Intepretations of Porosity and Saturations for Sepat-X and Sepat-XST1 Wells Offshore Terengganu Using Radioactive and Resistivity Logs.

by

Nurul Fahilin Md Saad

Supervised by

Mr Saleem Qadir Tunio

Final Report

submitted in partial fulfillment of the requirements for the

Bachelor of Engineering (Hons) Petroleum Engineering

January 2011

Universiti Teknologi PETRONAS

Bandar Seri Iskandar

31750 Tronoh

Perak Darul Ridzuan

VERIFICATION STATEMENT

This hereby verify that this report was written by **Nurul Fahilin Bt Md Saad (I/C no: 880818-02-5182)** and the work done was not plagiarised from any source and was completed solely by the author.

Name : Nurul Fahilin Md Saad

P11738

Petroleum Engineering

Date : 4 APRIL 2011

SALEEM QADIR TUNIO
Lecturer
Geoscience & Petroleum Engineering Department
Universiti Teknologi PETRONAS
Bandar Seri Iskandar, 31750 Tronoh,
Perak Darul Ridzuan, Malaysia.

ACKNOWLEDGEMENT

I would like to take this opportunity to thank all parties involved in helping me to complete this project successfully. Honourably thanking PETRONAS Carigali Sdn Bhd (PCSB) and the Geoscience and Petroleum Engineering Department of Universiti Teknologi PETRONAS (UTP) for giving me this chance to learn and completed this project and also for all their support and integrity which played a vital role in the success of this research.

I would like to thank the following for their respective professionalism and contribution to the program.

- *Mr SaleemQadir Tunio (Supervisor, Lecturer in*
- *Ms Hayati Bt Turiman, Head of Reservoir Evaluation (Domestic), Plant Supervisor*
- *Athirah Dahlan, Petrophysicist, Mentor 1*

Last but not least to all my fellow Final Year Project colleagues, friends and my family who have been giving me courage and advice throughout this course in order to complete my project.

ABSTRACT

This report basically discusses the results of the research in understanding the chosen topic, which is **Interpretations of Porosity and Saturations for Sepat-X and Sepat-XST1 Wells Offshore Terengganu Using Radioactive and Resistivity Logs.** In this report, the author has added the part of resistivity logging. Resistivity is the electrical resistance, measured in ohms, is defined as the ability of a material or substance to obstruct the flow of electrical current. Resistivity logging is crucial in calculating the fluid saturation by providing the Rw (water resistivity) and the Rt (true resistivity) to be used in the Archies' saturation equation.

The author has also made a comparison between the two methods of determining the pretophysical properties such as porosity, water saturations and hydrocarbon saturations from using the manual calculations and from using Interactive Petrophysics (IP) software. The author had also dertemined the fluid contacts and the fluid type in each sands.

PROJECT TIMELINES

<u>Gantt Chart for FYP</u>

Date **Activity**	W1	W2	W3	W4	W5	W6	W7	W8 16/03/2011	W9	W10	W11	W12	W13	W14	W15	W16- 17
Data Gathering																
Manual interpretations for Sepat-X																
IP interpretations for Sepat-X																
Submitting Interim report																
Manual interpretations for Sepat-XST1																
IP interpretations for Sepat-XST1																
PRE-EDX																
Submitting final report																
Final presentation																FINAL EXAM

TABLE OF CONTENT

LIST OF FIGURES:

LIST OF TABLES:

LIST OF EQUATIONS:

CHAPTER 1

1. Introduction

1.1. Project Background

The objective of evaluating formation is to interpret the combination of measurements taken inside a wellbore to detect and quantify oil and gas reserves in the rock adjacent to the well and minimize the uncertainties of the ability of the wells to produce hydrocarbons.

Formation evaluation is a matter of answering questions like limits of the porosity, permeability and water saturations that permits profitable production and does the formation in the well under considerations exceed these limits [4, 5]. The most common tools that are run downhole are the Spontaneous potential (SP), Gamma Ray and Natural Gamma Ray Spectroscopy (NGR), Caliper, Neutron-Density and Resistivity tool [4].

The Sepat-X and Sepat-XST1 is located in the Sepat field in offshore Terengganu. The field is in a tertiary sedimentary formation with proven hydrocarbon presence in other earlier wells [3]. The study will be on interpreting the two wells on their porosity and saturations using data from well logging and come up with a conclusion about the presence of hydrocarbon in the wells. Thus for this study, the usage of radioactive tools and resistivity tools are on the focus to calculate and interpret the porosity and saturations in the Sepat-X and Sepat-XST1 wells.

1.1.1. Problem Statement

To determine porosities, good data from the Neutron-Density tool is required because the porosity of the rock is indirectly related to the density of the rock. The less dense it is, one can assume the more pores it has [1, 4]. Same goes with the saturations of fluid in the formation, to get a reliable result, the porosity and resistivity should be correct. Thus to conclude, reliable interpretation needs reliable data [1,4].

1.2. Objective

The objective of the study is to see the relationship between the porosity and the saturations to recognize the presence of hydrocarbon or non-hydrocarbon fluid in the two wells.

CHAPTER 2

2. Literature Review

2.1. Petrophysical Parameters

Petrophysical parameters consist of the rock porosity and fluid saturations in the rock. Proper analysis of petrophysical parameter sensitivity from well log data can greatly improve the ability to discriminate hydrocarbon-bearing rocks [5].

2.1.1. Porosity

Porosity is the percentage of void spaces to the total volume of rock. There is two type of porosity, one is primary porosity that formed in between grains during deposition and another is secondary porosity that formed after deposition due to diagenesis effect such as compaction, fracturing, cementation or dolomization.

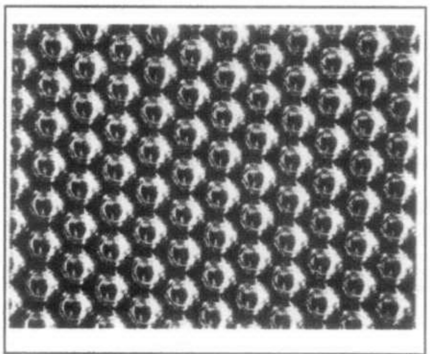


Figure 1: Perfect porosity of 48%[4,5]

Perfect porosity shown in Figure 1, is in uniformed sphere diameter in cubic packing which is 48% but realistically impossible in real condition and we only have until 30-35% porosity [4,5] such as shown in Figure 2.

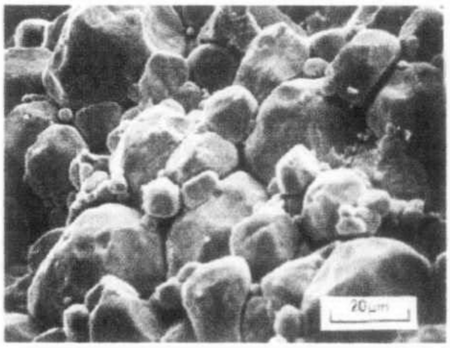


Figure 2: Porosity in real condition[4,5].

Porosity are effected by diagenesis such as[5]:

- Solution – water containing acid can dissolve the more soluble ions leading to increase in porosity.
- Dolomitization – process of transforming limestones into dolomite and enhanced porosity up to 13%.
- Fracture – formed by tectonic fracturing of the rock. It doesn't have much volume but it joined existing pores and enhanced permeability.
- Vugs – pore with cavities.

2.1.2. Saturations

Saturation of any given fluid in a pore space is the ratio of the volume of that fluid to the pore space volume [2, 4]. For example, a water saturation of 10% means that 1/10 of the pore space is filled with water; the balance is filled with something else such as oil, gas, or air as a pore cannot be "empty". As for porosity, saturation data is often reported in percentage units but is always a fraction in equations.

Porosity is the capacity of the rock to hold fluids. Saturation is the fraction of this capacity that actually holds any particular fluid. Porosity, hydrocarbon saturation, the thickness of the reservoir rock and the real extent of the reservoir determine the total hydrocarbon volume in place [4]. Hydrocarbon volume, recovery factor, and production rate establish the economic potential of the reservoir [4].

Water saturation (Sw) is the ratio of water volume to pore volume. Water bound to the shale is not included, so shale corrections must be performed if shale is present [2, 4]. We calculate water saturation from the effective porosity and the resistivity log [2].

Most oil and gas reservoirs are water wet; water coats the surface of each rock grain. A few reservoirs are oil wet, with oil on the rock surface and water contained in the pores, surrounded by oil. Some reservoirs are partially oil wet [1, 4]. Oil wet reservoirs are very poor producers as it is difficult to get the oil to detach itself from the rock surface. It is fairly easy to take a core sample, clean it and dry it, then make the rock oil wet. However, reservoir rocks are seldom clean and dry, so that same rock in-situ will often be water wet [1, 4].

2.2. Radioactive Logging Tools

Logging using radiation starts in 1940. The first radioactive tools recorded the natural gamma radiation emitted by the formations crossed through by boreholes [6]. Of the three identified nuclear radiation (alpha, beta, gamma), only gamma radiation can be used in well logging because of its sufficient penetrating power to go through formation and the steel casing.

The logging industry then moves rapidly to active nuclear bombardment and measurement. Thus in 1962 the density logs were introduced. The borehole is irradiated with gamma source and gamma ray counters will the count the reflected rays. In theory the difference between the number of gamma ray diffuse and the one that returns relates to the density of the formation [6,7].

In the late 1960s, the industry took a step further in logging technology and introduced the neutron logs [6]. Like density logs, it also measures the return gamma ray but varies by those generated by fast or slow neutrons.

2.2.1. Gamma Ray Logging

Gamma-ray measurements detect variations in the natural radioactivity originating from changes in concentrations of the trace elements uranium (U) and thorium (Th) as well as changes in concentration of the major rock forming element potassium (K) and are detected by the Geiger-Mueller counters [4, 6] as seen in Figure 3 and Figure 4.

Since the concentrations of these naturally occurring radioelements vary between different rock types, natural gamma-ray logging provides an important tool for lithologic mapping and stratigraphic correlation [6].

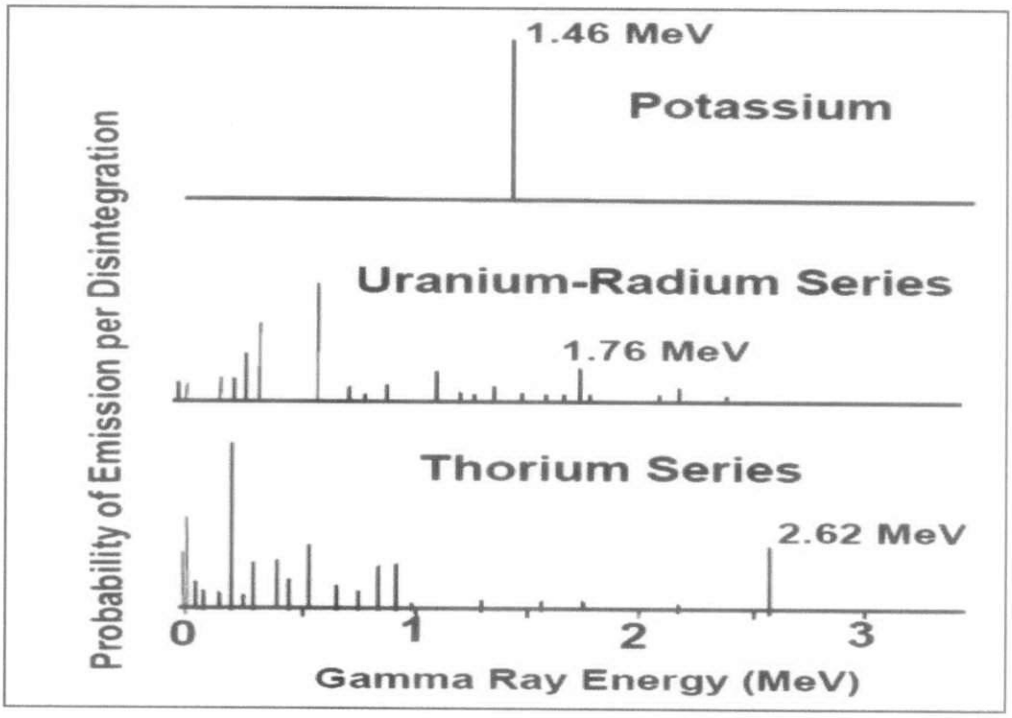


Figure 3: The gamma ray emission spectra[6].

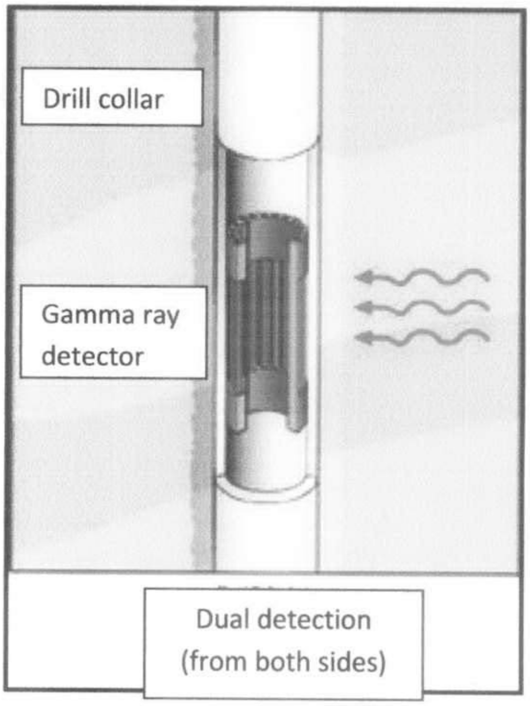


Figure 4: The gamma ray tool equipped with the Geiger-Mueller counter[6].

Gamma-ray logs are important for detecting alteration zones, and for providing information on rock types [6]. For example, in sedimentary rocks, sandstones can be easily distinguished from shales due to the low potassium content of the sandstones compared to the shales. Thus generally, low gamma ray reading can be associated with sandstone while high reading can be assume as non-sandstone or shale [1, 4, 6]. The log is presented with only 1 track that shows reading of the natural gamma ray in the formation as shown in Figure 5.

