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Identification and Characterization of Low Resistivity Pay Zone, Case Study "L" Field

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Abstract

In general, sandstone reservoir containing hydrocarbons has high resistivity values based on the response of well log measurement. This is because hydrocarbons are unable or difficult to conduct electric current (resistive). However, in some cases, rocks with low resistivity value have the potential to become hydrocarbon reservoirs.

On the other side, the decrease of production makes the company need new approach to increase oil production. One of the alternative methods is to reevaluate the well log data in suspended well, especially in low resistivity pay zone. Low resistivity pay zone is a unique reservoir that usually identified as water bearing zone, but in fact has hydrocarbon potential. Test production on several wells in L Field shows the presence of hydrocarbon with resistivity value less than 10 ohmm (2 – 5 ohmm). By focusing on the low resistivity pay zone, the company can also reduce the production costs by opening new layers on existing wells instead of drilling new wells.

This paper focuses on identifying the main causes of low resistivity pay zone in L' Field, South Sumatera Basin. By using openhole log, core data, petrography analysis, and cutting data, it can be concluded that the main cause of low resistivity pay zone in this area are the presence of illite & kaolinite as clay minerals, sand shale lamination, silty-fine sand grain size and conductive minerals.

Keywords: *Air Benakat Formation, Low resistivity pay zone, Low resistivity reservoir, Shalysand*

Introduction

The low resistivity reservoir was initially considered unattractive because in general reservoir which contain hydrocarbon would have high resistivity. However, in some cases, rocks with low resistivity have the potential to become hydrocarbon reservoir.

L field is mature oil field operated by Pertamina that located in Prabumulih, South Sumatra Basin with more than 250 wells. The main reservoir target is from Talang Akar and Baturaja formation which deposited in Fluvial Deltaic to Shallow Marine environment. However, decrease in production and the downturn of oil price made the company must find the alternative ways to increase hydrocarbon production, one of the best strategy is to reevaluate well logging data in suspended well especially in low resistivity pay zone which initially considered as water bearing zone.

In 2019, the journey began, it started with collecting & digitizing well log data at the shallow interval because most of the well in L Field only have digital log (las) in main reservoir. After reevaluating the openhole log, core and cutting data, several layers of prospect zone were defined. These layers were tested with various result, some have unsatisfied result but others have promising opportunity.

Data and Method

The integrated analysis of openhole log, core and cutting data were performed in order to have better understanding of low resistivity pay zone. From openhole data, Gamma ray log show sand shale lamination, with resistivity value of oil bearing zone is about 2-2.4 ohmm which shows at well L-82 and L-215. On the other side, the resistivity of Gas bearing zone around 3 – 4.3 ohmm at well L-170 & LC-13.

Core data acquisition and analysis were carried out from Air Benakat Formation in well L-306. The cored interval consists of silty-shale and sandy-shale which can be divided into a lower interval of parallel laminated, sideritic silty shale (interval 666.00-687.10 m), and upper interval of faintly laminated silty and sandy shale (interval 660.00-666.00 m). The depositional environment is interpreted to be low energy, outer shelf to offshore and the upper shale may represent a slightly shallower environment than the lower shale.

Petrography data shows that rocks are containing common silt to sand grains with mean grain sizes are 0.03 to 0.2 mm. Grains are angular to subrounded, locally concentrated and appear as burrow structure and as laminae form. Grains is dominant with Quartz with rock fragment (chert, granitic and volcanic type), K-feldspar, plagioclase, and accessories minerals such as glaucony, muscovite, phosphatic material and chlorite.

Clay matrix is locally disrupted with bioturbation, and partially also replaced by microcrystalline siderite. But at several intervals, has strongly been replaced by microcrystalline siderite, and rock is called sideritized silty/sandy claystone. Secondary minerals area occurring as grain replacement and locally preserved in primary pore and identified as siderite, kaolinite, calcite and pyrite. Illite and chlorite replace unstable grain and also recrystallized clay matrix. Calcite and pyrite is encountered filling chamber of foraminifera.

