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Experimental Study on Core Analysis for Determination of Sand Stone Resistivity

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The objective of this study includes the determination of porosity, grain density, permeability and resistivity characteristics of the sandstone reservoir. The Technical studies are carried out on eight core samples of the Sandston Reservoir. Then the core processing is done on core samples which include core cutting, core cleaning, core drying and sample preservation. Through which the Basic parameters such as length and diameter of the samples are determined. The effective porosity measured from Helium Porosimeter has been observed to be in the range of 7.2 to 14.4 %. The permeability to air, measured by air permeameter, has been found to be in low range i.e. 0.002 to 0.59md indicating that plugs are from tight sandstone reservoir. Grain density has been found to in between 2.62gm/cc to 2.67gm/cc, which also indicates the sandstone lithology. The resistivity measurement have been carried out at ambient temperature using the equipment known as LCR meter having two electrode system. The experiment has been carried out on eight core samples corresponding to the sub layer S2 of the sandstone reservoir. The brine solution of different salinities has been used for experimental studies that are 15g/l and 200 g/l as Nacl. The 15g/l brine solution represents the salinity of the formation and 200g/l brine solution has been taken mainly for removal of effect of clay conductivity during resistivity analysis. The values of tortuosity coefficient 'a' and cementation factor 'm' for both 15g/l as NaCl and 200g/l are also determined.

Key words: Core analysis, Sand stone resitivity.

Petro physics is the study of rock properties and its interaction with fluids. It deals in the study of physical properties of rocks in the laboratory and processing of the data, and relates the data to the field data from wells and its incorporation into physical models that describe the reservoir rock in place for reservoir performance estimation[1].

These studies are mainly carried out on the cores, taken from reservoir rock. Measurements, calculations and interpretations of certain reservoir properties and integration of these properties with other data such as well logs, initial well tests and actual production is the key to optimum reservoir management[2].

Core analysis is one of the direct and practical methods of analyzing the reservoir for its thickness, lithology, porosity, permeability and fluid saturation. Conventional cores are cut continuously through the prospective formations in a few wells spread over the field and analyzed. The resultant data are used to correlate and calibrate the well logs taken in these wells.

Core analysis can be defined as "a set of laboratory measurements to determine petrophysical parameters of core samples recovered from geologic formations. It is the only direct method of measuring and developing basic

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reservoir data to be utilized as the keystone in understanding technological and financial events that follow. It provides a various set of laboratory data for reservoir description and is the cornerstone which provides information to assist in understanding reservoir anatomy[3].

Information generated during core analysis is used for evaluating productive possibilities of wild cat wells and field extensions. For determining subsurface, structural features, Selecting DST intervals and for establishing a basis for interpretation of DST in terms of formation characteristics and for determining the best combinations or order of completions in case of several horizons in a reservoir[4].

It has applications on determining optimum spacing, new drilling locations, defining field limits, determining net pay, hydrocarbons in place, estimating initial production and probable recovery[5].

Methodology

Porosity studies

Porosity of a rock is the ratio of the pore volume to the bulk volume. In hydrocarbon reservoirs, the pore volume is the space available for oil, gas and water storage.The porosity is determined by core analysis using the Porosimeter. In laboratory any two of pore volume, bulk volume, and grain volume are measured and then porosity is determined[6].

Principle of Operation

Ultra porosimeter utilizes the principle of gas expansion, as described by Boyle's Law to determine the pore or grain volume

$$\text{Boyle's Law, } \frac{P_1 * P_2}{T_1} = \frac{P_2 * P_2}{T_2}$$

Where: P1, V1 and T1 are the initial pressure (psi), volume (cm3) and temperature (°K) respectively; and P2, V2 and T2 are the expanded pressure (psi), volume (cm3) and temperature (°K) respectively.The method consists of placing a dry core sample in a sealed chamber of known volume (V1), which is then filled with Helium gas to a convenient pressure (P1). The reference cell is pressured to 400psig. The second chamber, connected by a closed valve, is either evacuated or filled with gas at a different pressure P2-, usually atmospheric pressure. The valve between the two chambers is then opened and the gas expanded into a sample holder containing the sample to be analyzed, and the final pressure, (P-f) common to both chambers is observed.

Permeability studies

Permeability is the ability of the rock to allow a fluid, with which it is saturated, to flow through its pores, under non turbulent conditions[7].

Principle of Operation

The permeability is measured by making use of an instrument called 'micro permeameter.'The permeability is measured by flowing a fluid of known viscosity μ through a core plug of measured dimensions (Area and Length) and then measuring flow rate (q) and pressure drop (”p).

Micro permeameter consists of a Hassler's core holder, which can apply a finite confining pressure to the plug sample, placed within the core holder, with the help of air. Generally a confining pressure of 200 to 400 psi is applied with the help of these core holders. In some experiments hydrostatic core holders can also be used. These core holders make use of water, which is pressurized and used to apply the confining pressure, and are capable of applying a confining pressure of more than 1000 psi.The air required in case of Hassler's core holders are supplied through a separate cylinder, while air from either cylinder or compressor is the actual experimental fluid which is used for the purpose of determining permeability. The air used for the experimental purpose has to be sent through a drier in which silica gel is used.

Resistivity Studies

The resistivity of the reservoir rock is the function of salinity of formation water, effective porosity and quantity of hydrocarbon trapped in the pore space[8]. A rock that contains oil and gas will have a higher resistivity than the same rock completely saturated with formation water and the greater the connate water saturation, the lower the formation resistivity[9].

