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Interpretation of paleodepositional environment using biomarkers and carbon isotope ($\delta^{13}\text{C}$) in Talang Akar Formation, South Sumatra Basin, Indonesia.

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Abstract. Talang Akar Formation is a proven hydrocarbon source rock in South Sumatra basin. The formation contains dominant shale at the top, with some sandstone interbeds. This study uses 3 crude oil sample and 10 well-cutting obtained from two well (SMT-1 & SMT-2) in Prabumulih oil field. We used biomarkers and carbon isotopes ($\delta^{13}\text{C}$) data to determine the paleodepositional environment of Talang Akar Formation. The biomarkers data were obtained from gas chromatography (GC) and gas chromatography-mass spectrometry (GC-MS) analysis of normal alkanes, isoprenoids, triterpene, and steranes. Carbon isotopes ($\delta^{13}\text{C}$) include saturated and aromatic fractions. The pristine (Pr) to phytane (Ph) ratio is a good indicator of the depositional environment. Higher values of Pr/Ph ratio i.e. ≥ 3.0 indicate oxidizing conditions i.e. terrestrial while lower values in the range of 1.0-3.0 suggests siliciclastic-dominated marine conditions. However, very low values i.e. ≤ 1.0 indicate reducing conditions or fresh and brackish water conditions. The results in this research show that Pr/Ph ratios range from 7.90-16.66, characteristic of high wax crude oils, primarily originated in fluvial and deltaic environment containing a significant amount of terrestrial organic matter. Similarly, the resultant ratios of Pr/n-C₁₇ and Ph/n-C₁₈ in SMT-1 and SMT-2 wells range from 0.91-10.72 and 0.11-1.29 respectively, which reflect that most of kerogen was derived from humic source and tend towards an oxidative environment of deposition. Cross-plot of carbon-13 isotopes ($\delta^{13}\text{C}$) shows saturated versus aromatic fraction. The resultant plot indicate a deltaic to marginal marine environment for SMT-2 well and a more marine environment for SMT-1 well. The oil/source rock correlation analysis using biomarker data shows that the oils in Prabumulih field is correlated with the oils in source rock of Talang Akar Formation. This study concludes that the source rock contains abundant humic organic matter that was deposited in a transitional (Fluvio-deltaic) to marginal marine environment under oxic conditions.

1. Introduction

Opportunities to increase petroleum exploration and exploitation, especially in the South Sumatra Basin, must be supported by integrated study such as geological, geophysical and geochemical studies to get better results. Geochemical research has been carried out to increase petroleum exploration and exploitation. Starting from research on the chemical composition, oil-oil and oil-source rock correlations. Organic geochemistry is generally used to evaluate basins, plays and prospects. As a



prerequisite for understanding organic geochemistry, the formation of oil and gas beneath the earth's surface must be well understood [1].

Biomarkers are a highly developed part of organic geochemistry. Biomarkers are used to identify compounds contained in sediments that have a clear structural relationship with compounds of biological results. One of the uses of biomarkers in petroleum exploration is to identify the depositional environment and organic material. This study aims to characterize the samples and oil-source correlations by using biomarker were obtained from gas chromatography (GC), gas chromatography-mass spectrometry (GC-MS) and Carbon isotopes ($\delta^{13}\text{C}$) analyzes.

The South Sumatra Basin is a large basin divided into sub-basins as Jambi sub-basin (North Palembang), Central Palembang sub-basin, South Palembang sub-basin (Complex Palembang) [2][3]. The South Sumatra Basin includes proven active exploration lands as one of the large oil and gas producing regions except Kasai Formation, all formations including basement rocks have been proven potentially produce hydrocarbons. The South Sumatra Basin is an asymmetric basin bounded to the west and south by faults and uplifted exposures of pre-Tertiary rocks along the Barisan Mountains, to the north east by the sedimentary or depositional boundaries of the Sunda Shelf. The south-east boundary is represented by the Lampung High [4][5].

