1- Mud Logging:

Mud logging is one of the first direct evaluation methods available during the drilling of an exploration well.

Mud logging (Surface logging): ***is the process of studying the general physical characteristics of rocks during the drilling operations to report information about the drilling and well construction process.***

During the drilling operations, the fluid is continuously circulated down the inside of the drill pipe, through the bottom of bit and back up the annular space (Fig-3).

- The drilling mud carries broken rock fragments (**cuttings**) to the surface. *Traces of oil or gas* may be also brought up in the mud.
- The mud log may be of great use to the petrophysicist and geologist in operational decision making and evaluation.
- The information obtained by the mud logger is presented in the form of various logs such as the driller's log, the cuttings log, or the show evaluation log.

Fluid Drilling Mud:

Drilling mud consists of a variety of clay and other materials (barite, hematite) in a fresh or saline aqueous solution. We can classify borehole muds into two groups, those that are ***conductive and non-conductive***. The non-conductive muds include air, gas, and oil-base fluids having infinite resistivity. Current flow in conductive muds varies depending upon two factors: ***the type of mud and the temperature***.

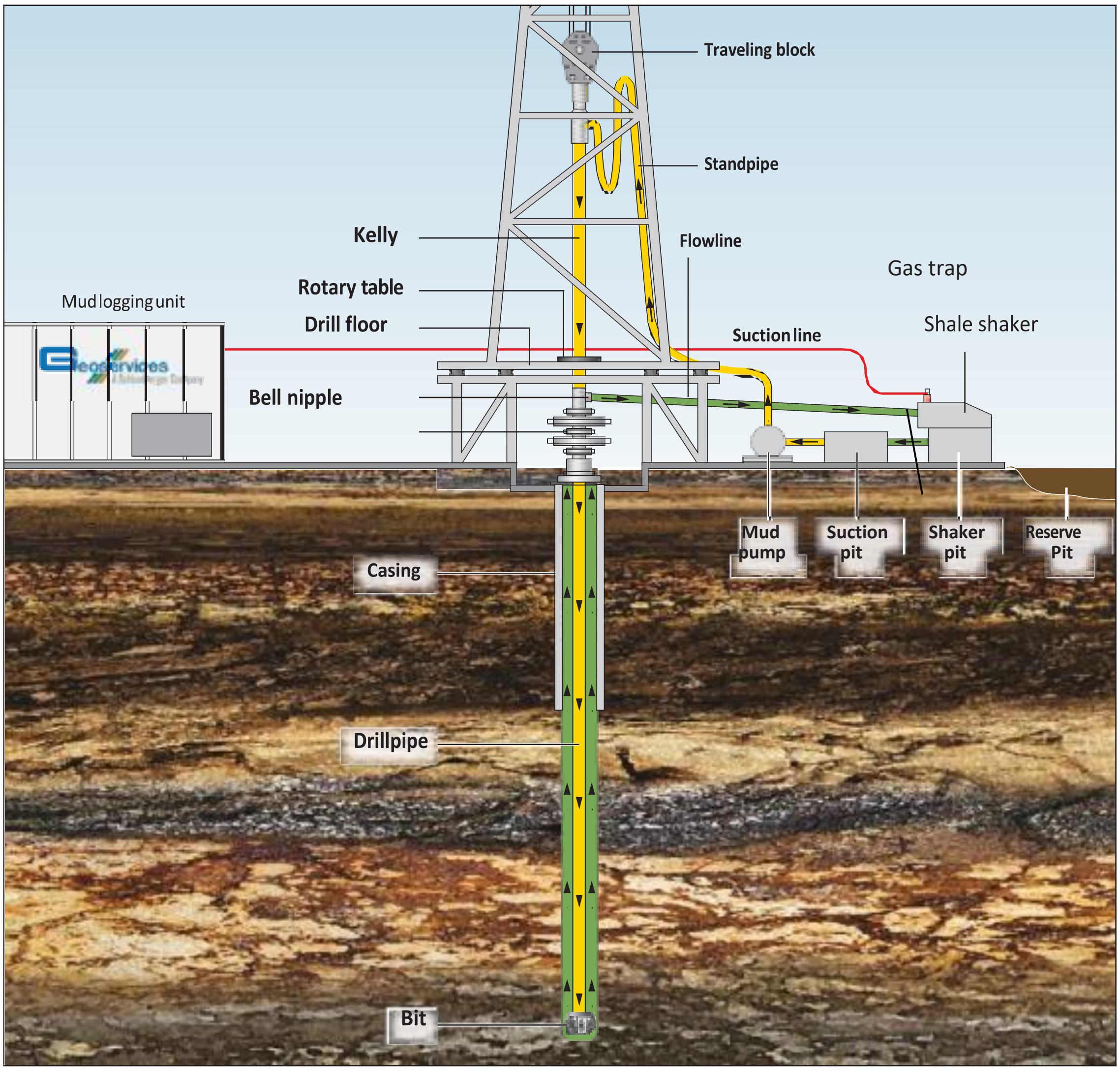


Fig.3: Mud circulation system

The density of the mud is kept high enough so that ***hydrostatic pressure in the mud column is always greater than formation pressure***. This pressure difference forces some of the drilling fluid to invade porous and permeable formations. When formation pressure is greater than the mud hydrostatic pressure the following may be seen:

- Large quantities of cavings (due to wellbore instability)
- Connection gases
- Trip gases
- Fluid incursions to the mud system

There are three main types of drilling muds:

1- *Water-Based Mud* (WBM)
2- *Oil-Based Mud* (OBM).
3- *Aerated Mud*.

There are many things to interest the drilling engineer:

1. ***Mud Properties***: must be control and record the properties of mud drilling such as density, pressure, viscosity, percentage of: solid, chloride, alkalinity and PH.
2. ***Leakage (Loss) of drilling mud***: can happen as a result of *surface losses, hole fill and down hole losses (thief zone)*
3. ***Rate of Penetration***: the changes in rate of penetration are very important to the geologists ***because*** they indicate a change in lithology.
4. ***Weight on the bit and rotary table speed.***
5. ***Mud system***.

A mud log gives information recorded vs. depth, include:

1- Weight on bit and drill string rotation speed.
2- Detection of gas and oil in the mud.
3- Mud pump speed and Mud pump pressure.
4- Identification of the lithology and formation type being drilled.
5- Identification of porous/permeable zones (These information supports wireline log data).
6- Detection of hydrogen sulfide (H_2S).
7- Hydrocarbon staining on the cuttings.

Mud Logging Unit:

***The mud logging unit* is the information center on the rig site to serve both exploration and drilling. It is located very close to the rig floor**.

A number of cables extend from the unit to a number of ***sensors*** installed at different locations on the drilling rig. These sensors are used to measure many important variables or parameters of the rig operations (Fig.4).

Fig.4: Mud Logging Unit

The sensors that feel all parameters in mud logging operations are:

1- Stand Pipe Pressure sensor (SPP).

2- Casing Pressure sensor.

3- Rotary Speed.

4- Mud Flow out.

5-Mud temperature, Weight and Conductivity.

6-Hydrogen Sulfide H_2S sensor.

To comprehend all of the information available, we need to understand four important areas of mud logging:

- ***rate of penetration and lag,***
- ***gas detection,***
- ***formation evaluation and sample collection,***
- ***hydrocarbon show evaluation***

3- Collecting Samples:

One of the most important jobs of the mud logger is sample collection. Most of the sample material is gathered at the shale shakers.

When the cuttings arrive at the shale shaker, they are covered in mud, unsorted by size, and generally unidentifiable.

