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DEPOSITIONAL ENVIRONMENT AND FACIES ANALYSIS OF THE PALEOGENE PERIOD IN SAWAHLUNTO AND SURROUNDING AREA, WEST SUMATRA: A CASE STUDY OF SANDSTONES AS POTENTIAL RESERVOIR

Muhammad Hafiz Prasetyo[1], Ray Diwatra Linggadipura[1] and Avi Krestanu[1]

[1] Undergraduate Student at Geological Engineering Study Program of Sriwijaya University, Palembang

Abstract

Sawahlunto and Sawahtambang Formation was formed at Eocene and Oligocene Age. Generally, based on stratigraphy, both of formation show that fluvial environment. Sawahlunto formation is sedimented on the meander river system and Sawahtambang Formation is sedimented with the condition on the type of braided river systsem. The research method used is the result of a field observation, porosity, granulometri, petrography and studioanalysisThe results of the data analysis can reconstruct and synthesize in determining the deposition environment of the research area for the application of the formation having reservoir potential on the sandstone deposit.Overall, facies analysis shows the sediment conditions of main channel, overbank deposit and flood plain. The result of granulometry data shows the Sawahlunto Formation has a value standard deviation with fine grain size, the value mesokurtik indicates the kurtosis, and skewness values generate data very positive describing dominant fine-grained grain size. Furthermore, on a sandstone of Sawahtambang Formation is sedimented on fasies main channel, it is based upon the analysis of the granulometri shows that these sandstones have the value standard deviation with coarse grain size, the values of curtosis indicates very leptokurtik, and the value of the skewness indicates a negative data which it is assumed that the dominant faction coarse grain size. The results of the porosity analysis show that the sandstones of Sawahtambang Formation more potential became reservoir with percentage values i.e 27 – 29 %.

Keyword: *Sandstone, Fluvial Deposits, Sawahlunto and Sawahtambang Formation*

Abstrak

Formasi Sawahlunto dan Formasi Sawahtambang pada daerah penelitian memiliki umur Eosen dan Oligosen. Secara umum, kondisi stratigrafi kedua formasi menunjukan lingkungan pengendapan fluvial. Pada Formasi Sawahlunto tersedimentasikan pada tipe meander river system dan Formasi Sawahtambang tersedimentasikan dengan kondisi pada tipe braided river systsem. Metode penelitian yang digunakan yaitu data hasil dari observasi lapangan, analisa porosititas, analisa granulometri, analisa petrografi dan analisa studio. Hasil dari analisa data tersebut dapat merekonstruksi dan melakukan sintesa dalam menentukan lingkungan pengendapan daerah penelitian yang bertujuan untuk penerapan aplikasi terhadap formasi yang memiliki potensial reservoar pada endapan batupasir. Analisis fasies secara keseluruhan menunjukkan kondisi endapan yaitu *main channel, overbank deposit,* dan *flood plain*. Hasil data granulometri memperlihatkan pada Formasi Sawahlunto memiliki nilai *standar deviasi* (SD) dengan ukuran butir halus, nilai kurtosis menunjukan *mesokurtik*, dan nilai *skewness* menghasilkan data *very positif* yang

menggambarkan ukuran butir dominan berbutir halus. Selanjutnya, pada batupasir Formasi Sawahtambang terendapkan pada fasies *main channel*, hal ini didasarkan atas analisa granulometri menunjukkan bahwa batupasir tersebut memiliki nilai standar deviasi (SD) dengan ukuran butir kasar, nilai *kurtosis* menunjukkan *very leptokurtik*, dan nilai *skewness* menunjukkan data negatif yang diasumsikan bahwa fraksi dominan berbutir kasar. Dari hasil analisa porositas menunjukkan bahwa batupasir Formasi Sawahtambang lebih potensial menjadi reservoar dengan nilai persentasenya yaitu 27 – 29 %.

Kata Kunci: *Batupasir, Endapan Fluvial, Formasi Sawahlunto dan Sawahtambang*

INTRODUCTION

Reservoir is an essential element in the petroleum system, due to the accumulation of oil and gas. In general, oil reservoirs have different characteristics depending on the composition, temperature and pressure on the place where the hydrocarbon content in it. Generally, reservoir rock consists of sediments, which are sandstones and carbonates (clastic sediments). Reservoir quality is important because we can determine a region has the potential for hydrocarbons to be developed or not. Porosity and permeability are the requirements that reservoir rock must possess. Porosity is the ratio between the empty spaces (pores) in the rock with the total volume of rock expressed in units that will determine the storage capacity of the reservoir fluid. Whereas, permeability is an ability of a rock to drain fluid. The sandstone reservoir is the most important and most common type of reservoir rock, in percentage, almost 5% of sandstone reservoir that contains petroleum from all reservoir rocks.

Administratively, this research is located in Sawahlunto and its vicinity, West Sumatera (Fig 1). Sawahlunto is one of the areas that is known as a region that produces and has a coal reserve with a high ranking due to the existence of a basin located on a mountainous path.