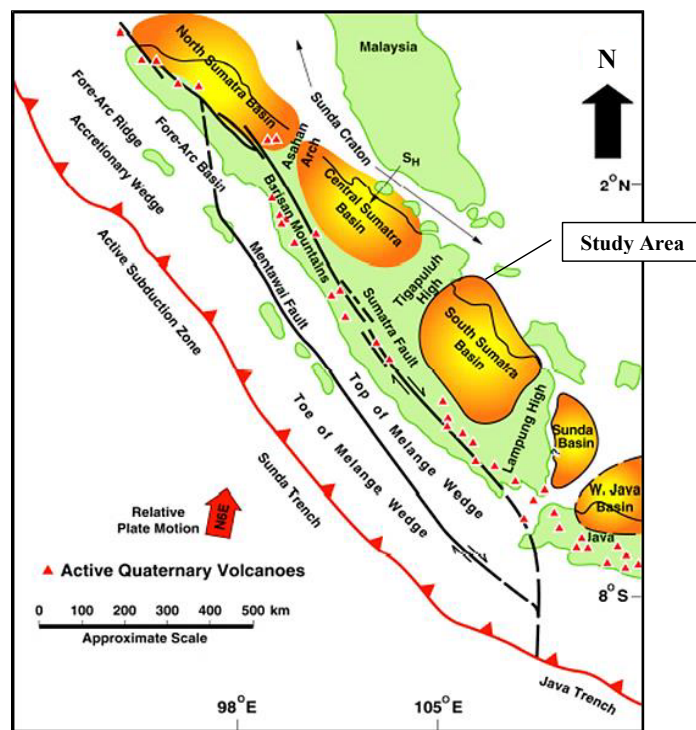


Figure 1. Location map of the study area [6].

2. Stratigraphy of South Sumatra Basin

Stratigraphy in South Sumatra Basin was control by process of megacycle system of transgression and regression sedimentation in regionally, just like sedimentation in west Indonesia (Figure 2).

Talang Akar Formation (TRM) is dominated by shale, siltstone, sandstone, lime-stone streak, and coal. Coals are found along the upper part to the bottom. The Upper part is composed by shale, sandstone and limestone streak. Sandstones are medium porosity, white to colored, fine to medium hard, fine to medium grain, sub rounded to sub angular, medium sorted, calcareous cemented, containing glauconite minerals. Shale are brown to brown grey, medium hard, blocky, slight calcareous cemented and trace carbonate speck. Siltstone are light grey to grey, medium hard, sandy, consolidated, slight calcareous, trace carbon speck. The bottom part is dominated by shale, sandstone, minor siltstone, and coal layer. Shale are brown to dark brown, medium hard, blocky to platy, non-calcareous, silty, carbonaceous. Sandstone are medium porosity, colored to off white, fine to medium grain, trace coarse grain, sub rounded, medium sorted, carbonate speck [7].

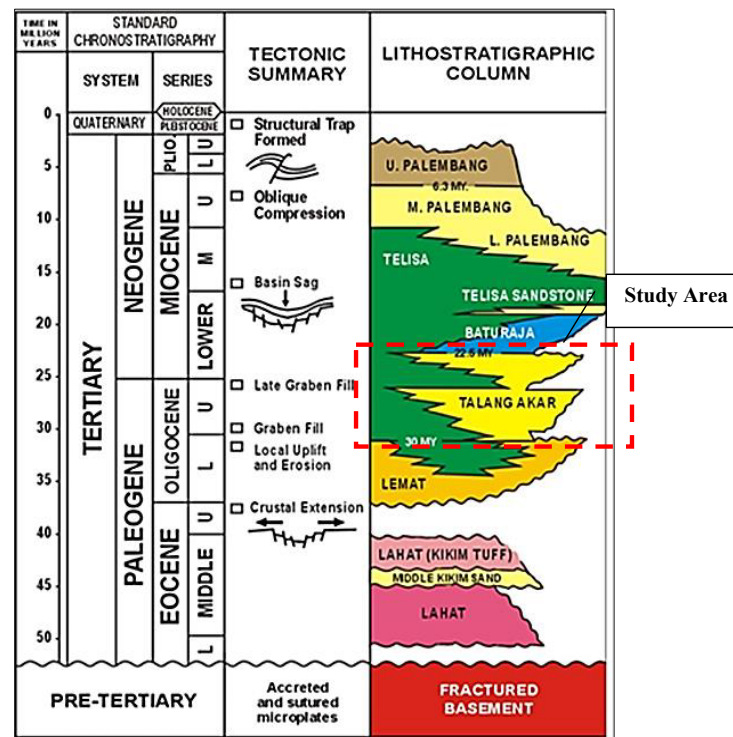


Figure 2. Stratigraphy of South Sumatra Basin [5].

The principal source rocks in the South Sumatra Basin are fluvio-deltaic marine, locally lacustrine and coaly facies of the Late Eocene to Middle Oligocene Lemat, and Late Oligocene to Early Miocene Talang Akar Formations. These rocks were deposited in the grabens and half grabens forms during the Late Cretaceous to Early Oligocene, and contribute to terrestrial derived oils. In addition, shales of the Telisa Formation provide a marine/paralic hydrocarbon source. Talang Akar sandstones constituted the

main reservoir target and the potential traps are anticlinal structure that developed in response to Plio-Pleistocene compression. The Baturaja limestones are the other prime reservoir target; the traps are structural or combined structural and stratigraphic trap potential has also been identified in the Baturaja Formation, with the potential trap dependent on facies change from porous reefal to tight platform carbonates [8].

