Introduction to Formation Evaluation

By

Abiodun Matthew Amao

Lecture Outline

- What is formation evaluation?
- Why do we evaluate formation?
- What do we evaluate?
- What data are we interested in?
- Who needs these data?
- What tools and methodology?
- Summary
- References

What is formation evaluation?

- Formation evaluation is the application of scientific principles, engineering concepts and technological innovations in the exploration and prospecting of hydrocarbon resources in geological formations in an environmentally sustainable and responsible manner.
- It involves detailed and systematic data acquisition, gathering, analysis and interpretation both qualitatively and quantitatively while applying scientific and engineering principles.
- It is an ever growing and evolving field of petroleum engineering
- **Petrophysicists** are engineers or geologists that specialize in the profession of formation evaluation.

Why do we evaluate formation?

- We want answers to the following questions:
- Is there any oil or gas there?
- Where are they located?
- How much of it?
- How much can we produce, which answers the question, “How much money can we make?”

What do we evaluate?

- We evaluate a reservoir; a reservoir is the "container" storing the hydrocarbon.

- A **conventional reservoir** will be characterized by the following properties;
  - Trap/Cap Rock
  - Source Rock
  - Porous and Permeable media
  - Hydrocarbons (Gas or Oil)

What data are we interested in?

- Rock Type
- Porosity
- Fluid Saturation (Volumes)
- Fluid Type
- Reservoir Structure
- Permeability (Ease of fluid flow within porous media)
- Reservoir Pressure (Drive)