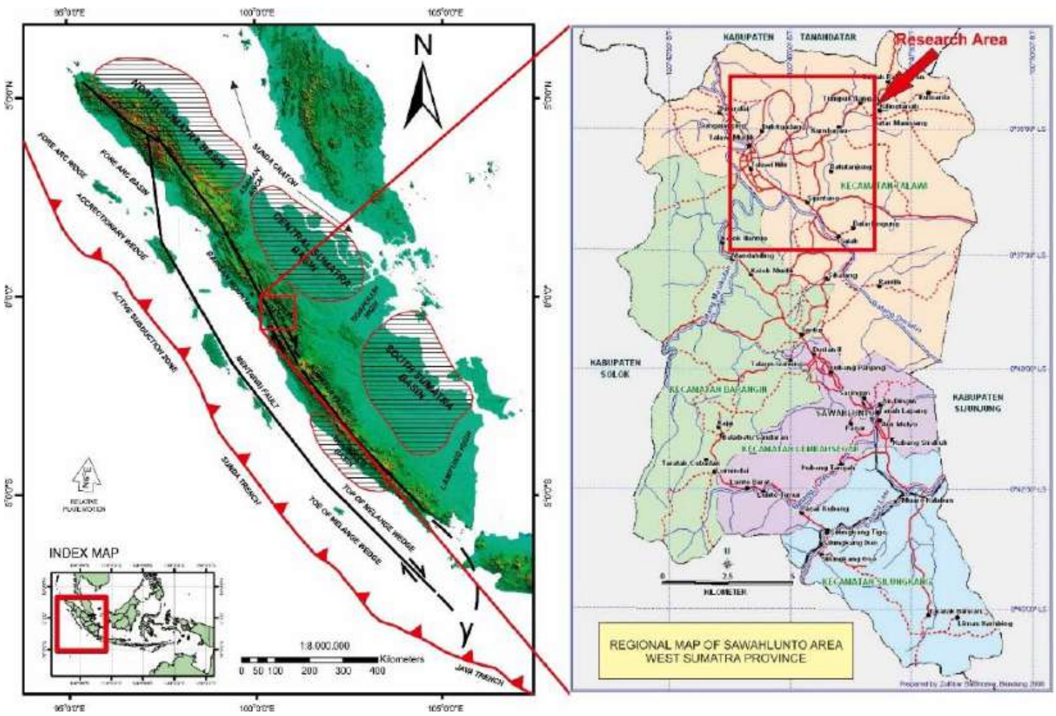

Figure 1. Map of research area based on tectonic conditions on the island of Sumatra

In addition to coal resources, Sawahlunto has a hydrocarbon potential characterized by oil drilling on the Ombilin Basin ever worked on.This research focused on Paleogen sediment in Ombilin Basin consisting of Sawahlunto Formation of Eocene age and Sawahtambang Formation of Oligocene age. Both of these formations have the potential of sandstone reservoirs, because these two formations are deposited in fluvial environments that can produce sandstone deposit which has good porosity and permeability. The purpose of this research is to know the facies and the environment of settling the research area, Furthermore, a comparison of these two formations is done to determine which formations that potential as good reservoirs with sandstone objects. The research method used several parameters such as field observation, measurement of stratigraphic cross section, laboratory analysis in the form of porosity analysis, granulometry analysis, petrographic analysis, and studio analysis.

Based on the results of drilling conducted by PT CALTEX Pacific Indonesia at Sinamar 1 well, shows at the top of the Sawahtambang Formation composed of sandstone lithology which has an average porosity of 15%, then with the deeper data (1520 m) in the middle of the Sawahtambang Formation , indicating that porosity increased to 20%. The results of the cutting data show at the top of the Sawahtambang Formation found that hydrocarbons are visible even with small amounts of flow, but in the middle of the Sawahtambang Formation, the amount of flow increases. This hydrocarbon source comes from lacustrine shale of Sawahlunto Formation. Thus it can be seen that Sawahtambang formation has the potential as a hydrocarbon reservoir in the Ombilin Basin (Koning, 1985).

GEOLOGY REGIONAL

STRATIGRAPHY

Ombilin Basin is a basin filled by pre-Tertiary rock formations up to Quaternary. All the formations that fill these basins have varying forming environments, from terrestrial to marine environments. In particular, this study focused on two formations formed on the Early Tertiary, the Sawahlunto Formation formed at Eocene and the Sawahtambang Formation formed at Oligocene. Both of these formations share a settling environment in the form of a river environment. According to Koesoemadinata and Matasak (1981), the Sawahlunto Formation is composed by the gray-colored, siltish-shale, siltstone, siltstone with sandstone intercalation, coal, and shale spheres generally carbon. Sandstones have the characteristics of a finer upward sequence, having a congested cross-linked sediment structure, ripple lamination, and a firm erosion base showing a point bar sequence. Coal generally coincides with gray-colored rocks and carbonaceous clays. The presence of carbonaceous, coal, and especially point-point sandbars indicates the deposition environment of this formation is a floodplain with a winding river where coal is deposited.

According to Koesoemadinata and Matasak (1981), Sawahtambang Formation has a relation of Sawahlunto Formation. The Sawahtambang formation is characterized by thick, massive sequences of sandy sandstone, light gray sandstones to brown, fine grained to very coarse, mostly conglomerate with gravel quartz fragments, very poorly divided, cornered, hard, and massive. The sequence feature of the Sawahtambang Formation consists of cycles or series of precipitation, where each cycle is limited by the erosion plane at its base and is followed by gravel, crossword, crossed and parallel laminate with an upward-smoothing elbow. Locally, at the bottom of the Sawahtambang Formation there is an insertion of layers of clay or shales and forming a separate unit, namely Rasau members, while at the top of this formation there are inserts of layers of clay with laminate structure, there are coal deposits that occur locally, and formed its own unit, namely Poro Members (Figure 2).

