Oil Water Contact Analysis and Hydrocarbon Saturation Estimation Based on Well Logging Data

Jarot Setyowiyoto [1] and Ariffin Samsuri [2]

[1] *Universitas Gadjah Mada Indonesia,* [2] *Universiti Teknologi Malaysia*
Email: j_setyowiyoto@yahoo.com Phone: +60167 285 312

Abstract

Oil water contact analysis, porosity calculation and hydrocarbon saturation estimation is very important stage in reservoir characterization and hydrocarbon reserve estimation. Well logging data studied comprises of gamma ray log, formation density and compensated neutron logs, electric logs i.e. spontaneous potential log, micro spherical focused log, laterolog deep and laterolog shallow,. The research has been done by qualitative and quantitative analysis. Qualitative analysis includes determination of porous zone, sand and shale base line, water bearing formation and hydrocarbon depletion zone. Quantitative analysis includes calculation of formation temperature, mud filtrate resistivity, shale volume, porosity, and water and hydrocarbon saturation. Porosity value is obtained from density log and than corrected by shale volume and hydrocarbon fluid contain. Hydrocarbon saturation is estimated from water saturations which are calculated from true resistivity (Rt), shale volume (Vsh) and corrected porosity (ϕ_c) parameters.

As a result, the lithology of the well # JS-35 is interbedded between sandstone and claystone. The hydrocarbon is trapped in ten porous zones that have the reservoir thick vary between 11- 90 feet. Oil water contact occurred in the 2229 feet depth characterized by the rapid change of resistivity, and underneath became oil depletion zone. The highest hydrocarbon saturation encountered in the zone no.1 that is 85,7% with 19 feet thick and formation temperature is 157.4 °F. In the zone have 31.7% porosity, 3% shale volume and 14.3% water saturation. Porosity is affected by clay volume and their density, whereas the hydrocarbon saturation is strongly influenced by porosity and their value of resistivity log.

Key words: oil water contact, porosity, hydrocarbon saturation.

Introduction

Physical properties of rock such as porosity, permeability and saturation are very important in the interpretation of geophysical data especially in an exploration geophysics, well logging, petroleum engineering, and sub surface petroleum geology. Exploration and development an oil field are always aim to finding new hydrocarbon reserve. Oil production from a well is also affected by several factors include hydrocarbon potential and petrophysic properties such as porosity and permeability. This study emphasized only on porosity and hydrocarbon saturation calculation which are estimated from well logging data.

Porosity is define as the ratio of the volume of void or pore space (Vp) to the total of bulk volume (V) of the rock. There are three log-derived porosity measuring tools in common use that are density, neutron and sonic log. Sonic log was less sensitive to borehole and mud cake variations than density and neutron log. So that the density, neutron or density-neutron combination has become the primary source of porosity calculation, displacing the Sonic (Dewan, 1983). Water saturation (Sw) is the important parameter for hydrocarbon saturation (Sh) calculation, Sh=1-Sw. Fluid content of a rock formation include water, gas or oil can be predicted by integrated log, especially resistivity log. When hydrocarbon are present in the rock formation, the mud filtrate will replace the oil and gas immediately around the bore hole. The resistivity profile will show a flush zone with a low to moderate resistivity since filled with mud filtrate, and in the virgin formation with an extremely high resistivity because of the high saturation in hydrocarbon.

Oil water contact analysis is needed for net pay estimation and boundary delineation between water and oil zone. It can be determined from the resistivity profile. The resistivity in the water zone will lower than in the oil zone.

Data and Method

Logging data drom well JS # 35 used in this study comprises of Spotaneous Potential Log (SP), Micro Spherical Focused Log (MSFL), Laterolog Shallow (LLS), Laterolog Deep (LLD), Gamma Ray Log (GR) and Formation Density Log (FDL). The study has been done by qualitative and quantitative analysis. Qualitative analysis includes determination of porous zone, sand and shale base line, water bearing formation, hydrocarbon depletion zone and oil water contact (OWC). Quantitative analysis includes calculation of formation temperature, mud filtrate resistivity, shale volume, porosity, and water and hydrocarbon saturation. Porosity value is obtained from density log and than corrected by shale volume and hydrocarbon fluid contain. Hydrocarbon saturation is estimated from water saturations which are calculated from true resistivity (Rt), shale volume (Vsh) and corrected porosity (ϕ_c) parameters. Quantitative analysis is principally based on shally sand interpretation by Darcy and Schlumberger method, include:

1. Determination of formation temperature (T_2):

$$T_2 = \frac{D(BHT \quad T_2)}{TD} + T_1$$

...........(1)

