Seal Caprock And Stratigraphic Trap Identification In Transition Member-Talang Akar Formation At Limau Area Using Cwt-Seismic Atribute, Integration With Sequence Stratigraphy And Biostratigraphy Datas

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Abstract

Limau area is an old field in the first drill by BPM in 1951 with the drilling of TL - 01 and on January 1, 2005 in return to PT.Pertamina (Persero) from JOB - PSEL. There currently are 8 blocks, 7 blocks already done waterflood in several layers. Original Oil In Place (OOIP) throughout Limau status in January 2005 amounted to 823 MMbbl, cumulative production is estimated to have reached 265.40 MMbbl with Recovery Factor = 32.24%. But the fact until now Limau-Niru Field still production on the flank anticline northeast, therefore, need to be studied in more detail to determine the resulting production of conventional structural or stratigraphic traps.

In this study the 9 data Biostratigraphy, 78 well logs in Limau-Niru and 3D seismic were examined. The method Consist of Several steps: 1), Integration electofacies well logs and biostratigraphic data is to identify the marker sequences as MFS, SB and FS. 2) Correlation of stratigraphic sequences in detail to identify each reservoir and distribution of inserts shale position within the time frame and the same genesis. 3) Picking seismic horizons corresponding to the marker sequences for identification of the type of reservoir distribution and shale, which might be as a seal Caprock. 4), Facies mapping for reservoir and shale distribution using CWT - attribute extract Gamp 10-55 Hz. 5) Direct Hydrocarbon identification using CWT - Gamp - 15 Hz for HC prone identification and validation than to be with Test Production. 6), Structural using 3D seismic mapping integration with well log data. 7). Analysis of potential reservoir and supporting data integration for determining the presence of the seal cap rock and stratigraphic trap.

From correlation in existing wells (TL - 260 and TG - 79) has determined there are at least 11 sequences in Limau area. The lowest limit of identification as MFS - 0 (TG - 79) allegedly Oligocene (base on pollen: Langiopollis sp1) with transition-shallow marine depositional environment (base on 6 ditch cuttings from the interval 2966 - 3400 ms) and is a member of the Lemat Formation the upper limit is SB - 1. Of SB - 1 to SB - 8 is thought to be lower Talang Akar Formation which is the Great Sand Member (GRM) and of the SB - 8 to bottom BRF (Top TAF) is Talang Akar Formation upper part which is Transition member (TRM). Correlation of stratigraphic sequences can be validated by the data biostratigraphy is only of the SB - 8 to Top TAF, where SB - 8 is bottom of Late Oligocene, MFS - 8 is Oligocene NP - 25, SB - 9 is Oligocene - Te, MFS - 9 is Oligo - Miocene and MFS - 10 is the Top Miocene N4 of the Outer Neritic depositional environment.

The Talang Akar Formation / TRM in Limau can be divided into three sequences with the lower limit specified in SB - 8. Above SB - 8 is a pile of alternating sandstone with shale that some of them containing HC, ie Y2, Y1, X0, X1. MFS - 8 is the position of the fine fraction which is quite extensive distribution Late Oligocene NP24 - NP25 (base on top appearance Dytocoecites bisectus and Coccolithus eopelagicus) and can serve as a seal Caprock. SB - 9 position on the MFS - 8 is the basis of the pile reservoir consisting of W3, W2 and W1. The next position is above the MFS - 9 is the position of the fine fraction that broad distribution and can serve as a seal Caprock. Likewise MFS - 10 is a fine fraction with a fairly wide spreading of Early Miocene N4 and can serve as a seal Caprock. Facies mapping using CWT attribute - Gamp 10-55 Hz and Gamp -15 Hz can identification of position the reservoir as traps HC which serves
Introduction

Limau field in South Sumatra Basin, located in the city Prabumulih approximately 90 km west of Palembang. These areas are included in the operating area EP.Pertamina (Figure 1).

Limau area is an old field that was first drilled by BPM in 1951 with the drilling of wells L5A-01 and on January 1, 2005 in return to PT.Pertamina (Persero) from JOB-PSEL. At the moment there are 8 blocks, 7 blocks already done waterflood in several layers. Original Oil In Place (OOIP) throughout Limau status in January 2005 amounted to 823 MMbbl, cumulative production is estimated to have reached 265.40 MMbbl with Recovery Factor = 32.24%. From a production history that is reflected as an oil producer Limau Field considerable potential is still relying on structural traps and current production has decreased naturally.

