

# SOURCE ROCK CHARACTERISTICS AND THERMAL MATURITY OF THE UPPER AND LOWER TALANG AKAR FORMATION IN JAMBI SUB-BASIN, SOUTH SUMATRA BASIN

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## ABSTRACT

*One of Indonesia's regions with considerable hydrocarbon potential is the Jambi Sub-Basin, which is part of the South Sumatra Basin. The purpose of this research is to evaluate the hydrocarbon generation potential and source rock properties of a number of stratigraphic layers in the Jambi Sub-Basin. Samples collected from 14 drilling sites were subjected to Total Organic Carbon (TOC) and Rock-Eval Pyrolysis analyses as part of the study. This analysis seeks to evaluate the quantity, quality, and ripeness of the organic material found in the layers under investigation. Other formations are believed to be potential source rock strata in the LTAF and the UTAF, according to the data. Both formations have fair to extremely good TOC values and poor to very good S2 values, indicates the potential for hydrocarbon generation. Type III-II kerogen, which makes up the majority of the organic material, points to a terrestrial origin from fluvial-deltaic to marginal lacustrine settings, with the possibility of creating a mixture of oil and gas hydrocarbons. The maturity range, as shown by thermal maturity markers like vitrinite reflectance and Tmax, is from immature to post-mature. In some areas, vitrinite reflectance readings have even reached the gas phase, indicating that LTAF typically exhibits a higher level of maturity than UTAF due to more intensive burial and longer thermal processes. This indicates the potential for hydrocarbon formation, particularly gas, in deeper layers. This study concludes that the LTAF and UTAF are interpreted as the most likely source rock layers in the Jambi Sub-Basin.*

**Keyword:** source rock, rock-eval pyrolysis, Talang Akar formation, thermal maturity, South Sumatra Basin

## INTRODUCTION

The South Sumatra Basin is one of the most important Tertiary basins in Indonesia, with significant hydrocarbon potential, and it remains a key focus of exploration and development activities. The presence of source rocks rich in organic matter, high-quality reservoirs, and favorable structural and stratigraphic traps has created a complex and productive oil system in this basin (Hall & Morley, 2020; Abdullah et al., 2022). In addition, its multi-phase evolution and varied depositional history have led to significant spatial variations in the geochemical characteristics of source rocks across different sub-basins.

Previous geochemical studies in the Jambi Sub-Basin have indicated the potential

presence of hydrocarbon sources in the Lahat and Talang Akar Formations, as evidenced by Type II–III kerogen and a range of maturity levels from immature to mature. However, no in-depth and comprehensive assessment has been conducted regarding the characteristics of the source rocks and thermal maturity in the Upper and Lower Talang Akar Formations at various well locations. Therefore, this study conducted a comprehensive assessment using TOC, Rock-Eval Pyrolysis, vitrinite reflectance, and burial history analysis to identify the most promising source rock intervals and evaluate the potential for hydrocarbon generation.

Although multi-well geochemical studies have been conducted in selected areas of the Jambi Sub-basin, these investigations mainly focused on shale gas potential and geomechanical properties rather than

comprehensive regional evaluation of source rock richness, kerogen characteristics, and thermal maturity distribution (Setyawan et al., 2020). To improve our understanding of petroleum evolution in the Jambi Sub-Basin, an integrated multi-well organic geochemical approach is required.

The purpose of this research is to evaluate the quantity, quality, and thermal maturity of the source rocks in the Jambi Sub-Basin using Rock-Eval Pyrolysis and Total Organic Carbon (TOC) analysis.

## REGIONAL GEOLOGY

### Regional Physiography

The three sedimentary basins that make up Sumatra Island are the North Sumatra Basin, the Central Sumatra Basin, and the South Sumatra Basin. The South Sumatra Basin is located southeast of the Central Sumatra Basin, with a border that runs from northeast to southwest in the Tigapuluh Mountains' northern section (Figure 1). This basin is bounded by the Lampung Highlands and the eastern coastal highlands to the south and east, the Barisan Mountains to the southwest, the Sunda Continental Shelf to the northeast, and the Tigapuluh Highlands to the north and northwest. In the Jabung Block area, the South Sumatra Basin consists of three sub-basins formed within a half-graben system.

