3) Write a short note on Quantitative interpretation of well log data.

- Resistivity :-

Electrical resistivity of a substance is its ability to impede the flow of electric current through substance. The unit used in logging is Ohm-m^2/m. written as Ohm·m. Most formations are logged for potential oil & gas saturation are made up of rocks which, when dry will not conduct electric current, in the rock matrix has Zero conductivity, i.e infinite resistivity. An electric current will flow only when pore structures of formation are water filled, having dissolved salts. These salts dissociate into positively charged cations (Na^+, Ca^{2+}) & negatively charged ions - anions (Cl^-, SO_4^{2-}) Under the influence of electrical field, these ions move, carrying an electric current through the solutions.

The greater the salt concentrations, the lower the resistivity of formation water and thus the formation.

The greater the porosity, the greater the formation water, thus the resistivity is lower.

Resistivity measurements are essential for saturation determination especially in Virgin or non-invaded Zone of reservoir. Resistivity measurements are also used to determine the resistivity close to borehole (flushed Zone), where mud filtrate has largely replaced original pore fluids.

Formation factor & Porosity

The Resistivity of a clean, water bearing formation is proportional to resistivity of brine with which it is fully saturated, the constant of proportionality is called formation resistivity factor, F,

$$F = R_o / R_w$$

According to Archie's equation, relationship between F & ϕ is given by

$$F = a / \phi^m$$

where

m - cementation factor

a - emphirical constant.

$F = \frac{0.62}{\phi^{2.15}}$ - for sands ; $F = \frac{1}{\phi^2}$ - for Complicated formations

→ The first relation is called Humble's formula

→ The second relation is Archee's formation factor relationship.

→ Humble's equation is satisfactory for sucrosis rocks.

→ $F = 1/\phi^2$ for chalky rocks

→ $F = 1/\phi^{2.2}$ to $1/\phi^{2.5}$ for compact rocks.

Water Saturation:

S_w is a fraction of pore Volume occupied by formation water and $(1-S_w)$ is a fraction of pore Volume occupied by hydrocarbons.

$$S_w^n = \frac{FR_w}{R_t}$$ n - Saturation exponent.

n = 2, usually.

$$S_w = \sqrt{\frac{FR_w}{R_t}}$$ ↳ Archie water saturation equation.

$$S_w = \sqrt{\frac{R_o}{R_t}}$$ ↳ when 100% saturated with water

$(FR_w = R_o)$

Ratio of R_t/R_o is called Resistivity Index.

Water Saturation S_{xo}, of flushed Zone can also be expressed by Archie's formula.

$$S_{xo} = \sqrt{\frac{FR_{mf}}{R_{xo}}}$$

where R_{mf} - Resistivity of mud filtrate

R_{xo} - Resistivity of flushed Zone

Ratio of saturation in Virgin, uncontaminated Zone of saturation in flushed Zone is given by

$$\frac{S_w}{S_{xo}} = \left(\frac{R_{xo}/R_t}{R_{mf}/R_w}\right)^{1/2}$$

Water Resistivities:

Formation water resistivity, R_w can be found from SP curve, water catalog, produced water sample or water saturation equation in a 100% water bearing formation.

$$SP = -k \log \frac{R_{mf}}{R_w}$$

k - Temperature dependant constant.

Porosity:

Porosity can be obtained from sonic log, density log or a neutron log provided lithology of formation is known. If the lithology of formation is not known or if mixture of known minerals exist, combination of two or more porosity & lithology sensitive logs can be used to define lithology & to provide accurate value of porosity.

Combination of two porosity log, sometime detects the presence of gas / light oil in formation. Sonic tool measure the interval transit time which is used to measure / determine porosity by time-average relationship.

t_f - transit time of pore fluid.
t_{ma} - transit time of rock Matrix

$$\phi = (t - t_{ma}) / (t_f - t_{ma})$$

$$\phi = C\left(\frac{t - t_{ma}}{t}\right) \quad \text{where } C = 0.67.$$

$$\phi = \frac{\rho_{ma} - \rho_b}{\rho_{ma} - \rho_f}$$

where, ρ_{ma} - Density of rock Matrix

ρ_b - Bulk Density

ρ_f - Density of pore fluid.

2. Qualitative log Interpretation of well log data.

By visual look at the log, an approximate evaluation of reservoir can be made. The following parameters can be easily recognised by a visual look of the logs.