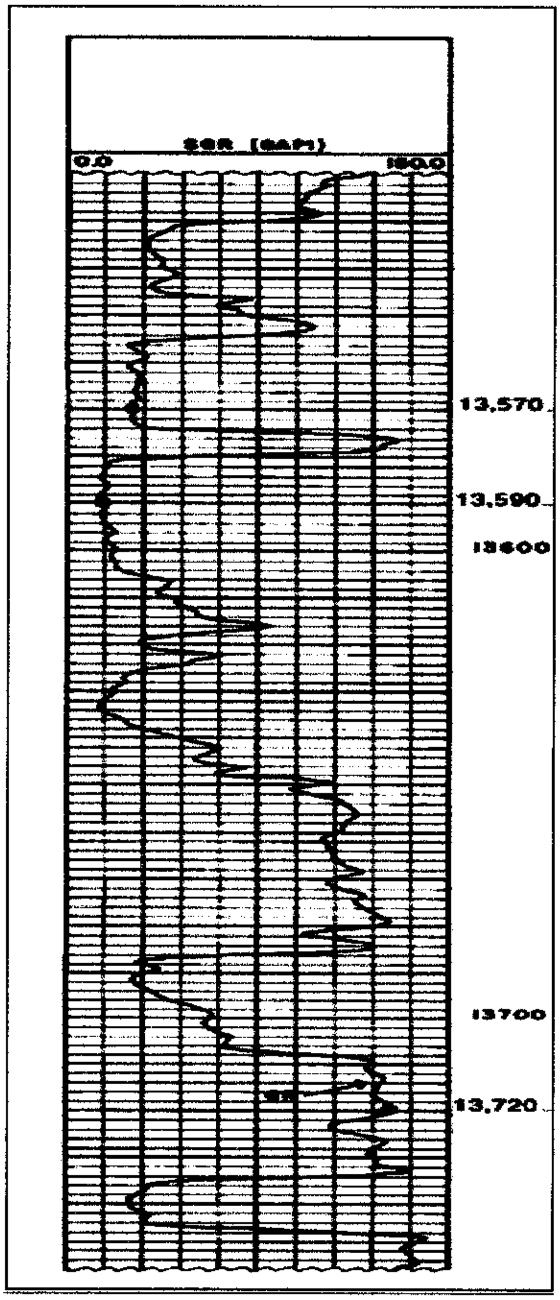


Figure 5: Gamma ray log presentation [6].

2.2.2. Neutron Logging

Neutron tools were the first logging instruments to use radioactive sources for determining the porosity of the formation [1]. After the later introduction of the gamma-gamma density tool, the neutron measurement was applied in conjunction with the density porosity reading in order to recognize and correct for effects of shale and gas. Neutron tool response is dominated by the concentration of hydrogen atoms in the formation [4, 6].

Open hole neutron logs run today utilize a chemical source (AmBe or PuBe). Neutron has a mass that is practically identical to that of the hydrogen atom [4]. After emission, they collide with the nuclei within the borehole fluid and formation materials. With each collision, the neutrons lose some of their energy [4, 6]. The largest loss of energy occurs when the neutrons collide with hydrogen atoms. The rate at which the neutrons slow-down depends largely on the amount of hydrogen in the formation [4, 6].

In cased hole, the tool function is the same. It differs in the source the tool use. Cased hole neutron uses a mechanical source (a pulse-activated accelerator source) that is 8 times more powerful [4,6]. This source will make sure that neutron can pass through the casing and still have the energy to travel trough the formation.

Neutron tool is usually combined with the density tool [1]. The Combination Neutron-Density Log is a combination porosity log. Besides its use a porosity device, it is also used to determine lithology and to detect gas-bearing zones [1, 4]. Where an increase in density porosity occurs along with a decrease in neutron porosity in a gas-bearing zone, it is called gas effect [1,4]. The tool is shown in Figure 6. The log scale spans usually from -0.15 until 0.45. The tool is often run with a gamma ray log for depth matching and a density log a best lithological assessment as seen in Figure 7.

The tool is used primarily to determine [6];

- porosity, usually in combination with the density tool,
- gas detection, usually in combination with the density tool, but also with a sonic tool,
- shale volume determination, in combination with the density tool,
- lithology indication, again in combination with the density log and/or sonic log,
- formation fluid type.

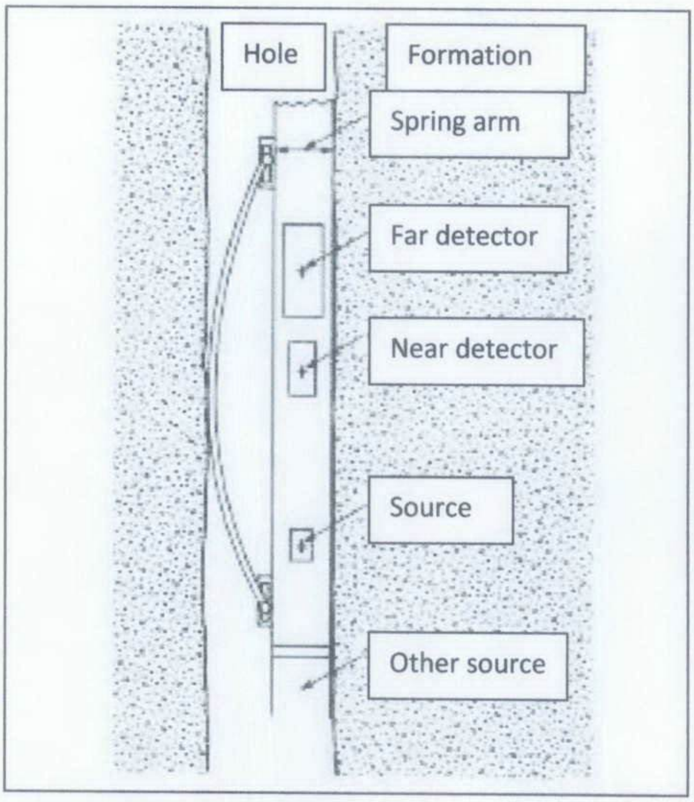


Figure 6: The Neutron tool[6].

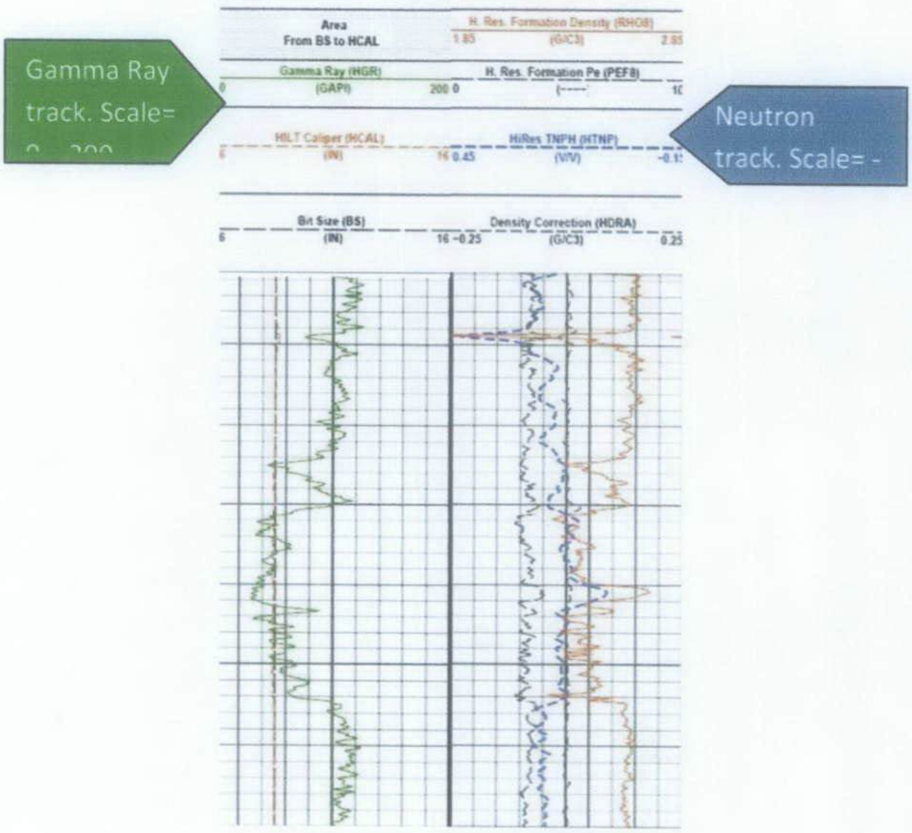


Figure 7: The neutron logs[6].

2.2.3. Density Logging

The density tool is a contact tool which consists of a medium-energy gamma ray source that emits gamma rays into a formation [1, 7] as shown in Figure 8. The gamma ray source is either Cobalt-60 or Cesium-137 [7]. Formulation bulk density is a function of matrix density, porosity, and density of the fluid in the pores such as salt, mud, fresh mud, or hydrocarbons [4, 7].

Density is one of the most important pieces of data in formation evaluation. In the majority of the wells drilled, density is the primary indicator of porosity [1]. In combination with other measurements, it may also be used to indicate lithology and formation fluid type [1, 5].

Dense formations absorb many gamma rays, while low-density formations absorb fewer [7]. Thus, high-count rates at the detectors indicate low-density formations, where as low count rates at the detectors indicate high-density formations. The density log gives reliable porosity values, provided the borehole is smooth, the formation is shale-free, and the pore space does not contain gas [1,7].

The log scale is in g/cm3 and spans usually from 1.85 until 2.95 as normal range for rocks do. The tool is often run with a gamma ray log for depth matching and a neutron log a best lithological assessment as seen in Figure 9. The formation density log is a porosity log that measures electron density of a formation.

Gamma rays can react with matter in 2 distinct manners [7]:

- Photoelectric effect: Where a gamma ray collides with an electron, is absorbed, and transfers all of its energy to that electron. The electron is ejected from the atom.
- Compton scattering: Where a gamma ray collides with an electron orbiting some nucleus. In this case, the electron is ejected from its orbit and the incident gamma ray loses energy.

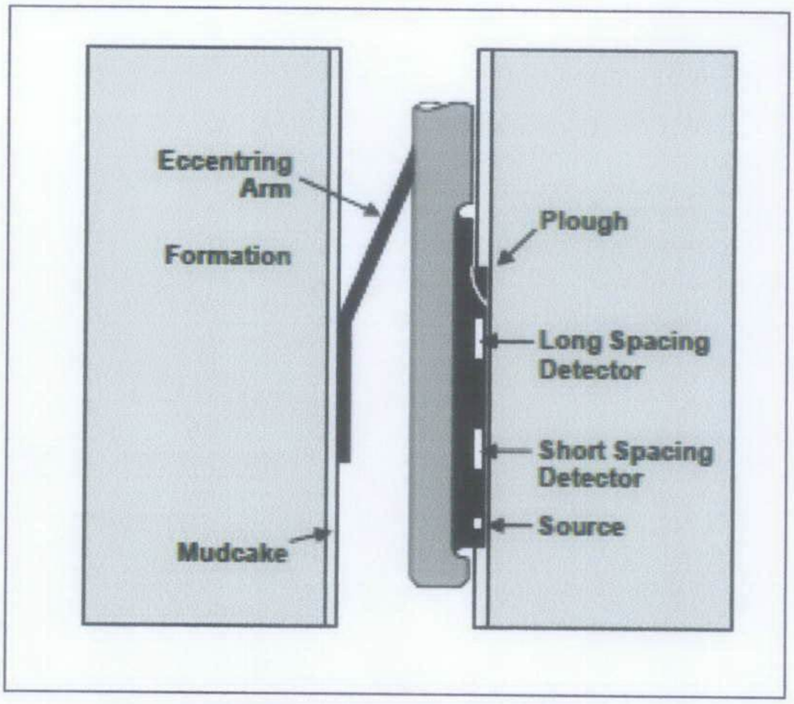


Figure 8: The Density tool[7].

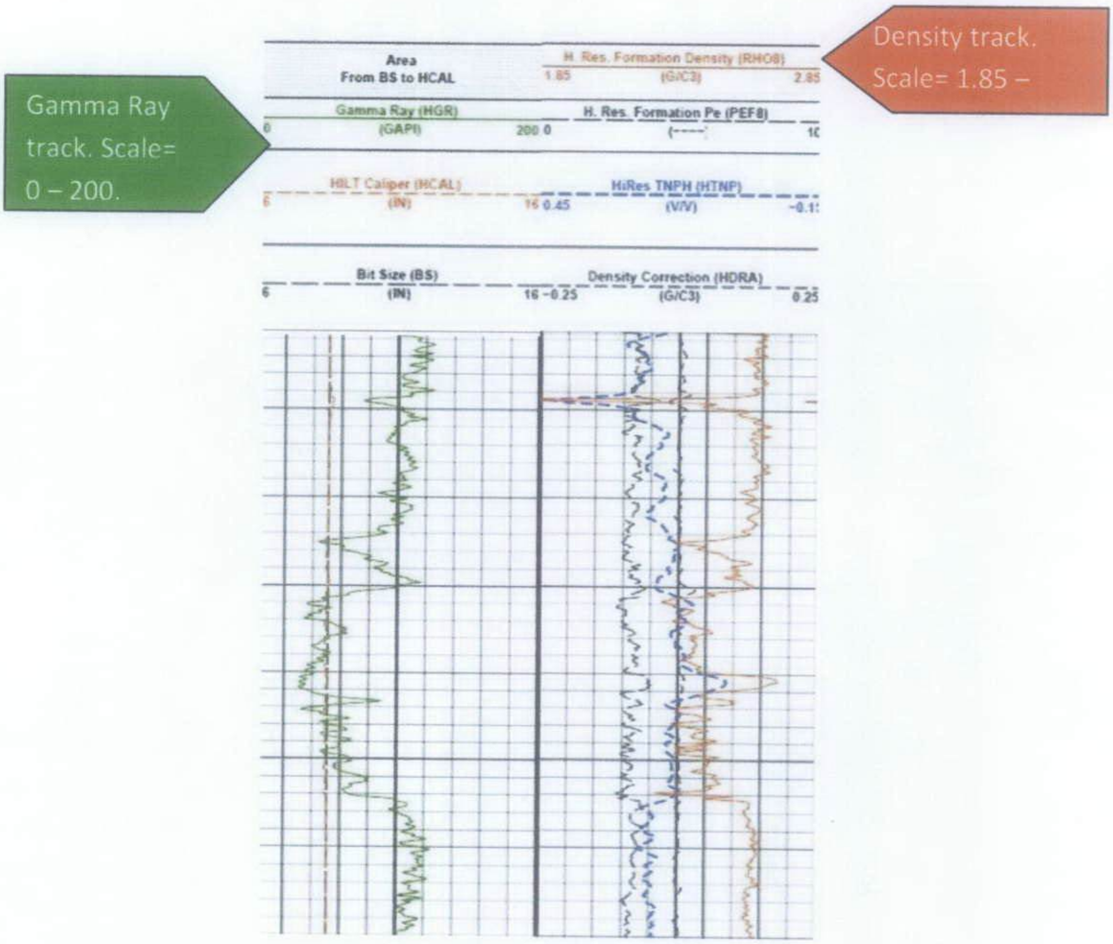


Figure 9: The density logs[7].