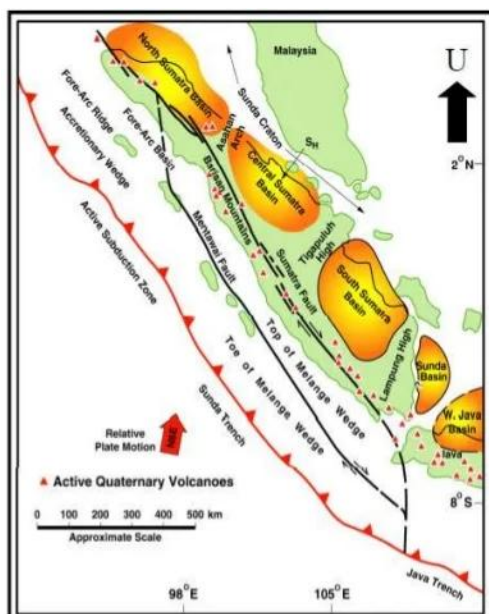


Figure 1. Physiography of the Central Sumatra Basin (Heidrick and Aulia, 1993).

## Regional Stratigraphy

The regional stratigraphy of the South Sumatra Basin represents a major megacycle initiated by a transgressive phase followed by a regressive phase (Koesoemadinata, R.P., 1980). The transgressive phase formed the Telisa Group, consisting of the Talang Akar Formation, Baturaja Formation, and Gumai Formation, while the regressive phase formed the Palembang Group, which includes the Air Benakat Formation, Muara Enim Formation, and Kasai Formation (Figure 2). Prior to the main transgressive phase, the Lemat Formation was deposited in a non-marine environment (Ginger & Fielding, 2005).

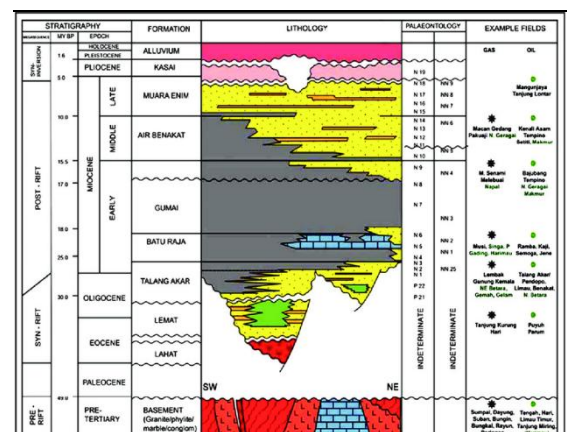


Figure 2. Regional stratigraphy of the South Sumatra Basin (Ginger & Fielding, 2005).

- 1) The Lower Talang Akar Formation (LTAf) was deposited in fluvial-lacustrine environments and is dominated by conglomerates, shales, coal, and fluvial-lacustrine sandstones.
- 2) The Upper Talang Akar Formation (UTAf) reflects stronger marine influence and is characterized by marine shales and sandstones deposited in fluvial-deltaic to marginal marine environments.

## Regional Tectonic Setting

The evolution of the South Sumatra Basin is divided into three main phases of formation (Figure 3): the syn-rift phase (40–29 million years ago), the post-rift phase (29–5 million years ago), and the syn-orogenic/inversion phase (5 million years ago to the present) (Pulunggono et al., 1992).