The mud logging unit will generally take a sample of the cuttings and stored in company laboratories. These samples are two types: ***washed*** and ***unwashed***. Washed samples are examined under a microscope (fig.9) in the mud logging unit to obtain on the following (***Cuttings Sample Description:***

1- ***Rock name*** (sandstone, limestone, dolomite, shale, anhydrite,…etc)
2- ***Grain Properties*** (type, texture: color, sorting, size, mineral contents).
3- ***Porosity* and oil shows** (visual inspection of porosity type)
4- ***Hydrocarbon indication*.**

Fig.9: Microscopic examination of cutting

4- Show Evaluation:

Hydrocarbon show detection and description is the key task of the wellsite geologist and of the mud logging crew. However, despite the importance of hydrocarbon detection, nearly all of the tests and indications of a hydrocarbon show are weak, which depends on experience.

Show evaluation is the complete analysis of the hydrocarbon- bearing formation with respect to lithology and type of hydrocarbon present.

A complete show evaluation identifies:

1. *The presence and type of hydrocarbon,*
2. *Determines the depth and thickness of the show*
3. *Assesses the porosity and permeability,*
4. *Assigns a show value that indicates the potential productivity of the formation.*

Types of Shows:

There are two types of shows are recognized: gas and oil.

1. ***A gas show***: the mud logger may see a significant increase in gas levels.
2. ***An oil show***: is an increase in heavier-than-methane gas levels as well as a physical indication of oil.

Identification of Oil Show:

Evaluation of oil in the drill cuttings (and drilling fluid) begins with inspection of those samples under the microscope and inspection in the ultraviolet-light box. Tests and visual inspection should be performed on the *mud, unwashed and washed bulk cuttings, as well as individual grains.*

Four tests are used to detect hydrocarbons, especially **Oil Show**: ***odor, staining, fluorescence, and cut.***

1- **Odor**: does not usually apply to cuttings, but it is a useful test on cores. Although difficult to standardize, odor falls into one of four categories: ***poor, slight, fair, or strong.***
2- **Oil staining**, like odor, is more useful when applied to cores. Staining is described in terms of both color and percentage of sample stained, e.g:
   - No visible oil stain
   - Spotty oil stain
   - Streaky oil stain
   - Patchy oil stain
   - Uniform oil stain

   The color of the staining can be related to the ***oil's gravity***, where lighter colored stains are indicative of high gravity oils and darker stains are indicative of lower gravity oils. A black asphaltic residue is indicative of dead, residual oil lacking volatile components.
3- **Fluorescence:** Liquid hydrocarbons fluoresce under UV light, and the amount, intensity, and color are the first and best indications of a show. Intensity is subdivided into none, poor, fair, or strong.
4- **Cut**: defines the leaching of oil from a sample by a solvent.

Application of Show Evaluation:

Complete show evaluation can help us:

(1) Identify the presence of hydrocarbons.

(2) Make recommendations for coring and testing programs.

(3) Show evaluations correlated with offset wells and wireline logs can assist in reservoir interpretation.

2- Cores and Core Analysis:

2-1 Introduction:

Coring is the removal of undamaged sample formation material from a wellbore and brought to the surface for physical examination.

The objectives of **Coring** are to bring a sample of the formation and its pore fluids to the surface in an unaltered state, to preserve the sample, and then to transport it to a laboratory for analysis. The objective **Core Analysis** is to reduce uncertainty in reservoir evaluation by providing data representative of the reservoir at in situ conditions.

Core information includes **Geological Evaluations** as: lithology, depositional environment, mineralology, formation age and geological sequence, fracture analysis.

Engineering Evaluations as: Porosity Distribution, Permeability Distribution, Permeability vs. Porosity Relationship, Hydraulic Flow Unit Distribution, Formation Heterogeneity, Oil/Water Contacts, Reservoir Fluid Saturations and Distribution, Wettability Relative Permeability, Capillary Pressure.

2-2 Coring Methods:

Through the years, many types of equipment and many different techniques have been devised for the taking of cores, some of which were successful and have evolved into the equipment and techniques of today. Generally, current methods of coring can be grouped into ***conventional and sidewall coring.***

1- Conventional Coring:

A core bit is located on extreme end of the drill stem and a core barrel is located immediately above the core bit for retaining the core after the cut.