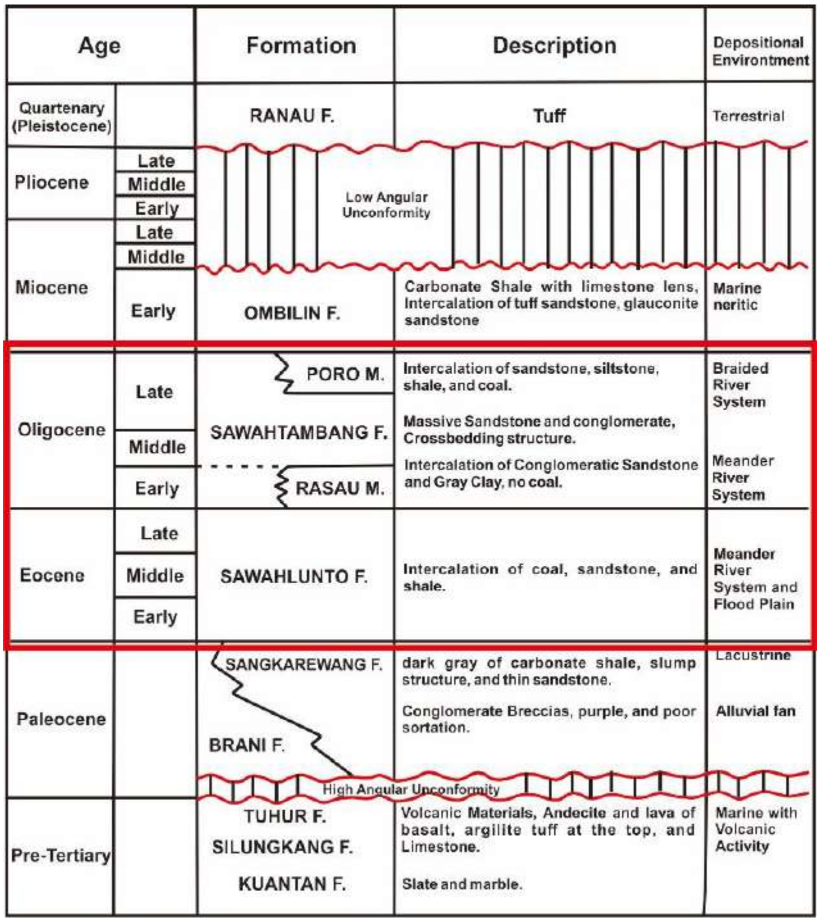

Figure 2. Stratigraphy regional of Ombilin Basin (Koesomadinata dan Matasak, 1981)

GEOLOGY STRUCTURE

According to Situmorang, dkk., (1991), The overall geometry of the Ombilin Basin is elongate on the NW-SE direction, bounded in the north and south by NW-SE striking Sitangkai and Silungkang faults respectively, which are more or less parallel to the present day active SFS. Locally three structural grains can be recognized within the Ombilin Basin.

The NW-SE striking basin-boundary faults which form parts of the SFS. The northern part of the basin is bounded by Sitangkai and Tigojangko faults. The Tigojangko fault extends southeastward to become Takung fault. The southern part of the basin is bounded by Silungkang fault.

The N-S trending fault system is clearly seen in the northeasthern part of the basin. It forms step-like faults, from the north to the south: Kolok, Tigotumpuk and Tanjungampalu faults. The development **of** those faults is associated with tensional phase during the early stage of basin formation, and seems to play a major role in the basin evolution (Figure 3). The basin development was initiated by transtensional movements which took place during the Paleocene time. The first asymmetrical graben was formed which can be interpreted as a result of early Tertiary strikeslip faulting along the SFS. Faulting was predominantly took place in the 'margin of the basin. The main depocentre was located to the northwest of the Kolok fault. This graben appears to be part of the Payakumbuh subbasin, which is presently covered by the Quaternary volcanic products.

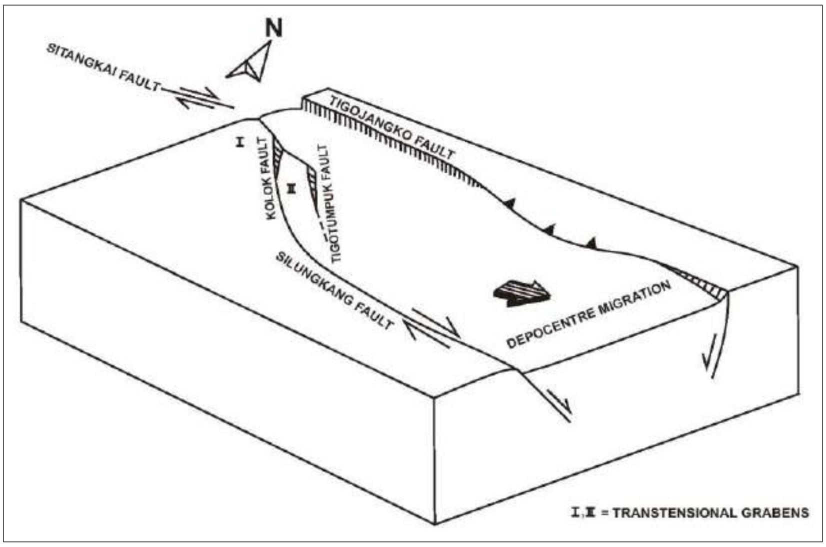

Figure 3. Schematic Model of the paleogene transtensional half grabens of the Ombilin Basin (Situmorang, dkk., 1991)

The E-W striking fault forms a left-lateral antithetic antithetic fault system with dominant dip-slip component. Detailed gravity map shows that this fault is acted as a major boundary for a number of subbasins, i.e. Talawi subbasin. In the Kolok area this fault is detected as thrust fault. Upthrusting of the Silungkang Formation onto the lacustrine deposits of the Sangkarewang Formation is also associated with this transgressive episode (Figure 4).

