

Characteristic of the Source Rock Of The Lahat and Talang Akar With Crude Oil In Sarolangun, Jambi sub-basin, Indonesia

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Abstract

The research location is situated in Sarolangun, Jambi Province, within the Jambi Sub-Basin. Oil has been produced in the Jambi Sub-Basin study area from Paleogene-Neogene aged source rocks. However, the success ratio of oil discovery in the Jambi Sub-Basin remains at 51%. This study aims to determine the geochemical aspects in characterizing the source rocks and oil. The data used for analysis include total organic carbon, rock pyrolysis, vitrinite reflectance, and biomarkers. Geochemical characterization of the Lahat Formation source rock reveals a kerogen type II-III, generating oil and gas, while the Talang Akar Formation has a kerogen type II, producing oil, and the upper part of the Talang Akar Formation also has a kerogen type II, generating oil. The Lahat Formation biomarker consists of higher plants and algae in anoxic conditions, with high C29 sterane and early mature Tm/Ts ratio. The lower part of the Talang Akar Formation biomarker has lacustrine-marine algae organic material in anoxic conditions, with high C27 sterane and early mature Tm/Ts ratio. The upper part of the Talang Akar Formation biomarker has higher plant and marine algae organic material, with high oleanane and early mature Tm/Ts ratio. The produced oil has biomarker characteristics indicating deposition in anoxic conditions, with a mix of algae-higher plant organic material, and early mature Tm/Ts ratio. Based on these results, the oil is positively correlated with the Talang Akar Formation, indicating that the organic material originates from a marine or lacustrine depositional environment.

Keyword: Geochemistry, Source rock, Jambi Sub-Basin.

1. Introduction

1.1 Sub Introduction

South Sumatra Basin is a potential and mature basin for hydrocarbon source. There are a number of sub-basins which is potential as the hydrocarbon source in this basin (Syaifuddin, 2016). The Jambi Sub-Basin, part of the South Sumatra Basin, is a sedimentary basin that has produced oil and gas, accumulated in Paleogene-Neogene aged source rocks (Satyana and Purwaningsih, 2003).

The Jambi sub-basin is part of the Tertiary sedimentation basin of South Sumatra, which is currently one of the locations for oil and gas exploration. In the Jambi Sub-basin there is a Gumai Formation which is composed of quite thick deep marine shale (Setyawan et al., 2020).

The Ministry of Energy and Mineral Resources (MEMR) in Indonesia plans to intensify exploration in the upstream oil and gas sector, seeking new reserves across Indonesia, in response to declining oil production and anticipated future decline in natural gas production (Zajuli et al., 2023).

Research on geochemistry has been conducted to enhance the exploration and exploitation of petroleum resources. This involves analyzing the chemical composition of oil and correlating it with potential source rocks. The field of organic

geochemistry plays a crucial role in assessing the potential of sedimentary basins, plays, and prospects for hydrocarbon accumulation (Syamsuddin et al., 2019).

The Sarolangun research area, located within the Jambi Sub-basin, is a hydrocarbon-producing region with a 51% success ratio in hydrocarbon production, despite limited exploration efforts (Jamaluddin, Maria and Ryka, 2019). The Jambi Sub-Basin features several key formations, including the Lahat Formation, Talang Akar Formation, Gumai Formation, and Air Benakat Formation, which serve as important reservoirs.

The source rock of the Talang Akar Formation is currently within the oil maturity window, ranging from early mature to peak mature, with no gas maturity window present, as indicated by vitrinite reflectance values ranging from 0.5-1.2% Ro. Burial history modeling also supports that maximum sediment burial occurred during the Pliocene (Sigit Wibowo, S., & Subroto, E. A., 2017).

The research area itself has seen a lot of conventional prospecting by companies and local residents. In fact, many illegal wells have been discovered in the research area in the village of Lubuk Napal. Under these conditions, oil can be reached at a low depth of 100-150 meters, possibly traps and migration have occurred on a large scale in the research area.

Given the limited research on oil and source rock in the Sarolangun area of the Jambi Sub-Basin, this study aims to conduct a more in-depth investigation into the geochemical aspects related to the origin and formation of oil in the region.

1.2. Aims and Objectives

The primary objective of this study is to analyze the characteristics of the source rocks of the Lahat and Talang Akar Formations and crude oil in the study area. Specifically, the research aims to establish a correlation between the source rocks of the Lahat and Talang Akar Formations and crude oil, based on the origin of organic material, depositional environment, and level of organic maturity, as determined through geochemical analysis.

1.3. Research Location

The research location is situated in Sarolangun Regency, Jambi Province, Indonesia (Figure 1). The study area comprises two sites: Bukit Suban village, which is partially located within the protected forest area of "Bukit Dua Belas National Park" and serves as a lithological sampling site, and Lubuk Napal village, where crude oil samples were collected (Figure 1). The Bukit Suban site is approximately 2 hours from Sarolangun city, while the Lubuk Napal site is about 1 hour from Sarolangun city.

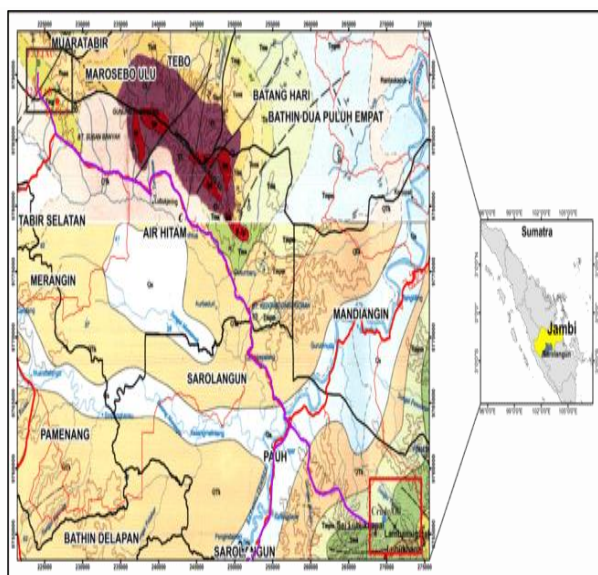


Fig. 1. Research Location Map (Arcmap)

2. Research Method

The study began with the determination of outcrop sample that penetrate the Lahat Formation and then Talang akar Formation which have shale layers in them.