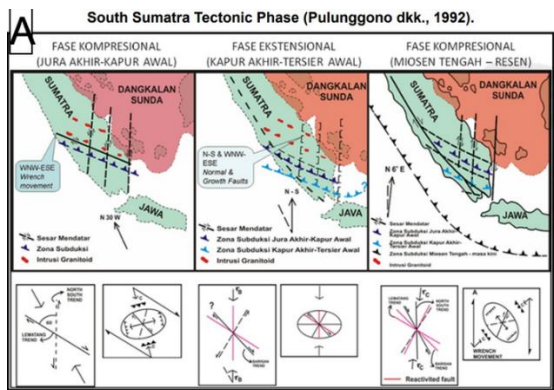


Figure 3. Tectonic Phases of the South Sumatra Basin (Pulunggono et al., 1992).

- 1) During the syn-rift phase, extensional tectonics related to subduction along western Sumatra formed a series of half-graben structures from the Eocene to Early Oligocene. This phase was associated with the deposition of the Lower Talang Akar Formations (Ginger & Fielding, 2005).
- 2) The post-rift phase was characterized by continued thermal subsidence, prolonged transgression, and subsequent regression, resulting in the deposition of the Upper Talang Akar Formation.
- 3) The syn-orogenic/inversion phase began around 5 Ma and continues to the present day, marked by compressional tectonics related to the uplift of the Barisan Mountains. This stage produced transpressional anticlines and hydrocarbon traps. (Ginger & Fielding, 2005).

## RESEARCH METHOD

This research applied Total Organic Carbon (TOC), Rock-Eval Pyrolysis (REP), and burial history analyses to evaluate the source rock characteristics and thermal maturity of the Lower and Upper Talang Akar Formation in the Jambi Sub-Basin, South Sumatra Basin. The TOC and S<sub>2</sub> parameters are used to assess the quantity and generative potential of organic matter, while HI, OI, TOC, S<sub>2</sub>, and T<sub>max</sub> are applied to evaluate the quality of organic matter and the characteristics of kerogen. Thermal maturity assessment is conducted using T<sub>max</sub>, vitrinite reflectance (R<sub>o</sub>), and burial history analysis.

The dataset was obtained from fourteen source rock wells with different analyzed intervals in each well (Table 1). Additional supporting data such as depth and formation

information were also integrated into the evaluation. Geochemical parameters were subsequently evaluated using standard source rock classification criteria proposed by Peters & Cassa (1994).

Table 1. Minimum and Maximum Sample Depths in Each Well

Well	Minimum Depth (ft)	Maximum Depth (ft)
AMB-1	3960	4980
AMB-2	4240	5950
AMB-3	4100	6000
AMB-4	2989	5238
AMB-5	5020	6320
AMB-6	4450	5850
AMB-7	5210	6220
AMB-8	5290	6080
AMB-9	755	5036
AMB-10	4648	8850
AMB-11	3980	4020
AMB-12	3242	6406
AMB-13	4684	11300
AMB-14	853	6168

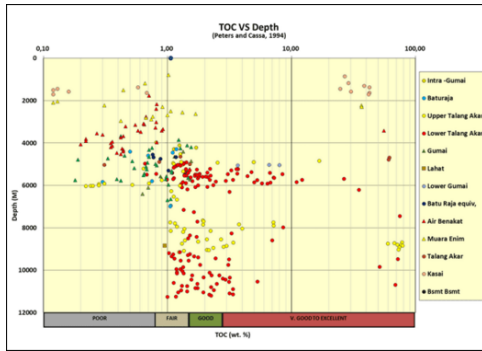
## RESULT

Source rock evaluation was conducted using geochemical data from 14 wells: AMB-1 to AMB-14. The goal of the study was to ascertain the quantity, quality, and level of maturity of the organic material in the source rock.