Where:
T2 = Formation temperature (°F)
D = Log depth (feet)
BHT = Borehole temperature (°F)
TD = Total depth (feet)
T1 = Surface temperature (°F)

2. Determination of resistivity of mud filtrate (Rmf):

$$Rmf_2 = Rmf_1 \frac{(T_1 + 6.77)}{(T_2 + 6.77)}$$

.... (2)

Where:
Rmf2 = Resisitivity of mud filtrate at formation (ohm-m)
Rmf1 = Resistivity of mud filtrate at surface (ohm-m)
T1 = Surface temperature (°F)
T2 = Formation temperature (°F)

3. Determination of shale volume (Vsh):

$$Vsh = \frac{GR\log\text{-}\ GR\min}{GR\max\text{-}\ GR\min}$$

.... (3)

Where:
Vsh = Shale volume (%)
GRlog = Gamma Ray Log (API Unit)
GRmax = Gamma Ray maximum (API Unit)
GRmin = Gamma Ray minimum (API Unit)

4. Determination of Porosity:

$$\Phi D = \frac{\rho ma \quad \rho b}{\rho ma \quad \rho f}$$

.... (4)

Where:
ΦD = Porosity from density log (%)
ρma = matrix density
ρb = bulk density
ρf = fluid density

5. Determination of porosity corrected by Vsh content:

$$\Phi Dc1 = \Phi - (Vsh \times \Phi Dsh)$$

.... (5)

Where:
ΦDc1 = Corrected porosity by Vsh (%)
Φ = Porosity (%)
Vsh = Shale volume (%)
ΦDsh = Log density-derived porosity in shale zone (%)

6. Determination of porosity corrected by hydrocarbon fluid content

$$\Phi Dc2 = \Phi Dc1\ (1 - 0.1\ Shr)$$
$$Shr = 1 - Sxo$$

$$Sxo = \frac{1}{Rxo\sqrt{\frac{Vsh^{(1\ Vsh/2)}}{Rsh} + \frac{\varphi Dc1}{axRmf}}}$$

.... (6)

Where:
ΦDc2 = Hydrocarbon fluid corrected porosity (%)
ΦDc1 = Vsh corrected porosity (%)
Shr = Residual hydrocarbon saturation
Sxo = Water saturation in flush zone
Rxo = Water resistivity in flush zone
Vsh = Shale volume
Rsh = Resistivity in shale zone
a = Cementation constant
Rmf = Resistivity of mud filtrate

7. Determination of water resistivity (Rw)

Water resistivity can be obtained from water bearing formation.

$$Rw = \frac{RmfxRt}{Rxo} \text{ ohm-m}$$

.... (7)

Where:
Rw = Water resistivity in uninvaded zone
Rmf = Resistivity of mud filtrate
Rt = True resistivity
Rxo = Water resistivity in flush zone

8. Determination of Water saturation (Sw)

$$Sw = \frac{1}{Rt\sqrt{\frac{Vsh^{(1\ Vsh/2)}}{Rsh} + \frac{\varphi Dc2}{axRw}}} \quad . (8)$$

Where:
Sw = Water saturation
Rt = True resistivity
Vsh = Shale volume
Rsh = Resistivity in shale zone
ΦDc2 = Porosity (%), hydrocarbon fluid correction.
a = Cementation constant
Rw = Water resistivity

9. Determination of hydrocarbon saturation (Sh)

$$Sh = 1 - Sw$$

.... (9)

Where:
Sh = Hydrocarbon saturation (%)
Sw = Water saturation (%)

Result and Discussion

As a result, the lithology of well # JS-35 is interbedded between sandstone and claystone. The hydrocarbon is trapped in ten porous zones that have the reservoir thick vary between 11-90 feet. Oil water contact occurred in the 2229 feet depth characterized by the rapid change in resistivity, and underneath became oil depletion zone. Qualitative analysis of the logs result some data base for the next qualitative analysis, that are:

GRmin = 50 API
GRmax = 175 API
Rsh = 4 ohm-m
ΦDsh = 0.194
ρf = 1.1
ρma = 2.65
BHT = 172 oF
Rmf = 0.322 @ 80 oF
T1 = 80 oF
TD = 2608 feet
a = 0.81

Hydrocarbon saturation and corrected porosity has been calculated in the tenth zone of sandstone reservoirs (Table1 and Table 2.)

Table 1- Formation evaluation result, log-derived porosity calculation corrected by Vsh.