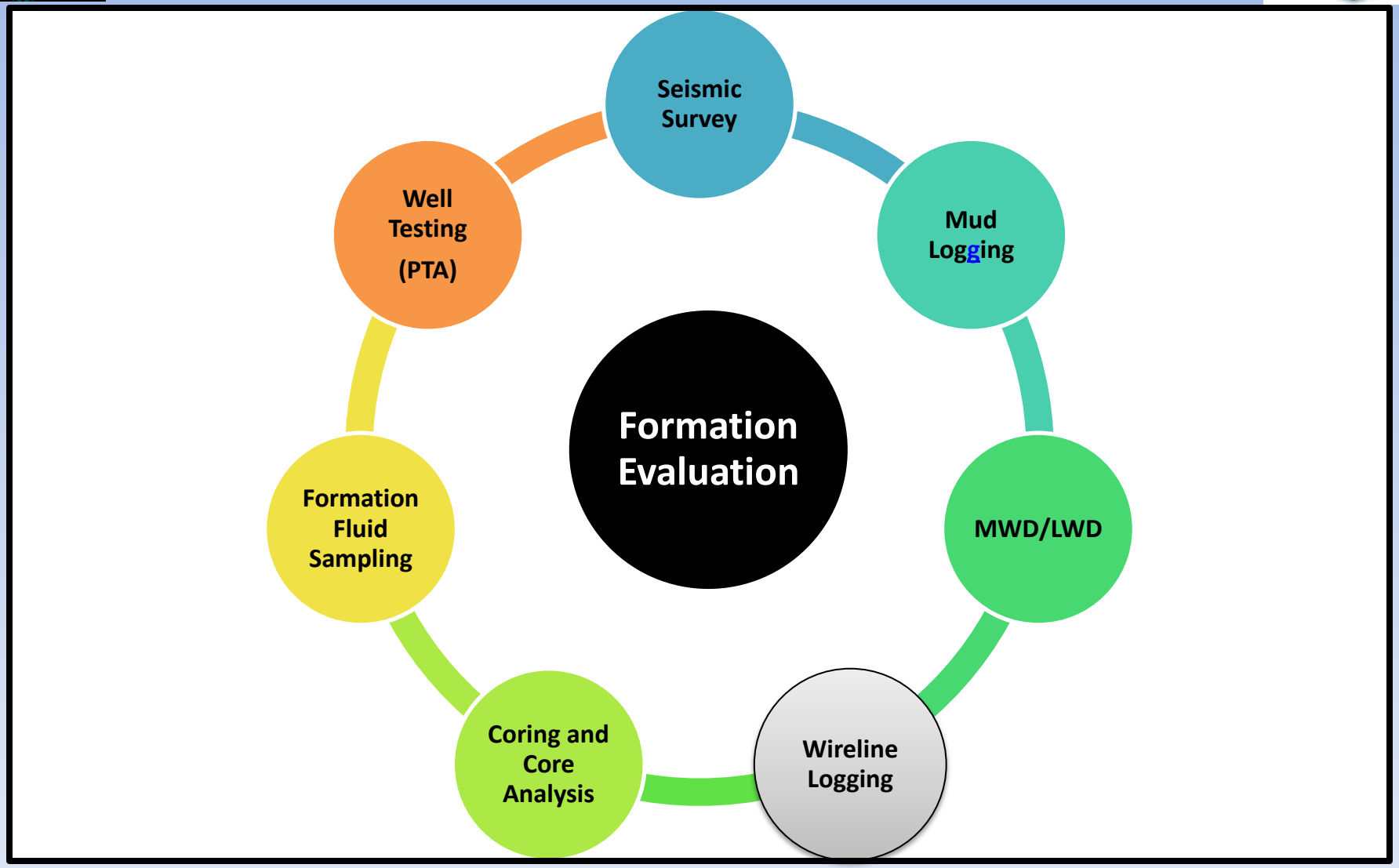
Scale in Formation Evaluation

Order of Magnitude (Meters)	Formation Evaluation Technique	Purpose
10^{6}	Satellite Imagery	Gross Structure
10^{5}	Basin Geologic Studies	
10^{4}	Seismic, gravity, magnetics	
10^{3}	Borehole gravimeter, Ultra long spacing electric logs	Local Structure
10^{2}	Drill Stem Tests	Productivity and Reserves
10^{1}	Wireline Formation tests	
10^{0}	Full diameter cores (Whole Core)	Local Porosity, permeability and Lithology
10^{-1}	Sidewall cores, LWD, Wireline	
10^{-2}	Core-plug analysis, micro-logs	
10^{-3}	Cutting analysis, mud logging	Local Hydrocarbon Content
10^{-4}	Core analysis	Rock Properties
10^{-5}	X-ray mineralogy	Rock and clay typing
10^{-6}	Scanning Electron Microscope	Micro-structure

Who Needs What Data?

Discipline	Data
Geophysicist	Time-Depth relationship for seismic profile
Geologist	Stratigraphy, Structural Sedimentary features, Mineralogy, bedding planes
Reservoir Engineer	Porosity, permeability, fluid contacts, reservoir pressure, producibility
Drilling Engineer	Reservoir targets, offset log data if any
Production Engineer	Rock mechanical properties, reservoir pressures, flow potential, flow assurance issues, fluid types
Manager	Hydrocarbon in place, recoverability, cost of development, profitability
Government (Regulator)	Keeps a record of All data, field development plan (FDP), Profitability for the national economy

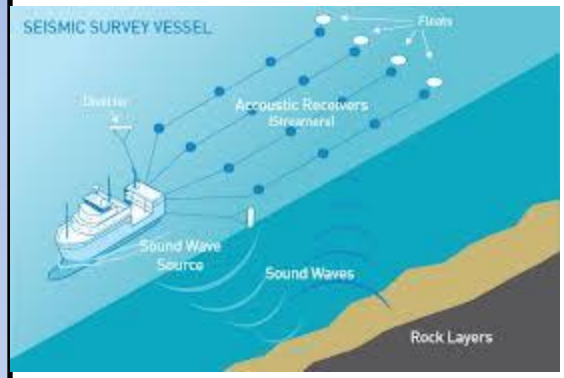
What tools and methodology?