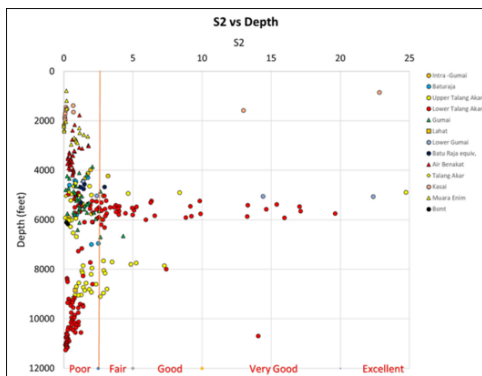
### a) Organic Matter Quantity

Based on the three graphs (Figure 4), TOC values range from moderate to high, particularly at depths greater than 4000 ft in the LTAF and UTAF intervals (Figure 4a). This shows more lowering depositional settings with little oxygen supply improving organic material preservation. On the contrary, other forms reveal low to moderate TOC levels at comparable depths, therefore suggesting that TOC is affected not only by depth but also by depositional environment.

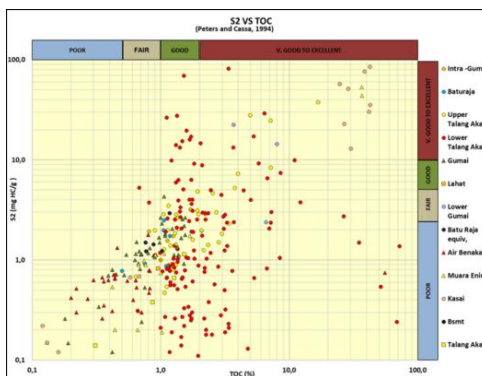
The S<sub>2</sub> vs depth graph, on the other hand, reveals that most samples have little to moderate generative potential (Poor-Fair) at all depths (Figure 4b). This pattern suggests that depth is not the primary element determining generative potential; rather, the amount and quality of organic matter including kerogen type and depositional circumstances, more strongly affect it.



(a)



(b)



(c)

Figure 4. Peters and Cassa (1994) geochemical parameter crossplots for source rock quantity: (a) TOC vs. Depth crossplot; (b) S2 vs. Depth crossplot; and (c) S2 vs. TOC crossplot.

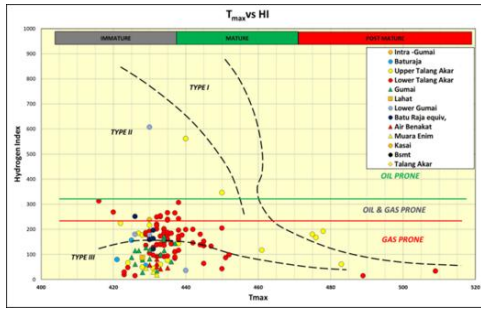
The Upper and Lower Talang Akar Formations have hydrocarbon-generating potential, according to source rock quantity analysis. These formations typically have TOC and S2 values falling into the Good to Very Good classes (Figure 4c), suggesting that there is enough organic matter and that there is a good chance that they will produce more. High S2 values signify a significant

hydrocarbon generation potential during thermal maturation, whereas high TOC values indicate a lot of organic content.

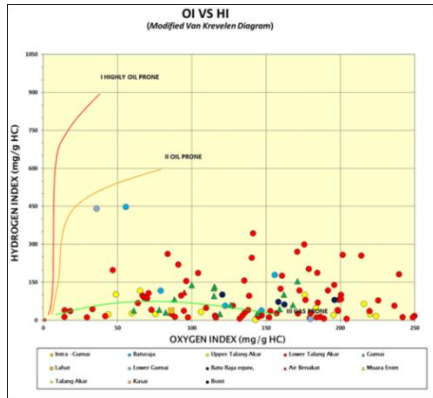
#### b) Organic Matter Quality

The majority of samples are in the Type II-III kerogen zone, which is predominantly Type III kerogen (Figure 5), according to the source rock quality analysis. While Type III kerogen predominates and indicates organic matter from terrestrial plants that is typically gas-prone, Type II-III kerogen suggests a combination of terrestrial and aquatic organic matter that may produce both oil and gas. In Tertiary sedimentary basins where coal and carbonaceous shale deposits predominate, Type II and Type III kerogen are frequently linked to hydrocarbon generation potential (Rashid et al., 2022). Changes in kerogen types across specific stratigraphic intervals indicate differences in depositional environments and organic matter sources. Although some intervals still have the potential for oil production, the source rock quality in the research region typically shows gas generation capability.