Source rock evaluation was conducted to determine the richness of organic material, kerogen type, and maturity of the source rock. The richness quality was classified according to Rock-Eval Pyrolysis analysis was used to obtain the necessary data. This study focused on evaluating the Lahat and Talang Akar Formation (both Upper and Lower members) to assess the richness of organic material and maturity in shale lithology.

The basic source rock analyses comprise screening, kerogen typing, and maturation. Further analysis, such as correlation between source rock and crude oil as well as crude oil to crude oil, has been done by using more sophisticated techniques, Biomarker. Qualitative data

comprise evaluation based on chromatograms and mass-fragmentograms,

3. Stratigraphy Of The Study Area

Based on (Ginger and Fielding, 2005), stratigraphically old to young tertiary time is composed of Formation: Lahat, Talang akar, Gumai, Baturaja, Air benakat, Muarenim and Kasai (Figure 2).

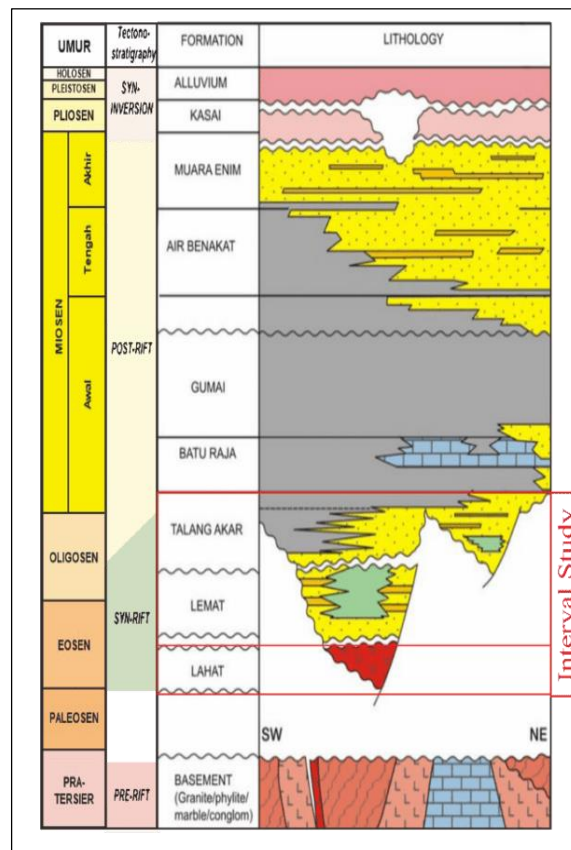


Fig 2. Regional stratigraphy of the South Sumatra Basin (Ginger and Fielding, 2005). The red box is the focus of the study area. (Ginger and Fielding, 2005).

1. Basement/Pre-tercier

The basement rock of South Sumatra and Central Sumatra is a Pre-Tertiary complex consisting of Mesozoic rocks and Paleozoic-Mesozoic metamorphic rocks. Based on radiometric dating results, this basement rock was formed during the Late Cretaceous period and extends up to the Paleocene-Eocene epoch (Bishop, 2001).

2. Lahat Formation

The earliest sedimentary rock deposited in the South Sumatra Basin system is the Lahat Formation, which was deposited unconformably and is only visible in the deepest part of the basin. The formation was deposited in an onshore or alluvial-fluvial to lacustrine environment. The Lahat Formation is very thin or even absent at the edge of the graben and intra-graben sections, whereas in the South Palembang Sub-Basin and Central Palembang Sub-Basin areas, it reaches a thickness of over 1000m.

3. Talang Akar Formation

This formation typically exhibits a gradual shift in depositional environment, transitioning from a lower fluvial setting to a deltaic environment. Lithologically, it comprises fine to coarse-grained sandstones, occasionally conglomeratic, with interbedded coal and shale. The sandstones are relatively

well-sorted, clean, and occur in thick layers with good porosity. In the Geragai area of the Jambi Sub-Basin, samples from the Lower Talang Akar Formation reveal an average value of 1.84%, ranging from 0.15% to 8.55% (Setyawan et al., 2020).

The Late Paleogene Talang Akar shales contain lack of organic carbons based on the TOC data and the S1+S2 values, suggesting poor to fair potential source rocks for generating a significant amount of oils (Sutriyo, E., Hastuti, E. W. D., & Susilo, B. K. 2016).

4. Gumai Formation

Transgression continued during the late Early Miocene and formed marine shale, siltstone, and sandstone deposits called the Gumai Formation with scarce carbonate deposits at the top of the basement. Glauconite shale dominated throughout the basin during peak transgression, forming a regional seal.

5. Baturaja Formation

The Baturaja Formation is included in the equivalent age range of planktonic foraminifera with an age range of N5- N6 Early Miocene. Other carbonate rocks are shale and calcareous shale deposited in a deep marine environment. Carbonates with good reservoir quality are generally found in the south of the basin and in the northern part of the Jambi Sub-Basin are rare (Ginger and Fielding, 2005). This formation was deposited continuously on top of the Talang Akar formation and consists of limestones. The build-up in the formation is associated with a carbonate platform. It has massive properties, with coral and algae boundstones overlying foraminifera grainstones, wackestones, packstones, and marls. The facies indicate the presence of open reef shoal, fore-reef, and back-reef sediments (Riskha, H. et al. 2017).

