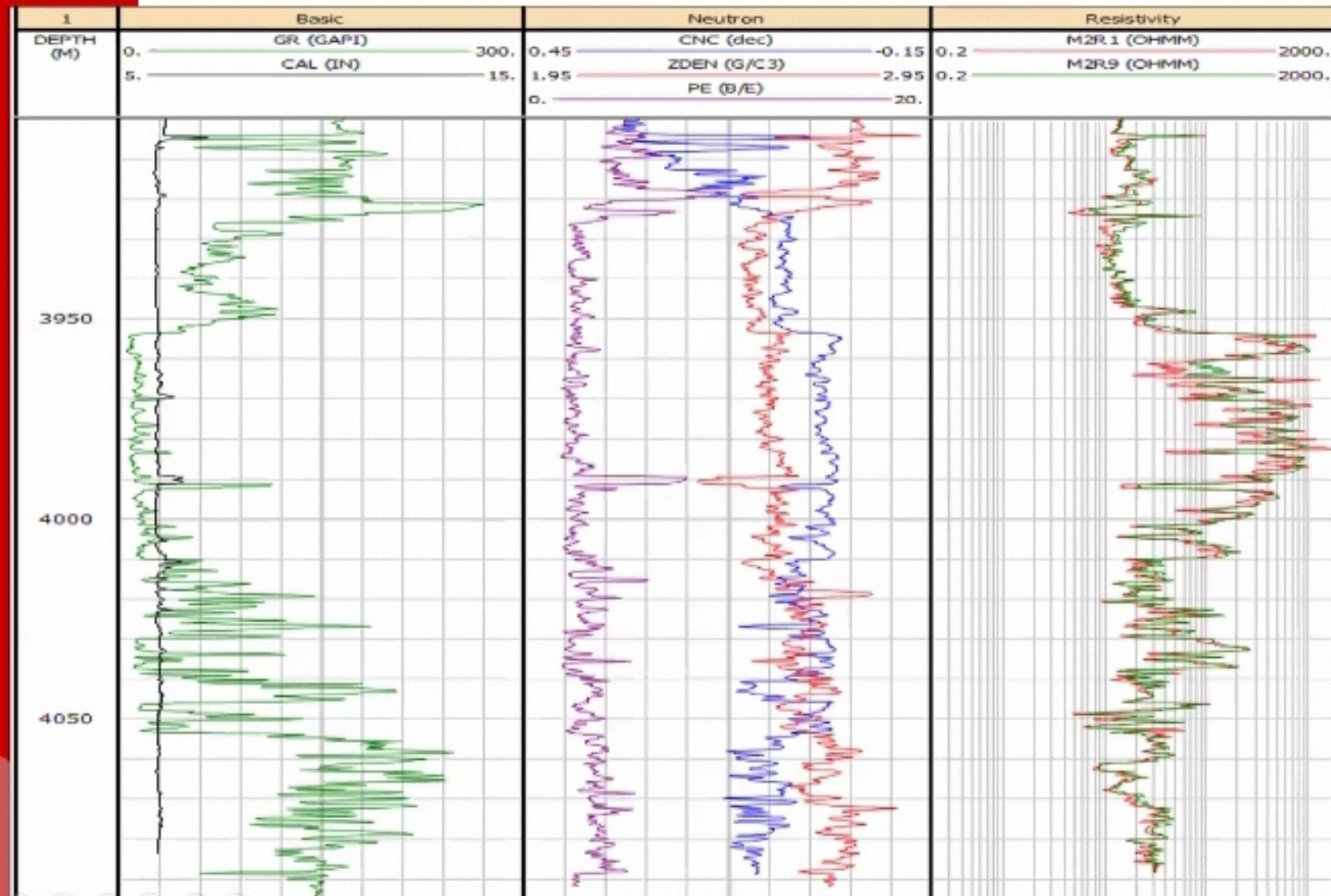




# Introduction

To Well Logging

## Density Tool



## Sonic Tools

Physics:

- ✓ Sonic (**sound**) wave
- ✓ When sent into the rock
  - ✓ Compresses grains
  - ✓ Shears grains