But the fact until now Limau Niru field still production on the flank northeast of anticline, therefore, need to be studied in more detail to find out the results from conventional production of structural or stratigraphic trap. Along with the above mentioned conditions, the oil and gas industry has been promoting searches stratigraphic oil trap or a combination of structural-stratigraphic, to replace or maintain production have declined. Around the year 2009 until in 2013 have been found and suspected oil produced from stratigraphic traps are among others in the Limau Niru field. Judging from historical production drilling generally average in the Limau region reached a depth of 1800 m, while drilling in Gunung Kemala (north Limau) already exists, which reached a depth of 3400 m and has not penetrated basement. So stratigraphically still quite thick sediments that have not been identified (at least from a depth of 1800 m to 3400 m) and allegedly still enough potential with fluvial depositional environment-transition to a shallow marine. Starting from the condition described above, in this study wanted to examine in detail the seal cap rock and stratigraphic traps are allegedly still quite a lot of presence and enough potential in the Limau area of South Sumatra. The existence of seal cap rock distribution is quite wide insulation is one of the key discovery that position stratigraphic traps are below it, but until now there has been much studied and examined in more detail.

Tectonic

History of tectonic development in South Sumatra basin in particular is inseparable from the basic tectonic framework of the island of Sumatra which began in the Late Triassic Period, which began the formation of the continental shelf in the western part of Indonesia ("Sunda Land") from amalgamation micro plates Mergui and Malacca. Based on seismic data and deep drilling had been detected of strike slip fault growing up until bedrock with a steep dip and have a WNW-ESE direction (N300E), known as fault Lematang (Pulunggono, 1986.1992). From the results of reconstruction of linear patterns and distribution of the granite intrusion in the southern Sumatra area, it can be presumed that at the end of the Mesozoic era known there are at least two series of oblique subduction between oceanic plates Indian and southeast Asian continental plate with the direction of convergence of N30W, ie at the end of the Jurassic period and early Cretaceous is the compression phase. This subduction fault movement formed sliding Late Jurassic and early
Cretaceous fault sliding a suspected fault and fault shear sliding Musi Lematang. Oblique subduction process in Sumatra Island has resulted in tectonic the direction of subduction zone ("trench") is accommodated by the mechanism of upthrust fault systems especially in the prism accretion and slip vectors are parallel to the subduction zone that accommodated the main mechanism Sumatra fault system at the time, according to Pulunggono, 1986,1992 are faults with WNW-ESE direction (direction Lematang). Then fault NS-trending faults and NNE-SSW such as faults and fault Kikim in the south to the north Lagan-Lenggaran develop into antithetic faults and tensional normal fault that cuts the fault Lematang are heading to and will form a complex graben called "Benakat Gulley. "(Figure 2). Tectonic and sedimentation development in the area around the Lematang fault the Jura-Cretaceous compression phase occurs fault shear Lematang, where the Early Cretaceous keep moving heading to be followed by the formation of antithetic NNE-SSW faults and normal faults which N-S direction (Pulunggono, 1986,1992). Compression phase which produce faults in the direction N300E, N-S and NNE-SSW, then at the end of the Cretaceous - Eocene-Oligocene transformed into strain phase, where the phase strain it is thought to be caused by the collision tilted "Wharton spreading centers" with the Asian Plate in the east "Investigator Fracture zone" which reduces the speed of subduction (John Clure, 1991).

So that this strain phase will lead to the formation of a graben or half-graben formed by fault-normal fault or previously existing growth faults and further is a Tertiary sediments accumulated. Then in the Middle Miocene epoch plate convergence rate increases again and the case which led to the compression phase inversion tectonics. From the geological cross-section of Figure 3, clearly visible differences in the composition of litho-stratigraphic penetrated by drilling on the north and south block of fault Lematang. The Kampung minyak oil wells and Suban Jerigi vertically penetrate F.Kasai, F.Muara Enim (average 400-500 m thick), F.Air Benakat (about 150-250 m), F.Gumai only about 100m and supposedly impregnable very thick to sharpness vector, ie slip vectors are almost perpendicular to bottom, while F.Baturaja and F.Talang Akar have not penetrated by drilling, but suspected its existence relatively thin. Whereas in wells Limau and Talang Akar, partly F.Muara Enim been exposed, and impenetrable approximately 100 m, F.Air Benakat impregnable approximately 150 m, F.Gumai reached thickness approximately 300 m and F. Talang Akar impregnable until it reaches a thickness more than 1000 m.