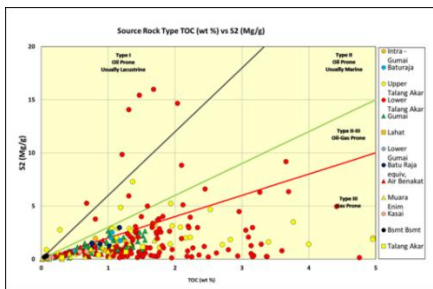
The source rock quality in both the Upper and Lower Talang Akar Formations is primarily characterized by Type III-II kerogen, which suggests a potential for generating a blend of gas and oil hydrocarbons. Conversely, Tmax readings reveal thermal maturity levels that span from immature to fully mature. In particular, the Talang Akar Formation has advanced beyond the early maturity phase, signifying that the process of hydrocarbon generation has commenced, predominantly producing gas.



(a)



(b)



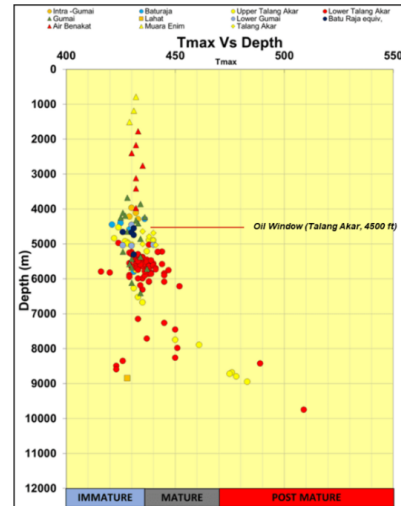
(c)

Figure 5. Peters and Cassa (1994) geochemical parameter crossplots for source rock quality According to Peters & Cassa (1994): (a) Tmax vs HI crossplot; (b) OI vs HI crossplot; (c) S2 vs TOC crossplot.

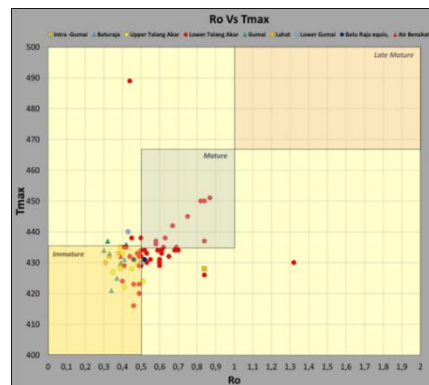
c) Organic Matter Maturity

Based on the relationship between Ro and Tmax, as well as depth and Ro, the maturity stages of the source rocks exhibit distinct disparities across the different formations (Figure 6). The Talang Akar Formation starts to transition into the early oil phase at roughly 4,500 feet deep (Figure 6a), whereas the LTA Formation enters the oil window at about 5,200 feet. This suggests differences in thermal conditions and the history of

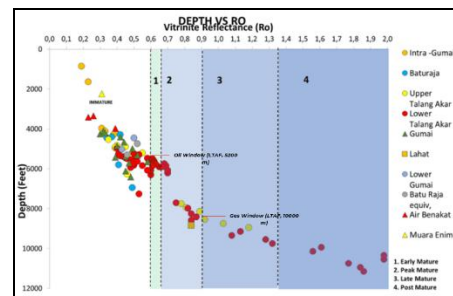
sedimentation. The gas window is thought to begin at depths exceeding 8,000 to 10,000 feet, with Ro values greater than 1.0 to 1.3%, indicating a high level of thermal maturity where the hydrocarbons produced are primarily gas (Figure 6c).



(a)



(b)



(c)

Figure 6. Crossplots of Geochemical Parameters for Source Rock Maturity According to Peters & Cassa (1994): (a) Tmax vs Depth crossplot; (b) Ro vs Tmax crossplot; (c) Ro vs Depth crossplot.