6. Air Benakat Formation.

During the middle Miocene a regression process occurred with the emergence of a change in the depositional environment of the deep sea to a shallower sea. With few exceptions in the center of the basin, sandstone reservoirs of quality are widespread throughout the South Sumatra Basin. In are berau, shale Air Benakat was analysis TOC value generated by the sample has a range of 0.38-0.42% (Afifah and Setiawan, 2019).

7. Muara Enim Formation

The Muara Enim Formation represents the final stage of the Tertiary regression phase. The formation was deposited conformably above the Air Benakat Formation in shallow marine, deltaic plain and non-marine environments. The thickness of the coal seam thins from south to north in the South Sumatra Basin. While the thickness of this formation varies in maximum thickness up to 50-750 m, with the age interpreted as Late Miocene to Pliocene (Ginger and Fielding, 2005).

The sedimentary environment and coal-bearing formation in Seam M2 of the Muaraenim Formation in Kendi Hill, South Sumatra, based on the measured stratigraphic cross-section, are Transitional Lower Delta Plain with sub-environments including crevasse splay, swamp, and distributary channel (Rajagukguk, Y.M & Nalendra, S, 2018)

8. Kasai Formation

According to (Ginger and Fielding, 2005), this formation was deposited during the formation of the Pliocene-Pleistocene mountain range and is largely the product of erosion derived from uplift by Bukit Barisan and the Thirty Mountains as well as uplift of the folds formed.

4. Regional Geologic Structure

The formation of the South Sumatra Basin is divided into four stages of tectonic megasequence phases (Pulunggono,

Haryo and Kosuma, 1992). The first phase, Upper Jurassic - Lower Cretaceous, was a compressional phase characterized by dextral shear faults, including the Lematang, Kepanyang, Saka, Musi, and South Coast of Lampung Lineament, accompanied by north-south trending wrench movements and granite intrusions.

The second phase, Upper Cretaceous - Lower Tertiary, was an extensional phase marked by the formation of north-south trending normal faults, resulting in the creation of graben and depressions. Sedimentation filled the basin, depositing the Lahat Formation on the bedrock, accompanied by volcanic activity.

The third phase, Miocene - Intra Miocene, involved uplift of the basin edges, followed by the deposition of clastic materials, including the Talang Akar, Baturaja, Gumai, Air Benakat, and Muara Enim Formations.

The fourth phase, Pliocene - Plistocene, was a compressional phase that led to the erosion of the Air Benakat and Muara Enim Formations in some areas, while the Kasai Formation was deposited in relatively lower areas. This phase also triggered northwest-directed uplift and folding throughout the basin, terminating Tertiary deposition. Additionally, volcanic activity occurred in the basin behind the arc.

The development of structures and the evolution of the South Sumatra Basin since the Tertiary period have resulted from the interaction of three primary structural trends: the northeast-southwest Jambi Pattern, the south-southeast Sumatra Pattern, and the north-south Sunda Pattern. This complex interplay has rendered the geological structure of the South Sumatra Basin more intricate than that of other basins on Sumatra Island. The Jambi Pattern is particularly evident in the Jambi Sub-basin, where northeast-southwest trending structures are closely associated with the formation of a graben system. The folding structures characteristic of the Jambi Pattern are attributed to the reactivation of normal faults during the Plio-Plistocene compressive period, accompanied by horizontal faulting (Ginger and Fielding, 2005).

5. Result

5.1. Evaluation of Source Rock

The quantity and quality of organic material can be determined by analyzing total organic carbon (TOC) data and rock-eval pyrolysis results. In the research area, the Lahat Formation sample (F1.FLA) has a TOC value of 1.18, indicating a good quantity of organic material.

The Lower Talang Akar Formation sample (F2.FTAB) has a TOC value of 3.18, suggesting a good to excellent quantity of organic material. The Upper Talang Akar Formation sample (F3.FTAU) has a TOC value of 4.06, indicating an excellent quantity of organic material (Magoon and Dow, 1994) (Figure 3).

Types of organic content are important in determining the potential of source rock. The material referred to this study is kerogen. Kerogen is an organic carbon deposited on rocks and composed of various organic contents such as algae, pollen, spores, and plant resins. Kerogen types will determine hydrocarbons that will be formed such as oil, gas, or oil and gas.

The type of organic content in the three samples was determined using Oxygen Index (OI) and Hydrogen Index (HI) values (Figure 4). The results are as follows:

Lahat Formation sample (F1.FLA): HI = 377 mg/gC, OI = 8 mg/gC, indicating a mixed kerogen type II/III capable of producing both oil and gas. Lower Talang Akar Formation sample (F2.FTAB): HI = 566 mg/gC, OI = 17 mg/gC, indicating a kerogen type II that is oil-prone. Upper Talang Akar Formation sample (F3.FTAU): HI = 545 mg/gC, OI = 32 mg/gC, also indicating a kerogen type II that is oil-prone (Magoon and Dow, 1994).

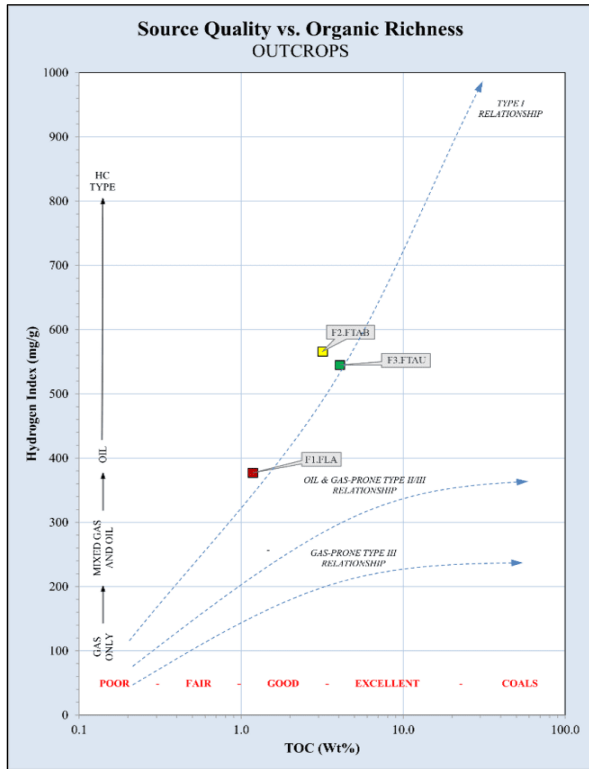


Fig 3. Crossplot of TOC vs HI, showing source rock quality and capability in area Bukit Suban, Sub-basin Jambi