2.3. Resistivity Logging

In combination with recorded depth, resistivity was the first formation parameter measured by wireline logging techniques. Resistivity is the electrical resistance, measured in ohms, is defined as the ability of a material or substance to obstruct the flow of electrical current [4,8]. Electrical current is generated by an electromotive force, called voltage [8].

The resistance is defined by Ohm's Law as the ratio of the voltage applied to the current that flows. Ohm's law is expressed mathematically as follows [8]:

$$\boldsymbol{V = I \times r} \text{ ...... Equation 1}$$

Well log resistivity measurement devices use different electrode spacings, different configurations, different electrode sizes, and perform measurements in an environment surrounded by a water-based drilling fluid [4,8]. Metric units are used for the resistivity measurement, and the log trace is scaled as ohm-meters^2/meter.

Log-measured resistivity values are generally a function of the amount of porosity and the water occupying the pore space and generally respond to the type and amount of water in the formation. Pure water is a very poor conductor. However, if salt is added to water, the solution becomes more conductive. Current is conducted through water by ions formed from the salt in solution in the water [8]. The more ions present in the solution, the more conductive the solution will be [8].

One of the most important parameter to be determined using the resistivity logs is the water resistivity (*Rw*) and the true resistivity (*Rt*). To determine the saturations both are needed for the Archies' equation. The *Rt* is determined by taking directly from the deep resistivity or Rdeep results from resistivity logging. While Rw is determined by using the Archies' and substituting the Sw value to be 1 as the value is taken in the water zone. The Rw is determined by using this equation [8]:

$$\boldsymbol{Rw = \emptyset^m \times Rt} \text{ ...... Equation 2}$$

2.4. Log Interpretations

Log interpretation is done so that these objectives can be achieved [1, 5];

1- Characterize reservoir quality and fluids contained.
2- To determine the size of the reservoir, the quantity of hydrocarbon in place and reservoirs producing capabilities.

Three basic log curves that are important to know are the gamma ray, the resistivity and the neutron-density [5]. There are two types of logging that can be done which are MWD/LWD (measure while drilling/logging while drilling) and wireline logging [1].

Gamma-ray logs are important for detecting alteration zones, and for providing information on rock types [1, 6]. For example, in sedimentary rocks, sandstones can be easily distinguished from shales due to the low potassium content of the sandstones compared to the shales [1, 6].

Thus generally, low gamma ray reading can be associated with sandstone while high reading can be assume as non-sandstone or shale [1]. From gamma ray logs reading, the cutoff value of sand and shale can be determined by using this equation;

$$\boldsymbol{Cutoff} = \left[\frac{GRmax - GRmin}{2}\right] + \boldsymbol{GRmin} \text{ ...... Equation 3}$$

Volume of shale can be estimated using this equation [1];

$$\boldsymbol{Vsh} = \frac{(GRlog - GRmin)}{(GRmax - GRmin)} \text{ ...... Equation 4}$$

The porosity is calculated using the density curve. The density tool is a contact tool which consists of a medium-energy gamma ray source that emits gamma rays into a formation [1,7]. In combination with other measurements, it may also be used to indicate lithology and formation fluid type [7]. Porosity is estimated using this equation [1];

$$\emptyset T = \frac{(\rho ma - \rho b)}{(\rho ma - \rho f)} \text{ ...... Equation 5}$$

But porosity value will be effected by environment such as the presence of fluid especially gas and oil. This is because as the porosity is determined using Density tool, the density of the fluid will greatly affect the total porosity count especially gas with its very low density and because of these effects, porosity value might be overestimated. The correction of porosity from the effect of oil and gas are done using these equations [1, 7];

$$\emptyset corrgas = \emptyset T \times \frac{2}{3} \text{ ...... Equation 6}$$

$$\emptyset corroil = \emptyset T \times 0.9 \text{ ...... Equation 7}$$

Last but not least is to find the water saturation,. Sw is an important parameter to estimate the saturation of hydrocarbon from using the equation [1];

$$Shc = 1 - Sw \text{ ...... Equation 8}$$

But before finding the hydrocarbon saturation, Sw is estimated using the Archies' equation [1] and that is;

$$Sw^n = \frac{(a \times Rw)}{(\emptyset^m \times Rt)} \text{ ...... Equation 9}$$

2.5. Sample Calculations

For the sample calculations, a log sample was taken from well X, as seen in Figure 10, as a sample for quicklook interpretation and to determine the Sand 1 cutoff value, volume of shale porosity and water saturations at depth of 15XX m.

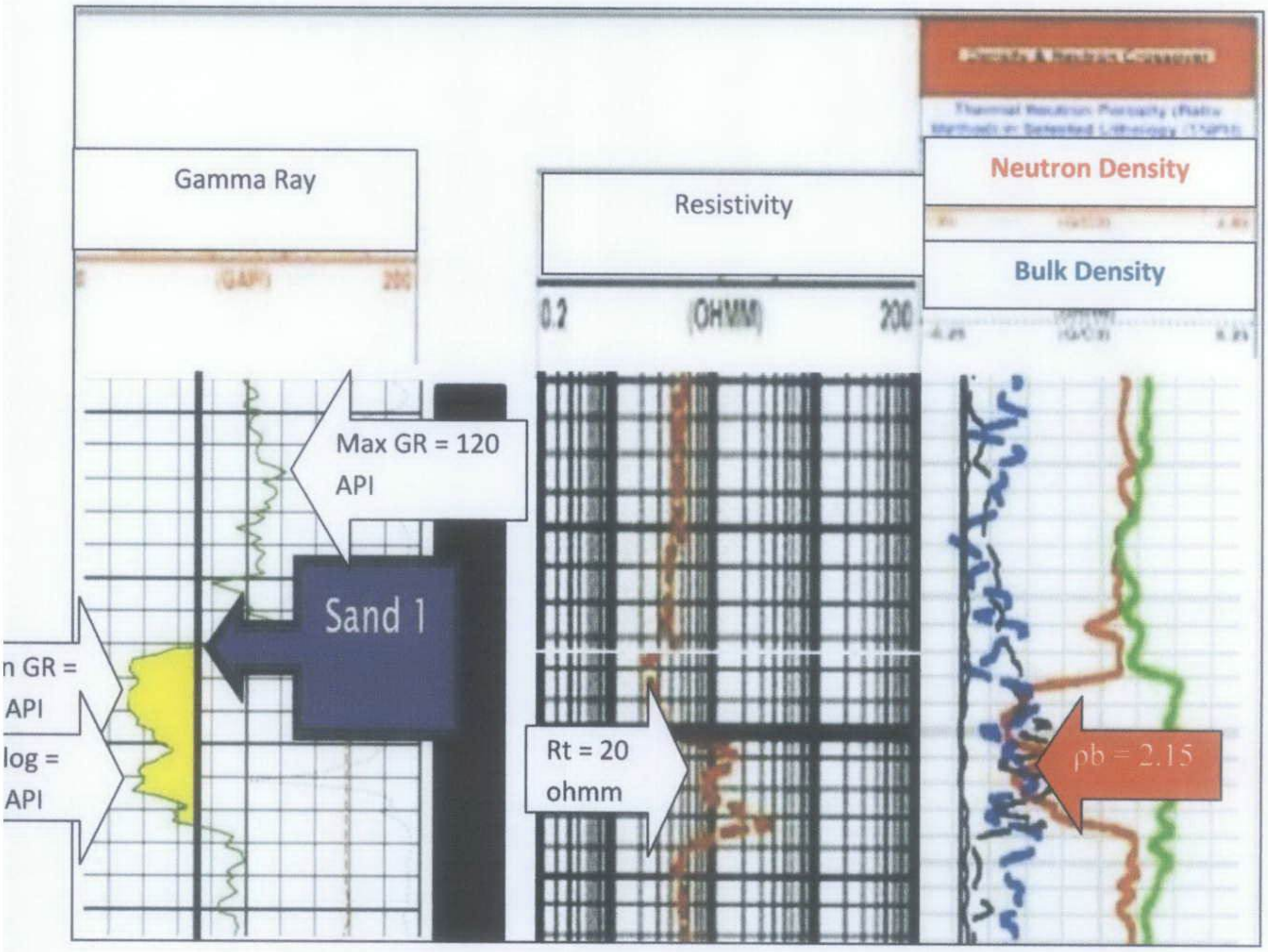


Figure 10: Log sample from Well X[3].

2.5.1. Cutoff Value

The cutoff value was calculated to determine and differentiate the reservoir and non-reservoir area [4]. The cutoff is calculated using Equation 3.

Calculation of cutoff value;

$$Cutoff = \left[\frac{GRmax - GRmin}{2}\right] + GRmin$$

$$= \left(\frac{120-30}{2}\right) + 30$$

$$= 75\ °API$$

From the calculation the cutoff is determined to be at 75° API.

2.5.2. Volume of Shale

Volume of shale (Vsh) is calculated to determine the quality of the reservoir whether it has high or low percentage of shale [4]. Vsh can be determined using Equation 4 by taking the value of GRlog from the log sample.

Calculation for volume of shale;

$$Vsh = \frac{(GRlog - GRmin)}{(GRmax - GRmin)}$$

$$= \left(\frac{40-30}{120-30}\right) \times 100$$

$$= 17\%$$

From the calculation, the value of Vsh is calculated to be at 17% which means at the area, there area, 83% of the matrix is sand.

2.5.3. Porosity

Porosity is important to determine whether the reservoir has good percent of rocks that can contains fluid especially in estimating the amount of hydrocarbon stored in the reservoir. Porosity can be calculated using Equation 5 and by taking the ρb or ρlog as 2.15 taken from the sample log of Well X at the Density log column and the values of ρma and ρf can be referred in the Glossary.

Calculation for porosity;

$$\emptyset T = \frac{(\rho ma - \rho b)}{(\rho ma - \rho f)}$$

$$= \frac{(2.65-2.15)}{(2.65-1)}$$

$$\emptyset T = 30\%$$

Thus the total porosity is calculated to be 30% which is a good value of porosity.

2.5.4. Water Saturations

Water saturations is determined using Equation 7 or more known as the Archies' equation. The electrical properties, a, m and n values can be referred in the Glossary and the Rt is taken from the Well X log in the Resistivity log column.

Calculation for water saturation;

$$Sw^n = \frac{(a \times Rw)}{(\emptyset^m \times Rt)}$$

$$Sw^2 = \frac{(1 \times 0.12)}{(0.30^2 \times 20)}$$

$$Sw = 0.25$$

From the calculation we know that the water saturation is 25%.

2.5.5. Hydrocarbon Saturations

Hydrocarbon saturations is calculated to estimate the hydrocarbon reserves [4]. The value can determined from using Equation 6.

Calculation for hydrocarbon saturation;

$$Shc = 1 - Sw$$

$$= 1 - 0.25$$

$$Shc = 0.75$$

Thus the hydrocarbon saturations is determined to be 0.75 or 75%.

CHAPTER 3

3. Methodology

Completing this project, the author focuses on the:

I. Calculating the sand cutoff for each well using gamma ray logging results.

II. Calculating the volume of shale and determining the sands also using the gamma ray logging results.

III. Determining the porosity of the sands using the density logging results.

IV. Determining the water resistivity of each well.

V. Calculating the saturations of the water and hydrocarbons of each well.

3.1. Project Activities

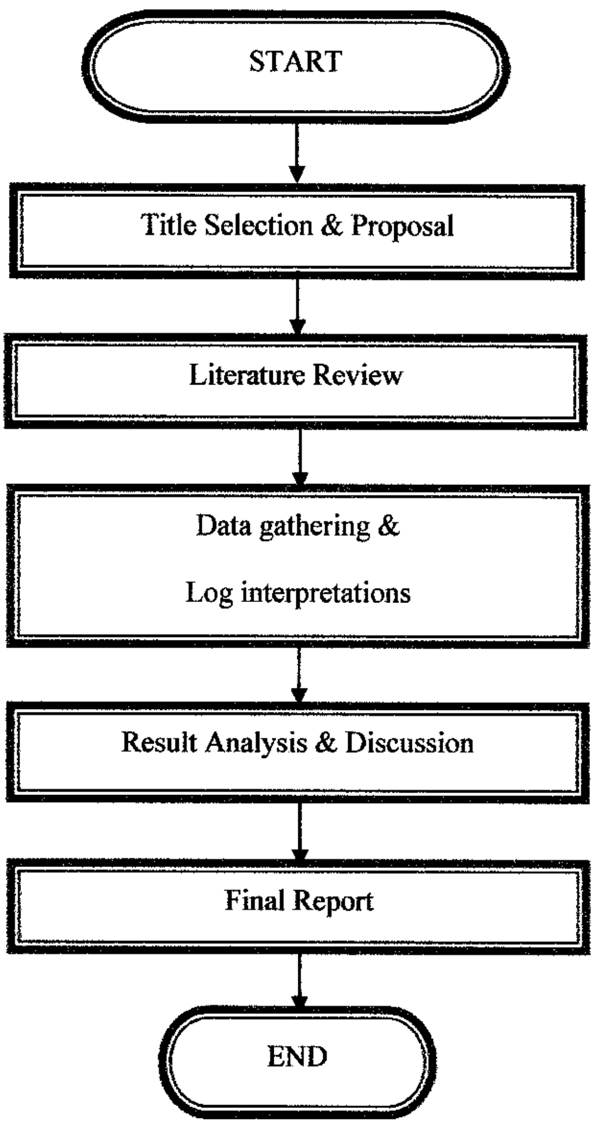


Figure 11: Project flow chart.