1) Permeable bed identification:

a) SP Deflection:

When salinity of the mud is different from formation water salinity, permeable beds can be detected by SP excursions from shale lease line.

b) Resistivity seperations:

Against the permeable bed, there will be invasion. There will be seperation between deep & shallow investigation resistivity curves. (LLS & LLD)

c) Microlog seperation:

Due to invasion in a permeable bed, the mudcake will be deposited on borehole. Two microlog readings are altered differently by mudcake. If micro inverse is taken, we will know the conductivity near the borehole.

2.) Quantitative Evaluation of shaliness:

→ This can be performed using SP, gamma ray log & neutron log.

a) SP Curves:

SP deflections from shale base line are affected by presence of shale. The higher the proportion of shale, more reduction in SP deflection from that of the clean formation.

b) Gamma ray Curve:

In clean shale section, gamma ray tool will detect a huge level of natural activity i.e 100% shale. Clean reservoir rocks have a low level of radioactivity. In shaly reservoir, the gamma ray tool will detect a natural radioactivity proportional to shaliness provided these rocks contain no other radioactive minerals other than shale.

c) Neutron log:

Neutron log is used to determine porosity.

3) Lithology:

→ Two curves FDC - CNL log will track limestone

→ In sandstone, reduction will read 6-8 pu lower than formation density.

→ Coal will show very low density reading, very high neutron & sonic porosity reading & low gamma ray.

4) Gas:

→ Apparent porosity (neutron & density log) is affected opposite to gas zone. Clean gas zone can be easily found by very low neutron reading & high density porosity values.

5) Oil - water Differentiation:

→ A simultaneous observation of porosity log & resistivity logs often allows to detect hydrocarbon bearing beds, which do not exhibit density / neutron gas separation.

→ Clean formation with the same porosity values will have higher resistivities.

14) Discuss recording, transmission & processing of log data.

→ Logging is an important part of drilling & Completion processes.

→ Gives Qualitative information about hydrocarbon & qualitative information about rock & fluid properties

→ Log measurements are made using a Sonde lowered on a cable from a winch mounted on on a logging truck.

→ Truck & the units are laboratories containing the recording equipment (optical & tape), control panel & computer.

Equipments on a logging truck:

1) Main winch
2) Auxillary Winch
3) Winch man's control panel.
4) Surface logging panels with recording equipment - printer & Memory devices.

→ Depth Measuring system
→ Power generator
→ A workstation
→ Output device - printer, cd, writer.

Downhole wireLogging tool:

→ Composed of sonde - detector, receiver & for measurement of induced phenomena, there will be emitters.
These components are mounted on a hydraulic system & some electronics like pre-amplifier & transformer
→ Downhole electronic catridge - power supply to emitter, detector, filtering, amplification, transmission & power supply & control.
→ Telemetry system for Digital transmission & Recording equipment.

Storage of Log data:

→ Log data are stored in two formats called
1) LAS (Log ASCII standard format)
2) DLIS (Digital log interchange format)
→ Data can be transmitted by fax, radio, television to a log computing centre / company office.

10) What is stratigraphic correlation? How does well log data help in determining the subsurface formation?

Stratigraphic Interpretation:

→ Sequence stratigraphic interpretation is a fundamental unit for sequence stratigraphic analysis.

→ Sequence is defined as relatively comfortable genetically related ts successions of strata bounded by unconfirmities.

→ A sequence can be divided into system tracts, which are defined by their position within the sequence.

Sequence type:

1. Lowland system tract
2. Trangressive system tract
3. High stand system tract
4. Shelf Margin systems tract

This involves identification of petroleum systems in a basin - Source, reservoir, seal.

→ Gas hydrate is a solid state of mixture of gas and water that can only exist under special temperature & pressure conditions.

→ Detailed Velocity analysis help to document these features.

→ Hydrate accumulation may form a viable exploration target

→ Stratigraphic correlation is premier job in merged structural interpretation. Straligraphic correlation consists of four steps.

1) Select critical wells for fine horizon calibration.

2) Combine well data & seismic data of main seismic lines to determine the stratigraphic correlation scheme.

3) Compare well data & seismic data to unify the geologic zone of oil.

4) Establish drilling zone database of merged 3D survey. This mainly ~~aims~~ to aims to characterize the lithology, depositional environment and metallurgy.