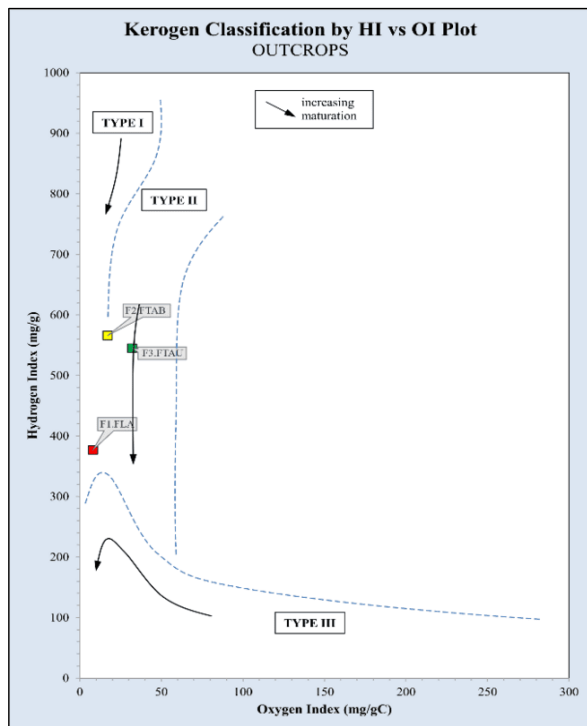


Fig 4. Crossplot diagram HI Vs OI sample source rock in area Bukit Suban, Sub-basin Jambi.

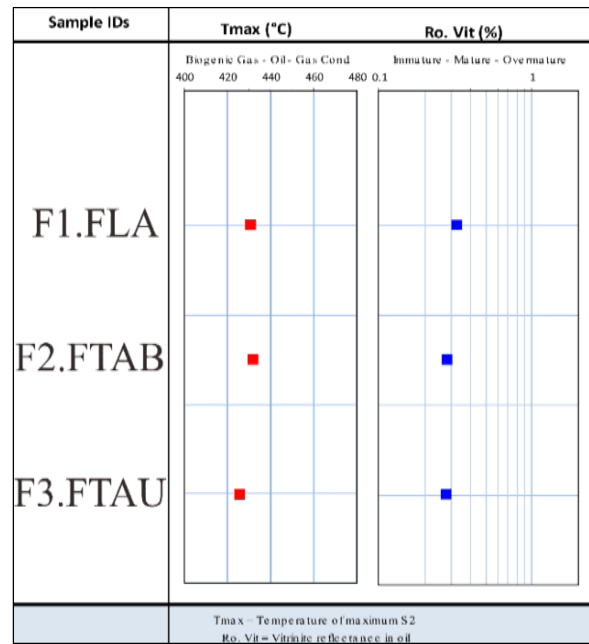


Figure 5. Maturity sample source rock of ratio Tmax and Ro in area Bukit Suban, Sub-basin Jambi.

The maturity of the organic material was determined using Tmax and Ro values. The results are as follows: Lahat Formation sample (F1.FLA): Tmax = 431°C, Ro = 0.33%, indicating an immature sample. Lower Talang Akar Formation sample (F2.FTAB): Tmax = 432°C, Ro = 0.28%, indicating an immature sample. Upper Talang Akar Formation sample (F3.FTAU): Tmax = 426°C, Ro = 0.28%, indicating an immature sample (Magoon and Dow, 1994) (Figure 5).

5.2. Source Rock- Oil Biomarker Analysis

5.2.1 Biomarker Source Rock

Gas chromatography biomarker analysis was performed to record normal alkanes and isoprenoids, utilizing normal alkane peaks, comparison plots of Pr/Ph values with Pr/nC17, and comparison plots of Pr/nC17 vs Ph/nC18. The results are as follows: Sample F1.FLA (Lahat Formation): normal alkane peak after nC22 is nC25. Sample F2.FTAB (Lower Talang Akar Formation): normal alkane peak after nC22 is nC29. Sample F3.FTAU (Upper Talang Akar Formation): normal alkane peaks after nC22 are nC25 and C29. The normal alkane peak patterns suggest that the organic material in all samples is derived from higher plants. (Figure 10)

Table 1. Value of ratio isoprenoid sample source rock

Kode Sample	Pr/Ph	Pr/nC17	Ph/nC18
F1.FLA	0.65	0.85	1.21
F2.FTAB	0.69	0.90	0.93
F3.FTAU	0.08	1.00	34.07

Additionally, isoprenoid analysis (Table 2) and the Pr/Ph vs nC17 plot diagram (Figure 6) reveal that the organic material in the source rock samples is of algal/bacterial origin, deposited in a highly anoxic environment. Specifically, the Lahat Formation sample F1.FLA, Lower Talang Akar Formation sample F2.FTAB, and Upper Talang Akar Formation sample F3.FTAU all exhibit similar characteristics, indicating a common depositional environment.

