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Low Resistivity Reservoir in Talang Akar Formation : Reservoir Characterization and Production Enhancement

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Abstract

The reservoir with low resistivity value was initially considered unattractive because of high Sw value, but eventually provided satisfying production. This paper will present the reservoir characterization of low resistivity reservoir and the success of the oil and gas production enhancement in Talang Akar Formation, especially in TLJB Field in South Sumatera.
The typical oil resistivity from the Talang Akar Formation in South Sumatera is mostlikely >10 ohm.m. But, in TLJB Field, lately known that the typical resistivity cut-off for oil is only >3 ohm.m and gas is only >7 ohm.m. Mudlog with gas chrome up to C5 and trace oil shows do not always indicate oil reservoir, in fact, most of them indicate gas condensate reservoir. Reservoir characteristics was evaluated by combining cutting data, mudlog, core analysis, open hole logging, wireline formation testing and well testing. The most reliable data in determining reservoir fluid is wireline formation tester, by evaluating gradient of reservoir pressure and fluid scanning. Cutting and core analysis was carried out to find out clay mineralogy, type of sedimentology, and value of Swc. Re-evaluation of petrophysics was performed, because of standard petrophysical analysis gives over-estimated Sw, eventhough the water cut is very low when produced. Pressure transient analysis identify that most of the reservoir have a high skin value, then stimulation is needed. Solubility test of cutting indicate that HCl-HF is the most appropriate type of acid. For gas reservoirs, acidizing with HCl-HF gives very satisfying results. However, for oil reservoirs, acidizing does not have a significant effect, then fracturing is a suitable method for oil reservoirs.
By understanding the characteristics of the low resistivity reservoir and the proper stimulation method, it is expected to unlock the opportunities for discovering the hydrocarbon potential and increase the production.

Keywords : low resistivity, stimulation, reservoir characterization, production enhancement

Introduction

Low resistivity pay has been a long standing problem in hydrocarbon identification. The reservoir with low resistivity value was initially considered unattractive because of high Sw value, but eventually provided satisfying production.

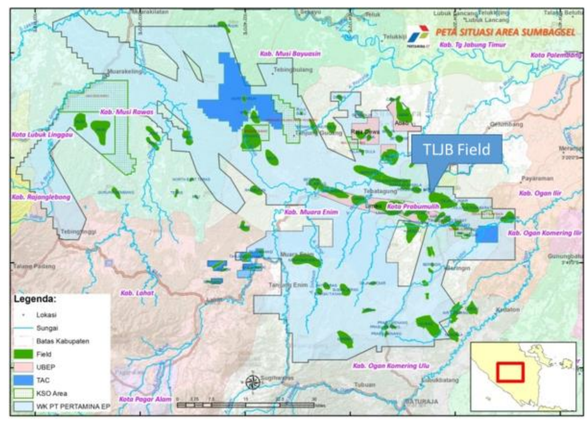

Figure 1. TLJB Field Location

TLJB Field is located in Prabumulih area, South Sumatera Basin. The first drilling was carried out in 1951. The main prospect of the field is Talang Akar Transition Member (TAF-TRM) sandstone reservoir. The reservoir primarily deposited at shallow marine. This field was initially considered as a part of the flank of the large TLJ field area which TLJ Field is a waterflood area.
In 2016, T-244 well drilling was conducted with an initial completion target of layer A. The Rule of thumb cut-off resistivity in the TLJ area was 10 ohms.m for oil. The resistivity value in this well is only 7-20 ohms.m with the Sw value reaching 68%. However, the results of well production tests produce 2 mmscfd of gas with 50 bopd oil and only 17% water cut. Due to the unavailability of gas facilities and other layers not showing interesting oil indications,

this well was temporarily suspended. Then it was concluded that the TLJ and TLJB fields are separate reservoirs. Hence, the TLJB field development plan is proposed.
A year later, while waiting for the gas production facility which is estimated to be only onstream in 2022, to get production for this new well drilling, workover for T-244 had to be done. There is no other choice, in early 2017 a trial of perforation in layer E that was estimated as an oil reservoir with a 6 ohm.m resisitivity which gave Sw value of 67-80% was conducted. However, the production test was very surprising. It obtained 130 bopd oil with only 9% water cut.
At the end of 2017 workover was carried out to the H layer which has a resistivity value of 7-9 ohms and a Sw value of 58-75%. The test results are 2 mmscfd gas, 12 bcpd condensate and only trace water. In addition, the results of the pressure transient test indicated the value of skin 32 with delta P skin reaching 942 psi.