SEM image shows quartz (Qz) surrounded with clay matrix and the matrix is partially recrystallized to illite and kaolinite and replaced by siderite (Sid). Pyrite (Py) disperses in the matrix and locally is seen concentrated. Chamber of foraminifera filled by kaolinite, pyrite and clays, but sometimes by filled by cements and creates primary intraparticle pore. SEM image observations shows the abundance of clay matrix that would reduce reservoir porosity and permeability. The presence has disrupted the smooth fluid flows.

XRD result of L-306 showed that mineralogy are controlled by clay mineral (49%-62%), followed with quartz (26%-34%). Common siderite is recorded in several depth (2%-20%). The presence of high quartz is synchronized with thin sectioned observations that the rocks are containing common silt to sand grains.

Result and Discussion

Based on integration of openhole log, core and cutting data, the main causes of low resistivity pay zone are clay minerals, sand shale lamination, grain size and conductive minerals.

Clay minerals are classified into two, namely allogenic and authigenic clay. Allogenic clay is detrital clay, which comes from an area and is then transported from its source to another place with certain media. Authigenic clay is a clay mineral formed insitu during burial and affected of chemical reactions between rock fluids (pore water) and minerals (lithic fragments, feldspar, volcanic glass, and ferromagnesian minerals). Authigenic clay minerals in sandstones are generally divided into three, namely:

1. Discrete Particle or pore filling, clay structure formed from migrating clay flakes to fill voids between rocks. The clay flakes do not follow the shape of the rock grain surface but will form their straightness according to the direction of migration. This structure is usually formed in kaolinite clay minerals.
2. Pore-lining or grain coating, clay minerals are formed on the surface of the rock grains to cover the rock grains (coating). The clay minerals that make up the structure are chlorite, illite, smectite.
3. Pore bridging clay, formed when the clay-covered granules have touched each other to form new clumps, Clay minerals that make up the pore bridging clay structure are illite, smectite, and mixed illite-smectite.

Clay minerals can reduce resistivity readings because they contain bound water that is retained in the clay minerals. It is affected by the amount of these compensating ions constitutes the Cation Exchange Capacity which is commonly referred to asthe CEC (meq/ 100 g dry rock) or Qv (meq/ cm total pore volume). CEC is related to the specific surface area of a clay mineral. It has its lowest value in kaolinite and its highest values in montmorillonite. The larger the surface area it will hold very significant bound water.

Based on XRD data, it can be showed that illite and kaolinite are the dominant clay, where Illite has a high surface area. In authigenic clay which is distributed as pore-lining and pore bridging clay, it will hold very significant bound water in the clay which is spread out in hydrocarbon reservoirs. So that the reading of the hydrocarbon fluid is disturbed by the clay bound water.

Sand shale lamination is one of the factors that affect the reading of the resistivity log. Core and cutting data shows that the formation has sand shale lamination with thickness around 0.5 to 1 cm, meanwhile, the vertical resolution of the conventional log is about 5 to 80 cm. Thomas-Stieber Crossplot also shows that the distribution of clay minerals is Laminated (20-80%). This might affect the reading of the resistivity log because the lamination is too thin to be resolved. The reading of resistivity might appear low because the shale content of the lamination has higher conductivity (low resistivity) than the layer with hydrocarbon content, thus could bypass the potential zone.

Identification of grain size distribution on the target layer using petrographic data represented by the L-306 well. Petrographic analysis shows a silt-sandstone lithology with mean grain sizes are 0.03 to 0.2 mm. Grains are angular to subrounded, the finer the grain size of the rock, the higher the water saturation in the rock which cannot be replaced by hydrocarbons (Swirr). Reservoir with fine-very fine grain size would lead to high irreducible water saturation (Swirr). This would reduce the value of resistivity log although there might be hydrocarbon in its pores.