3. Research Methods

This study uses 3 crude oil sample and 10 well-cutting from two well (SMT-1 & SMT-2) in Prabumulih oil field. Based on biomarkers and carbon isotopes ($\delta^{13}\text{C}$) data to determine the paleodepositional environment of Talang Akar Formation. The biomarkers data were obtained from gas chromatography (GC) and gas chromatography-mass spectrometry (GC-MS) analysis. Carbon isotopes ($\delta^{13}\text{C}$) include saturated and aromatic fractions.

4. Results and Discussion

From previous work about oil–oil and oil–source rock correlations of the South Sumatra Basin reservoirs compared four groups of oils that have different characters, namely oil derived from the sea or lacustrine, oil originating from a land deposition environment, petroleum derived from the depositional environment of lacustrine and biodegradable petroleum [9].

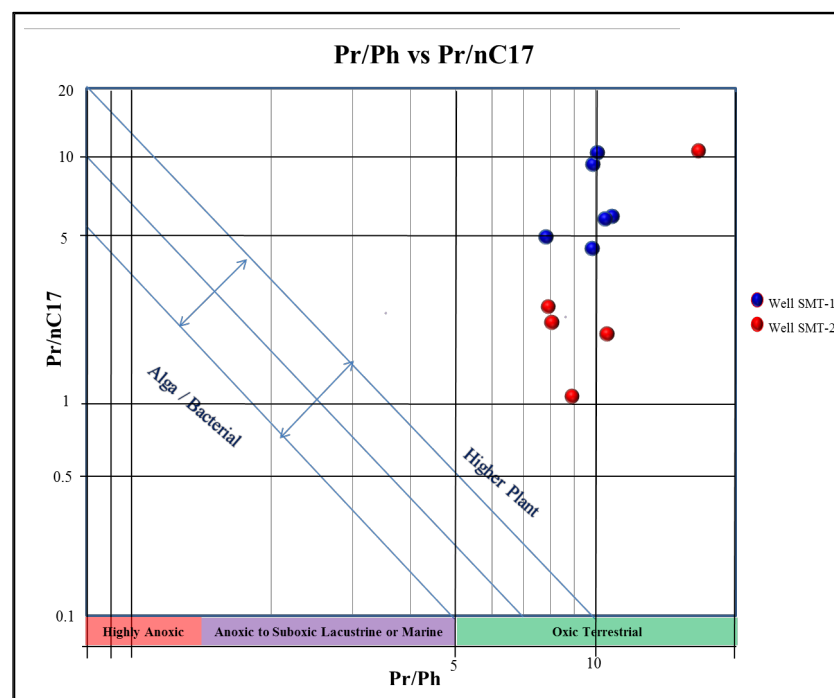


Figure 3. Plot of pristane/n-C17 versus pristane/phytane showing the depositional environment and the conditions of the studied rock samples.

Figure 3 shows a cross plot $\text{Pr}/\text{n-C}_{17}$ and Pr/Ph , the results in this research show that Pr/Ph ratios range from 7.90-16.66, characteristic of high wax crude oils, primarily originated in fluvial and deltaic environment containing a significant amount of terrestrial organic matter. The source rock samples in Prabumulih oil field are predominated by higher plant in oxic condition. Gas chromatography and gas chromatography-mass spectrometry analyses indicate that the oils in the South Sumatra Basin were derived from terrestrial higher plant material. These oils are characterized by high ratios of pristane to phytane. The comparison between Ph and Pr very high is a specific characteristic of coal. Ratio Pr/Ph is very high reflecting a condition the environment of deposition was very oxide. Three samples of coal shale and one other has a value of Pr/Ph is lower when compared with coal from the depths of 2885 m, although it is still quite high (> 3) to reflect an environment of deposition which is rich in oxygen. Oxidative environmental conditions that are reflected with ratio $\text{Pr}/\text{Ph} > 3$ the sediments analyzed deposited on areas that are associated with the delta and the coast. Thus it can be inferred that hydrocarbons produced by coal, petroleum or shale analyzed sediment is from a delta.