3.2. Gantt Chart

The Gantt chart is provided together with the report in the Project Timelines section. Noted that the gantt chart is a guideline for the FYP2 project. It can be changed from time to time depending on circumstances. Attached in the Appendix 2 is the gantt chart for FYP1.

During the course of FYP1, the main activity was to gather as much literature review that will help the author understands better about the project. The author had done a literature research on the tools of radioactive logging , the methods of performing quicklook manual calculations to interpret logs and also on how to use the software.

Thus for FYP2, the main objective is to use all the knowledge gathered and to perform the interpretations using the data given to interpret the two wells of Sepat-X and Sepat-XST1.

CHAPTER 4

4. Result & Discussions

The results from well Sepat-X and Sepat-XST1 petrophysical interpretations are presented in this section.

4.1. Petrophysical Properties

Petrophysical properties involved parameters need to be known before any calculations are performed. This includes the electrical properties that consist of the turosity constant, cementation exponent and saturation exponent. Other parameter that is needed is the water resistivity.

4.1.1. Electrical Properties

To calculate saturations using Archies' the electrical properties which are the turosity constant (a), cementation exponent (m) and saturation exponent (n) must be determined[13]. But during the course of this research, no core data was given thus the value of a, m and n will be assumed to be 1, 2 and 2 respectively.

4.1.2. Water Resistivity

The water resistivity or Rw is determined using the Pickett Plot[9,16], it is done so as to help in the determination of the saturations using the Archies' equation in manual calculations. For Sepat-X the identified water zone is in sand E09 at depth of 1783 MDDF until 1790 MDDF where the average Rt are 30 ohm.m with porosity with an average of 0.15. For Sepat –XST1 well, the water zone is identified to be in the E08 sands at depth interval of 1865 MDDF until 1875 MDDF where the average Rt is 40 ohm.m and porosity of 0.12.

The Pickett Plot is plotted using the values of true resistivity (Rt) and porosity extracted using Interactive Petrophysics. After plotting, the plot shows the Rw to be 0.07 ohm.m for Sepat-X well and For Sepat-XST1 well the Rw is 0.06 ohm.m. The results were shown in Figure 12 and Figure 13 respectively. Comparing the two methods, the Rw is almost similar.

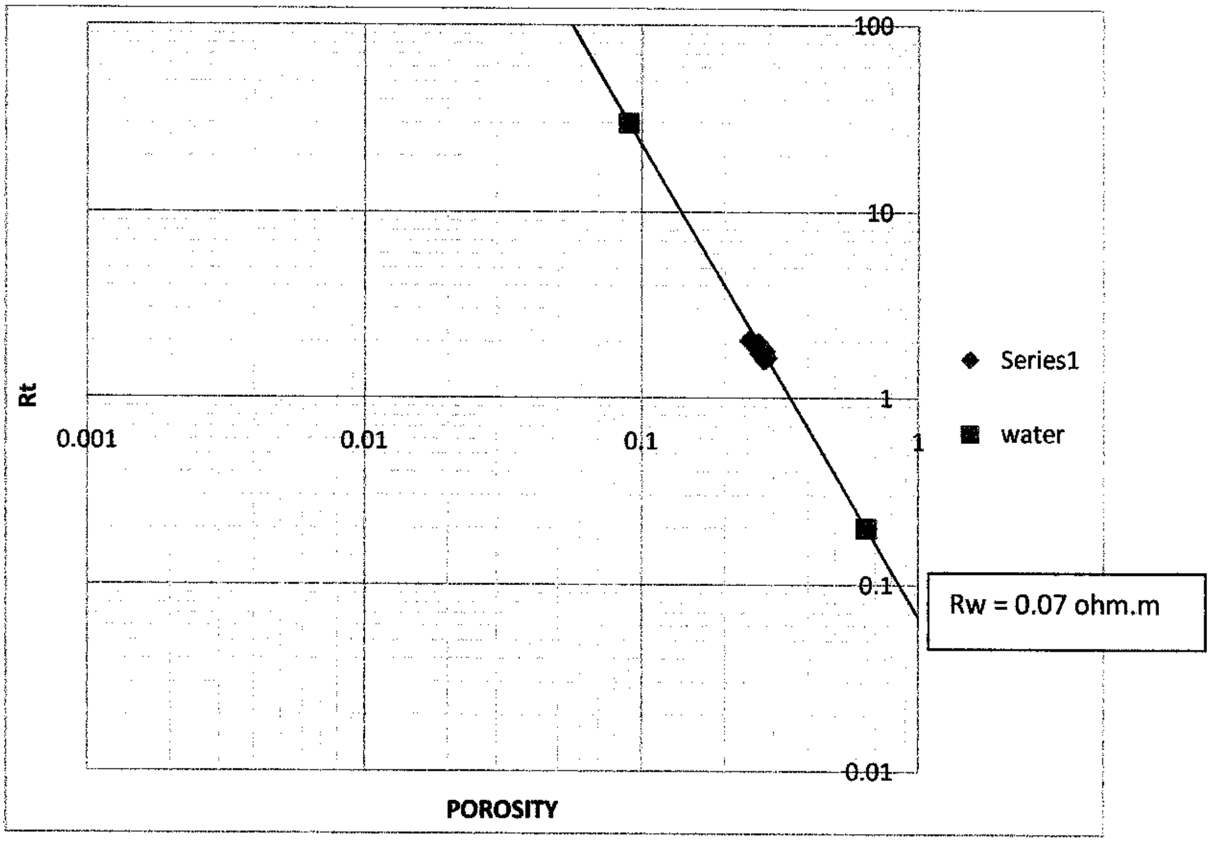


Figure 12: Result of Rw using Pickett Plot for Sepat-X well[9,16].

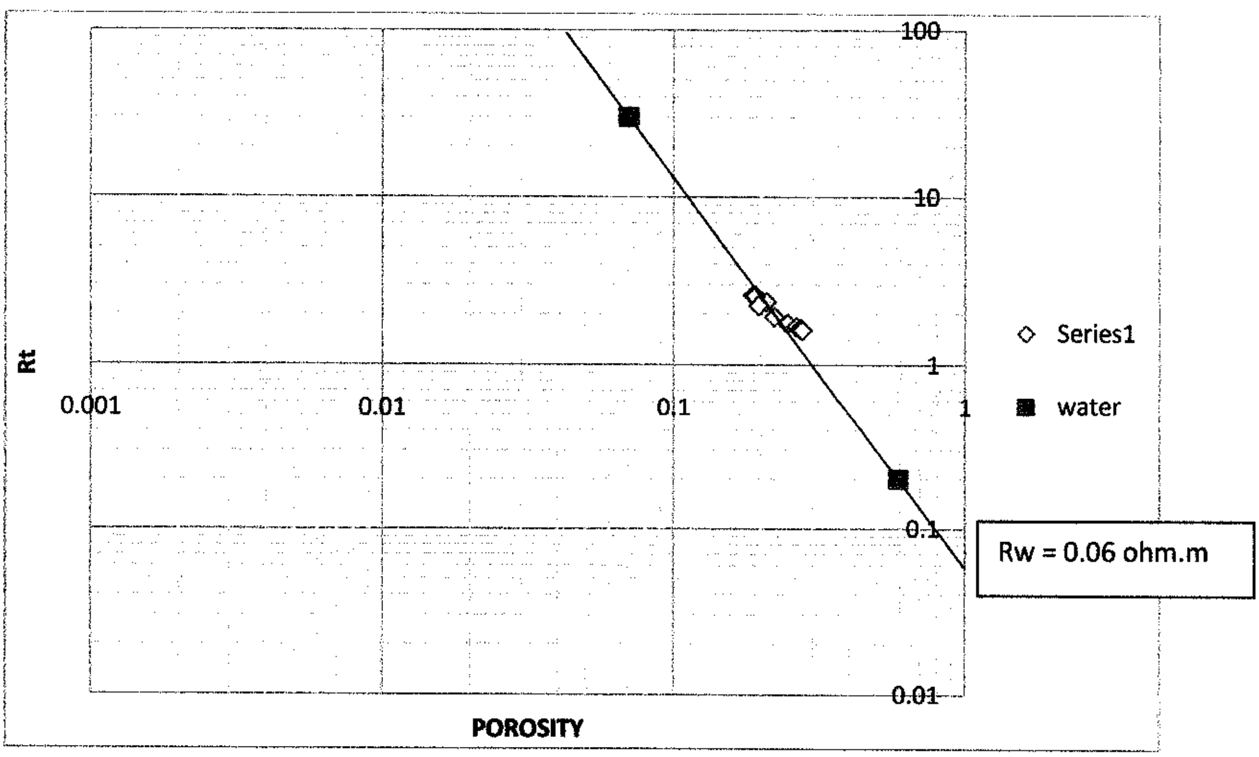


Figure 13: Result of Rw using Pickett Plot for Sepat-XST1 well[9,16].

4.2. Formation Evaluation

The formation evaluation of Sepat-X and Sepat-XST1 will be conducted on each reservoir. Results of the porosity and saturations for each zone were discussed and the fluid type will be identified from the fluid gradient. The author will display one example of the calculations for formation section but the rest of the sections will be tabulate and compared in the result summary.

4.2.1. Well Sepat-X

Sepat-X full log consists of 14 reservoirs, but for comparison purposes of the petrophysical interpretations from using mathematical method and also the one from Interactive Petrophysics the author will be doing interpretations on 7 reservoirs since some reservoirs did not have enough pressure data for fluid typing.

I. D35 Sands

From looking at the logs, the author can see the gamma ray showing a low value and thus indicating sandstone, a small crossover between the Neutron and Density curve was also observed and the resistivity curve was also showing high peaks up to 30ohm.m.

Thus from all the indications by the log curves, one can safely say it is hydrocarbon bearing. The crossover between the Neutron and Density curve is called the butterfly effect which also a gas show. The supporting log Sepat-X D35 is shown in Figure 14.

The value from the manual calculations shows that the average corrected porosity at sand D35 is around 20.2% and the water saturations (Sw) to be 29% with the hydrocarbon saturations (Shc) 71%. The value obtained from Interactive Petrophysics (IP) is almost similar with average porosity is 23%, Sw of 27.6% and Shc of 72.4%.

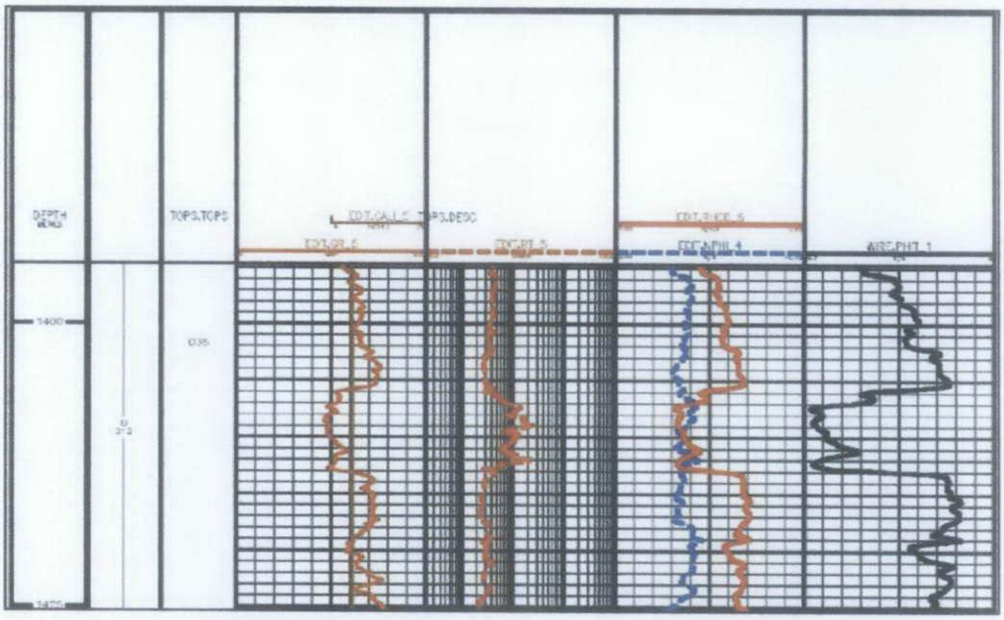


Figure 14: Supporting log for D35 sands for Sepat-X well.

For the manual calculations the results is tabulate in the Table 1 below.

Table 1: Petrophysical result for sand D35 in Sepat-X well.

Porosity	Sw	Shc
ρlog average = 2.15 g/c3	Rw = 0.07 ohmm (3ohmm @89.3°F at 1783MDDF , 0.15 porosity)	$Shc = 1 - 0.29$ *Shc* = 0.71 ~71% hydrocarbon
$\emptyset T = \frac{2.65 - 2.15}{2.65 - 1.00}$ = 0.303	RT = 20 ohmm	
$\emptyset corrgas = 0.303 * \frac{2}{3}$ = 0.202	$Sw = \sqrt[2]{\frac{1(0.07)}{0.202^2 \times 20}}$ *Sw* = 0.29	

II. D55 Sands

Log response for D55 sands shows a decrease in the gamma ray, but there are also occasional peaks thus showing that in unit has sandstone but it's not clean and has effects of shale. The author also observed crossover between the Neutron and Density curve with high value resistivity up to 20 ohm.m. These reactions on the logs show that the sand is hydrocarbon bearing and most probably containing gas as shown in Figure 15 (in appendix 2).