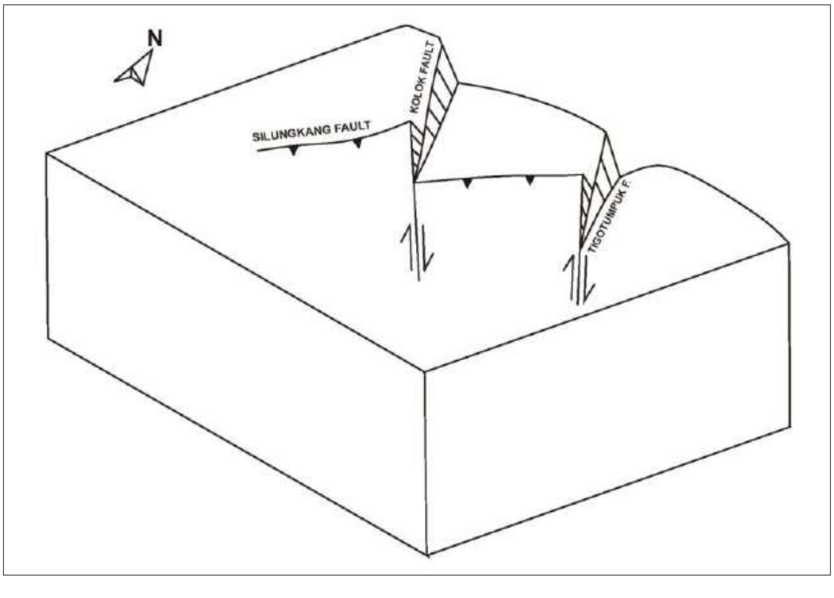

Figure 4. Schematic Model of the Upthrusting Silungkang Fault (Situmorang, dkk., 1991)

The final structural development was characterized by transtensional phase during the Early Miocene time, the fourth graben was formed to the southeast of the earlier depocentres bounded by the **N-S** trending Tanjungampalu Fault. The Neogene shallow to deep marine sediments of the Ombilin Formation was deposited in the graben which formed the deepest portion of the Ombilin Basin. Those tectonic episodes have produced complicated structures which were then affected by Plio-Pleistocene orogeney (Figure 5).

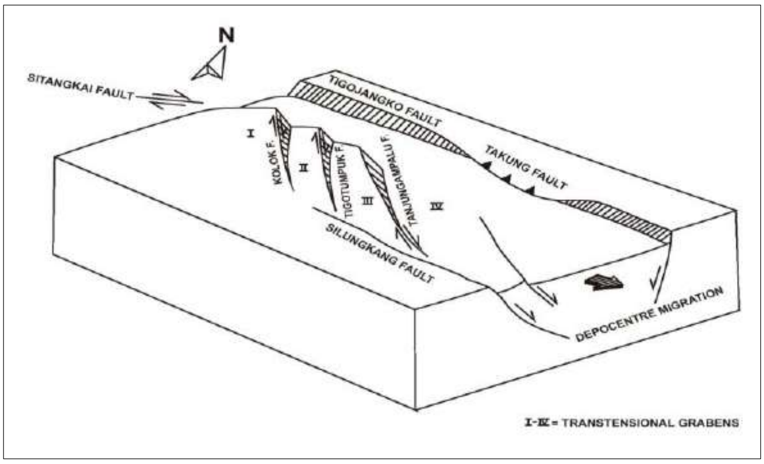

Figure 5. Schematic Model of the Neogene Transtensional Half Grabens of the Ombilin Basin (Situmorang, dkk., 1991)

RESULT & ANALYTIC METHOD

FACIES AND DEPOSITIONAL ENVIRONMENT

Based on the stratigraphy measured section in the research area found there are two formations as the focus of the research object is Sawahlunto Formation and Sawahtambang Formation. From result of litostratigraphy data obtained from stratigraphy measured section, indicate that Sawahlunto Formation is deposited on depositional environment of meander river system with facies in the form of main channel, flood plain and overbank (Figure 6). This determination is based on suspension deposit that almost dominates and is associated with fine sandstone. The main channel facies characteristic is that there is an erosional contact at the bottom of the layer, this is influenced by the strong flow rate of the river (bedload). Lithology composers in this facies is the deposited of coarse fractions of coarse until fine sandstone with a sediment structure cross bedding and parallel laminate. The characteristics of the flood plain facies have a lithology composition of suspended sediment in the form of clay, shilt, shalestone and there are fine sandstone inserts. At facies overbank has characteristic that is the intercalation of claystone and sandstone that have sediment structure in the form of parallel lamination. Overbank facies are accumulated in the flood plain area with sediment formed fine fraction.