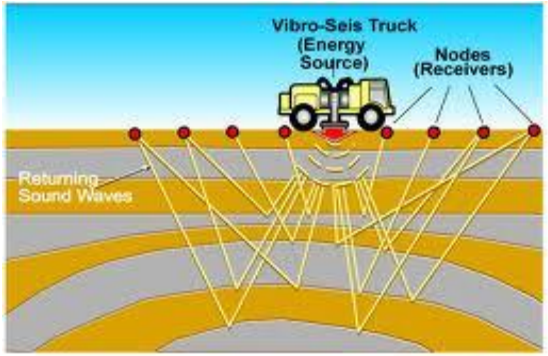


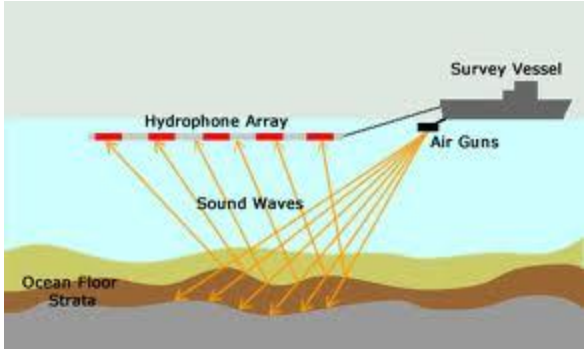
Data from Seismic Survey

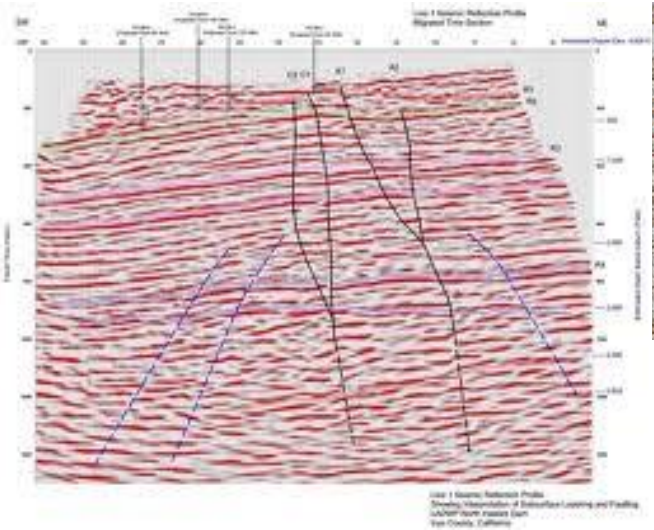
- Vertical Seismic profile of the earth
- Structure of reservoir
- Location of traps and seals
- Depth of structure and geologic layer
- Presence of fluids
- 3D high resolution surveys
- Time Lapse seismic (4D Seismic)

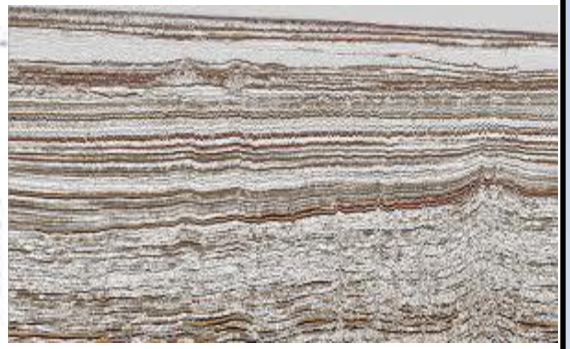
Seismic surveys







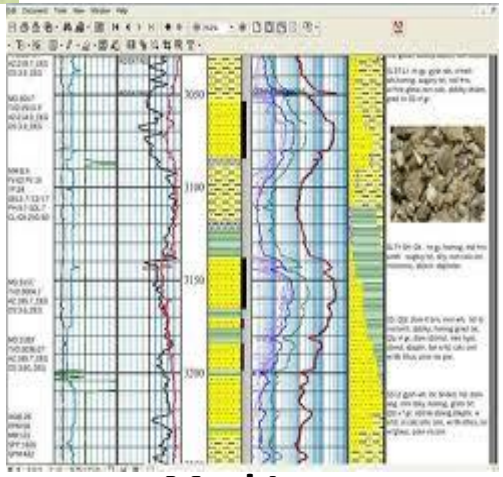




Data from Mud Logging

- **Mud logging**: Analyzing, evaluating and monitoring drill cuttings and circulating mud during the drilling process. Data we can get include;
- Lithology, mineralogy and their estimated depths
  - Hydrocarbon shows and type
  - Chromatographic analysis of gas
  - Hazardous gas e.g. H_2S
  - Rate of penetration
  - Fossil record
  - Overpressure zones
  - Drill cutting porosity