Each mineral has different conductivity properties. Conductive minerals are minerals that are good at conducting electricity when an electric current is applied. These minerals can reduce the resistivity log reading, so it will read low even though the rock contains hydrocarbons. Conductive minerals usually contain Ferrum (Fe) or Magnesium (Mg) element (ferromagnesian minerals such as Pyrite ($FeS2$) and Siderite ($FeCO3$).

Petrography and SEM analysis from Well L-306 showed the presence of these two minerals. SEM image detailed shows that that siderite replace partially clay matrix, where the clay matrix is locally dissolved resulting secondary pore (SP) and pyrite disperse within it.

Conclusions

The main causes of low resistivity pay zone On L Field are:

- Clay minerals composed by Illite & Kaolinite which hold very significant bound water in the clay that can disturb the reading of hydrocarbon content in the reservoir.
- Very thin sand shale lamination that can affect the reading of the resistivity log because of bad resolution. It can also make the resistivity of reservoir with hydrocarbon content appear lower because the shale content of the lamination has high conductivity (thus low resistivity).
- The grain size of silt-sandstone would lead to high irreducible water saturation (Swirr), because the finer the grain size of the rock, the higher the water saturation in the rock which cannot be replaced by hydrocarbons (Swirr). Therefore, reservoir with fine-very fine grain size would reduce the value of resistivity log although there might be hydrocarbon in its pores.
- Conductive minerals with composition of pyrite and siderite. These two minerals has good conductivity properties thus can reduce the resistivity log reading even though the rock might contains hydrocarbons.

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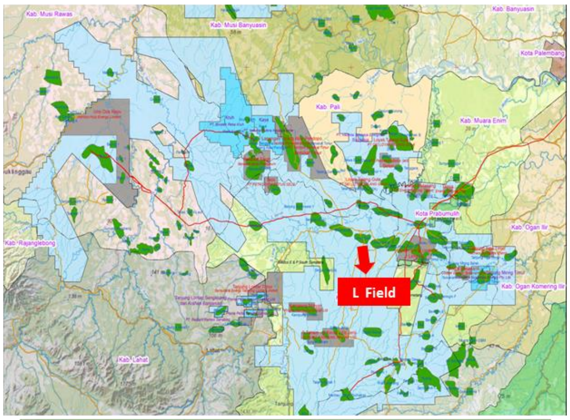


Location of L Field in South Sumatera Basin

Well	Zone	Average Resistivity	Test Data
L-170	3rd Layer	3.1 Ohmm	Gas 1.2 MMSCFD, no water
L-82	1st Layer	2.4 Ohmm	Oil rate 160 BOPD, wc 3%
LC-13	6th Layer	4.5 Ohmm	Gas 2.4 MMSCFD, no water
L-215	1st Layer	2 ohmm	Oil Rate 64 BOPD, wc 75%
L-195	6th Layer	1.5 ohmm	Swab WC 100% Cumm 310.5 bbls