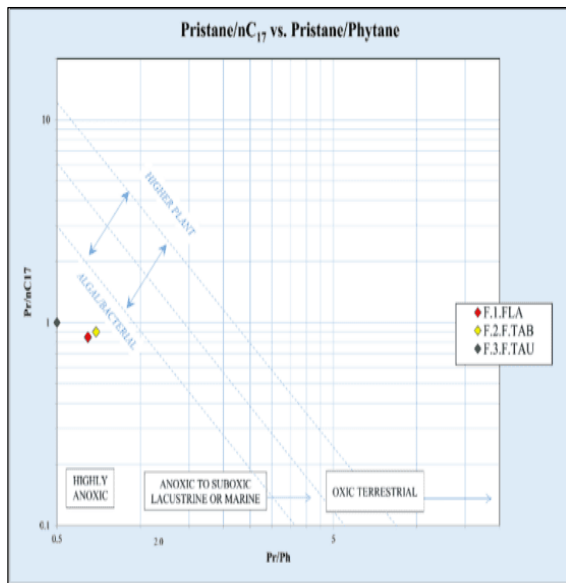


Fig 6. Crossplot sample source rock in area Bukit Suban, Sub-Basin Jambi.

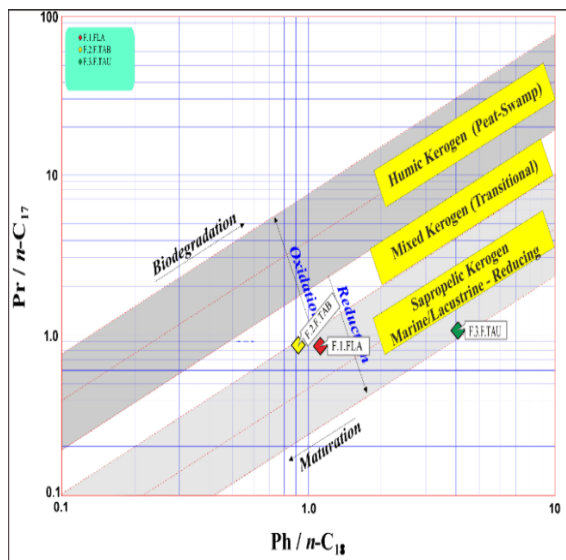


Fig 7. Crossplot Pr/nC17 vs Ph/nC18 source rock (Connan and Cassou, 1980) (Satyana and Purwaningsih, 2003).

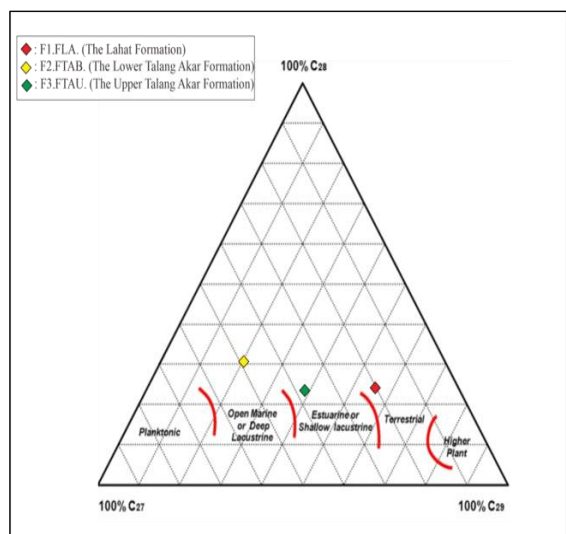


Fig 8. Diagram plot steranes C27-C29 sample source rock (Huang and Meinschein, 1979).

Pristane/phytane (Pr/Ph) ratios have been used to evaluate the redox potential of the depositional environment and the origin of organic matter (Didyk et al., 1978; Zhang and Huang, 2005; Duan et al., 2008; Hao et al., 2011; Hakimi et al., 2011; Cheng et al., 2013; and Tao et al., 2015; Syaifudin, M. and Subroto, E.A., 2024). A plot diagram of Pr/nC17 vs Ph/nC18 was used to interpret the origin and maturity of the organic material (Figure 7). The results indicate that: The Lahat Formation sample F1.FLA contains sapropelic kerogen, deposited in a reducing environment, and has reached maturity. The Lower Talang Akar Formation sample F2.FTAB also contains sapropelic kerogen, deposited in a reducing environment, and has reached maturity. The Upper Talang Akar Formation sample F3.FTAU contains sapropelic kerogen, likely derived from a marine environment (as indicated by a high Pr/nC18 value), deposited in a highly reducing environment, but has not yet reached maturity.

Sterane analysis was performed to determine the depositional environment (Table 2), utilizing diasterane. Hopane analysis performed using tricyclic terpane ion m/z 191 to determine the depositional environment. The results are as follows:

Lahat Formation sample F1.FLA: tricyclic terpane pattern indicates a lacustrine origin, with peak carbon values at C21, C24, and C26. Lower Talang Akar Formation sample F2.FTAB: tricyclic terpane pattern indicates a paralic shale origin, with peak carbon values at C21, C23, and C24. Upper Talang Akar Formation sample F3.FTAU: tricyclic terpane pattern indicates a deltaic/marine shale environment, with peak carbon values at C19, C21, and C23 (Figure 10).

Based on data of H29 and H30 (hopane) distribution, the pattern of H29 H30 is evaporates-carbonate sediment (Zumberge, 1984; Connan et al., 1986; Hakimi et al., 2011; Grosjean et al., 2012; Xiangchun et al. 2013; ten Haven et al., 1988 vide Rabbani et al., 2014; Wang et al., 2015; and Syaifudin, 2016; Syaifudin, M. and Subroto, E.A., 2024).

Additionally, analysis of the C29 and C30 hopane patterns reveals the depositional environment. The results indicate that Lahat Formation sample F1.FLA: clastic depositional environment, with a dominant C29 hopane peak. Lower Talang Akar Formation sample F2.FTAB: clastic depositional environment, with a dominant C29 hopane peak. Upper Talang Akar Formation sample F3.FTAU: clastic depositional environment (Figure 8).

