



RESEARCH ARTICLE

Inversion Geochemistry as a Method for Interpreting Source Rock Criteria of Oil Samples: A Case Study from the Bobonaro Area, Maliana Basin, Timor-Leste

Joanico Pires¹, Eddy Ariyono Subroto^{2,*}, Asep Heri Patria Kesumajana³

¹ Instituto de Geociências de Timor-Leste - Instituto Público (IGTL/IP), Timor Leste; formerly Institut Teknologi Bandung

² Department of Geological Engineering, Universitas Pertamina, Jakarta Selatan 12220, Indonesia; formerly Institut Teknologi Bandung

³ Department of Geological Engineering, Institut Teknologi Bandung, Bandung 40132, Indonesia

* Corresponding author : eddy.as@universitaspertamina.ac.id

Tel.: +62-812-201-4087

Received: Jul 31, 2025; Accepted: Dec 3, 2025.

DOI: 10.25299/jgeet.2025.10.1.1.24362

Abstract

In general condition, crude oil samples are difficult to obtain. However, when the crude oil samples are obtained, researchers will be able to estimate the possibility of their source rock, as long as the samples are analyzed in sufficient detail. In this study, the samples used as case studies are the Pualaka and Suai Loro oil seepage samples from Bobonaro area, Maliana Basin, Timor Leste. The petroleum samples obtained happened to be in relatively fresh condition. The analysis carried out included analysis using GC and GC-MS with the objects of analysis being biomarkers, i.e. triterpane compounds with m/z 191 and steranes with m/z 217. The results obtained showed that the two seepage oils were suspected to belong to one oil family whose source rock was estimated to be deposited in a marginal marine area with a dominant algae supply and few higher plants with Pre-Tertiary geological age. The maturity of the two petroleum samples was relatively high, at the stage of peak oil generation. By knowing such characters, researchers will be able to predict sedimentary rocks in the basin area that are of the same type as petroleum characters using inversion geochemistry technique. The most possible source rock of the crude oils is the Babulu Formation.

Keywords: Bobonaro, Timor Leste, source rock, crude oil, inversion geochemistry

1. Introduction

Geochemical analysis of source rock potential and characteristics is increasingly important these days in oil and gas industry. Located in the outer part of Banda volcanic arc, many oil and gas seepages have been reported in Timor-Leste onshore area. Numerous exploration drillings have been carried out in the past with results that were limited to technical discoveries and not commercially viable.

In Timor-Leste, to locate a potential source rock which can generate oil and gas became increasingly important due to the country's dependency on country income obtained from petroleum fund. Study of oil and gas in the onshore Timor-Leste has been carried out and reported by experts and companies over the last century until the present day, e.g. Gageonnet and Lemoine (1957), Gageonnet (1958), Charlton and Gandara (2014), Peters et al. (2014).

Prior to 1956, oil and gas drilling was carried out mostly along the oil and gas seepages (Crostella and Powell, 1975). This includes two wells in Aliambata with the total depth of 140m and 220m, and one well in Matai, Suai area, with the total depth of 170m. In 1956, Timor Oil Company initiated serious exploration and between 1957 and 1970, Timor Oil decided to drill 21 wells in Aliambata, Suai, and Betano areas. Around 21 wells drilled by Timor Oil were shallow wells and resulted in the discovery of 160 bopd in Matai and 200 bopd in Cota-Taci. In 2016, Australian company, Timor

Resources Pty. Ltd. joint ventured with Timor-Leste National oil company, Timor Gap EP, explored onshore petroleum resources in two blocks, i.e. Block A and Block C. Timor Resources have successfully acquired two new 2D seismic surveys (2018 and 2019) across both blocks and allowed better understanding of the prospectivity of the petroleum potential in onshore area. The five-well exploration program has been designed to test a number of play types with multiple targets in each well and three of the wells have been drilled by Timor Resources at the end of 2022.