Test Result of Low Resistivity Reservoir in L Field

Figure 1. Location of L Field and test data of low resistivity pay zone

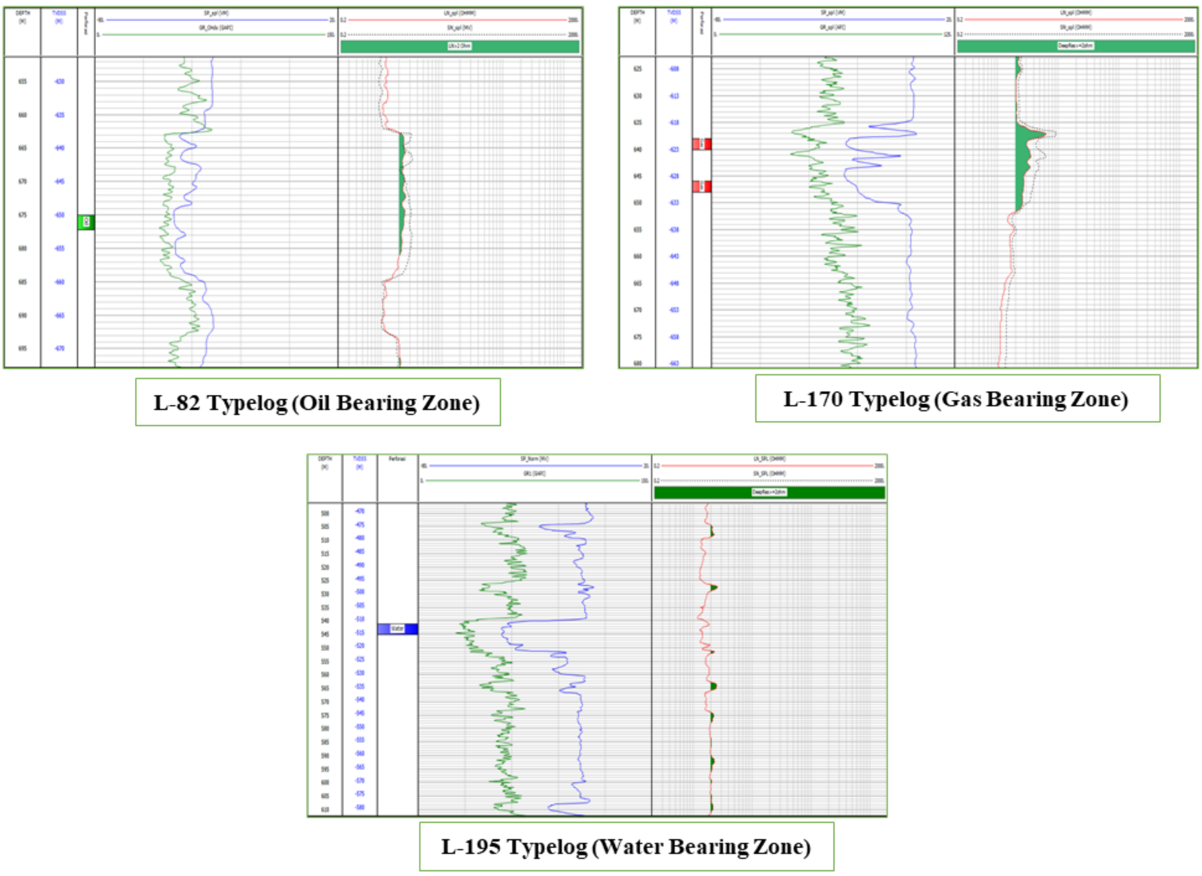


Figure 2. Typical typelog of low resistivity pay zone at L field, in well L-82 with average resistivity about 2.4 ohmm resulted oil after perforated, whereas in well L-170 resulted gas with average resistivity of 3.1 ohmm and in L-195 with average resistivity about 1.5 ohmm resulted water.