Data and Method

For detailed evaluations related to the potential for low resistivity and to reduce uncertainty of hydrocarbon types, a more comprehensive data collection was carried out on the next well drilling. Initially, reservoir characteristics were evaluated conventionally, by combining cutting data, mudlog data, and open hole logging. From gamma ray data, it shows that the reservoir is a laminated sand-shale. From the open hole log data, indications of hydrocarbons have been seen, but always produce high Sw values even though shally-sand models have been used. In addition, it is still quite difficult to distinguish between gas and oil hydrocarbons as well as the difference between oil and water.
At the time of drilling the T-244 well, wireline formation tester (WFT) data was carried out. However, it was only pressure test data collected. Fluid type estimation has been evaluated by drawing a gradient from the pressure at each point on every reservoir. The WFT results cannot provide representative results because the reservoir is thin layer and the type of the reservoir is a laminated sand-shale, so an exact position is needed in order to obtain representative pressure gradient data. To reduce the uncertainty of estimated water, oil, and gas fluids that have low contrast, the next drilling well was conducted advanced WFT using downhole fluid analysis (DFA) and fluid sampling. This method was very powerful method in determining the type of fluid in a reservoir in TLJB Field. However, not all hydrocarbon evaluations can be done with this method. Only data points that have good mobility can provide representative fluid results. For data points with low mobility, data collection tends to require a long time in order to obtain conclusive results. Data retrieval operationally limited by duration because the tool can be stuck if the tool takes too long station at one point. For reservoirs which no representative DFA data is obtained, well to well correlation and log type analogy was conducted to estimate reservoir fluid type.
Coring data acquisition and core analysis were also carried out from the main reservoir A and B layer in well T-246. The core analysis shows that causes of low resistivity were evaluated as sand-shale lamination, the presence of metallic minerals, the effects of fine grains, and microporosity.
Well T-246 depth core interval 1387.00-1405.30 m by core description can be subdivided into three genetic units delineated by Glossifungites surfaces at 1404.3 m, 1399.05 m and 1391.14 m.

Figure 2. Core Photograph

The lower unit consists essentially of bioturbated shaly sandstone which is underlain and overlain by shale. The shaly sandstone is interpreted to have been deposited in a lower shoreface environment at about storm wave base and was not usually prone to winnowing by waves or currents. The shales were deposited in a deeper offshore situation. The middle unit is composed of interbedded shaly sandstone and shale and, like the underlying section, is interpreted to have been deposited in transitional lower shoreface to offshore environments. The upper unit consists of sandstone which is bioturbated but contains possible traces of hummocky or swaley cross lamination. The depositional environment is interpreted to be middle to upper shoreface, above storm wave base and within the realm of winnowing by waves and currents. Visible porosity petrographic observations are measured 4.0%-16.0%. Overalls the reduce porosity due to the high carbonate cementation. Dominant of porosity systems has resulting from dissolution of unstable grain, cements and matrix. Minor primary intergranular and intraparticle pore types also occur.

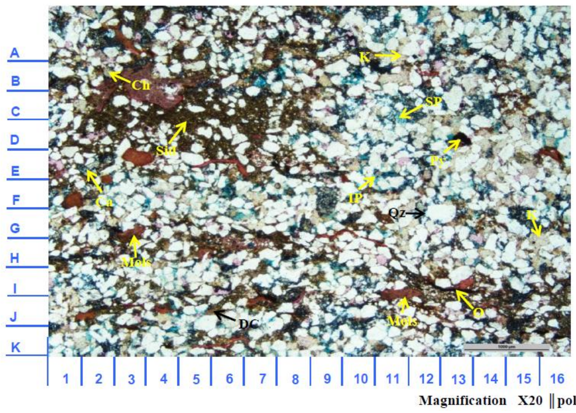

Figure 3. Petrography Photomicrographs of Conventional Core (Example Depth 1387.30 m)

Secondary minerals are occurred in primary intergranular pores and as unstable grain, rock fragments. Secondary minerals are consisting of calcite, dolomite, siderite, kaolinite, illite, and pyrite. Locally kaolinite, siderite and pyrite attached on grain surfaces. SEM image also recognized some intergranular pore also filled by detrital clay matrix and quartz overgrowths; Clays coating grain also recorded in some SEM images. General porosity in SEM image is poor to moderate, and locally good. Most of pore types are secondary pore, even though primary intergranular pore also recorded but minor. Microporosity can identify in higher magnification, and it can be enhanced porosity value.

XRD results are controlled by quartz, 60%-72% followed with carbonate, 13%-35% and 3%-20% clays. XRD analysis shows that there are significant metallic minerals. The main metallic mineral that present in the rocks is siderite. In addition there are also a small portion of pyrite and hematite. This metallic mineral causes the rock to be more conductive, hence the resistivity value is low.