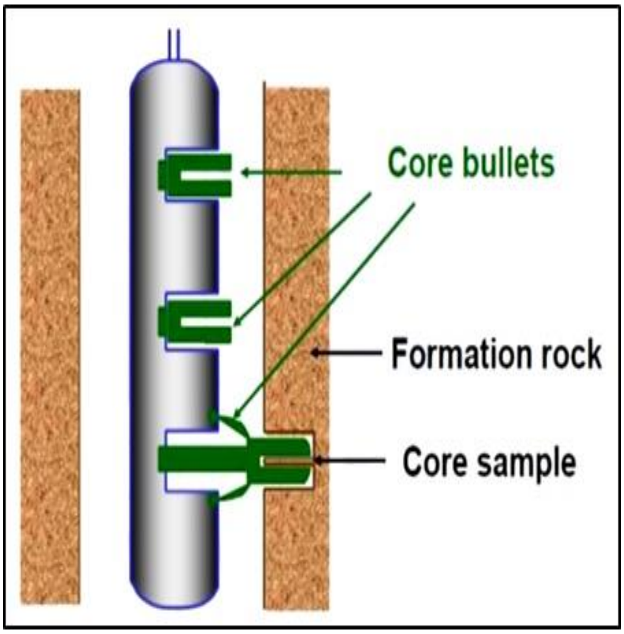
When the decision is reached to cut a conventional core (e.g., at a drilling break, a planned depth reached), the drill pipe is removed from the hole and dressed with a hollow core bit and a hollow barrel equipped with a nonrotating inner barrel (Fig.10). Drilling fluid circulates between the inner and outer barrels in order not to flush the core.

Fig. 10: Conventional Coring

2- Sidewall Coring:

In sidewall coring, a sample is obtained from the wall of a previously drilled open hole at chosen depths (Fig.11). The tool is designed somewhat like a perforation tool, but instead of a bullet, a short tube is driven into the side of the borehole and retrieved by means of a cable attached to the body of the tool.

One advantage of this method is obvious: ***samples can be obtained from zones that were not cored at the time of initial penetration***. In addition, with the aid of wireline logs, ***these samples can be taken at very precise positions in the hole.***



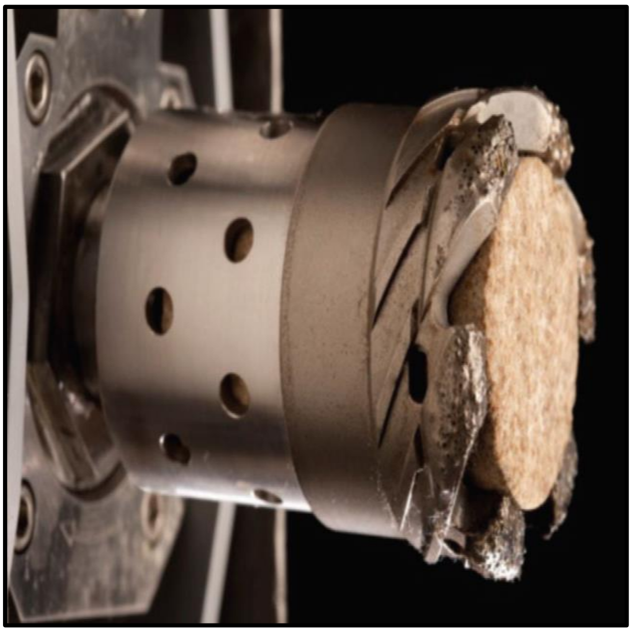


Fig.11: Sidewall Coring

2-3 Core Analysis Techniques:

There are three types of core analysis techniques. The technique used depends all the coring method, ***the type of rock to be analyzed, and the type of data to be obtained.***

(1) Conventional or Plug Analysis:

The plug analysis method is used most frequently. In this method, a small plug sample, which is easy to work within the laboratory, is cut at selected intervals from the whole core (Fig.12). The data obtained from the small plugs are then assumed to represent the reservoir rock properties of the sampled interval.