In the petroleum geochemical field, a technique has been known widely, geochemical inversion or inverse geochemistry. This technique was formerly introduced by Bissada (Bissada et al., 1992). Since then, this technique has been adapted by many authors, e.g. Andriany et al. (2012), Jorge et al. (2021). With the increasingly advanced science and the rapid development of apparatus for analyzing geochemistry, it becomes possible to carry out inversion geochemistry. This technique is actually similar with the correlation technique between source rock and crude oil. However, the correlation between source rock and crude oil is carried out with known geochemical analysis of both. In inverse geochemistry, the situation is different. The only known data are those from geochemical analysis of crude oil samples which are generally analyzed using gas chromatography (GC) and gas chromatography-mass spectrometer (GC-MS).

Interpretation using biomarker data obtained from GC and GC-MS analyses have been done world-wide and many are considered as the standard interpretation. Therefore, by using the results of the interpretation based on biomarker data contained in crude oil samples, basic matters of the source rock can be interpreted, such as the origin of the organic material, depositional environment, and maturity. By knowing these three basic things, it will be possible to interpret the sedimentary rocks around where the oil is found as potential source rocks for the crude oil.

The purpose of this study was mainly to identify geochemically oil seepages collected from the study area in Timor Leste and then to interpret the possible source rock that is responsible for yielding such crude oils using geochemical inversion techniques.

2. Results and Discussion

2.1 Samples

Two crude oil samples, namely Pualaka and Sungai Loro, have been collected from Maliana Basin, onshore Timor Leste (**Figure 1**). The two samples were then analyzed using GC and GC-MS techniques. Widely, the exploration targets for oil and gas in Timor-Leste is mainly from the Permian to Middle Jurassic rocks succession (**Figure 2**) deposited within the sag-rift basin of East Gondwana Interior rift ([Peters et al., 1999](#)).

2.2 Geochemical analysis results and interpretations

Evaluation of geochemical fingerprints on Pualaka and Suai Loro samples was carried out based on the results of

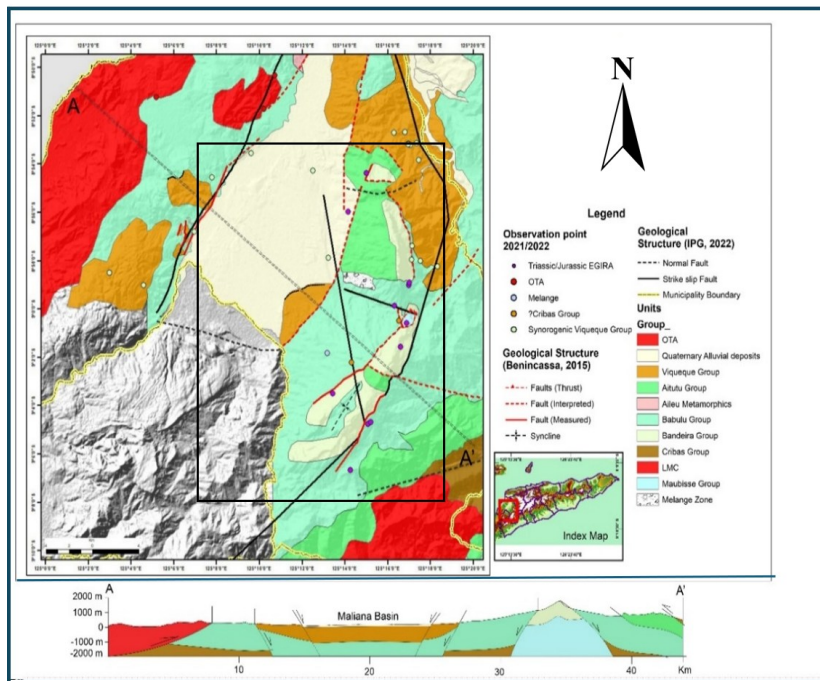


Fig. 1. Map of the study area that belongs to Bobonaro area of the Maliana Basin ([IPG, 2022](#)).