Mud Logging Units



Mud Log

Data From MWD/LWD

- **Measurement While Drilling (MWD) and Logging While Drilling (LWD)** : These describes continuous measurement taken by down-hole sensors during drilling. The tools (subs) are made up with the BHA (bore hole assembly) drill string. **It is an indirect measurement**. Data gotten;
  - Porosity, Lithology
  - Acoustic
  - Formation Pressure and Temperature
  - Resistivity
  - Nuclear Magnetic Resonance (NMR)
  - Hole deviation from vertical, azimuth from geographic coord.
  - Tool face angle, ROP etc.
  - Gamma Ray

MWD/LWD Tools

Data from Wireline Logging

- Most versatile of the formation evaluation methods, **it is an indirect measurement**; we can get the following data;

Open Hole Logging	Cased Hole Logging
• Porosity • Fluid Sample (Types) • Water Saturation • Hydrocarbon movability • Lithology • Formation dip and structure • Sedimentary Environment • Travel times of elastic waves • Permeability • Fracture and Vugs • Rock mechanical properties	• Flow rates • Fluid types • Pressure • Residual oil saturation • Cement evaluation (Bonding)

Truck, Skid, Tools and Cable

Data from Core Analysis

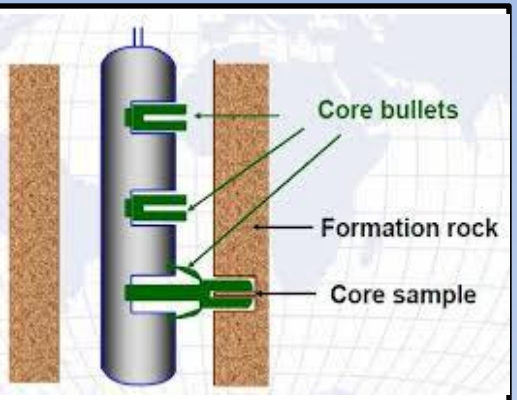
- Coring: Get unaltered formation sample, bring it to the surface with its native fluid, preserve both and transport to a laboratory for detailed analysis.
  - Conventional Coring- Used of core bit and BHA
  - Wireline Cores: Sidewall core guns and Rotary sidewall coring tool

- Data gotten from cores are; (**These are direct measurements done on the core samples**)
- *Routine core analysis*: Porosity, Permeability, Lithology, grain density, Fluid saturation etc.
- *Special core analysis*: Relative permeability, pore-size distribution, mineralogy, SEM, CT-Scan, Electrical properties, mechanical properties, Capillary pressure, etc.