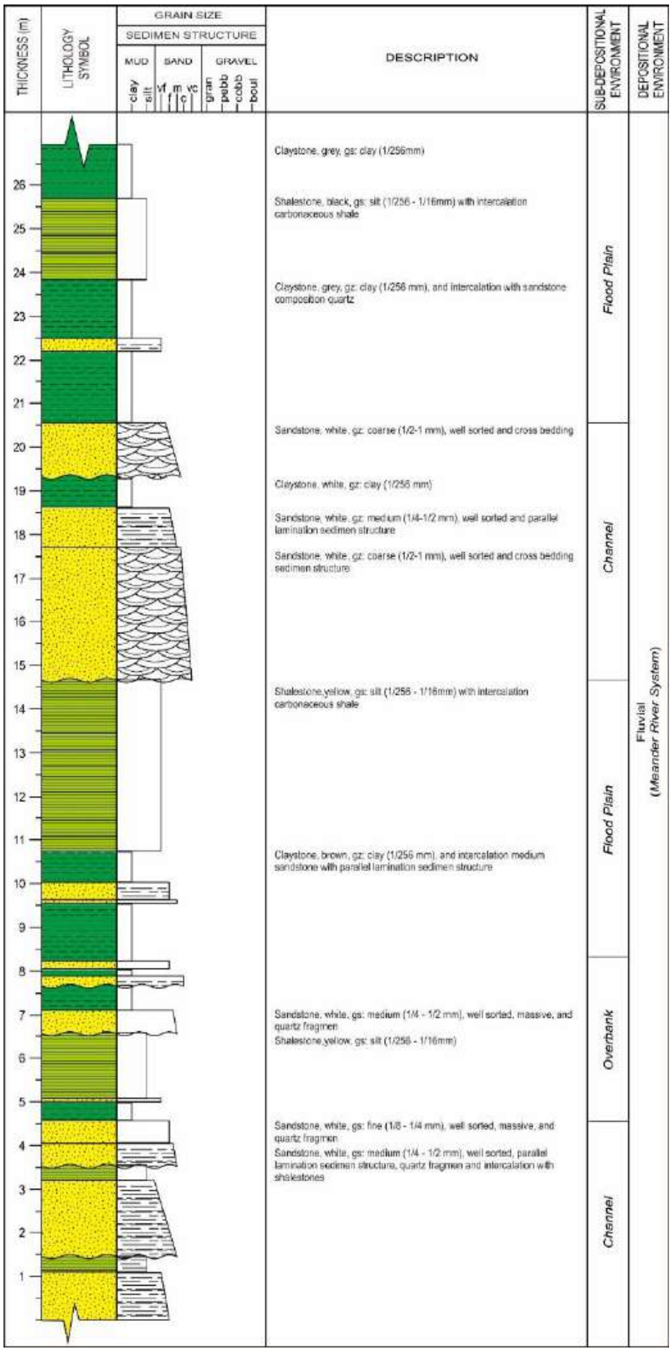

Figure 6. Stratigraphy column on Sawahlunto Formation

Based on lithostratigraphy data that characterize the texture of lithology of Sawahtambang Formation, the deposition environment condition of the formation shows the most dominant facies of channel. In determining the type facies consider the condition of lithology that changes vertically. In the Sawahtambang Formation channel development has a change of grain size from old to young with coarse fractions and has a finite upward sequence deposition pattern (Figure 7).

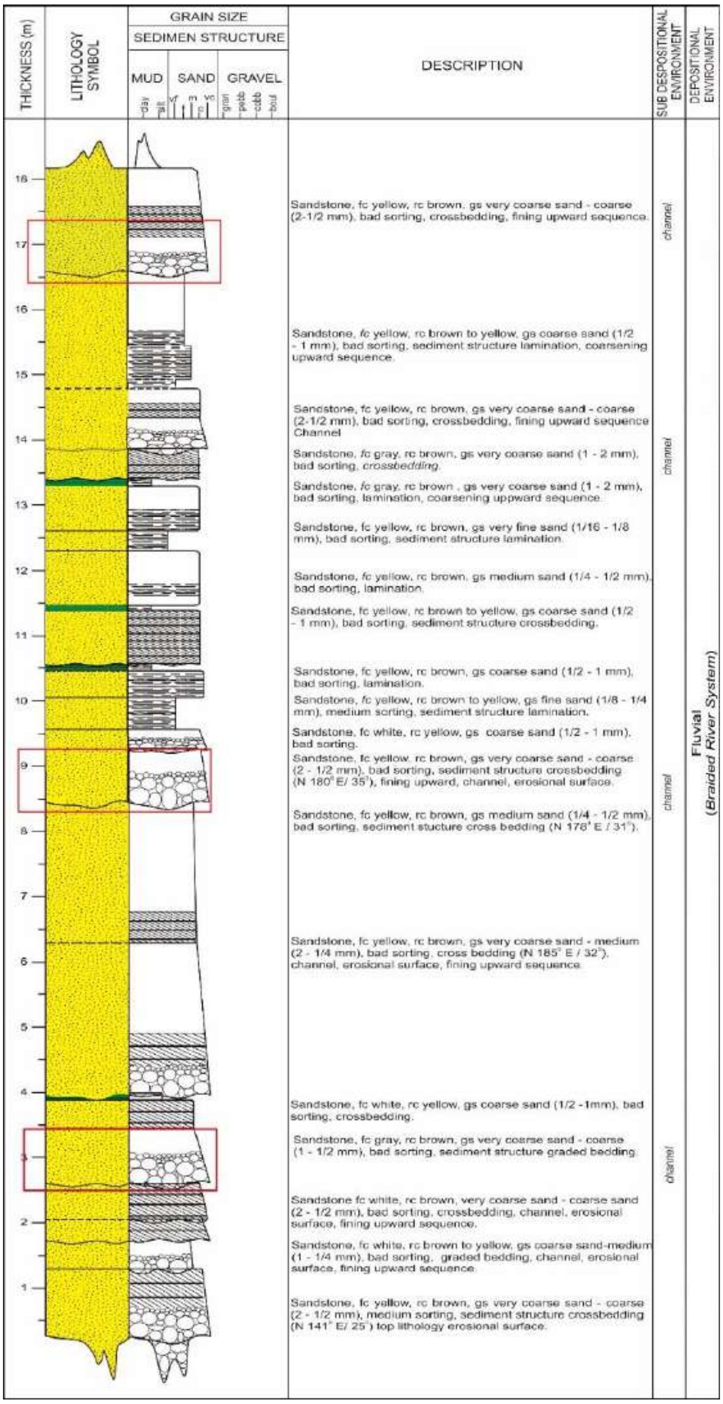

Figure 7. Stratigraphy column on Sawahtambang Formation

In addition, the Sawahtambang Formation sandstone condition has the development of a crossbedding structure as well as at the bottom of the channel an erosional contact shows that the sedimentation pattern takes place with a strong river velocity. Thus, the stratigraphic relationship of Sawahtambang Formation in the study area has a special characteristic, which is dominated by medium to rough grain sandstones with large coating thickness. The facies formed on the Sawahlunto Formation and Sawahtambang Formation are seen in the morphology of the fluvial precipitation environment (Figure 8).