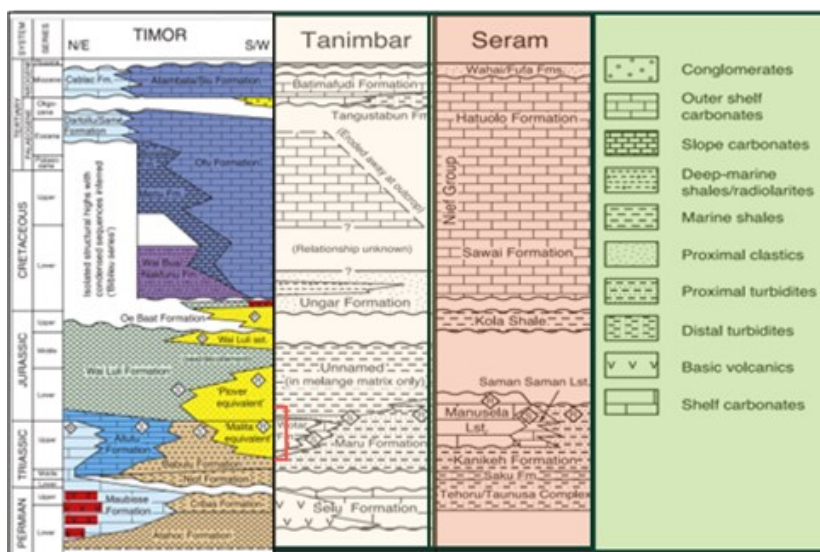


Fig. 2. Stratigraphy of the Timor in comparison with that of the surrounding areas, namely the Tanimbar and Seram areas ([Kaneko et al., 2006](#)).

gas chromatography (GC) and gas chromatography-mass spectrometry (GC-MS) analyses.

GC fingerprints show a distribution pattern of n-alkanes with the lowest configuration being n-alkane C₇ to the highest being carbon C₃₃ (Figure 3). The pristane/phytane ratio is 1.87 for the Pualaka sample which provides an indication of a suboxic depositional environment, while the same ratio for the Suai Loro sample is 3.30 indicating a suboxic depositional environment, but having relatively more oxic than that of source rock of the Pualaka oil. The Pr/nC₁₇ ratio < 0.5 and the Ph/nC₁₈ ratio < 0.3 indicate a shale source rock from a marine environment. The plot of Pr/nC₁₇ against Ph/nC₁₈ has placed the Pualaka and Suai Loro

samples into a transitional depositional environment area where the source of organic material is a mixture of types II and III (Figure 4).

The presence of unusual concentrations of saturated hydrocarbon biomarkers in oil can be used to interpret the depositional environment of organic material origin. Steranes fragmentogram of m/z 217 samples from Pualaka and Suai Loro shows a regular distribution pattern of diasteranes (marked with alphabetical sign) and steranes (marked with numerical sign) with a relatively higher abundance of diasteranes compared to steranes (Figure 5). This phenomenon indicates the source rock is most likely comprising marine shale lithology.

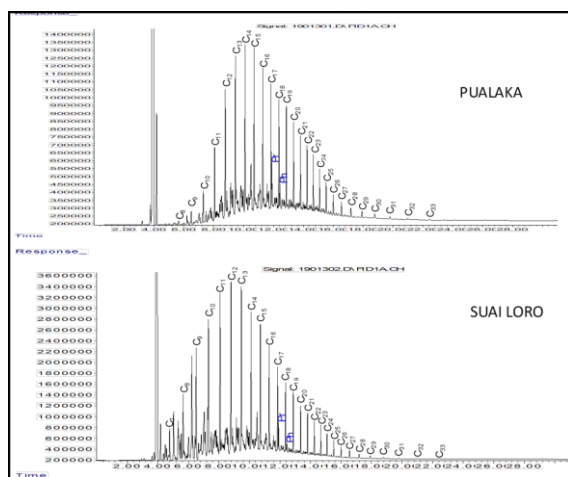


Fig. 3. Gas chromatography fingerprints show the distribution of n-alkanes in oil samples from Pualaka and Suai Loro.