Lemat Formation has been considered as syn-rift sediments until now, consist of terrestrial sediment (fluvio-lacustrine), creating source rock with fluvio lacustrine characterization. While based on existing publications, showing that oil having fluvio-deltaic characterization and generated by source rock from Talang Akar Formation with fluvio-deltaic characterization. A number of potential reservoir rocks in the South Sumatra Basin occur within the regressive and transgressive sequences. The Muara Enim and Air Benakat Formations from the regressive sequences have good potential as reservoirs. The transgressive sequences are represented by the Talang Akar and Baturaja Formations.

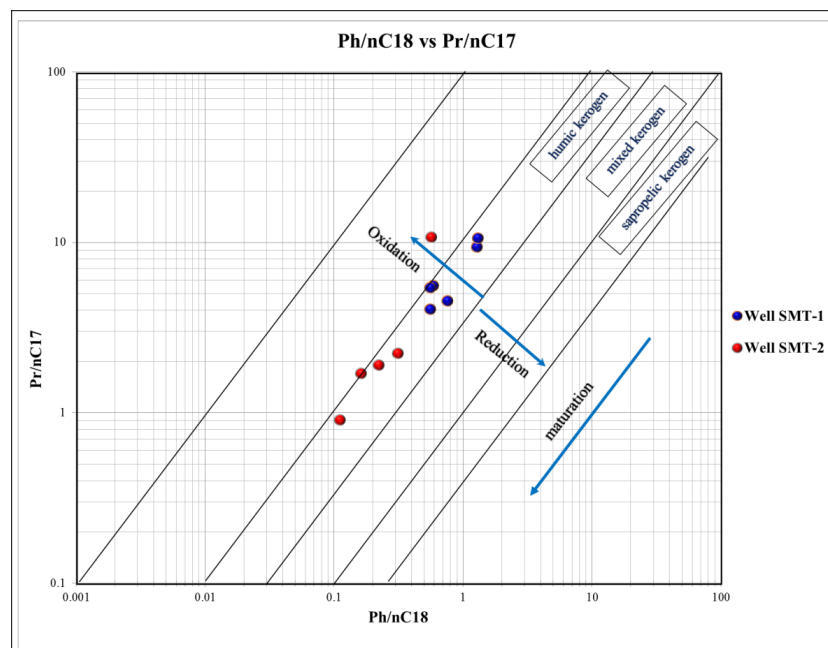


Figure 4. Plot of pristane/n-C17 versus phytane/n-C18 showing the organic sources and maturation of the studied rock samples.

The plot between Pr / n-C17 and Ph / n-C18 (Figure 4) obtained from GC data is done to analyze the oxidation conditions and type of organic material rock samples according to the classification, Pr/n-C17 and Ph/n-C18 ratios are used in addition to other parameters to determine source rock facies, maturity and the level of biodegradation of hydrocarbons. Low ratios indicate a more mature sample, because the isoprenoids will break down more readily than n-alkanes during maturation. The ratios can be used together with other parameters to rank related, non-biodegraded oils and bitumens based on thermal maturity. The ratio between the acyclic isoprenoids and n-alkanes can be used to estimate the origin of the organic matter and its maturity (Pr/n-C17 and Ph/n-C18). Lower plants, algae and bacteria contain smaller quantities of n-alkanes relative to acyclic isoprenoids, compared to the higher terrestrial plants but care should be taken because organic input and biodegradation may affect the ratio [10]. The resultant ratios of Pr/n-C₁₇ and Ph/n-C₁₈ in SMT-1 and SMT-2 wells range from 0.91-10.72 and 0.11-1.29 respectively, which reflect that most of kerogen was derived from humic source and tend towards an oxidative environment of deposition (Figure 4).

Cross-plot of carbon-13 isotopes ($\delta^{13}\text{C}$) shows saturated versus aromatic fraction indicate a deltaic to marginal marine environment for SMT-2 well and a more marine environment for SMT-1 well. Deposition of the Talang Akar Formation began in the Late Oligocene in the form of alluvial fan and braided stream environments filling topographic lows and depressions. Therefore, the Talang Akar Formation locally occurs overlying the pre-Tertiary rocks. This sedimentation continued in Early Miocene in a fluvial, deltaic and marginal-shallow marine environment. During the time, the connection to open marine conditions became more significant and the sea gradually encroached into the basin.