Table 2. Value of distribution regular steranes m/z 217 source rock.

Kode Sample	C27	C28	C29
F1.FLA	19.24	25.25	55.31
F2.FTAB	47.30	31.67	20.90
F3.FTAU	38.00	24.37	37.66

The maturity level of the samples was analyzed using the Tm/Ts ratio and the C30M/C30H ratio, plotted on a diagram (Figure 10). The results are as follows:

Lahat Formation sample F1.FLA: Tm/Ts = 2.08, moretane/hopane = 0.10. Lower Talang Akar Formation sample F2.FTAB: Tm/Ts = 3.06, moretane/hopane = 0.14. Upper Talang Akar Formation sample F3.FTAU: Tm/Ts = 2.81, moretane/hopane = 0.23. Based on these results, all source rock samples in the study area are classified as early mature (Figure 9).

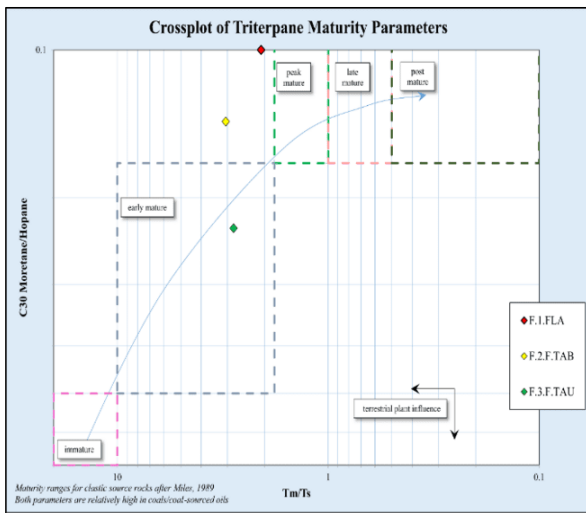


Fig 9. Crossplot ratio maturity Tm/Ts Vs C30M/C30H source rock.

Hopane analysis was performed using tricyclic terpene ion m/z 191 to determine the depositional environment. The results are as follows:

Lahat Formation sample F1.FLA: tricyclic terpene pattern indicates a lacustrine origin, with peak carbon values at C21, C24, and C26. Lower Talang Akar Formation sample F2.FTAB: tricyclic terpene pattern indicates a paralic shale origin, with peak carbon values at C21, C23, and C24. Upper Talang Akar Formation sample F3.FTAU: tricyclic terpene pattern indicates a deltaic/marine shale environment, with peak carbon values at C19, C21, and C23 (Peters et al., 2005b) (Figure 10).

Additionally, analysis of the C29 and C30 hopane patterns reveals the depositional environment. The results indicate that Lahat Formation sample F1.FLA: clastic depositional environment, with a dominant C29 hopane peak. Lower Talang Akar Formation sample F2.FTAB: clastic depositional environment, with a dominant C29 hopane peak. Upper Talang Akar Formation sample F3.FTAU: clastic depositional environment (Figure 8).

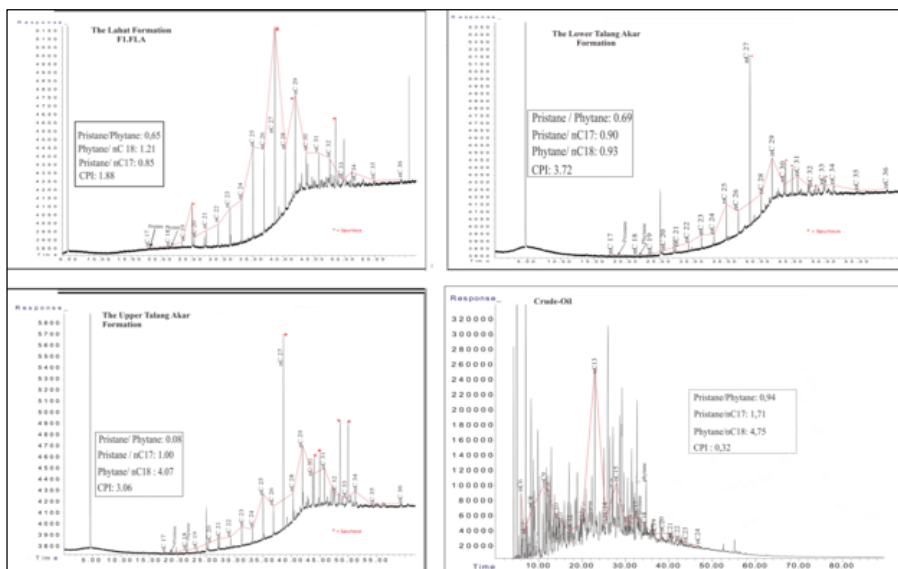


Fig 10. Gas Chromatography analysis sample source rock in area Bukit Suban, Sub-basin Jambi.