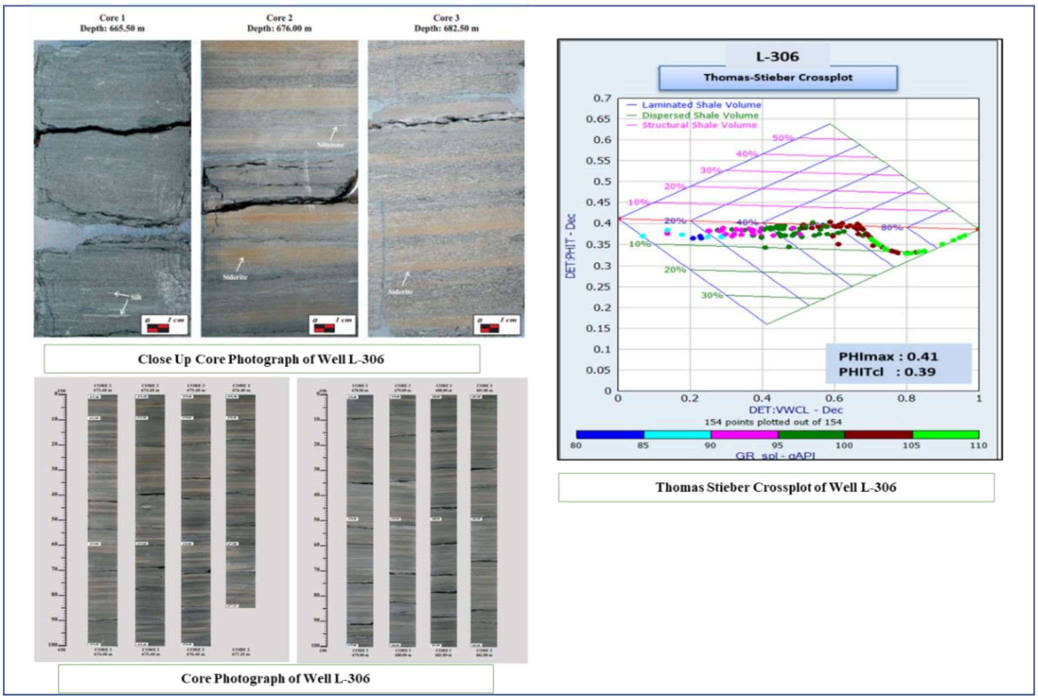
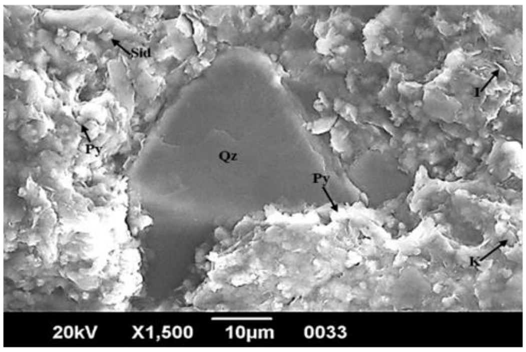


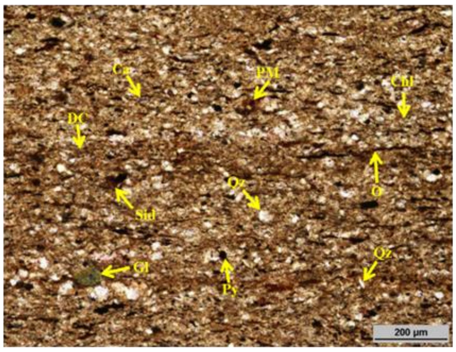
Figure 3. Core Photographs show parallel lamination, with the presence of Siderite as conductive minerals. Thomas Stieber crossplot also show the dominance of laminated shale volume.

No	Depth *meter*	Clay Minerals %				Carbonate Minerals %			Other Mineral %								Total %		
		Smectite	Illite	Kaolinite	Chlorite	Calcite	Dolomite	Siderite	Quartz	K-Feldspar	Plagioclase	Pyroxene	Pyrite	Hematite	Halite	Gypsum	Clay	Carbonate	Other
1	666.55	-	33	12	8	tr	-	10	31	3	3	-	tr	-	-	-	53	10	37
2	667.40	-	30	11	8	tr	-	20	26	2	3	-	tr	-	-	-	49	20	31
3	667.92	-	34	14	9	tr	-	6	31	3	3	-	tr	-	-	-	57	6	37
4	669.50	-	31	12	9	tr	-	6	34	3	5	-	tr	-	-	-	52	6	42
5	670.00	-	35	14	10	tr	-	2	32	3	4	-	tr	-	-	-	59	2	39
6	670.77	-	34	13	9	tr	-	2	33	4	5	-	tr	-	-	-	56	2	42
7	671.25	-	32	12	8	tr	-	7	34	3	4	-	-	-	-	1	52	7	41
8	675.4	-	34	13	9	tr	-	7	31	3	3	-	-	-	-	1	56	7	37
9	683.80	-	37	15	10	tr	-	4	28	3	3	-	-	-	-	-	62	4	34

XRD Data of Well L-306



SEM Analysis of well L-306



Petrography Analysis of Well L-306

Figure 4. Based on XRD Data, the clay minerals are dominated by Illite and kaolinite whereas from SEM & Petrography Analysis show the presence of Siderite, Pyrite and Glauconite.