**Regional Stratigraphy**

The stratigraphic sequence in South Palembang Sub-Basin has been done by Tobler, 1908 in Spruyt, 1956 in Pulunggono 1986. Subsequent research in the mid-twentieth determine the existence of unconformity between sedimentary Tertiary and pre-Tertiary rocks beneath it. Since then the discussion and review of Tertiary stratigraphy of sedimentary deposition has been documented in the reports of petroleum geology. The division lithostratigraphy South Palembang Sub-basin begins with sequences transgression with sedimentation of non-marine volcanic deposits (Lahat Formation or lemat Formation), sediment paralik (Talang Akar Formation lowe part) is often referred to as GRM (Great sand members), shallow marine sediment (Talang Akar Formation above or often referred to as TRM / Transition Member and Formation Baturaja), and deep-sea sediment (Formation Gumai). Sequent transgression at the top followed by a sequence of regression with sedimentation of Air Benakat Formation, Muara Enim Formation and Kasai Formation. Overall sedimentation sequences are generally known as megacycle, where at the bottom of the form facies transgression (Telisa Group), which is mainly composed of coarse until fine clastic material, and on top form regression facies (Palembang Group), which consists of coarse clastic material. From bottom to top of the stratigraphic sequence in South Palembang Sub Basin illustrated in (Figure 4).
Methodology

In this study consisted of 9 Biostratigraphy of data, 78 well logs and 3D seismic were examined. The method consist of Several steps as follow: 1). Electrofacies integration of well log and biostratigraphy of data to identify marker sequences as MFS, SB and FS. 2). Correlation of stratigraphic sequences in detail to identify each reservoir and distribution of inserts shale positions within the time frame and the same genesis. 3). Picking seismic horizons corresponding to marker sequences to identify the type of reservoir distribution and shale are likely to be seal Caprock. 4). Facies mapping for each reservoir and shale distribution extract using CWT-attribute Gamp 10-55 Hz. 5). Direct Hydrocarbon identification using CWT-Gamp-15 Hz for HC prone identification and validation than to be with Test Production. 6). Structural using 3D seismic mapping integration with the well log data. 7). Analysis of potential reservoir and supporting data integration to determine the presence of the seal cap rock and stratigraphic trap.

Sequence stratigraphic of Talang Akar Formation in Limau area

To determine of the marker sequence, the sequences stratigraphic correlation has been done with the data integrated biostratigraphy through wells TB-33A, TB-32, TL-237, TL-227, TL-8A, TLM-49, TL-233, TL-221st and TL-229, and with reference wells in L5A-260, L5A-261 and GNK-79 towards vertical down marker sequences will try to determine under SB-8 with the approach of using the data elektrofasies. The markers sequence will be very useful in conducting seismic correlation horizon picking through existing wells chek shot. As a key wells are wells that have data chek shot that is well L5A-240, L5A-260 and GNK-79. From the results of these correlations have been able to set the marker sequence from the oldest to the relatively younger and still resides in the sediment column included in Talang Akar Formation, namely: SB-0 is estimated as the surface of the bedrock (basement), MFS-0, SB-1, MFS-1, SB-2, MFS-2, SB-3, MFS-3, SB-4, MFS-4, SB5, MFS-5, SB-6, MFS-6, SB-7, MFS- 7, SB-8, MFS-8, SB-9, MFS-9, SB-10 and MFS-10. Interval of bottom BRF (Top TAF), MFS-10 to SB-8 is interval sediments representing Transition Member (Member of the upper part of F.Talang Akar) and the interval of the SB-8 to SB-1 is a group that represents sediment of Grid Sand Member (Member of the bottom of F.Talang Akar) and SB-1 until SB-0 thought to be the Lemat Formation that are unconformable above the basement rocks. The lowest limit of identification as MFS-0 (GNK-79) allegedly Oligocene (based on pollen: Langiopollis sp1) with a transition - shallow marine depositional environment (base on 6 ditch cuttings from the interval 2966 -3400 md) and is a member of the Formation lemat the upper limit is SB-1. (Figure 5).