From the manual calculations the average corrected porosity is of 18%, Sw around 32.9% and the Shc at 67.1%. But from the IP software, the porosity is about 17.6% with Sw at 32.4% and Shc is 67.6%. The value from both method were slightly different but the differences are not huge. The result from IP was slightly lower but that is maybe due to the values of bulk density read is much more accurate than the one used to calculate porosity manually.

III. D60 Sands

The gamma ray logging tools show a decrease and stays level on one value thus we can say that D60 sands can be considered as a clean sand. The Neutron-Density shows a small separation suggesting that the fluid in the unit is oil. The resistivity is also quite high with values up to 10 ohm.m. As shown in Figure 16 (in appendix 2).

From the manual calculations the value of average corrected porosity is 21.8%, Sw is 38.4% and the Shc is determined to be 61.6%. From IP, the value of porosity is 23.8%, Sw equals to 35.2% and the Shc is 64.8%. The value differs with the water saturations from IP is much lower making the hydrocarbon saturations to rise.

IV. E06 Sands

From the logs we can see the gamma ray responds by decreasing thus showing there is sand there but it also has occasional peaks suggesting the unit is not a clean sandstone reservoir. The Neutron-Density shows slight separation same with the previous unit suggesting it is oil with resistivity of 10 ohm.m. As shown in Figure 17 (in appendix 2).

From the manual calculations the corrected porosity is determined to be 19.1%, Sw is 43.8% and Shc is 56.2%. Results from IP shows the porosity is 21.0%, Sw is 39.8% and Shc is 60.2%.

V. E07 Sand

The gamma ray curve shows a fairly level low response suggesting the unit contains clean sandstone, the Neutron-Density shows a slight separations suggesting the fluid is oil and the resistivity is fairly low with values on average of 3 ohm.m. As shown in Figure 18 (in appendix 2).

The manual calculations shows the average corrected porosity is 19.1%, Sw of 64.0% and Shc of 36.0%. From IP the porosity is determined to be 24% with Sw of 69.7% and Shc of 30.3%. The result varies with IP showing higher value of water saturations and lower values of hydrocarbon saturations but the both values did not differ too high.

VI. E08 Sand

The gamma ray responds shows the unit consist sandstone reservoir but it is not clean sands. The Nuetron-Density shows very small separation with very low value of resistivity higher in the upper sand of the unit (4 ohm.m) and goes lower down to 2 ohm.m.

All the responses may suggest the fluid in the E08 is oil and water. This show the oil water contact might have occurred in this sand unit. As shown in Figure 19 (in appendix 2).

The manual calculations show the porosity to be 10.9% with Sw of 109% which suggest it is water saturated. But from IP the value of porosity is around 21.0% with Sw of 89.1% and Shc to be 10.9%. This shows the amount of hydrocarbon in E08 sand is very low and consists of huge amount of water.

VII. E09 Sand

From the gamma ray log there are shows of some amount of sandstone with shale. The Neutron-Density shows slight separation with low resistivity between 3ohm.m and 2 ohm.m. These responses suggest the fluid in sand E09 is water. As shown in Figure 20 (in appendix 2).

From the manual calculations, the porosity is determined to be 12.1% with Sw of 126%. From IP the porosity is calculated to be 12.5% and the Sw is 122%. These results show that unit E09 is water saturated.

4.2.2. Well Sepat-XST1

This well contains 9 known reservoirs but the author will only use 6 to compare the result from manual calculations and from IP.

I. D35 Sand

From the gamma ray respond, we can see that there is sand in the D35 upper with gas sign from the Neutron-Density log and also high resistivity up to 30ohm.m. As shown in Figure 21 (in appendix 2).

From the manual calculations, the porosity is about 22% with Sw of 25% and Shc of 75%. While results from IP shows porosity of 30%, Sw of 18% and Shc of 82%. Thus from the calculations and log responds we can say that D35 sand contains gas.

II. D55 Sand

In the lower D55 sand, gas effect was read from the Neutron-Density log and high resistivity was also noticed with values up to 20 ohm.m. As shown in Figure 22 (in appendix 2).

From the manual calculations the porosity is 20%, Sw is 50% and Shc is 50%. Result from IP shows the porosity is calculated to be 28%, Sw is 36% and Shc is 64%. Thus it can be concluded that D55 does contains gas.

III. D60 Sand

The gamma ray shows very good respond with sand column noticed and also some slight crossover in the Neutron-Density which suggest the effect of gas. The resistivity values are also high with an average 10 ohm.m. As shown in Figure 23 (in appendix 2).

From the manual calculations the result was porosity is 16%, Sw is 34% and Shc is 66%. From IP, the porosity is 24%, Sw 23% and Shc is 77%. Thus this means this unit indeed have hydrocarbon in it and most probably be gas.

IV. E06.1 Sand

The lower sand shows an overlapped between the Netron-Density curve, thus we can say that it is most probably oil. The resistivity was also high up to 30 ohm.m.
As shown in Figure 24 (in appendix 2).

The manual calculations show the porosity is 32%, Sw is 14% and Shc is 86%. While the results from IP are porosity is 30%, Sw is 15% and Shc is 85%. From the petrophysical results and the log response we can safely say that E06.1 contains hydrocarbon and it is most probably oil.

V. E07 Sand

In the E07 upper, we can see a small separation between the Neutron and Density curve. The resistivity is also quite high up to 10 ohm.m. As shown in Figure 25 (in appendix 2).

The manual calculations show the porosity is 22%, the Sw is 35% and the Shc is 65%. From the IP the results are, porosity is 24%, Sw is 32% and Shc is 68%. Thus from the calculations and log response we can safely say that E07 contains hydrocarbon and it is probably oil.

VI. E08 Sand

In the lower E08, the gap between the Neutron and Density curve is quite big and the resistivity value is low with average of 3ohm.m. As shown in Figure 26 (in appendix 2).

From the manual calculations the porosity is 12% and Sw is 118%. While from IP, the porosity is 14% and Sw is 101%. Thus we can say that the fluid in E08 is water.

4.3. Fluid Typing

Fluids typing for each unit of sands were determined by plotting Pressure plot for each sand and interpreting the gradient. Each fluid have will show a different gradient such as[10,11];

I.	Gas	= 0.05 – 0.11psi/ft
II.	Light oil	= 0.27-- 0.30 psi/ft
III.	Oil	= 0.31 – 0.36 psi/ft
IV.	Water	= 0.40 – 0.45 psi/ft

4.3.1. Sepat-X Fluid Typing

The pressure plot for Sepat-X sands was plotted and the gradient was determined as shown in Figure 27. The result of the interpretations is shown below in Table 2.

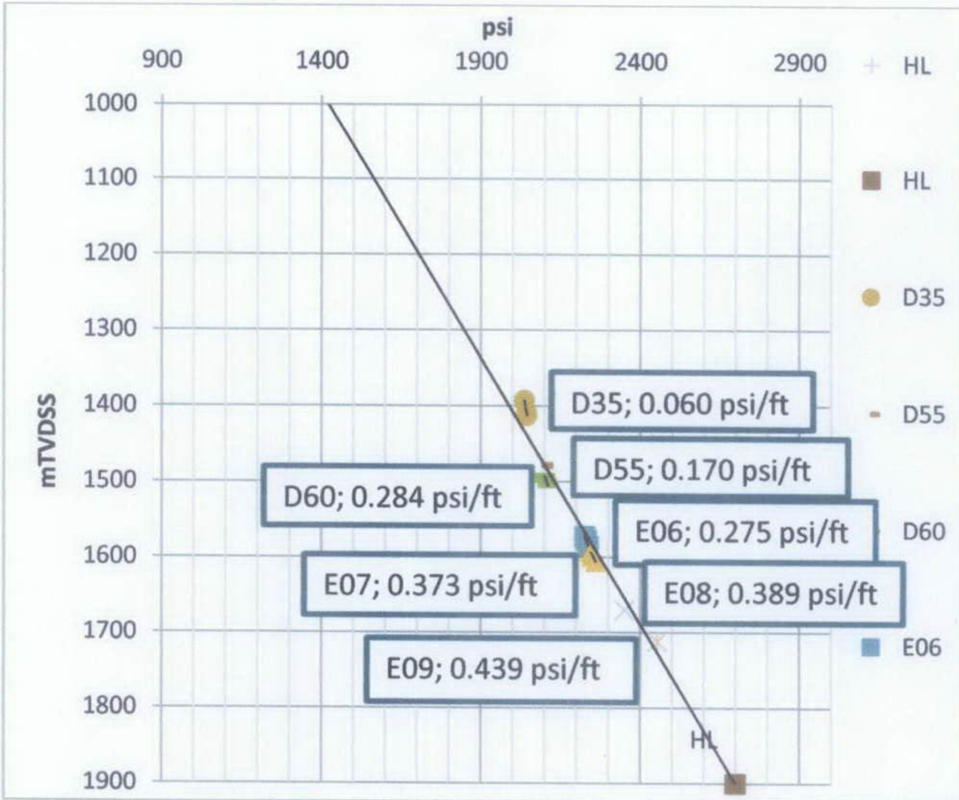


Figure 27: Pressure plot for Sepat-X sands[10,11].

Table 2: Fluid type in Sepat-X well.

SAND	Pressure (psi)	GRADIENT (m/psi)	GRADIENT (psi/ft)	FLUID
D35	2036.26	2.47	0.123394788	GAS
	2043.27			
	2044.12			
D55	2093.67	1.785	0.17074797	GAS
	2094.51			
D60	2099.19	1.075	0.283521048	OIL
	2103.19			
	2110.97			
E06	2225.73	1.11	0.274581195	OIL
	2230.5			
	2237.11			
E07	2244.76	0.817	0.37305401	OIL
	2249.75			
	2260.3			
E08	2168.8	0.784	0.389	OIL
	2168.99			
	2171.22			
E09	2164.14	0.694	0.439171652	WATER
	2164.86			

4.3.2. Sepat-XST1 Fluid Typing

The pressure plot for Sepat-XST1 sands was plotted and the gradient was determined as shown in Figure 28. The result of the interpretations is shown below in Table 3.

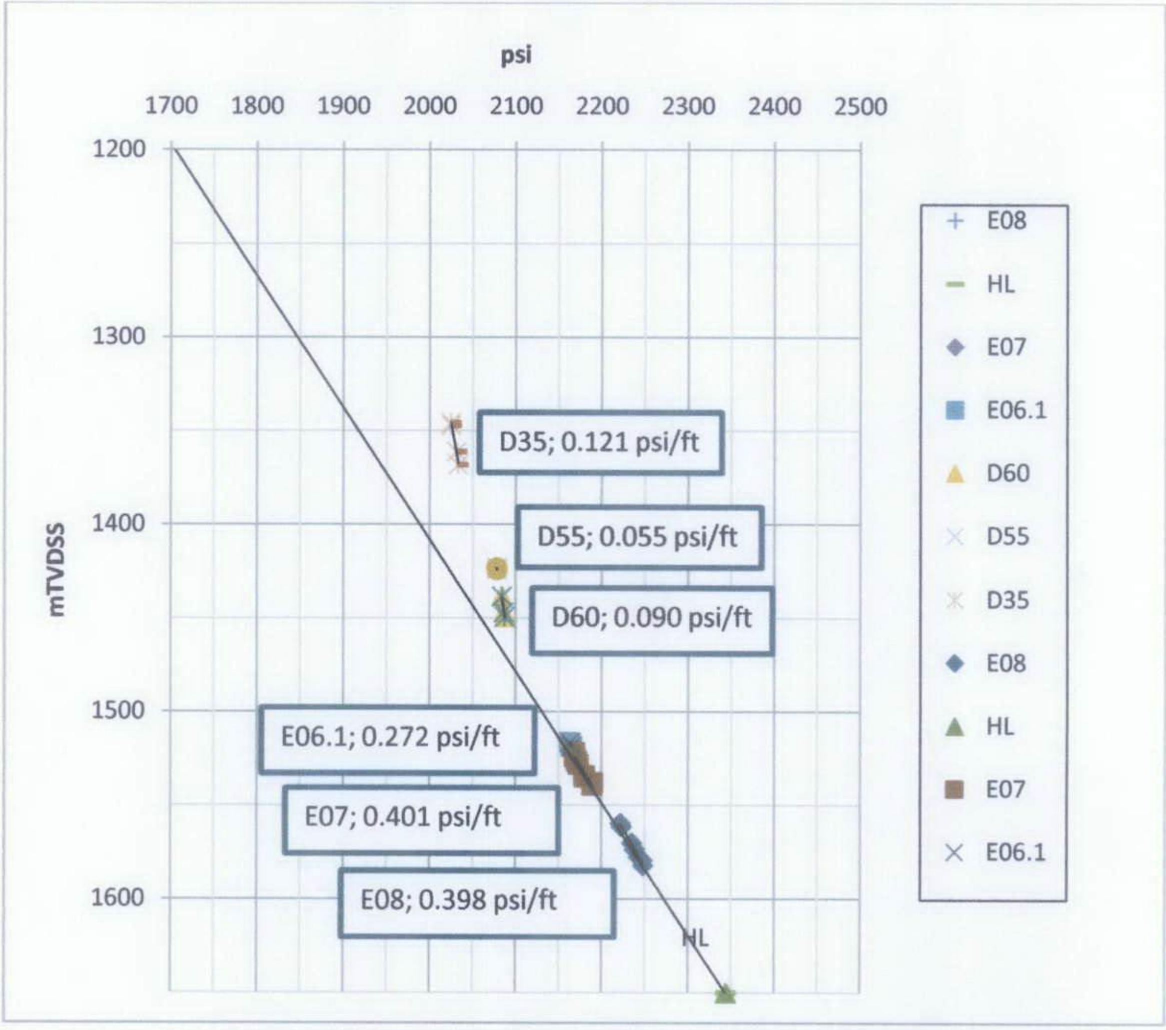


Figure 28: Pressure plot for Sepat-XST1 sands[10,11].