No	Depth meters	Clay Minerals %				Carbonate Minerals %			Other Mineral %								Total %		
		Smectite	Illite	Kaolinite	Chlorite	Calcite	Dolomite	Siderite	Quartz	K-Feldspar	Plagioclase	Pyrite	Hematite	Gypsum	Barite	Halite	Clay	Carbonate	Other
1	1387.10	-	5	2	-	19	7	4	63	-	-	-	-	-	-	-	7	30	63
2	1387.30	-	6	3	-	1	11	10	69	-	-	-	-	-	-	-	9	22	69
3	1388.60	-	3	1	-	6	21	8	61	-	-	-	-	-	-	-	4	35	61
4	1391.50	1	17	2	-	5	-	8	62	4	-	1	-	-	-	-	20	13	67
5	1394.80	-	3	-	-	3	15	9	68	2	-	tr	-	-	-	-	3	27	70
6	1395.50	-	2	1	-	-	27	2	68	-	-	-	-	-	-	-	3	29	68
7	1396.20	-	4	1	-	2	13	10	67	2	1	-	-	-	-	-	5	25	70
8	1398.30	-	5	1	-	2	10	20	60	1	-	tr	1	-	tr	-	6	32	62
9	1401.80	-	5	2	2	1	14	5	67	4	-	tr	-	-	-	-	9	20	71
10	1404.00	-	6	2	-	4	9	3	72	3	1	tr	-	-	-	-	8	16	76

Table 1. XRD Analysis from Conventional Core Layer A and B

In addition to metallic minerals, the rocks also contain reactive clay and microporosity in the form of illite and kaolinite with several smectites and chlorites. The existence of illite which has a high cation exchange capacity (CEC) causes high capillary pressure so that the Sw value becomes higher.

For the other layers that do not have core data, an XRD analysis of the cutting data is performed. From this analysis it is also known that there are some reactive clay in the form of smectite and illite. There are also trace metallic minerals in the form of pyrite and hematite.

No	Depth meter	Clay Minerals %				Carbonate Minerals %			Other Minerals %							Total %		
		Smectite	Illite	Kaolinite	Chlorite	Calcite	Dolomite	Siderite	Quartz	Plagioclase	K-Feldspar	Pyrite	Hematite	Gypsum	Barite	Clay	Carbonate	Other
1	1464-1466	-	6	2	-	4	5	-	75	1	3	1	tr	-	3	8	9	83
2	1466-1468	-	8	2	-	5	2	-	74	1	2	1	3	-	2	10	7	83
3	1488-1490	2	52	8	-	5	-	-	25	-	4	2	1	-	1	62	5	33
4	1492-1494	-	18	3	-	3	23	-	47	-	3	1	tr	-	2	21	26	53
5	1496-1498	1	28	5	-	4	1	-	54	-	3	2	tr	-	2	34	5	61
6	1518-1520	1	30	5	-	5	15	-	39	-	3	1	tr	-	1	36	20	44
7	1520-1522	2	37	6	-	4	2	-	43	-	3	1	tr	-	2	45	6	49
8	1576-1578	1	13	4	-	5	-	-	70	-	3	1	1	-	2	18	5	77
9	1580-1582	2	45	10	-	4	-	-	33	-	3	1	1	-	1	57	4	39

Table 2. XRD Analysis from Cutting Data

During the completion of the well, generally reservoir oil in TLJB Field cannot flow naturally, hence pressure transient analysis (PTA) cannot be carried out. However, retrieval of the reservoir shut-in pressure profile data after the swab job is conducted. From the pressure data, it shows that the influx reservoir tends to be small. In a gas reservoir, which can flow naturally, PTA is carried out and the results identify that most of the reservoir have a high skin value, then stimulation is needed. Solubility test of cutting indicate that HCl-HF is the most appropriate type of acid. For gas reservoirs, acidizing with HCl-HF gives very satisfying results. However, for oil reservoirs, acidizing does not have a significant effect, then fracturing is a suitable method for oil reservoirs.

Result and Discussion

Complete subsurface data acquisition and comprehensive evaluation is absolutely necessary to unlock the potential of low resistivity reservoir. From the evaluation and data collection, determining the type of reservoir fluid is quite difficult if only done by evaluating open hole logging and mudlog data. Downhole fluid analysis is the most powerful method for predicting fluid content in a low resistivity reservoir. Retrieval of data and core analysis needs to be done to determine the cause of low resistivity and rock character. It can be known with more accurately the type of fluid in the TAF-TRM reservoir in TLJB Field so as to minimize the uncertainty of field development activities. The following are the results of the evaluation of the fluid type of each TLJB layer by combining open hole log data, mudlog, well correlation, WFT, DFA, and well test data.