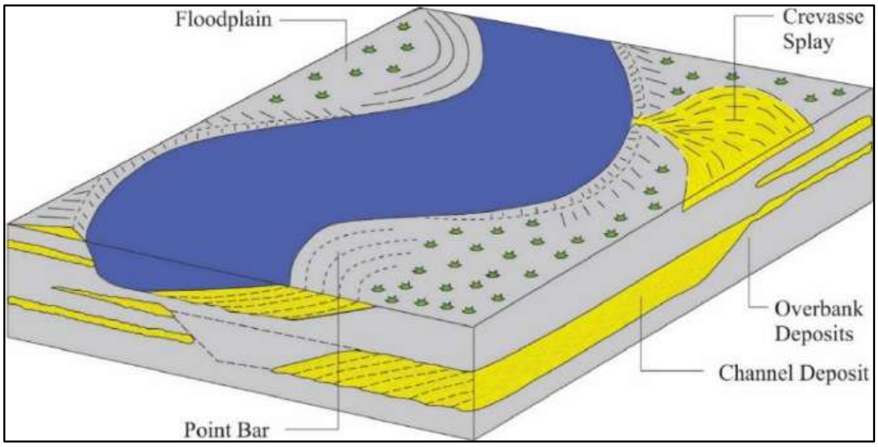

Figure 8. Fluvial environmental morphology model showing the existence of facies

In the observed outcrop there is generally seen a cycle of grain size changes gradually upward from gravel to medium grained sandstone, fine fraction rocks are generally present only as thin insertions between coarse fraction rocks, there are also many channel formations with geometry that tend to be symmetrical with part center channel filled by coarse lag deposits (Figure. 9), and also abundant crossbedding sedimentary structures at the measurement site. Based on the results of granulometry analysis conducted, indicating that the depositional environment of this unit in the form of a river with the transport mechanism of saltation and suspension. In the measured stratigraphy section data the channel shows a pattern that intercepts with other channels so it can be assumed that after the channel is formed a new channel will be formed. Based on the texture and facies contained in the Sawahtambang Formation, the deposition of the environment conditions is a braided river.

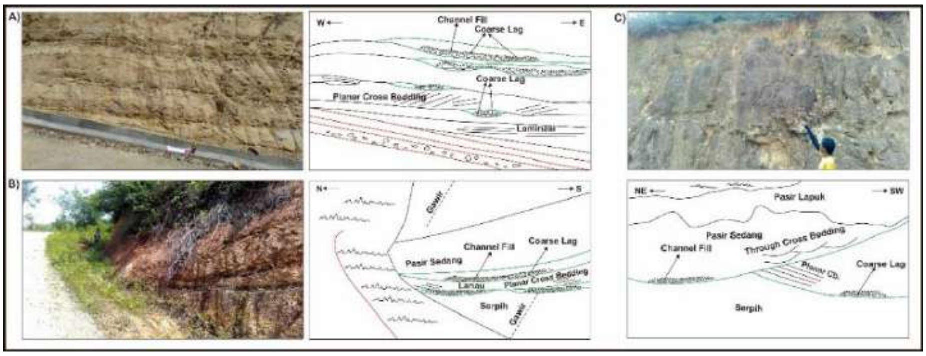

Figure 9. The appearance of the channel at the research area, A) the bottom of the stratigraphy column of the Sawahtambang Formation, B) the bottom of the stratigraphic column of the Sawahlunto Formation, C) the upper part of the stratigraphic column of the Sawahlunto Formation

GRANULOMETRY ANALYSIS

The result of statistical calculation of granulometry data on Sawahlunto and Sawahtambang Formation is poured into Arithmetic Curve which shows standard deviation, kurtosis, and skewness values (Figure 10). The result of analysis Sawahlunto Formation at the bottom of stratigraphic measurement shows mean value 5,92, standard deviation 1,6, kurtosis 0,74, and skewness 1,02. Subsequent data at the center showed a mean of 5.9, standard deviation 1.8, kurtosis 0.87, and skewness 1.04. The upper part shows a mean value of 2.46, standard deviation 1.8, kurtosis 0.85, and skewness 1.05. The result of granulometry data analysis on MS02 on the bottom of the measured stratigraphic measurement shows the mean value 1.03, standard deviation 4,15, kurtosis 2,14, and skewness -0,7. The subsequent data at the center shows the mean value of 0.6, standard deviation 1.15, kurtosis 2.5, and skewness -1.24. The top shows the mean value 1, standard deviation 1.3, kurtosis 0.6, and skewness 0.6.