Formation factor is defined as the ratio of resistivity R_o, of the rock when 100 % or completely saturated with brine, and resistivity R_w, of the brine.

$$\text{Formation Factor} = \frac{\text{Resistivity of completely saturated rock}}{\text{Resistivity of brine}}$$

FF depends upon the lithological characteristics of the rock and the effective porosity.

$FF = a / f^m$

a = Tortuosity factor, m = Cementation factor. Resistivity index is defined as the ratio of rock resistivity R_t (true resistivity), at any condition of gas, oil and water saturation to the resistivity of rock R_o, when completely saturated with water. Resistivity index is denoted as I_R.

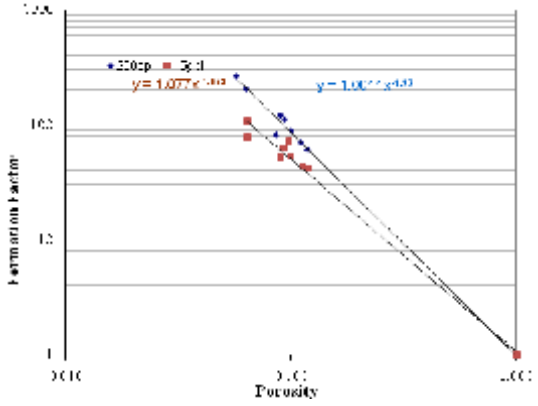
$$\text{Resistivity index } (I_R) = \frac{\text{Resistivity of rock at any saturation } (R_t)}{\text{Resistivity of completely saturated rock } (R_o)}$$

$$RI = R_t / R_o = S_w^{-n}$$

RESULTS

The core samples are studied with saturation of 15 and 200 g//l of Nacl and the values are measured.

Combining the values of "a" and "m" for plugs saturated with 15g/l and 200g/l is plotted in the log – log plot as is shown in Fig.1. Thus comparing the results it is found that there is increase in the cementation factor of 200g/l as Nacl. The eight core samples were processed by core cutting, core cleaning and core drying and it is observed the average value of the diameter of core plug is 3.8 cm, and the average value of length of the core samples is found to be 3.71 cm. The porosity studies have been carried out on eight plug samples then the following results were obtained which is shown in the table. The effective porosity measured from Helium Porosimeter has been observed to be in the range of 4.7 to 15.8 %. Grain density has been found to in between 2.62gm/cc to 2.67gm/cc, which also indicates the sandstone lithology. The values are listed in table 1.



Tortuosity constant "a": 1.08 Tortuosity constant "a": 1.0
Cementation Factor "m" : 1.67 Cementation Factor "m" : 1.93

Fig.1. Formation Factor vs Porosity

After Porosity studies the eight core samples were subjected to permeability measurements and the following results were

Table 1. Porosity and Grain Density Data

Sample No	Porosity%	Grain Density(gm/cc)
Plug 1	10.6	2.65
Plug 2	13.3	2.63
Plug 3	14.4	2.64
Plug 6	13.5	2.64
Plug 7	11.3	2.65
Plug 9	10.1	2.66
Plug 10	8.2	2.70
Plug 11	7.2	2.68

Table 2. Permeability for core samples

Sample No	Air Permeability(mD)
Plug 1	0.08
Plug 2	0.14
Plug 3	0.59
Plug 6	0.11
Plug 7	0.12
Plug 9	0.25
Plug 10	0.02
Plug 11	0.002

Table 3. 'a' and 'm' values

Parameter	15 gpl as Nacl	200gpl as Nacl
a	1.08	1.00
m	1.67	1.93

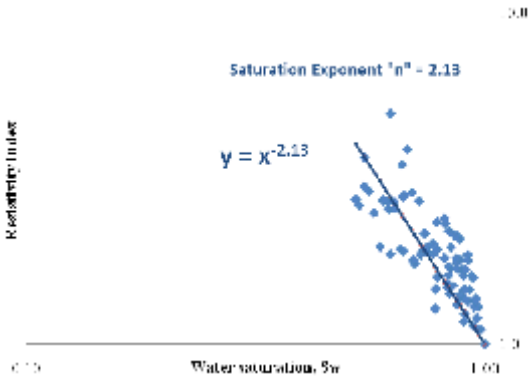


Fig. 2. Resistivity Index vs Water Saturation

tabulated. The permeability to air, measured by air permeameter, has been found to be in low range i.e. 0.002 to 0.59 md indicating that plugs are from tight sandstone reservoir. The values are listed in table 2.

Combining the values of "a" and "m" shown in Table 3 for plugs saturated with 15g/l and 200g/l is plotted in the log – log plot as is shown in Fig 1.

Thus comparing the results it is found that there is increase in the cementation factor of 200g/l as Nacl.

The values of 'n' have been observed in the range of 1.55 – 5.79. On lumping of all resistivity index data and log-log plot of resistivity indices versus brine saturation is shown in Fig 2., the value of 'n' has found as 2.13

CONCLUSIONS

The Porosity studies are done on the eight core plug samples through which the Porosity and grain density values are determined and tabulated. Then the permeability studies are conducted on the core samples and values are determined.

The Resistivity study of the core plug samples is done through which the Resistance, Formation Factor, Resistivity index and Saturation of the plug samples are determined.

These analyses are conducted to understanding the core properties effectively for hydrocarbon exploitation. Under Routine core analysis for eight core plugs samples, results have been observed. For each core, based on core analysis results, different methodologies have to be adopted. Further research has to be conducted on methodologies for different cores. Research on carbonate core also to be considered.

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