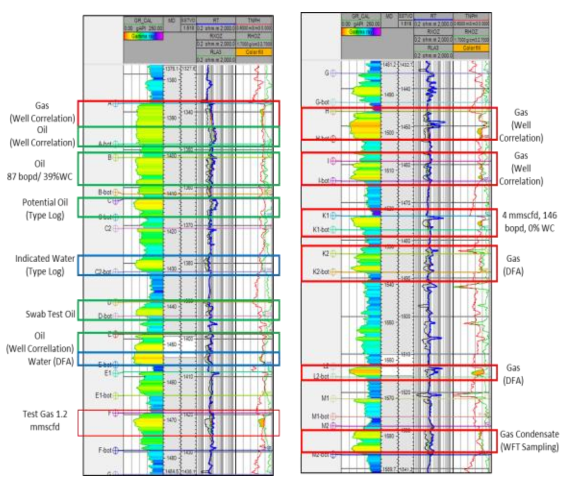

Figure 4. Type Log and Type of Reservoir Fluid

The causes of low resistivity in TAF-TRM sandstone reservoir in TLJB Field are sand-shale lamination, the presence of metallic minerals, the effects of fine grains, and microporosity. Siderite is the dominant metallic mineral that make the rock become more conductive, then pyrite and hematite become the next suspect. Illite and kaolinite with several smectites and chlorites that have a high cation exchange capacity (CEC) causes high capillary pressure so that the Sw value becomes higher.

Petrophysical evaluation is still a homework that needs further evaluation. Shally-sand petrophysical model gives more pessimistic result compared to fractional flow from core and test data.

Well	Layer	Sw Petrophysic	Test Data
T-244	A	40-68%	50 bopd/2.3 mmscfd/17% WC
T-244	B	45-60%	75 bopd/45% WC
T-244	E	67-80%	130 bopd/9% WC
T-244	H	58-75%	2 mmscfd/12 bpcd/WC trace
T-245	A	48-80%	206 bopd/9% WC
T-246	B	75-81%	87 bopd/39% WC
T-246	F	65-80%	1.2 mmscfd
T-246	K1	81-83%	146 bopd/4.3 mmscfd/0% WC

Table 3. Sw Petrophysics vs Test Data

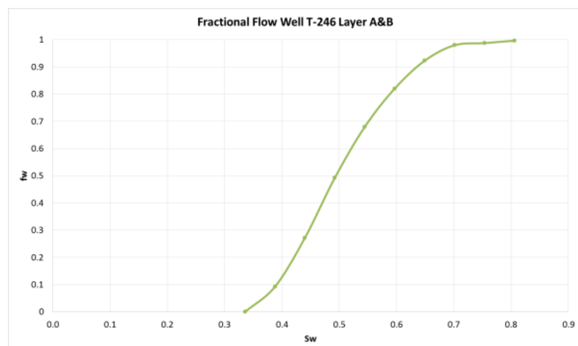

Figure 5. Fractional Flow Generate From Layer A & B Core Data

By understanding the characteristics of the low resistivity reservoir and the proper stimulation method, it is expected to unlock the opportunities for discovering the hydrocarbon potential and increase the production. In TLJB Field, it can increase production from <100 bopd in 2017 to 700 bopd at this time.

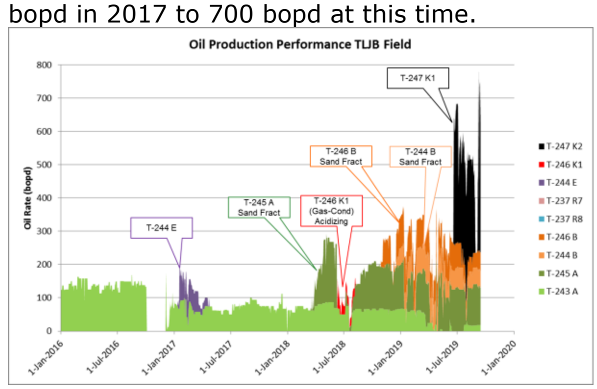

Figure 6. TLJB Field Oil Production Performance

Conclusions

1. Complete subsurface data acquisition and comprehensive evaluation is absolutely necessary to unlock the potential of low resistivity reservoir.
2. The causes of low resistivity in TAF-TRM sandstone reservoir in TLJB Field are sand-shale lamination, the presence of metallic minerals, the effects of fine grains, and microporosity.
3. By understanding the characteristics of the low resistivity reservoir and the proper stimulation method, it is expected to unlock the opportunities for discovering the hydrocarbon potential and increase the production.
4. Shally-sand petrophysical model gives more pessimistic result compared to fractional flow from core and test data. The next phase of the study will focus on re-evaluating petrophysical to get the more accurate Sw value.

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