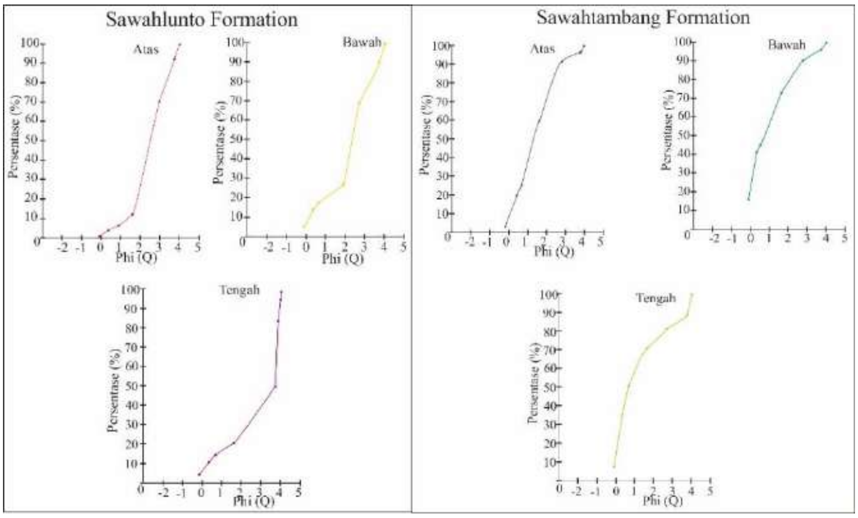

Figure 10. Arithmetic Curve for Statistical Analysis of Standard Deviation, Kurtosis, and Skewness

Granulometric analysis performed on each part of Sawahlunto Formation generally yields a probability curve showing the sedimentation mechanism in the form of saltation (Figure 11). The results of the statistical calculations in each section of the formation also generally resulted in the standard deviation (SD) values tend to have relatively poor disaggregated grains, the kurtotic values indicate the mesokurtic conditions, and the skewness value yields very positive to positive data, so that predominantly the lithology is sedimented in the form of fine-grained lithology. The results of this analysis prove that the sedimentation acies in Sawahlunto Formation are facies deposited on the meander environment.

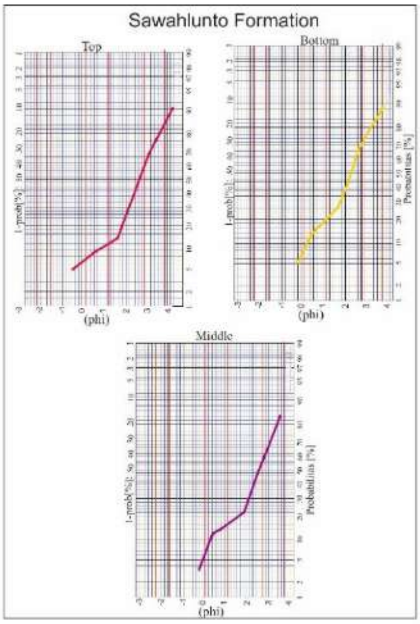

Figure 11. Probability curve for sedimentation analysis in Sawahlunto Formation

Granulometric analysis performed on each part of the Sawahtambang Formation generally yields a probability curve showing a sedimentation mechanism in the form of saltation (Figure 12). The results of the statistical analysis on each part of this formation also generally show the standard deviation (SD) values tend to be poorly disaggregated, the kurtosis values indicate very leptokurtic to platykurtic conditions, and the skewness value produces negative to nearly symmetrical data, so the dominant lithology sedimentation of coarse grained lithology. The result of this analysis proves that the sedimentation facies in Sawahtambang Formation are facies deposited in the braided environment.

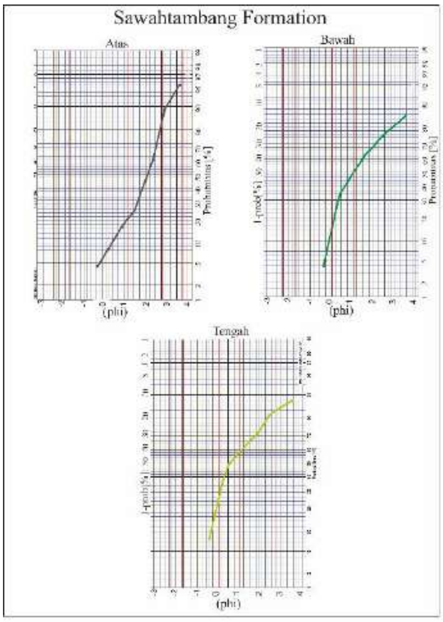

Figure 12. Probability curve for sedimentation analysis in Sawahtambang Formation

ANALOG RESERVOIR

The reservoir characteristic is a process to describe qualitatively and quantitatively the reservoir character using all available data (Sukmono, 2002). The reservoir characteristic is important to observe the subsurface condition, especially in the oil and gas reservoir sections. Determination of this reservoir is focused on the clastic sediment of sandstone. Sampling of sandstones was performed on stratigraphic columns from measurable cross-sectional measurements in the Sawahlunto Formation and Sawahtambang Formation. The reservoir-analyzed sandstones are at the bottom, middle and top of the stratigraphic columns of each formation, so they can show better reservoir characteristics in the facies and the precipitation environment of the sandstone.

Based on porosity calculation result using bluedye petrography method, it is found that 3 samples taken at the bottom, middle, and top of the Sawahlunto Formation have porosity value with a considerable range, ie 19.6 - 48.4%. While 3 samples from Sawahtambang Formation have porosity value with range 27,5 - 28,8% (Table 1). Then the porosity value of these two formations is inserted into the table of good rock porosity classification as reservoir by Koesoemadinata (1978). Based on the classification table, it is found that 2 samples in Sawahlunto Formation (R 04 and R 05) have a special porosity value of rock as reservoir, while one other sample has good rock porosity value as reservoir. Then 3 samples on the Sawahtambang Formation have a very good porosity value of rock to be reservoir.

In general, the samples from these two formations possess the ability of reservoir rocks, except that based on rock pore conditions of each sample in thin section, the 3 Sawahlunto Formations do not show the interconnected pore conditions of each other, whereas 3 Sawahtambang Formation samples show a pore condition which are interconnected with each other (Figure 13).