Fig.12 Plug Samples

(2) Whole-Core Analysis:

The whole-core analysis method is used when the plug analysis method becomes invalid because the heterogeneities such as fractures or vugs. This method uses the whole core for rock property measurement in as long a length as possible (Fig.13). The technique requires larger equipment in the laboratory, and not all commercial laboratories are equipped to perform this type of analysis.

Fig.13: Whole Core Samples

(3) Sidewall Core Analysis:

Considering the process under which these cores are obtained and the sample size of the core, the measured data will have limited value in some areas in addition to the in some situations, this rock sample is all that is available. It is, therefore, desirable to look at the relative value of rock properties as determined from sidewall samples (Fig.14) and those obtained from conventional cores.

These studies indicate in general that:

(1) Sample porosities in softer, looser sands are only slightly higher than those of conventional cores.

(2) Sidewall sample permeability is decreased in higher permeability formations.

(3) Water saturations from the sidewall cores are lower and oil saturations slightly higher than conventional core data.

Fig. 14: sidewall Core Samples

2-4 Types of Cores Analysis:

1- Routine Core Analysis (RCAL):

Routine core analysis attempts to give only the very basic properties of unpreserved core. These are basic rock dimensions, core porosity, grain density, gas permeability, and water saturation (Fig.15).

2- Special Core Analysis (SCAL):

Special Core Analysis attempts to extend the data provided by routine measurements to situations more representative of reservoir conditions (Fig.15). SCAL data is used to support log and well test data in gaining an understanding of individual well and overall reservoir performance. However, SCAL measurements are more expensive.

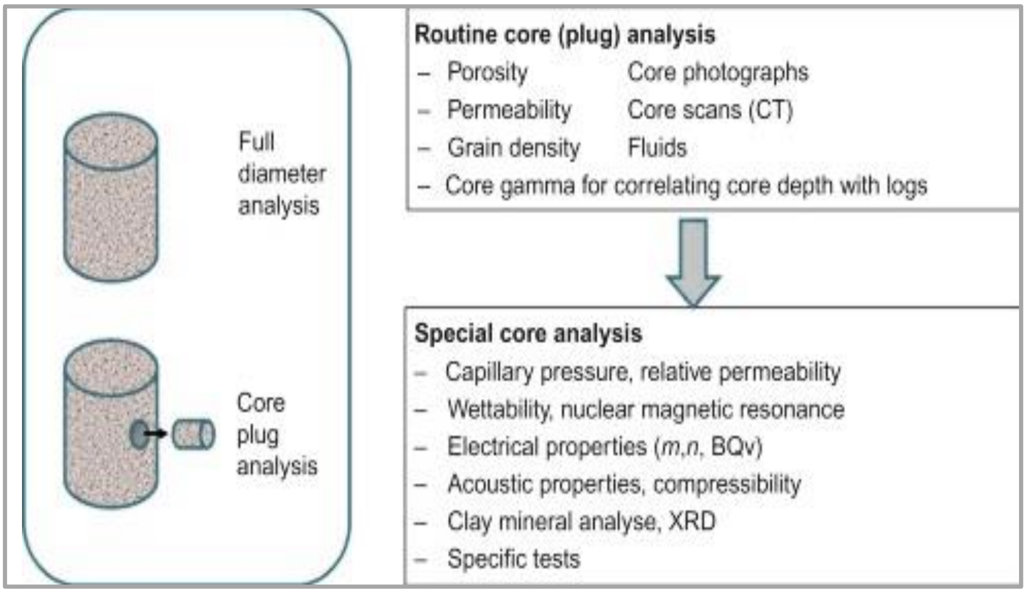


Fig.15: Routine and Special Core Analysis