No.	Depth (feet)	GR Log (API)	T2 (oF)	Rmf (ohm-m)	Vsh (%)	ρB (gram/cc)	ΦD (%)	ΦDc (Vsh) (%)
1	2194	55	157.4	0.17	3	2.13	33.5	32.9
2	2294	62	160.9	0.167	7	2.1	33.5	34.1
3	2320	75	161.8	0.166	15	2.15	32.3	29.4
4	2347	90	162.8	0.165	26	2.18	30.3	25.3
5	2374	80	163.7	0.164	18	2.18	33.5	30
6	2424	90	165.5	0.162	26	2.2	29	24
7	2442	85	166.1	0.162	23	2.29	29	24.5
8	2467	65	167	0.161	11	2.25	25.8	23.7
9	2515	75	168.7	0.159	18	2.25	25.8	22.3
10	2560	55	170.3	0.158	3	2.2	29	28.4

The highest hydrocarbon saturation of 85,7% encountered in the zone no.1 with 19 feet thick and formation temperature is 157.4 °F. In this zone have 31.7% porosity, 3% shale volume and 14.3% water saturation.

Tabel 2 - Formation evaluation result, hydrocarbon saturation and porosity calculation corrected by hydrocarbon fluid content

No.	Depth (feet)	ΦDc1 (%)	Rxo (ohm-m)	Rt (ohm-m)	Sxo	Shr	ΦDc2 (%)	Sw (%)	Sh (%)
1	2194	32.9	3	10	0.64	0.36	31.7	14.3	85.7
2	2294	34.1	4	9	0.518	0.482	32.5	25.1	74.9
3	2320	29.4	5	30	0.503	0.497	27.9	15.3	84.7
4	2347	25.3	4	10	0.59	0.41	24.3	28.1	71.9
5	2374	30	6	15	0.44	0.56	28.3	20.9	79.1
6	2424	24	4	10	0.611	0.389	23.1	29.4	70.6
7	2442	24.5	4	9	0.616	0.384	23.6	31	69
8	2467	23.7	5	15	0.407	0.593	22.3	27.2	72.8
9	2515	22.3	2.5	10	0.436	0.564	21	33.6	66.4
10	2560	28.4	2	15	0.873	0.127	28	22.8	77.2

The porosity values of the tenth porous zone of sandstone are vary, range 21-32.5%, it is affected by density and clay volume. The porosity generally decreases with increasing in clay volume (Fig.1). Hydrocarbon saturation of the tenth sandstone porous zone are also vary, range 66.4 – 86.7%, influenced by porosity and the value of resistivity. The hydrocarbon saturation increases with increasing in porosity (Fig.2). The resistivity of the hydrocarbon zones are vary, range 9-15 ohm-m

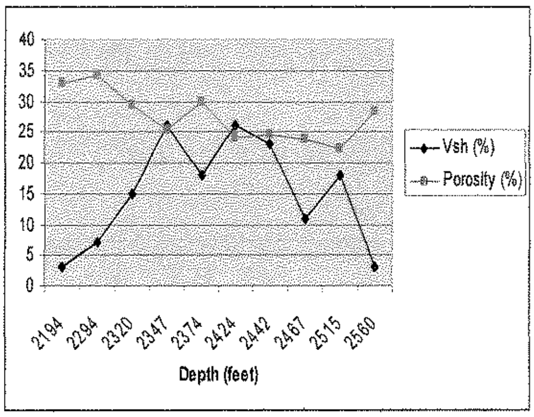

Figure 1- Cross plot of depth vs. porosity and clay content (Vsh).

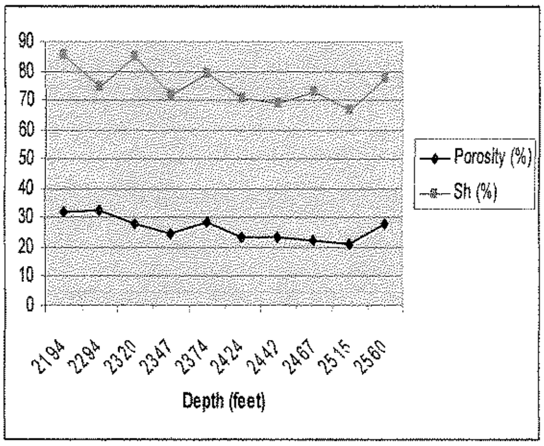

Figure 2- Cross plot of depth vs. porosity and hydrocarbon saturation.

Conclusion

Determination of oil water contact is very important, encountered in the 2229 feet depth and characterized by the rapid change in resistivity value. The porosity values of sandstone porous zone are vary, range 21-32.5%. The porosity generally decreases with increasing clay volume. Hydrocarbon saturation of porous zones are also vary, range 66.4 – 86.7%, primarily affected by their porosities.

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