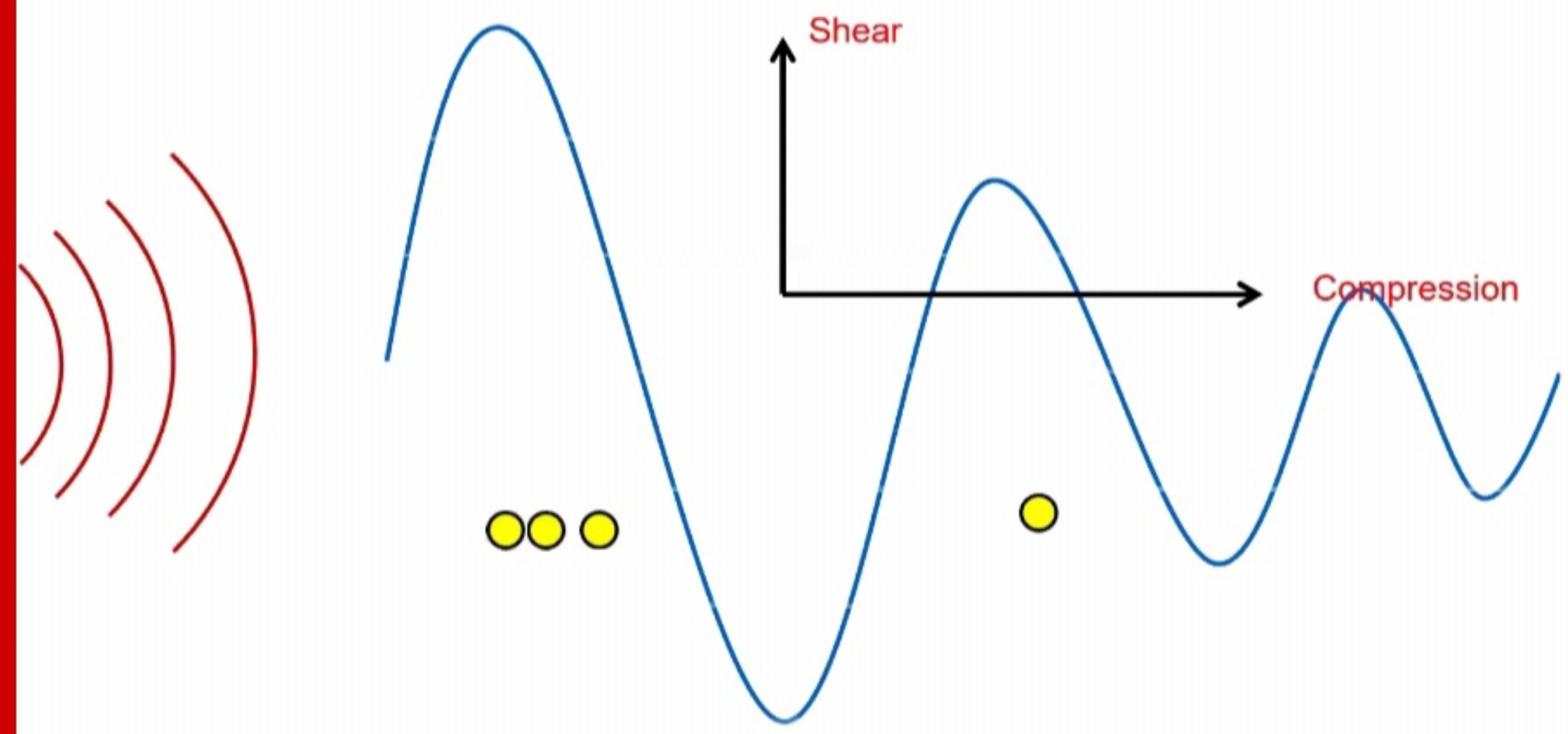
## Sonic Tools - **Detection**: Sound Listening Tools

Physics:

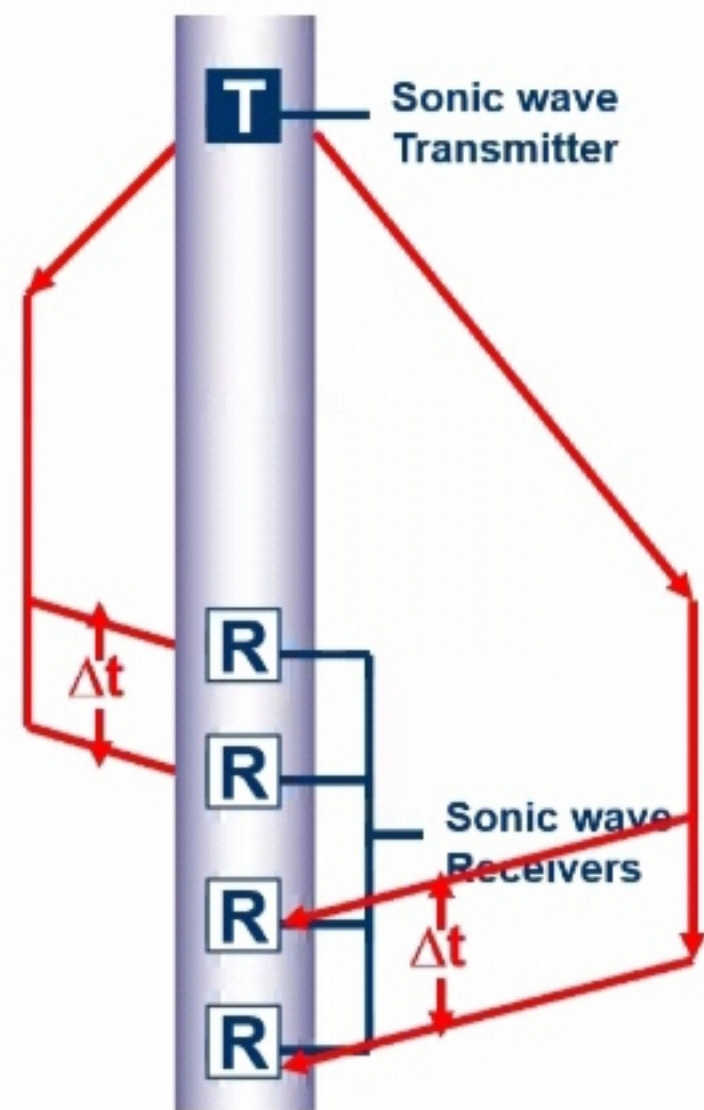
- ✓ Sonic (**sound**) wave
- ✓ When sent into the rock
  - ✓ Compresses grains
  - ✓ Shears grains
- ✓ From this, we can find out the rock strength