## DISCUSSION

The LTAF and UTAF formations demonstrate levels of maturity that vary from underdeveloped to fully mature, highlighting differences in thermal conditions based on depth and location. These differences suggest that both formations have experienced extended thermal changes, which enhances their ability to produce hydrocarbons, transitioning from oil to gas at greater maturity levels, especially in the deeper areas.

The Lower Talang Akar Formation was deposited in a fluvial–deltaic environment before undergoing transgression that shifted the depositional setting into a more marine environment (Utari et al., 2023). This fluvial–deltaic system supplied abundant terrestrial organic matter through rivers, floodplains, swamps, and delta plains into the basin. The dominance of terrestrial material and the presence of thin coal intervals resulted in the formation of predominantly Type III kerogen, which is generally gas-prone.

A study of burial history in the South Sumatra Basin shows that the Talang Akar Formation mainly reached the early mature to mature stage during the Pliocene period because of ongoing burial and thermal subsidence (Yoza et al., 2023). Based on the burial history analysis of Well AMB-13, the LTAF experienced deeper burial due to post-rift thermal subsidence, leading to thicker sediment accumulation and higher thermal maturity reaching the gas window (Figure 7).

It is concluded that Lower Talang Akar Formation (LTAF) represents the best source rock in the Jambi Sub-Basin due to its higher TOC, S<sub>2</sub>, and thermal maturity values compared to Upper Talang Akar Formation (UTAF). The LTAF entered the oil window at depths of approximately 4500–5200 ft and progressed into the gas window at depths greater than 8000–10,000 ft as a consequence of long and progressive burial accompanied by thermal subsidence, with the kitchen area likely located within the deepest half-graben depocenter of the Jambi Sub-Basin. The results of the exploration indicate that this area still holds potential for oil and gas, with more mature zones typically producing a mixture of oil and gas, while deeper sections tend to have higher gas content and produce gas derived from thermogenic processes.

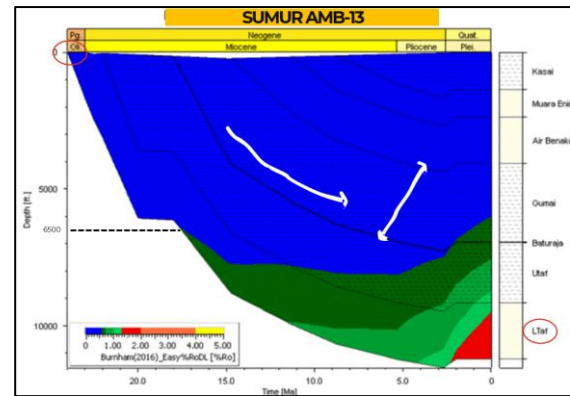


Figure 7. Burial History Graph of Well AMB-13.

## CONCLUSION

Based on geochemical analysis (Rock-Eval and TOC), the following conclusions may be drawn:

- 1) The formation potential is generally rated as good to very good, as evidenced by TOC levels ranging from fair to very good and S<sub>2</sub> values ranging from poor to very good during the LTAF interval. Type III–II is the most prevalent kerogen, indicating that terrestrial origins account for the majority of the organic content, with some mixed sources contributing as well. From immature to post-mature stages, the thermal maturity level varies.
- 2) In the UTAF interval, TOC values vary from poor to extremely good, and S<sub>2</sub> values also range from poor to very good. In a manner similar to the LTAF interval, the kerogen in this location is primarily made up of Type III–II, and its thermal maturity varies from immature to late mature. In general, the LTAF interval has superior source rock quality than the UTAF interval.

By examining the distribution of thermal maturity, areas that are dominated by UTAF can be identified as having prospects for oil exploration in the early stages, whereas areas that are interpreted as being closer to the basin center and dominated by LTAF show a higher potential for gas exploration.

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