The gradient from each sand is then used to determine the fluid type in the sands. The gradient is used because different fluid will give out different gradient. Thus by using this method we can predict the type of fluid in each sands.

Table 3: Fluid type in Sepat-XST1 well.

SAND	PRESSURE	GRADIENT (m/psi)	GRADIENT (psi/ft)	FLUID
D35	2024.51	2.515	0.121186929	**GAS**
	2025.05			
	2031.26			
	2033.01			
D55	2078.03	5.5	0.055415478	**GAS**
	2078.23			
D60	2084	3.383	0.09009315	**GAS**
	2086.3			
	2087.3			
E06.1	2163.36	1.12	0.272129577	**OIL**
	2165.18			
E07	2168.8	0.76	0.401033061	**OIL**
	2168.99			
	2171.22			
	2172.96			
	2179.76			
	2180.23			
	2189.57			
	2188.93			
E08	2221.81	0.766	0.39789181	**WATER**
	2222.98			
	2234.89			
	2238.3			
	2243.33			
	2247.17			
	2247.93			

4.4. Fluid Contacts

The fluid contacts were determined from pressure plot using the pressure data[12]. The importance of determining the contacts is so the author that can roughly differentiate which reservoir contains either gas, oil or water which will help later when quicklook calculation is performed so that certain corrections can be made on the calculations.

For Sepat-X the gas oil contact (GOC) was determined to be at 1490 mTVDSS or at D60 sands and the oil water contact (WOC) is determined to be at 1660 mTVDSS around halfway through the E08 sands. The result is shown in Figure 29.

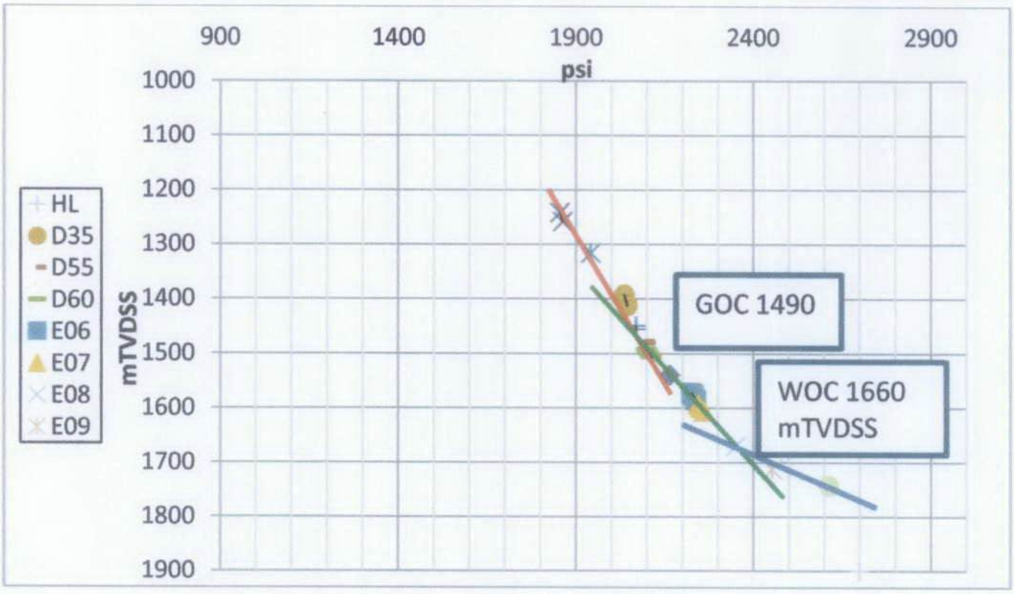


Figure 29: Fluid contacts for well Sepat-X[12].

For Sepat-XST1 the gas oil contact (GOC) was determined to be at 1495 mTVDSS at lower D60 sands and the oil water contact (WOC) is determined to be at 1560 mTVDSS at E08 sands. The result is shown in Figure 30.

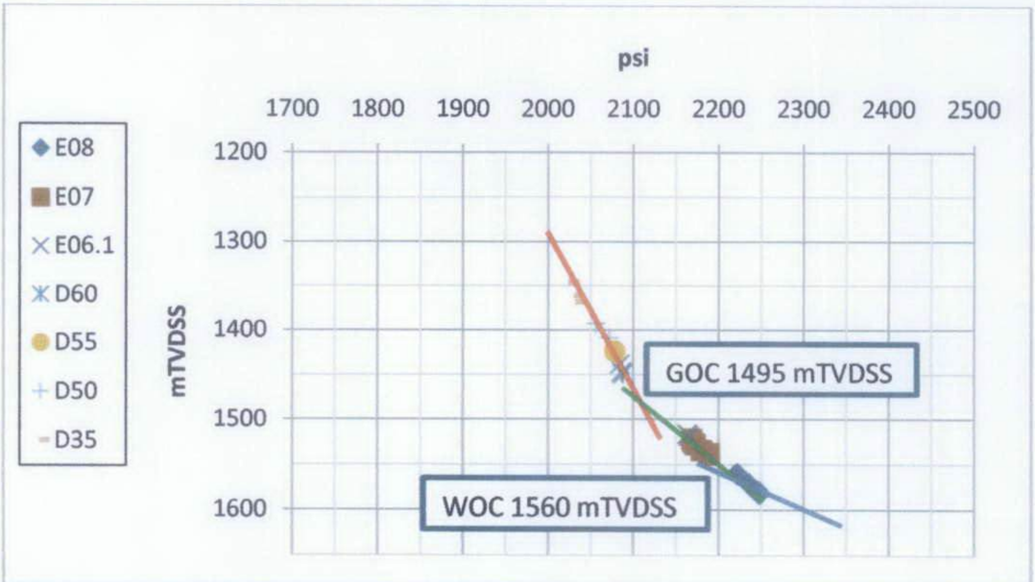


Figure 30: Fluid contacts for well Sepat-XST1[12].

4.5. Result Summary and Discussion

The result summary of the petrophysical interpretations from manual calculations and IP for well Sepat-X and Sepat-XST1 are tabulated and compared in Table 4 and Table 5.

Table 4: Petrophysical summaries for Sepat-X well.

Sand Unit	Φ (%)		Sw		Shc	
	Manual	IP	Manual	IP	Manual	IP
D35	20.2	23.0	0.290	0.276	0.710	0.724
D55	18.0	17.6	0.329	0.324	0.671	0.676
D60	21.8	23.8	0.384	0.648	0.616	0.648
E06	19.1	21.0	0.438	0.602	0.562	0.602
E07	19.1	24.0	0.640	0.697	0.360	0.303
E08	12.1	21.0	1.54	1.09	-	-
E09	12.1	12.5	1.26	1.22	-	-

Table 5: Petrophysical summaries for Sepat-XST1 well.

Sand Unit	Φ (%)		Sw		Shc	
	Manual	IP	Manual	IP	Manual	IP
D35	22.0	30.0	0.249	0.183	0.751	0.817
D55	20.0	28.0	0.500	0.357	0.500	0.643
D60	16.0	24.0	0.342	0.228	0.658	0.772
E06 .1	32.0	30.0	0.140	0.149	0.860	0.851
E07	22.0	24.0	0.352	0.323	0.648	0.677
E08	12.0	14.0	1.18	1.010	-	-

From the table above, it can be concluded that the results from both methods are almost similar and are in support of the logs and contacts presented.

CHAPTER 5

5. Conclusions

In recent decades, the use of logging to determine the fluid type in the reservoir has become an essential and a must do for every exploration or production project to minimize the risk of losing money in unproductive reservoirs. Thus this project is done to show how logging is used to show between the hydrocarbon and non-hydrocarbon fluid by using the two wells as an example.

The results from the studies of Sepat-X has average porosity ranges from 13% to 24% and water saturations in the hydrocarbon zones ranges from 28% until 70%. The author had also observed signs of hydrocarbon with gas signs can be clearly seen in the upper sand units until unit D60 at depth 1490 mTVDSS (gas oil contact, GOC). Starting from unit D60 until E07, a lot of oil signs can be seen from the Neutron-Density reactions as shown in the logs. The small parting of the two curves accompanied with high resistivity is suggesting the presence of oil. Water shows was also detected at depth 1660 mTVDSS (water oil contact, WOC) in the E08 sand. The contacts are also proved with results from the pressure plot (Figure 29) and the fluid type (Table 2) was also determined using the same method. Thus it can be concluded that this well is hydrocarbon bearing containing gas and also oil with relatively good porosity.

While the results for Sepat-XST1, the average porosity ranges from 14% until 30% and water saturations in the hydrocarbon zones ranges from 15% until 36%. The author had also observed gas in the upper sands until unit D60 and the GOC was determined to be at 1495 mTVDSS. Oil were observed from unit E06.1 until unit E07 and the WOC is at 1560 mTVDSS (as in Figure 30). The contacts was supported by the result from the fluid typing (Table 3) that shows gas had stop right before unit D60 which contains oil until unit E07 and water gradient was observed in unit E08. Sepat-XST1 was also determined to be hydrocarbon bearing with oil and gas and good porosity in the reservoir.

APPENDIX 1

Date Activity	W1 05/08/2010	W2	W3	W4	W5 01/09/2010	W6	W7 17/09/2010	W8	W9	W10	W11	W12 20/10/2010	W13 – W16	W117
Submitting topic														
Submitting Preliminary report														
Literature Review														
Submitting Progress report														
Data Gathering														
Seminar (optional)														
Submitting Interim report														
Oral presentation													FINAL EXAM	