Determination of the Maximum Flooding Surface and Sequence Boundary with biostratigraphic data integration

Traditional techniques stratigraphic sequence (Posamentier and Vail, 1988) Subdivide the rock record is based on a sequence boundary, not on flooding surfaces as suggested by Galloway (1989). But to facilitate analysis of two ways Posamentier and Vail and Galloway we use an integrated manner, the initial phase is going to be easier to determine the Maximum Flooding Surface (MFS) with the characteristics of the TST and HST meeting at maximum GR controlled by the abundance of fossils in the MFS. Then determine the next MFS in the same way after that the new determine the position of Sequence Boundary (SB), which is between MFS-1 and MFS-2 or between MFS-2 and MFS-3 and so on. Sequence Boundary usually characterized by erosional base on the bottom of the bell-shaped layer or tabular or in the fields marked by the presence of a stepping depositional environment, for example from the HST to LST or HST to TST or from terrestrial sediment directly into Nertik or vice versa (Kendal, 2005).

The sequence stratigraphic correlations Limau regions that can be controlled by the data biostratigraphy is only of SB-8 to the Top TAF, where SB-8 (lower of Late Oligocene), MFS-8 (Late
Oligocene / NP-25), SB-9 (Late Oligocene/Te), MFS-9 (Oligo-Miocene aged) and MFS-10 (upper part of Miocene-N4) to environmental conditions Outer Neritic deposition (Figure 6 and Figure 7).

Sequence Stratigraphic Correlation

For Talang Akar Formation / TRM in Limau area can be divided into three sequences with the lower limit specified in SB-8. Above the SB-8 is the base of sandstone layers alternating with shale that some of them containing hydrocarbon, ie Y2, Y1, X0, X1. MFS-8 is the position of the fine fraction is quite extensive distribution with aged Late Oligocene / NP24-NP25 (base on top appearance Dyctyococcites bisectus and Coccolithus eopelagicus) and can serve as a seal Caprock. SB-9 position above the MFS-8 is the base of the reservoir consisting of W3, W2 and W1. The next position is above the MFS-9 is the position of the fine fraction are spread widely and can serve as a seal Caprock. Similarly, the MFS-10 is a fine fraction with a fairly wide spreading of Early Miocene/N4 and can serve as a seal Caprock (Figure 8).

Correlation horizon picking the marker sequence and subsurface mapping

Interpretation horizon picking begins on seismic cross section that passes through key wells that have data check shot, where the seismic trajectories through wells GNK-79, GNK-81, L5a-260 and L5A-240. After that then carried throughout the track seismic interpretation provided (Figure 9). The conversion process from the time structure map to the depth domain using velocity data obtained from seismic data that has been corrected with the data as well as data marker check-shot. This process is done keeping in mind that in the study area Top-BRF, MFS-10, SB-10, MFS-9, SB-9, MFS-8 and SB-8 penetrated almost all the wells, so it can be used as a validator depth regionally and as the main reference in conducting time-to-depth conversion to other layers underneath.

Manufacture of several attributes that are based on the analysis of continuous wavelet transform (CWT), such as time-frequency gradient at 15Hz and gradient on the frequency range 10-55Hz. Both of these attributes are used as secondary data to help identify the fluid content and identification of sand-prone.

Extract attribute to support the determination of seal caprock and trap stratigraphy

The main picking horizon in this study is the use of marker sequences and top formation that is well-known marker: BRF, Top TAF, MFS-10, SB-10, MFS-9, SB-9, MFS-8 and SB-8. To extract certain layers are considered sufficient prospect is the time domain, and then with the guide from markers sequences that have been operated in accordance with the position of the prospects layer, above or below how milli second against a known marker, after the extract in this case using CWT attribute Gamp 10-55 Hz to determine the distribution of sand-prone and Gamp 15 Hz to indicate the existence of hydrocarbons in place (Nurcahya et al, 2004).