Table 1. Porosity and permeability value

Sample	Pearmebility (mD)	Porosity (%)
R 01	189	28,8
R 02	204	29,9
R 03	183	27,5
R 04	260	31,7
R 05	325	48,4
R 06	73	19,6

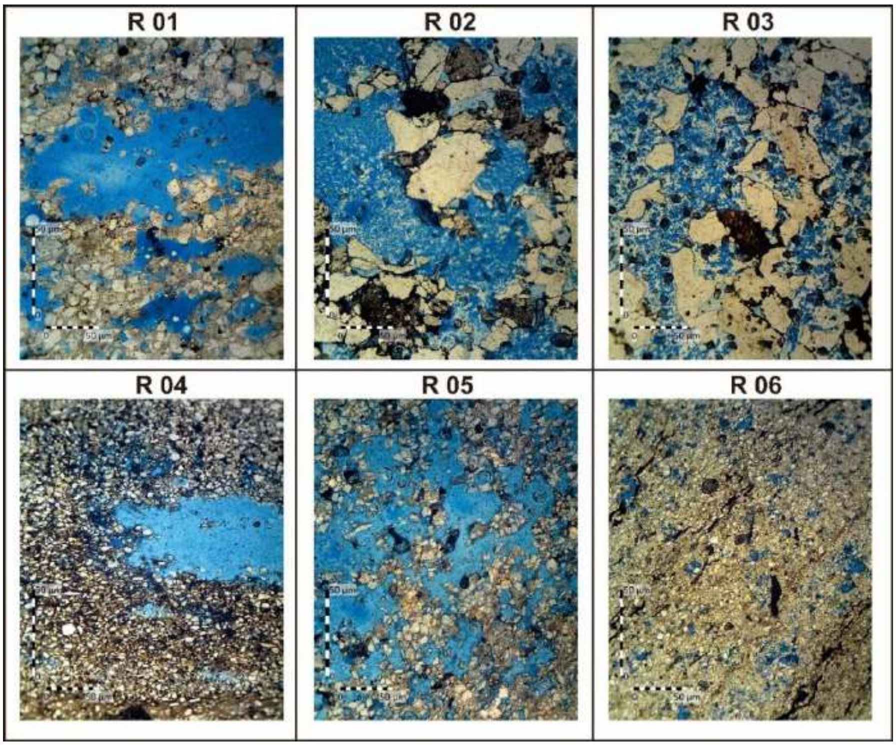

Figure 13. Thin section using bluedye petrography method to know porosity on Sawahtambang Formation (R 01, R 02, R 03) and Sawahlunto Formation (R 04, R 05, R 06)

DIAGENESIS

The comparison of the diagenesis process in formation form it can know the condition of the growing reservoir. The first diagenesis requires compilation of compactions. The process of lithologic compaction will affect porosity. The relationship between the grains will show the pattern can affect the pores between the grains. In the sample R 04 is characterized by the change of clay minerals that continue to contain the compaction so that it becomes transformed into mica. In that example the grains in lithology have interrelated patterns of relationships that can be categorized as pseudomatrics. This causes the gap between the grains that function as the pores will be more closed and grains together. Compaction process it causes the relationship of granules in the sample R 04 Sawahlunto Formation included in the concave convex category. In example R 03 does not fit significantly. It is based on data showing the pattern of relationship between the grains are not fused because it still has a high pore. In addition, the relationship between the grains present in the sample R 03 is the point of contact. The percentage of porosity based on the lithologic compaction on the samples R 01, R02, R03, R 04, R05, and R06 were 19%, 19%, 17%, 15%, 15%, and 14%. Based on these data, the lithologic compaction diagenesis will bring the quality of porosity so that the composition of the dominant mica and the relationship between the grains together into the pseudomatrix category and the porosity becomes low.

The next diagenesis is the cementation of the lithology. This is nowadays when the finer sedimentary material fills the interstellar cavity and becomes the granular binder it can cause the porosity percentage to decrease. From the analysis performed on both formations it can perform the percentage comparison of cementation on both samples and can be developed into porosity percentage. Based on the sample. The arrangement of mutual funds. Mutual funds. Mutual funds. While the sample R 05 has a cementation composition of 10% and a porosity of 15% and sample R 06 cementation 10.5% and porosity 14%. Based on these data it can provide information about the condition of lithology that has a dominant cement composition then it can cause the porosity percentage of reduced cementation capacity is not dominant then the percentage of porosity will increase. Based on diagenesis condition of each sample having reference to compaction and cementation then can compare the quality of reservoir. Referring from the data that has been analyzed it can be concluded with the quality of reservoir Sawahtambang Formation better with Sawahlunto Formation.

DISCUSSION

Research in reservoir determination in this study only surface data used so that to further accurate data analysis need to know the subsurface data. Although the result of reservoir analysis shows Saawahlunto Formation sample is smaller than Sawahtambang Formation sample, Sawahtambang Formation is considered to have better ability as reservoir because it has interconnected rock pores, making it easier to drain fluid. Based on research by Koning (1985), Sawahtambang Formation has better potential to be reserved compared with Sawahlunto Formation. Thus it can be correlated with the results of research of researchers, although with different research methods. Thus indicating that the braided river system deposition with main channel facies is more potential in reservoir determination due to the uniformity of the granules that make the pore cavity closely related.

CONCLUSION

Based on data from stratigraphic cross-sectional measured shows the depositional environment of Sawahlunto Formation is deposited on the meander river system and Sawahtambang Formation is deposited on braided river system environment. Facies analysis based on lithostratigraphy data and sedimentary structure at paleogen period of research area consist of flood plain, overbank and channel facies. Based on reservoir analysis with petrographic method and water volume calculation indicated that Sawahtambang Formation has more potency to have sandstone reservoir included in good until excellent with porosity value 27% - 29% and pearmeability 183-204 mD(Koesomadinata, 1978).

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