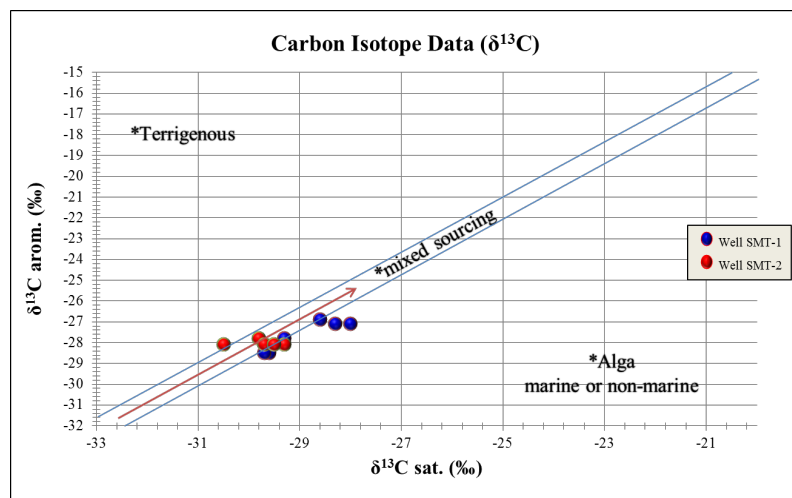


Figure 5. Plot of carbon-13 isotopes ($\delta^{13}\text{C}$) showing the depositional environment of the rock samples.

All samples contain C27-C29 steranes. In some cases the relative abundance of C27-C29 steranes can be used as indicators of the nature of the photosynthetic biota, both terrestrial and aquatic, while triterpanes are usually indicators of depositional and diagenetic conditions [11]. Land plant inputs are usually inferred from a dominance of the C29 steranes. The C29 steranes of this type of crude were not derived from C29 sterols of land-plant origin (frequently proposed as the source of C29 steranes). The

presence of these compounds shows a high contribution from terrestrial plants, especially from dipterocarpaceae species which produce resin. Biomarker compound with composition $C_{29} > C_{28} < C_{27}$, giving an indication of the dominant contribution of organic matter from terrestrial plants. The presence of diasterane compounds that are quite dominant indicates that the source rock of oil is deposited in an environment rich in clay minerals. The composition of styrene shows $C_{29} > C_{28} < C_{27}$ which gives an indication of the origin of mixed organic matter between algae and terrestrial plants.

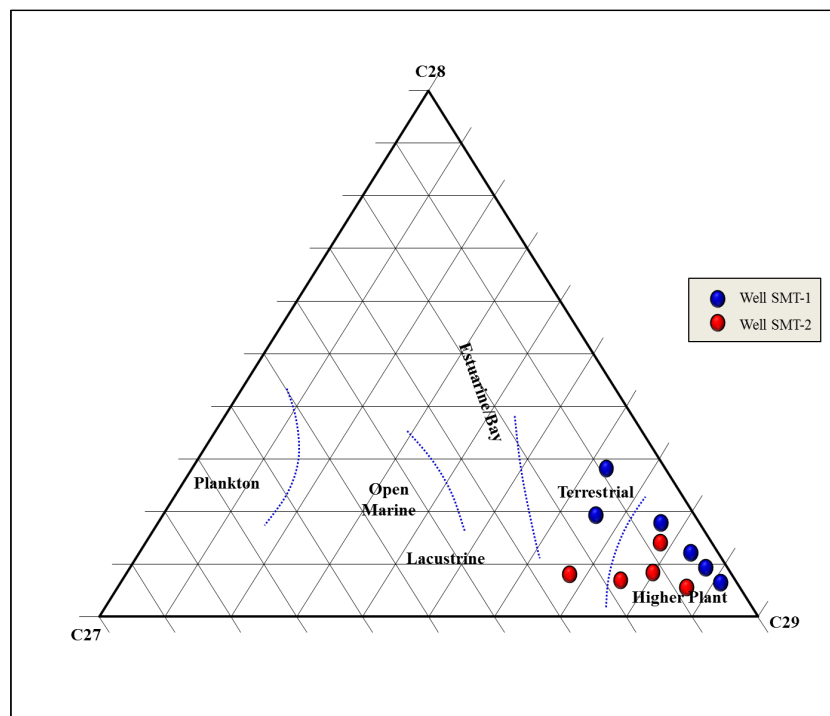


Figure 6. Facies interpretation using triangular diagram displaying C_{27} - C_{29} steranes distribution [12].

The depositional environment of the study area is a transitional environment for oxic conditions with material organic higher plants and marine algae. Based on oil–oil and oil–source rock correlations, Talang Akar Formation those were depositional environment (transitional) and precursor (terrestrial) [12].

5. Conclusions

Pristane to phytane ratios of the samples are relatively high ranging from 7.90-16.66. Higher values of Pr/Ph ratio i.e. ≥ 3.0 indicate oxidizing conditions i.e. terrestrial while lower values in the range of 1.0-3.0 suggests siliciclastic-dominated marine conditions. However, very low values i.e. ≤ 1.0 indicate reducing conditions or fresh and brackish water conditions

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