Attribute Spectral decomposition perform frequency decomposition of seismic data into three sections: low, medium, and high. Low frequency (bright color) will be associated with a layer of thick and high frequency (dark color) will be associated with a thin layer or shale (frequency = 1 / time). The third of these frequencies can be combined to obtain subsurface images with a thin layer of expectation will be better identified. In addition relates to the thickness of the layers, spectral decomposition also linked to the seismic wave attenuation. The existence of hydrocarbons will make attenuation seismic waves such that low-frequency effects shadow. To improve the ability of identification, then the calculation of time-frequency gradient in the low frequency 15Hz. Results that have been made is to extract attributes on the position W3 layer just above the SB-9 in sequence stratigraphy. (See Figure 10).
Cut off the determination of reservoir properties

Data core, log and production are used to determine the cutoff value vclay, porosity and permeability (Figure 11 and 12) of each channel and sand bars facies. Cut off value obtained from the data cores compared to the cutoff obtained from log data in order to obtain a realistic cutoff value. Value cut off for water saturation relative permeability obtained by the transformation of the data into a fraction of the flow of water from special core analysis / water cut (Figure 13). Cut off value used for each facies as follows:

Channel Sand
- Vclay Cutoff: 0.38
- Porosity Cutoff: 0.13
- Cutoff permeability: 15 md
- Water saturation Cutoff: 0.58

Sand Bar
- Vclay Cutoff: 0.4
- Porosity Cutoff: 0.12
- Cutoff permeability: 10 md
- Water saturation Cutoff: 0.64

Reservoir summary / lumping obtained by applying the cutoff with the following restrictions: a gross sand thickness of a top up with sand bottom, net sand is clean sand thickness to be cutoff with vclay, net reservoir sand is sand that to be cutoff net with porosity and permeability and a net net pay sand reservoir which to be cutoff with Sw which is the thickness of the hydrocarbon column. For layer sandstone has data quality below the cut-off value of the above, it is classified as a non reservoir lithology, lithology means can not pass fluids (non-permeable).

Analysis determination of stratigraphic trap and seal caprock

As an example a case in this regard have been choise W3 and X1 layers, Based on log data and data core, the layer is sedimentation result of distributary channel facies models and in some places is deposited as sediment bars, spread almost evenly in the area Limau-Niru, from the slice attribute CWT- Gamp-10-55 Hz layers W3 (Figure 14a) looks like distribution of sand prone (bright yellow-red) and in some places as a lateral facies changes into shally (dark blue), but in terms of production data at the top of this anticline structure (area E) it did not result in the production or already into water, whereas production resulting from the flank of the anticline at northeast area (area A), the north (area B) and the area southwest (area D) (See Figure 14b). Zone MFS-9 is the maximum flooding surface which is a position of condent-section impermeable shale section, so it is a fairly effective lateral cover and serves as a cap rock for prospect-layer coating which are below it. MFS zone of the slice-9 (Figure 15) appears distribution of shale (in blue) with bright yellow spots, the spots of bright yellow color is alleged is an area that is leaking and can leak. CWT Horizon slice with attribute-Gamp-15 Hz in layers W3 (Figure 16), it seems clear distribution of hydrocarbon prone at flank of anticline spread in the region in the northeast and southwest.

From the structural cross-section A-B passing through the area-A and structural cross-sectional C-D whice are passing through the area-D, it appears that the wells in the area and has a value of production HC pretty good reservoir properties Por. = 0.20 – 0.23, VCL = 0.08 to 0.15 and SW = 0.27 to 0.31, while in the area E which is the top structure of its wells are not producing and when viewed from the value of its reservoir properties Por = 0.05 to 0.09, VCL = 0.47 to 0.55, SW = 0.67 - 0.98, so has the quality of the reservoir which is below the cut-off by the cut off reservoir (Por = 0.12, Vcl=0.39 and k = 15 md), thereby W3 layer at top structure a facies changes so that changing the value of properties into a zone that is impermeable reservoir (Figure 17). Likewise, the conditions for X1 in the down flank coating reservoir properties (Por = 0.18 to 0.20, VCL = 0.10 to 0.12, Sw = 0.18 to 0.29), while at the top of the structure of reservoir...
properties (Por = 0.05 to 0.09, VCL = 0.55 - 0.67 and Sw = 0.67 - 0.99).