## Sonic Wave motion in a formation



### The Sonic Tool

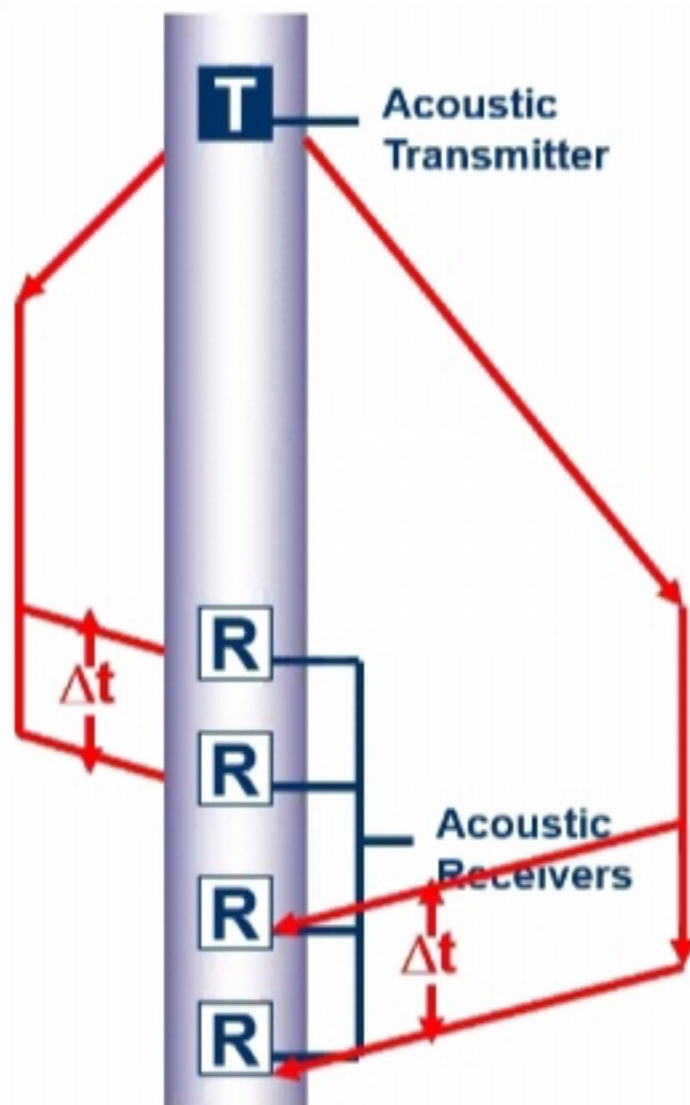


Long spaced sonic tools have **transmitter** and **receivers** which allow for a greater depth of formation investigation

The transmitter emits sound wave into the formation

The receivers measure the travel time ( $\Delta t$ ) it takes the compressional wave to go through the formation and reach the receivers