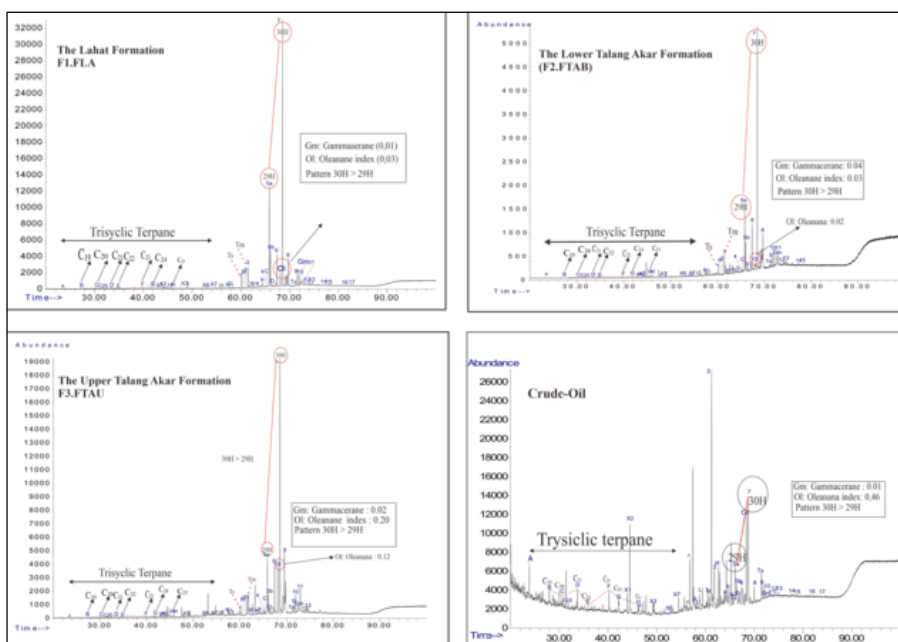


Fig 11. Analysis ion m/z 191 hopane sample source rock Bukit Suban, Sub-basin Jambi.

5.2.2. Crude-Oil Biomarkers

Gas chromatography biomarker analysis was performed to record normal alkanes and isoprenoids, utilizing normal alkane peaks, comparison plots of Pr/Ph values with Pr/nC17, and comparison plots of Pr/nC17 vs Ph/nC18. The normal alkane peaks from gas chromatography fingerprints indicate that the crude oil samples in the study area are biodegraded and contain organic material with normal alkane peaks before nC20, specifically at the nC13 carbon peak, suggesting a marine algae origin (Figure 12).

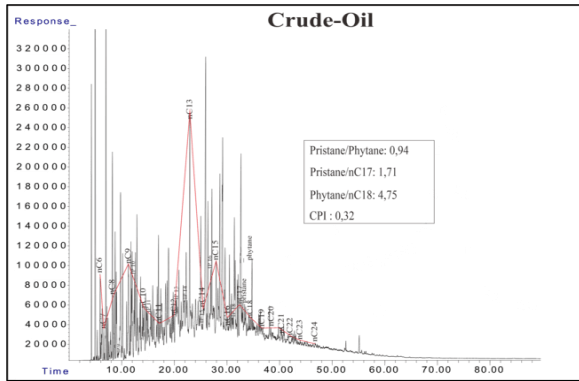


Fig 12. Finger print gas chromatography sample crude oil in area well lubuk napal

Isoprenoid analysis was performed, and the results are plotted on a Pr/Ph vs Pr/nC17 diagram (Figure 13a). The crude oil sample has a Pr/Ph ratio of 0.94 and a Pr/nC17 value of 1.71, indicating that it contains algae/bacterial organic material, as well as high-level plant material, suggesting a mixed origin.

Additionally, the Pr/nC17 vs Ph/nC18 plot (Figure 13b) shows that the crude oil sample has a Pr/nC17 value of 1.71 and a Ph/nC18 value of 4.75, indicating that it originates from marine algae, deposited in a highly reducing environment, and is immature.

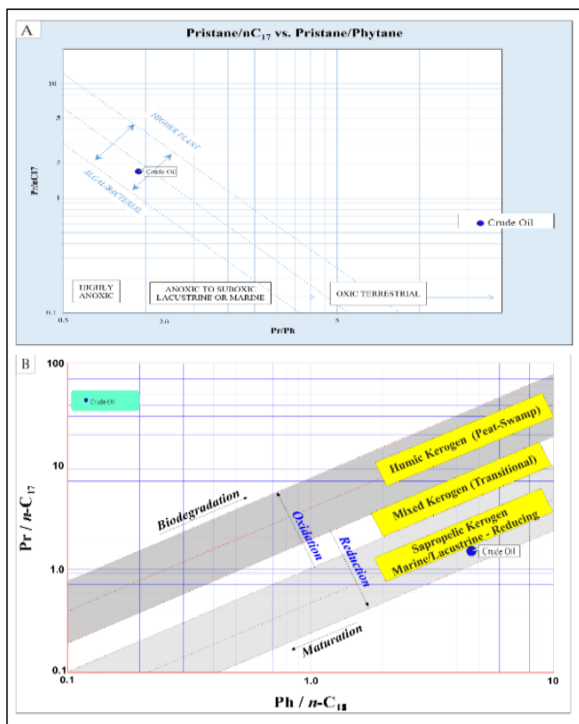


Fig 13. A. Crosplot Crude Oil ratio Pr/Ph vs Pr/nC17. B) Crossplot sample crude oil Pr/nC17 vs Ph/nC18.

Sterane analysis was performed to determine the depositional environment, utilizing diasterane data and the regular distribution of sterane (Huang and Meinschein, 1979). The presence of diasterane, albeit with a relatively low value of 0.93, suggests that the crude oil sample originates from a clastic source rock with poor clay material content.

Further analysis of the regular sterane distribution triangle diagram (Figure 13) reveals the following composition: C27 = 52.90%, C28 = 28.72%, and C29 = 18.37%. These values indicate that the crude oil was deposited in an open marine shale environment, dominated by organic marine algae.

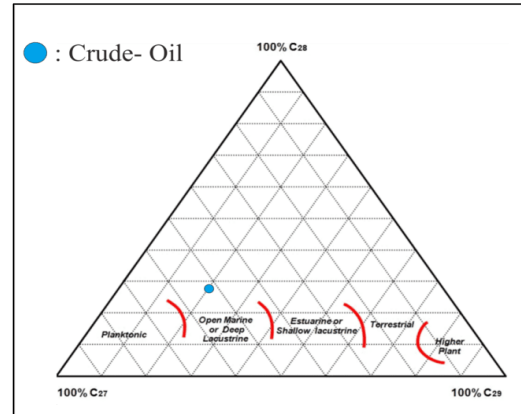


Fig 14. Plot diagram sample crude oil ratio distribusi steranes regular (Huang and Meinschein, 1979).