Tools for Coring on Different Scale

Core bits

Sidewall Core Guns

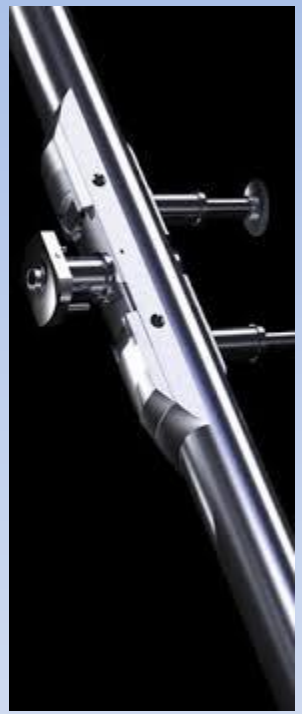


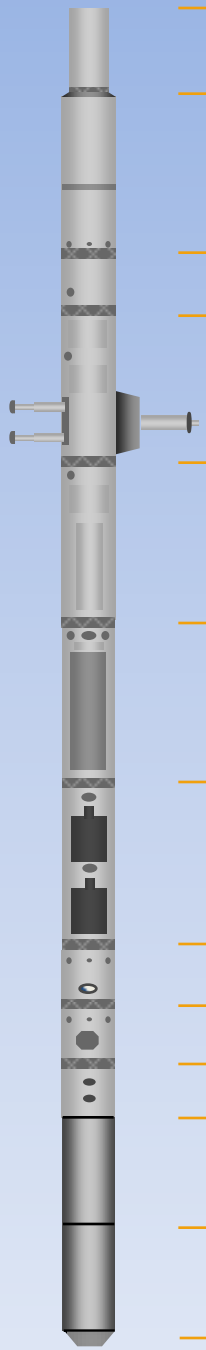
Data from Fluid Sampling

- Reservoir fluid is sampled using the following methodology;
  - Drill stem testing (DST) or Production Tests
  - Wireline formation testers
  - LWD Formation Testers
  - Surface Samples at the wellhead or separator

- Data acquired include;
  - Fluid Type,
  - PVT data, Fluid Composition from Lab tests
  - Pressure and temperature
  - Viscosity, GOR, API
  - Asphaltene and wax content
  - Presence of H_2S

Formation Tester





Telemetry

Hydraulics

Electronics

Packer

Drawdown / Pump

Large Volume Pump

Tank Carrier

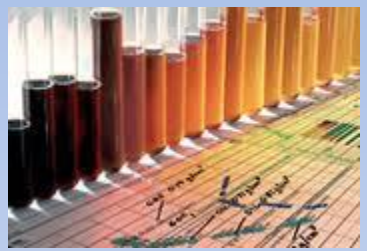
Borehole Exit

V.P.C.

Extraction manifold

Tank

Tank



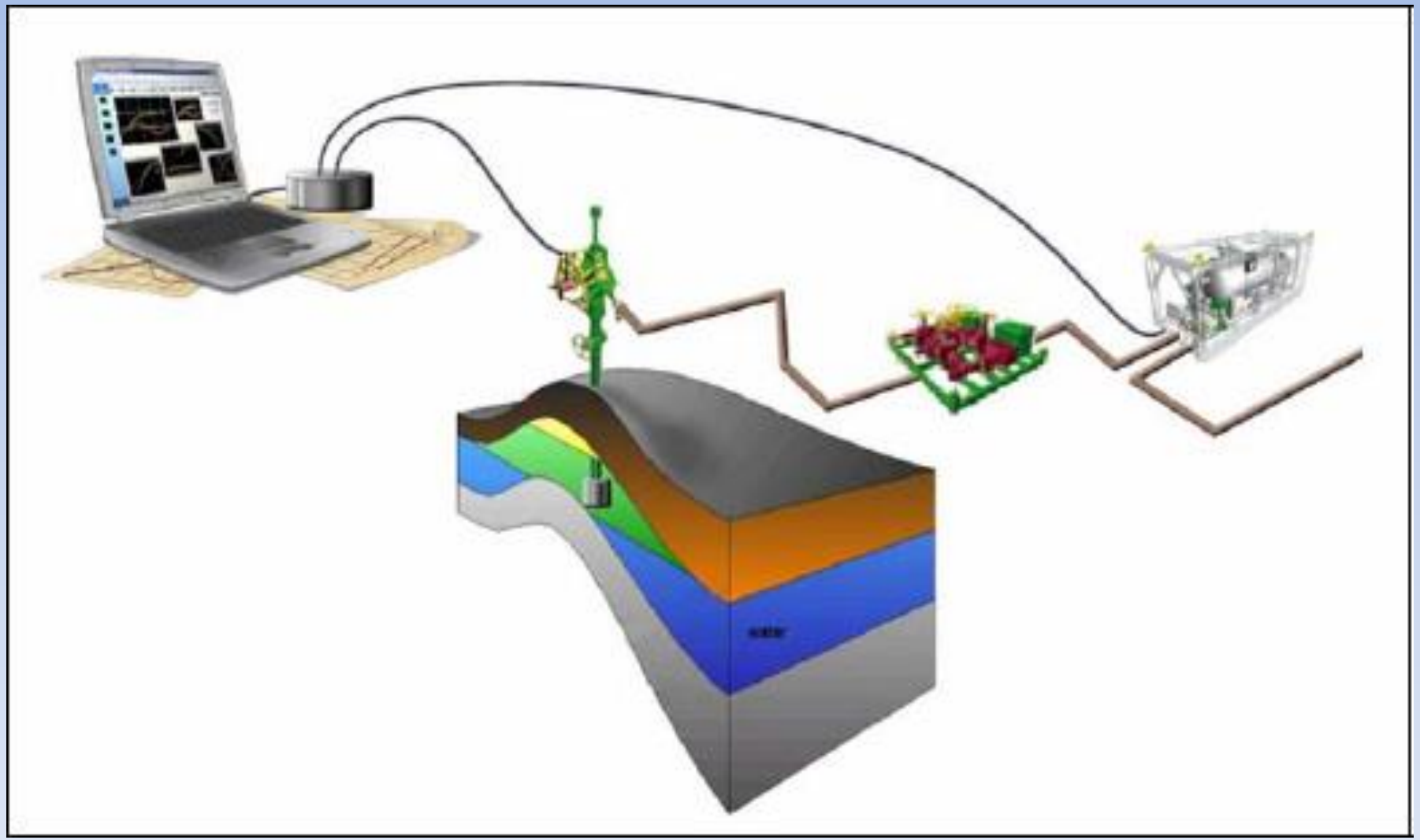
Well Testing
(Pressure Transient Analysis)