## The Sonic Tool

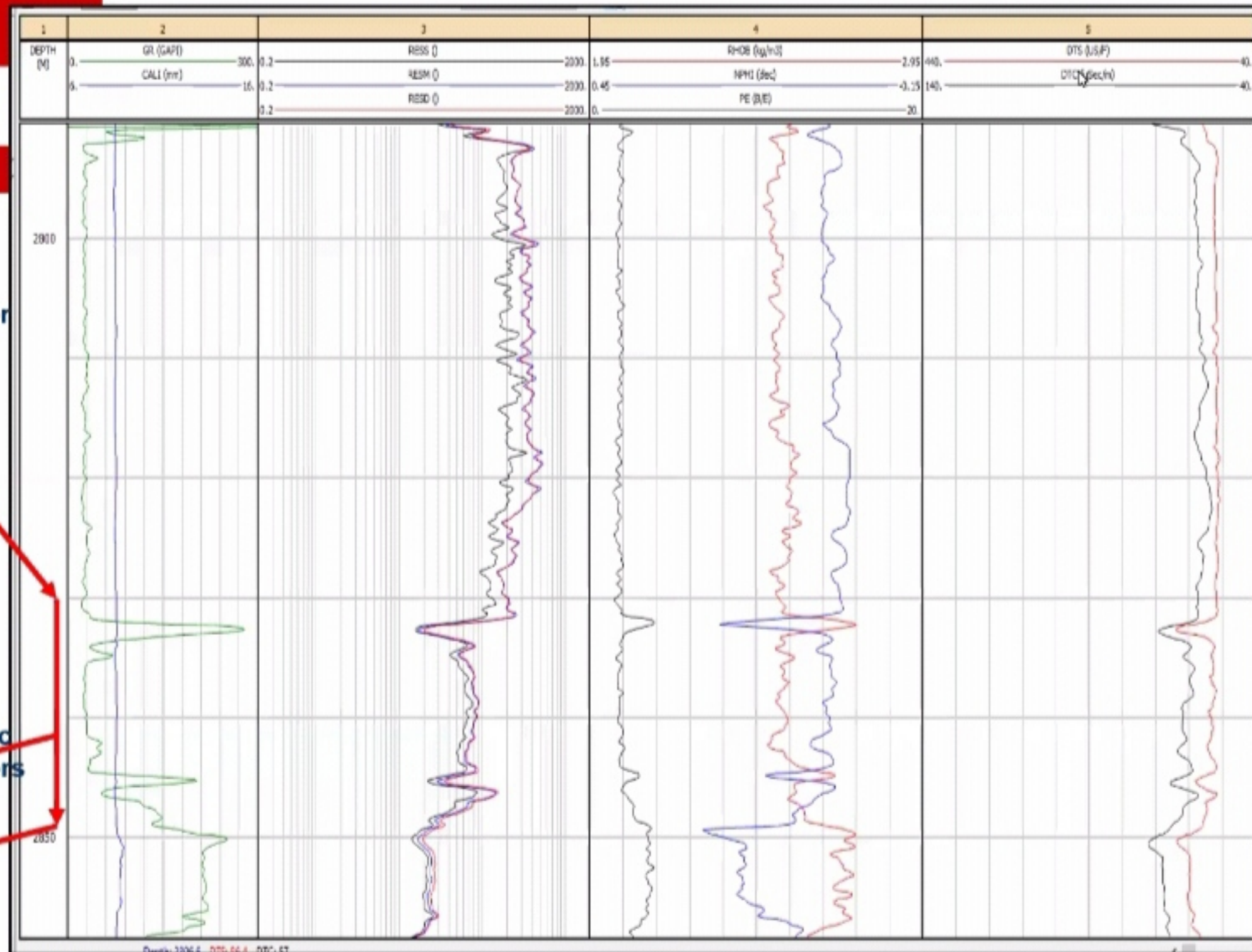
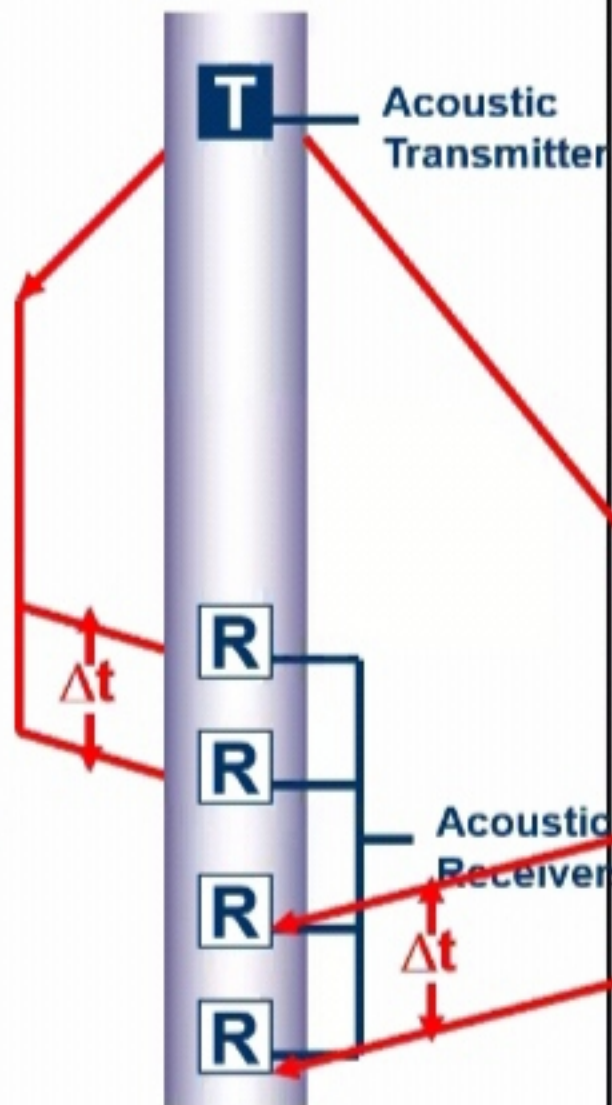




# Introduction

## To Well Logging

### The Sonic Tool



## Conclusions

- Many tools are available for formation rock evaluation
- Each tool uses
  - Physical property to measure
  - Tool design to capture the rock property
    - Porosity
    - Clays
    - Density
    - Fluids saturation
    - Rock strength (mechanical properties)
- The combination of tools you run is dependent on what you want to evaluate

# Thank You

**Wish you all the best in your career**