The depositional environment of the crude oil sample was further elucidated through analysis of the C29 and C30 hopane patterns, which can distinguish between clastic and carbonate sources. The sample exhibits a low C29/C30 ratio of 0.28, with a dominant C29 hopane peak, indicating a clastic source rock origin.

Additionally, the maturity level of the crude oil was assessed using the Tm/Ts and C30M/C30H ratios, plotted on a diagram (Figure 10). The sample has a Tm/Ts value of 2.02 and a moretane/hopane ratio of 0.15, indicating an early mature stage of maturity (Figure 15).

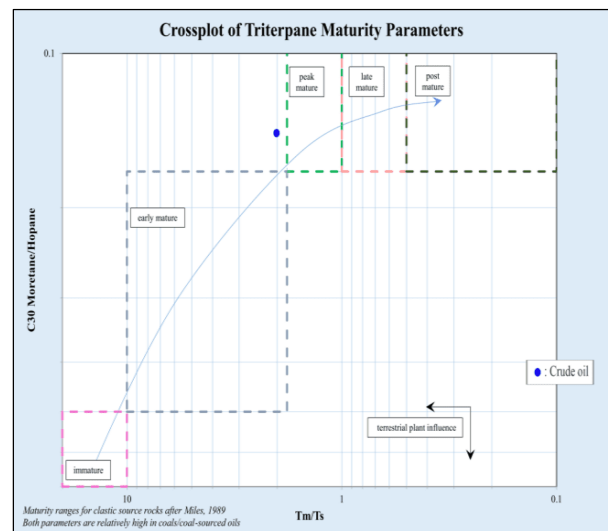


Fig 15. Plot Tm/Ts Vs C30M/C30H Maturity level of crude oil.

6. Discussion

6.1. Oil-Source Rock Correlation

The Pr/nC17 vs Ph/nC18 plot diagram, modified after Cannon and Cassou (1980), reveals a genetic similarity

between the crude oil samples and the Upper Talang Akar Formation. This similarity is characterized by high Pr/nC18 and Pr/nC17 values, indicative of a marine algal environment with reducing conditions (Fig. 16) (Satyana and Purwaningsih, 2003).

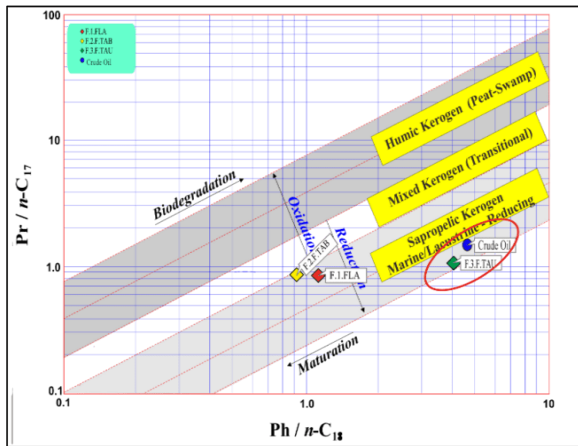


Fig 16. Correlation Oil-Source Rock of value ratio Pr/nC17 vs Ph/nC18 of isoprenoid.

Furthermore, correlation analysis using a regular sterane distribution diagram (Huang and Meinschein, 1979) reveals that the crude oil samples exhibit genetic similarities, characterized by the dominance of C27, indicating a marine algal origin. This suggests a positive correlation between the crude oil and the Talang Akar Formation source rock, which is also dominated by marine algae organic material (C27) (Figure 17).

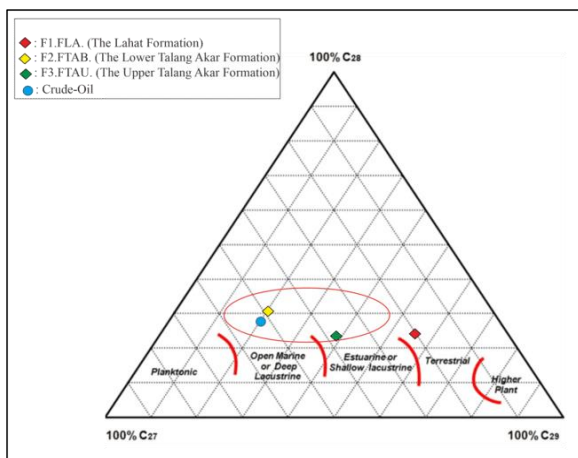


Fig 17. Correlation Oil- Source rock ratio distribution steranes regular

Furthermore, correlation analysis using hopane data, specifically the C29/C30 ratio, indicates that the crude oil sample originates from a clastic environment, characterized by a dominant C29 peak and a low C29/C30 value. This suggests a genetic similarity between the crude oil and the Upper Talang Akar Formation source rock sample, which is also derived from clastic organic material (Figure 9).

7. Conclusions

1. Evaluation of the source rock samples reveals the following characteristics:

- Lahat Formation: good organic material quantity, kerogen type II/III, capable of producing oil and gas.

- Lower Talang Akar Formation: excellent organic material quantity, kerogen type II, oil-prone.

- Upper Talang Akar Formation: excellent organic material quantity, kerogen type II, oil-prone. However, the maturity level, as indicated by T_{max} and R_o values, suggests that all source rock samples are immature. Notwithstanding, these formations can be considered valuable for earth research and geological heritage, representing potential source rock sites .

2. The source rock and crude oil samples from the study area exhibit an early mature stage, as indicated by the T_m/T_s and moretane/hopane ratios.

3. The source rock-crude oil correlation in the study area, based on isoprenoid (Pr/nC17 vs Ph/nC18) and sterane (C27-C29) distributions, suggests a positive correlation between the crude oil and the Talang Akar Formation source rock, indicating a common origin from marine or lacustrine organic material.

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