- **Pressure Transient** Analysis (PTA), is the recording of variation of pressure with time through a wellbore in a reservoir after a disturbance (shut-in, open to flow etc.) to normal well operations. It is also called;
  - Well Testing
  - Flow Tests
- Well testing is possible because pressure and flow rate can easily be measured in a well and an analysis of the measurement history reflects reservoir parameters.
- Pressure measurement can be;
  - Static (one time measurement)
  - Last the Duration of a Well test
  - Continuous e.g. Downhole pressure gauges in wells

Reservoir Properties Obtainable from Various Tests

Well Test	Reservoir Properties Obtainable
Drill Stem Tests	Reservoir Behavior, Skin, Permeability, Fracture Length, Reservoir pressure, reservoir limit, boundaries
Drawdown Tests	Reservoir Behavior, Skin, Permeability, Fracture Length, reservoir limit, boundaries.
Buildup Tests	Reservoir Behavior, Skin, Permeability, Fracture Length, Reservoir pressure, boundaries
Step-rate Tests	Formation parting pressure, Permeability, Skin
Falloff Tests	Mobility in various banks, Skin, Reservoir pressure, Fracture length, Location of fronts, boundaries.
Interference and Pulse Test	Communication between wells, Reservoir behavior, porosity, Interwell permeability, vertical permeability
Layered Reservoir Tests	Properties of individual layers, Horizontal K, Vertical K, Skin, Average layer pressure, outer boundaries
Multiple Formation Testers	Pressure profile

Typical Well Test



Summary

- Lots of evaluation tools are available in petroleum engineering, engineers have to be aware of these tools, the data and the scale of the acquired data, relative to the reservoir.
- It is best to integrate all available data when analyzing Petrophysical data; the whole picture must be consistent.
- Different companies have different names for their proprietary tool, but tool's scientific principles are the same.

References

- Richard Bateman, “Open-hole Log Analysis and Formation Evaluation”, IHRDC Publishers New York
- Crombe et. Al., “Innovations in Fluid Sampling”, Schlumberger Oilfield Review, Autumn 1998.
- Baker Atlas Training Manual, Montrose Training Center, Montrose Scotland, 2001.

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