APPENDIX 2

Formation Evaluation

1. Supporting Logs for Sepat-X

Figure 15: Supporting log for D55 Sands

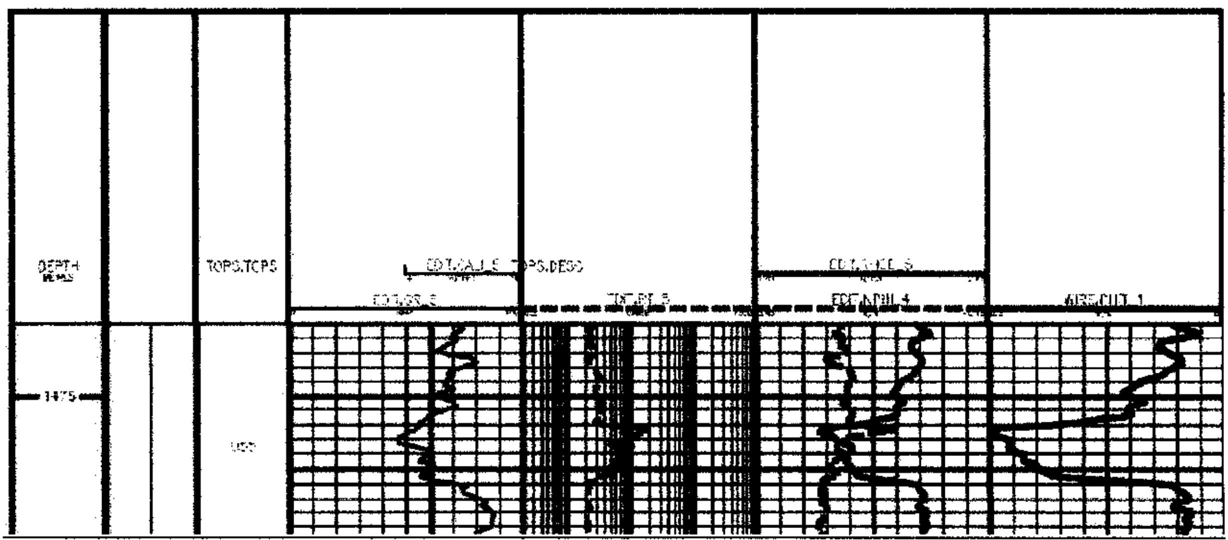


Figure 16: Supporting log for D60 Sands

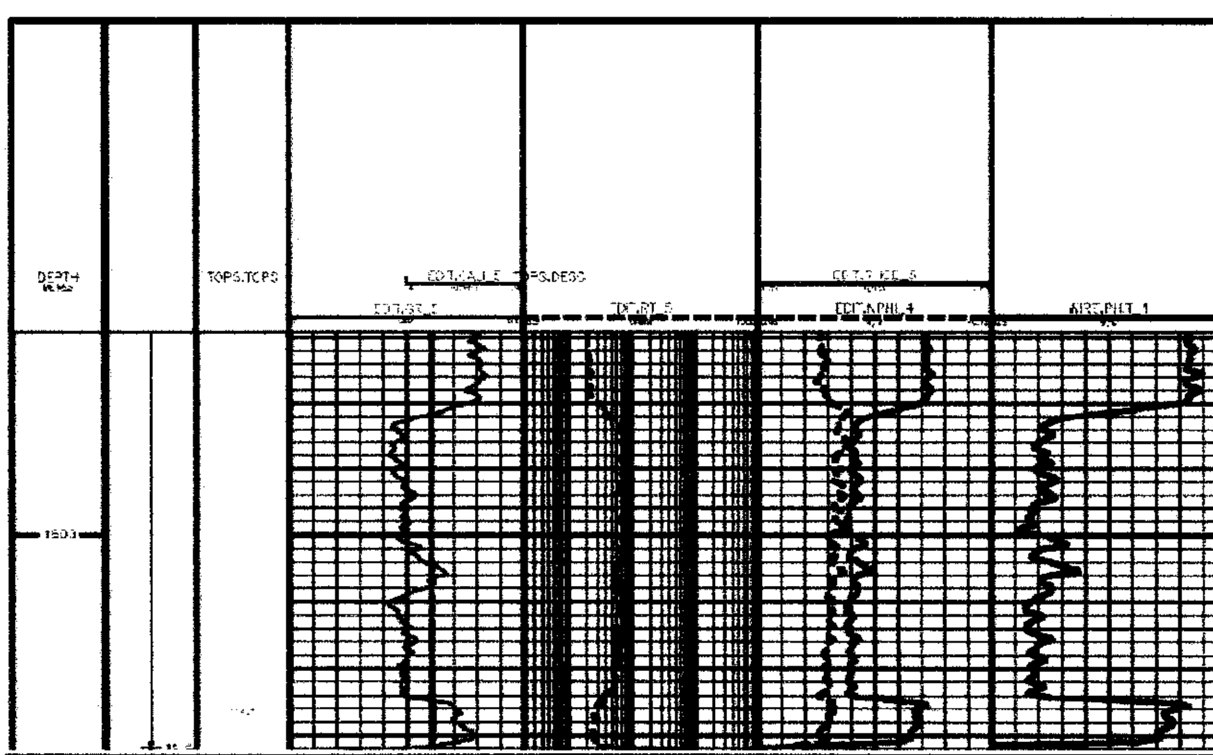


Figure 17: Supporting log for E06 Sands

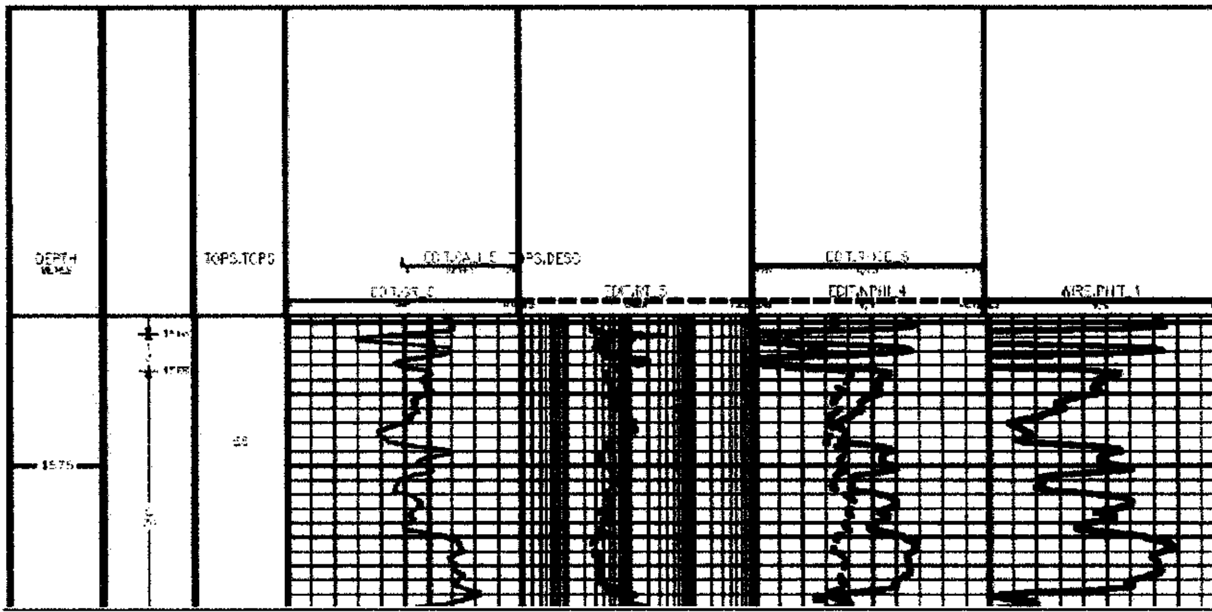
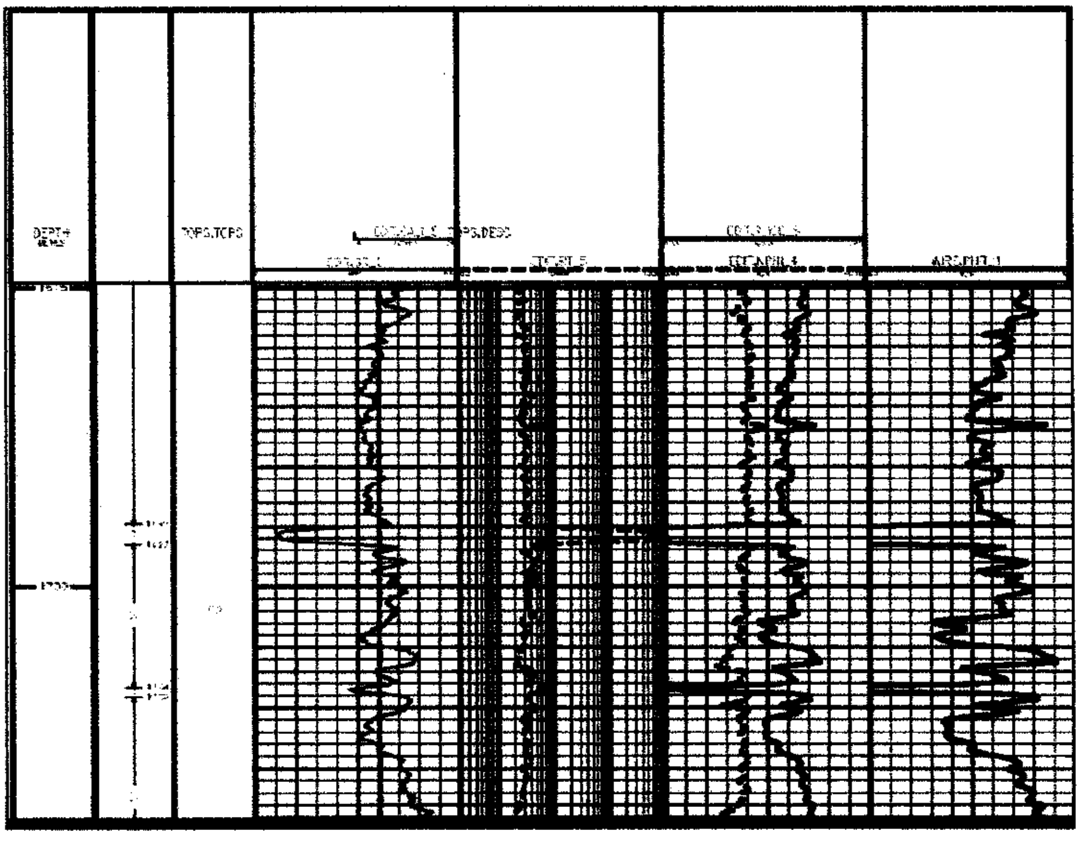