16) How is well log data interpreted? What are overlay & crossplots, also discuss their applications:

Interpretation of well log data:

→ Quick look log analysis refers to a number of techniques for plotting log data in a simple way that reveals formation content / lithology.

Three branches of quick look analysis are

1. Overlays of curves
2. Crossplots of curve readings.
3. Algorithms for calculators

overlays:

→ One curve is overlaid on other & tracing is made (manually / computer) & end result is called overlay.

→ Relative deflection between two curves usually indicates a formation property of interest. Commonly used overlays are:

1. Hydrocarbon saturation
2. Lithology, porosity, hydrocarbon typing

Eg. of overlays:

1. R_o Vs R_t - The formation factor overlay.
2. Logarithmic movable oil plot.

Crossplots:

→ Crossplots are two dimensional visual representation of log response equation to various mineralogies. Rocks containing one or more than two mineralogies can be evaluated using multiple crossplots.

Dual Mineral Crossplots:

→ Method of interpreting well logs for formation having lithology that are mixtures of silica, limestone, dolomite, anhydrite & Clay. It uses a crossplot of neutron-density log data to arrive at values of porosity & Apparent Matrix density of formation.

Lithology Crossplots:

→ Used for the interpretation of formation of complex lithologies

→ It presents simultaneously the data from three of major plots such as: Neutron porosity log, Formation density log & Sonic log.

Triporosity Method:

→ This method plots the total porosity of fractured reservoir rock containing matrix porosity, fracture & Vug porosity.

17) What are the well logging methods used to get information about Lithology:

1. Sonic logging:

→ Measures the travel time of elastic wave through the formation, which is used to derive velocity of elastic waves through formation.

→ Calibrates the seismic data & derive porosity of formation

→ These are complex tools that make use of both P & S waves. But in sonic waves, we are interested in the first arrivals of P waves.

→ Time between transmission of Pulse and reception of first arrival of P waves is one way time between Transmitter & Ricever.

2. Neutron logging:

→ Induced gamma ray spectrometry tools emits accelerator type pulsed neutron generates neutrons at 14 Mev of energy.

→ At high energies, class of interactions between atomic nuclei and borehole of formation occurs

resulting in fast neutron scattering.

→ Incident neutron has enough energy to raise the nucleus of atoms to higher level. The excited nucleus return to its ground state with the emission of radiation

→ Some fast nuclei interaction results in gamma emission.

Lithodensity log:

→ It is a typical formation density tool that uses a caesium 137 source emitting gamma rays from a short spaced & long spaced detector

→ Final density value obtained is more accurate than basic formation density tool because the harder gamma rays are less prone to attenuation by borehole effects.

→ Soft gamma rays may undergo photo-electric absorption.

→ Litho porosity crossplots presents the data from three of major plots such as: Neutron plot, Formation Density log, Sonic log.

18) Disauss the limitations & utility of various crossplots used in well logging?

→ Crossplots are two dimensional visual representation of the log respons equations to Varoies mineralogies Rocks containing more than two mineralogies can be evaluated using multiple crossplots.

→ Density - Neutron cross plots → Bulk density Vs Neutron porosity for porosity & mineralogy determination.

→ Density - Acoustic crossplots → Bulk density Vs Acoustic travel time for determing of mineralogy & porosity.

→ Neutron log porosity : Acoustic cross plots → Neutron log porosity Vs Acoustic travel time for determination of mineralogy & porosity.

→ Density - Photoelectric factor crossplot → Bulk density Vs Photoelectric factor for determination of mineralogy & porosity.

→ Stingle plots → R_t Vs Another log value that is proportional to porosity for determination of mineralogy & water Saturation

→ M-N plots → Plots of Acoustic - Density crossplot of

slope(M) & Neutron density crossplot slope (N) for mineral identification.

→ Apparent Matrix density Vs. Apparent Acoustic matrix travel time for the determination of mineralogy.

→ Apparent Matrix density Vs Apparent Matrix Volumetric photoelectric factor for the determination of mineralogy.

→ Shear Vs Compressional travel time for determination of mineralogy.

→ Porosity log crossplots - Density, Acoustic, Neutron logs are used for both lithology & porosity determination

Limitations of Crossplots:

→ Depth information is lost on crossplot; while this is a basic feature of log overlay.

→ Crossplots must either be prepared laboriously by hand or generated from computer processing of digital log tapes.

→ True porosity & mineral composition of any zone are found by interpolation.