To layer X1 is suspected as the sealing layer is a shale zone of MFS-8. Facies changes to layer W3 also occurs in the southwest region, where the down flank has a value of reservoir properties (Por = 0.18 to 0.20, VCL = 0.16 to 0.19 and Sw = 0.29 to 0.38), while towards the top of the structure to be (Por = 0.04 to 0.07, VCL = 0.38 - 0.75 and Sw = 0.65 - 0.99). From examples such cases it can be concluded that the multiple layers that exist in the Limau area is a stratigraphic trap with cap rock is shale layer zone which is intraformational in MFS-8 and in the MFS-9. While the types of stratigraphic traps can be is wedge layer, channeling or any facies changes (see Figure 17).

Conclusion

1. In Limau area the sequence stratigraphic correlation can be controlled by the data biostratigraphy is only of SB - 8 to the Top TAF, where SB - 8 (Late Oligocene bottom) , MFS - 8 (Oligocene NP - 25) , SB - 9 (Oligocene - Te) , MFS-9 (Oligo - Miocene) and MFS - 10 upper Miocene N4to the Outer Neritic depositional environment (Figure 6 and Figure 7)

2. Horizon slicing using seismic attribute Gamp -10-55 Hz can identify the distribution of the sandstone layer (Sand prone) (Figure 14 and Figure 16).

3. Horizon slicing using seismic attribute Gamp -15 Hz can identify indications of hydrocarbon content in a layer (HC prone) (Figure 14 and Figure 16).

4. Based on the data core, the data log and production test data could have been made value of cut off reservoir properties to limit or distinguish the rock reservoir and non - reservoir rock or shale rock that spread widely as insulation. The value of cut off reservoir properties as follow : For Channel sand Vclay cutoff = 0.38, Porosity cutoff = 0.12, (k) cutoff = 15 md, Sw cutoff = 0.58.

5. As an example the case of layers W3 , X1 and R7 of the integration of existing data can be summed up as a stratigraphic trap because of the wedge shape, channeling or any change facies. As the seal cap rock is main MFS-8 and MFS-9 which has a spread widely.

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Figure 1  Location of study

Figure 2. Tectonic South Sumatra Basin and subdivision of sub-basin at South Sumatra Basin (Jastek Pertamina, 2003)

Figure 3. Inversion structure at surrounding Lematang fault in Limau Anticlinorium (Duncan S, Macgregor, 1995)
Figure 4. Stratigraphic succession at South Palembang Sub-basin (Pertamina, 2003, modification Taat, P., 2015).

Figure 5. Identification of marker MFS-8, MFS-9 and MFS-10 (well TL-227).

Figure 6. Sequence Stratigraphic Correlation in Limau Niru area, defined of SB-1 up to SB-10.

Figure 7. Identification of marker sequence SB-8, MFS-8, SB-9, MFS-9, SB-10 and MFS-10 (well TL-237).

Figure 8. Correlation of Sequence Stratigraphic from west to east pass through TB-33A, TB-32, TL-227, TL-237, TL-240, TL-8A, TLm-49, TL-221, TL-23.
Figure 9. Horizon picking at section Inline-2196 with check shot LT-240

Figure 10. Extract slice CWT - Gamp-15Hz on W3 with HC prone indication (color yellow-red bright)

Figure 11. Cut off Facies Channel Sand base on core data

Figure 12. Cut off Facies Bar Sand base on core data

Figure 13. Cut off Sw for Facies Channel sand and Bar sand

Figure 14. Extract attribute seismic CWT Gamp 10-55 Hz and Gamp-15 Hz for Sand prone and HC prone indication on W3

Figure 15. Extract attribute seismic CWT Gamp 10-55 Hz on MFS-9 (dark blue color is shale distribution)
Figure 16. Extract attribute seismic CWT Gamp 10-55 Hz on W3 (dark blue color is shale or water and bright yellow-red is HC).

Figure 17. Section A-B and C-D show of facies change from difference value reservoir properties laterally (Reservoir W3, X1 for example as Stratigraphic trap).