Figure 18: Supporting log for E07 Sands

Figure 19: Supporting log for E08 Sands

Figure 20: Supporting log for E09 Sands



2. Supporting Logs for Sepat-XST1

Figure 21: Supporting log for D35 Sands

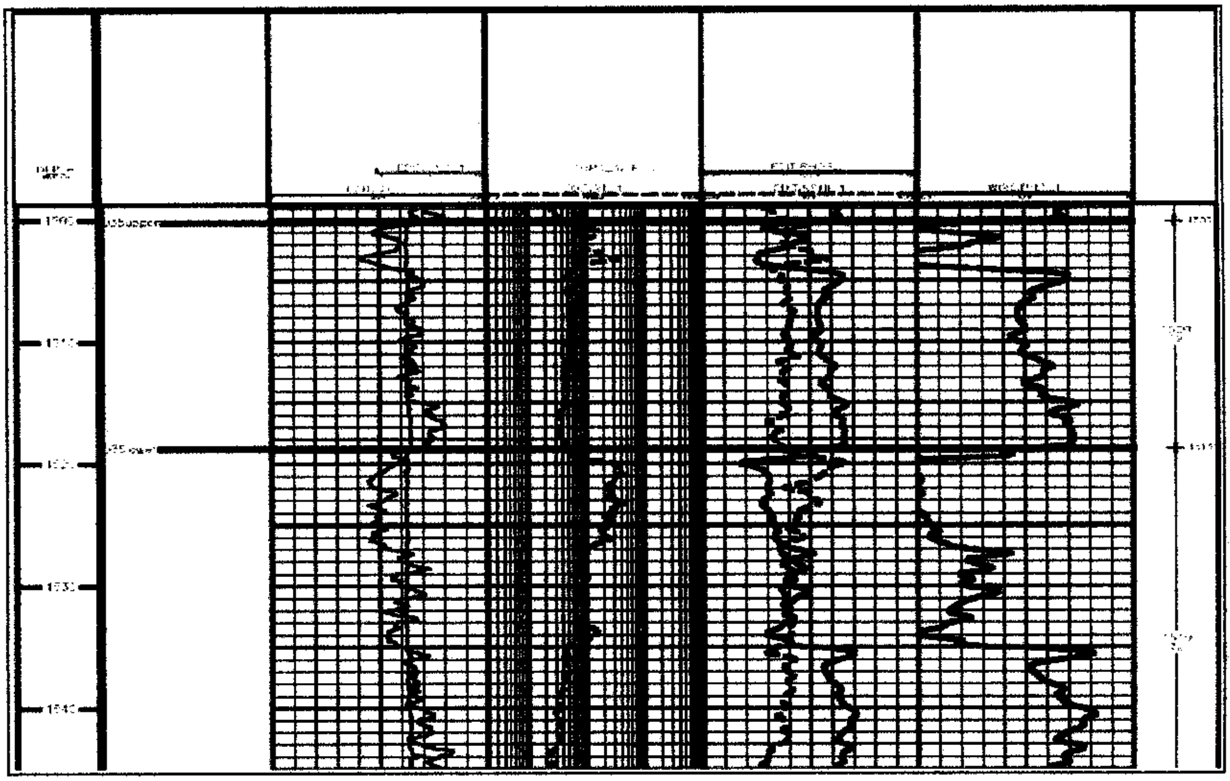


Figure 22: Supporting log for D55 Sands

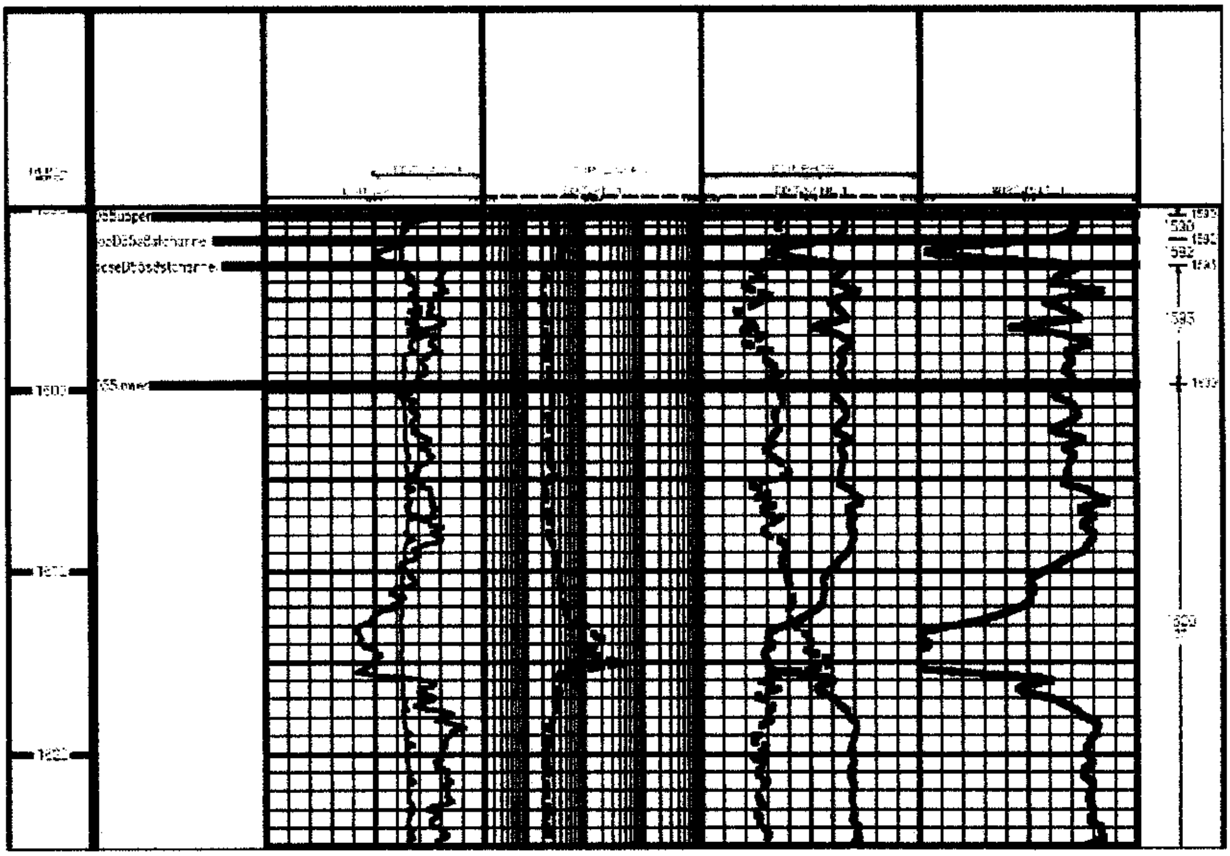


Figure 23: Supporting log for D60 Sands

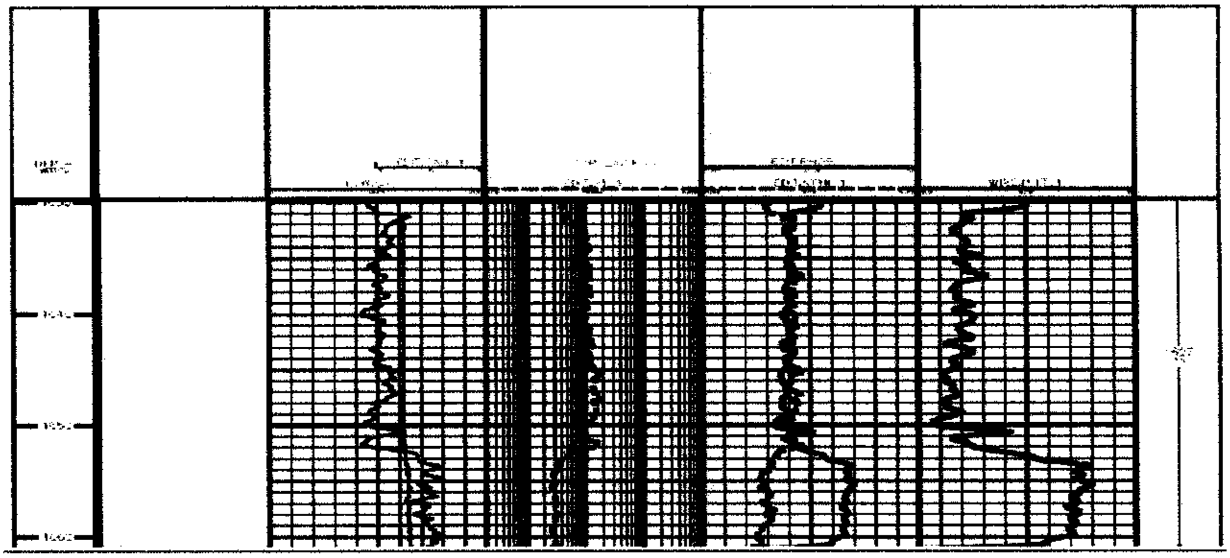


Figure 24: Supporting log for E06.1 Sands

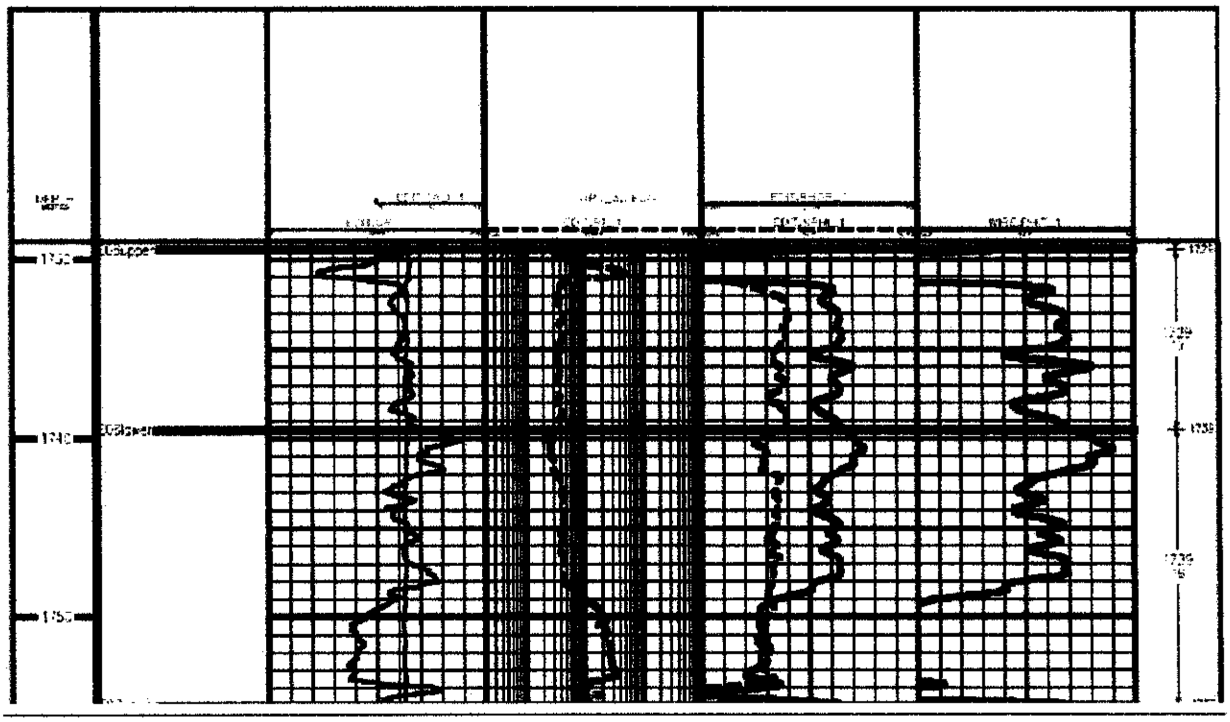


Figure 25: Supporting log for E07 Sands

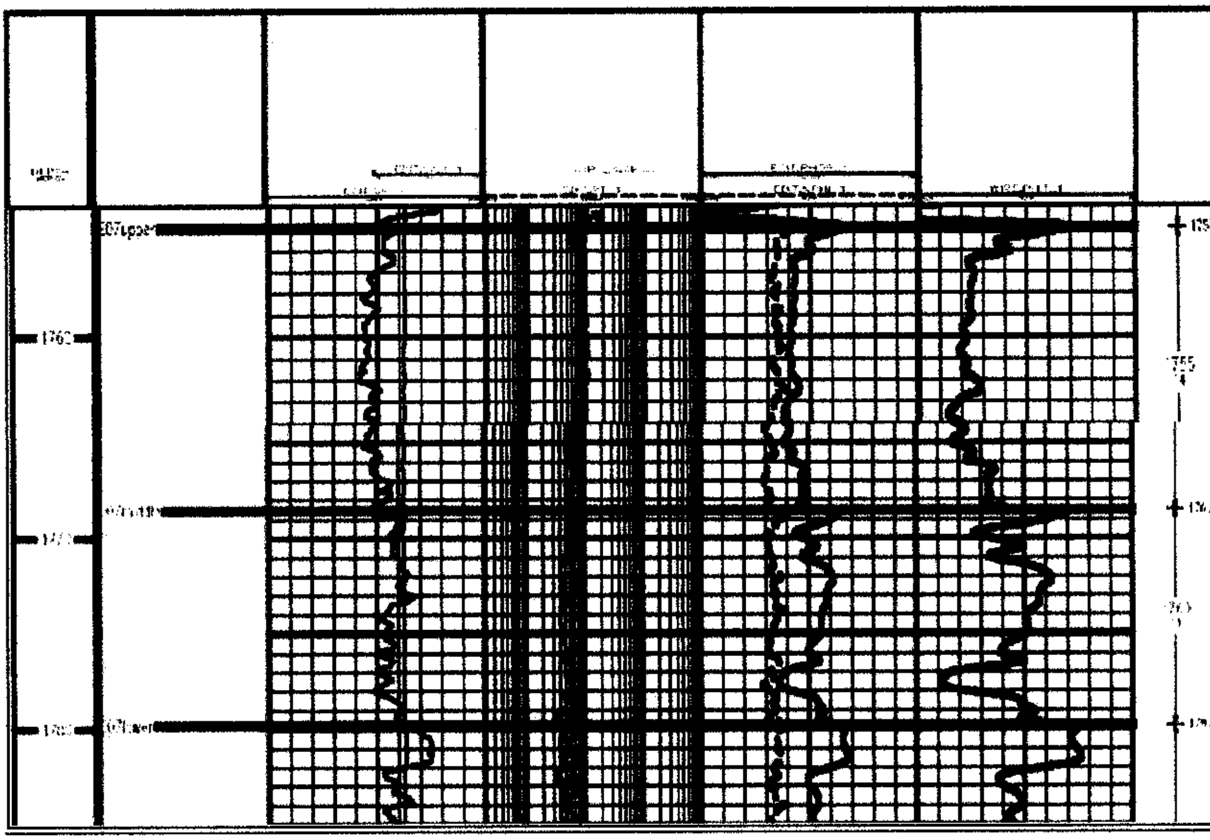
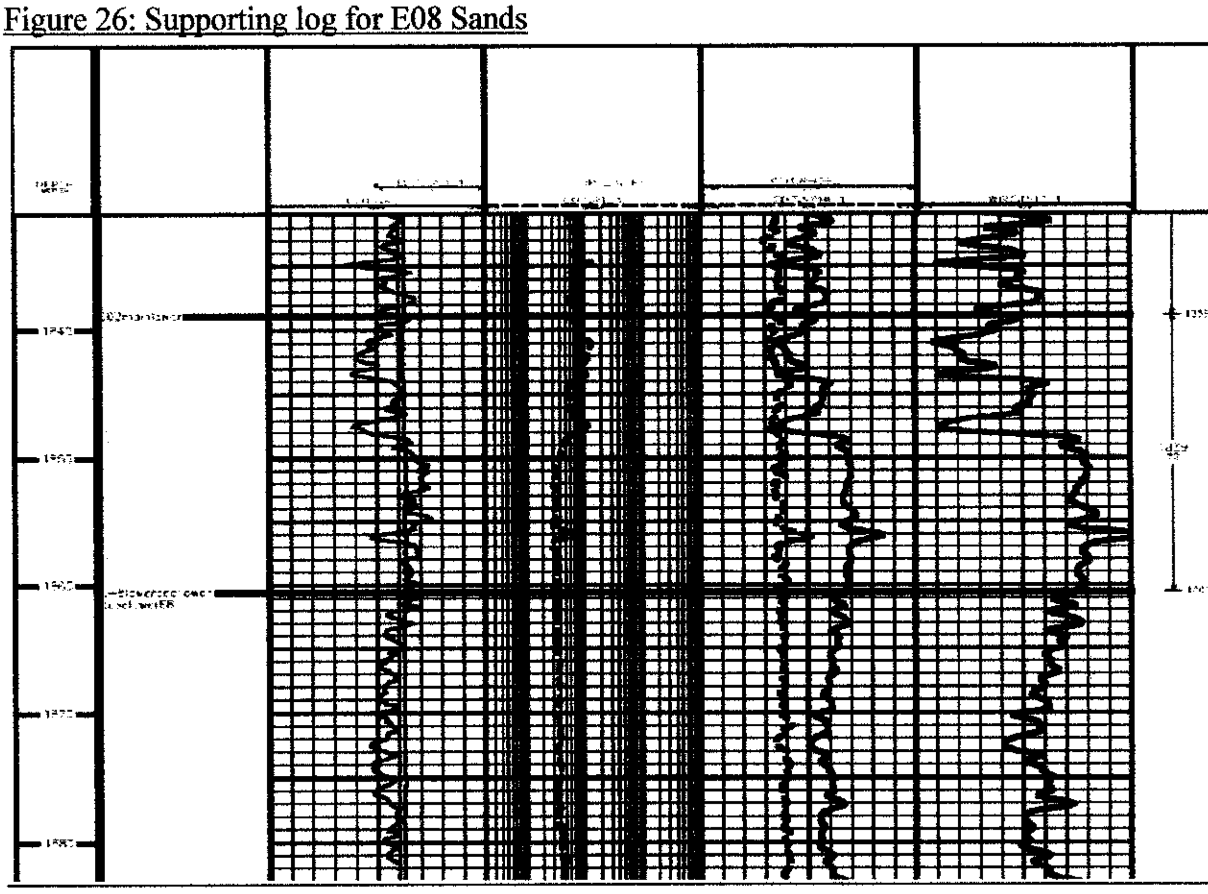


Figure 26: Supporting log for E08 Sands



REFERENCES

1. R. E. Fearon and E. S. Mardock, 2004, *The Quantitative Interpretation of Radioactivity Logs*, SPE Journals 03v02p0418.
2. Gharib Hamada and Musaed Al-Awad, 2007, *Petrophysical Evaluation of Low Resistivity Sandstone Reservoirs*, Journal of Canadian Petroleum Technology.
3. The Yat Hong, 2008, *Preparing a Gas Field Development Plan – Tangga Barat Cluster Gas Project*, International Petroleum Technology Conference, IPTC 124888.
4. *Crains' Petrophysical Handbook* - http://www.spec2000.net/
5. http://en.wikipedia.org/wiki/Formation_evaluation
6. Dr Paul Glover, *Radioactivity Logging*, Petrophysics MSc Course Notes.
7. Thomas W. Engler, *Density Logs*, PET 370.
8. Baker Hughes, *Baker Atlas Introduction to Wireline Log Analysis*, CD# 050616_0936.
9. Baker Hughes, *Baker Atlas Interpretation Charts*, CD#05907812_0832
10. Wenzheng Yue, Tshinhua University, 2004, *Identifying Reservoir Fluids by Wavelet Transforms of Well Logs*, SPE Journals 88559-MS.
11. Cheng Bing Lie, Schlumberger Sugar Land Product Center, 2002, *New Method of Identifying Fluid Type of Reservoirs in Tough Conditions*, OTC 14078-MS.
12. Charles Collins, Shell Exploration and Production West, 2007, *An Integrated Approach to Reservoir Connectivity and Fluid Contact Estimates by Applying Statistical Analysis Methods to Pressure Gradients,* SPWLA 2007_HH.
13. Patrick M. Lasswell, OMNI Laboratories, Inc, 2006, *Core Analysis for Electrical Properties*, SPWLA 2006-v4n3a1.
14. Andre Poupon, Schlumberger Technical Services, 1971, Evaluation *of Water Saturation In Shaly Formations*, SPWLA 1971-vXn6a1.
15. C. R. Porter, Phillips Petroleum Company, 1963, *A Statistical Method for Determination of Water Saturation from Logs*, SPWLA 1969-vXIIn4a1.
16. Dr. Roberto Aguilera, 2000, *The Use of Pickett Plots for Reservoir Enhancement Characterization*, WPC 30160.

GLOSSARY

V Voltage

I Current

r Resistance

Rw Resistivity at the water zone

Vsh Volume of shale calculated using gamma ray log

GRlog Gamma ray reading at depth

GRmax Average gamma ray reading of shale in the formation

GRmin Average gamma ray reading of sand in the formation

ØT Total porosity calculated from density log

ρma Density of matrix

ρSS = 2.65

ρLS = 2.71

ρDL = 2.80

ρb Density at depth

ρf Density of fluid

ρfreshwater = 1

ρsaltwater = 1.1

Shc Hydrocarbon saturation

Sw Water saturation

n Saturation exponent

n = 2

a Turosity constant

a = 1

m Cementation factor

m = 2

IP Interactive Petrophysics

Øcorr Corrected porosity