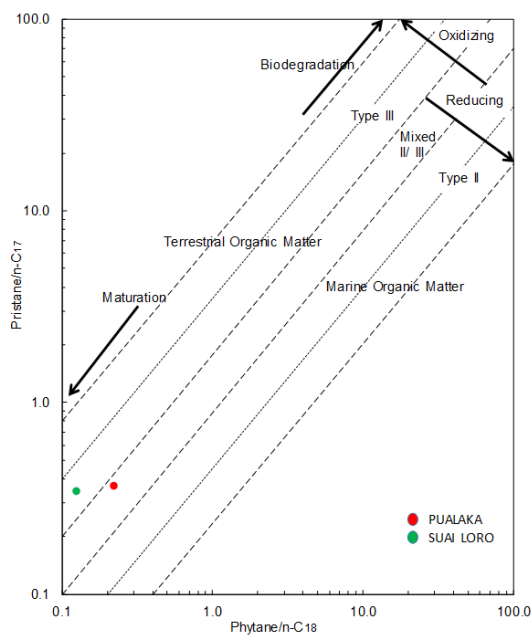


Fig. 4. A cross plot between Ph/nC₁₈ vs Pr/nC₁₇ showing depositional environment, organic material type, and relative maturity for the two crude oil samples.

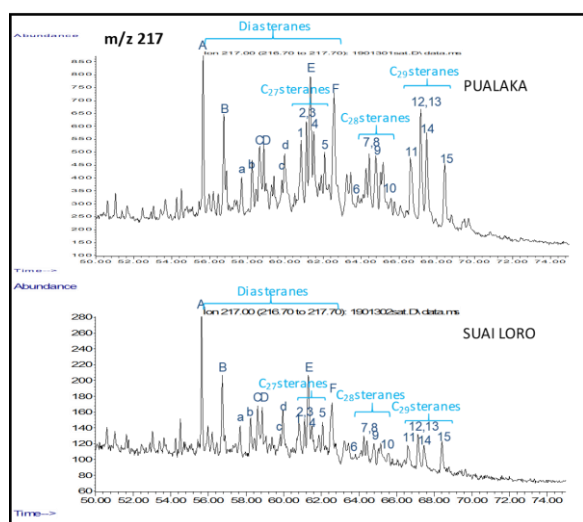


Fig. 5. Partial fragmentogram (m/z 217) shows the distribution of steranes in oil samples from Pualaka and Suai Loro. Explanation of the peak labels is given in text.



Fig. 6. Ecosystem conditions of origin of the organic material for two crude oil samples from Pualaka and Suai Loro.

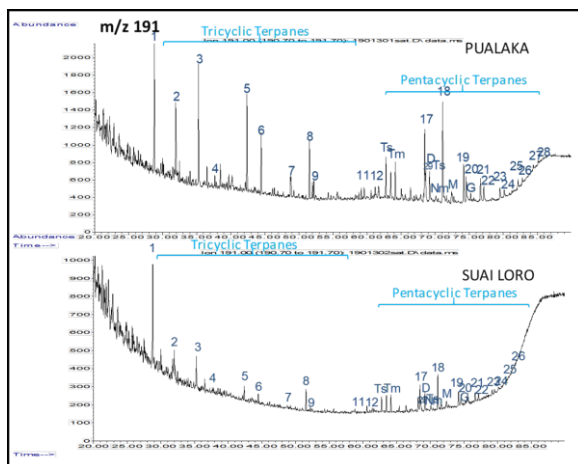


Fig. 7. Partial fragmentogram (m/z 191) showing the triterpanes distribution of oil samples from Pualaka and Suai Loro. Explanation of the peak labels is given in text.

The distribution of C₂₇ (1-5 in **Figure 5**), C₂₈ (7 to 10), and C₂₉ (11-15) steranes are usually used to infer the ecosystem and depositional environment of organic materials contained in the source rock (Volkman, 1986, Syaifudin, 2016). This application is based on the sterol precursors produced by aquatic organisms which are mostly in the form of C₂₇, while those produced by higher plants are often dominated by C₂₉ compounds. Steranes in the two oil samples show ion chromatogram configuration with both C₂₇ and C₂₉ always appearing dominant. This shows that the hydrocarbons in all crude oils are thought to originate from aquatic depositional environments which are mostly related to the supply of the main supporting organic material in the form of planktonic organisms. By plotting the sterane compositions of C₂₇, C₂₈, and C₂₉ into the ternary diagram in **Figure 6** (Huang and Meinschein, 1979), it can be seen that the organic matter input of the Pualaka and Suai Loro samples is probably to derive from algae deposited in a transitional marine environment.

The m/z 191 fragmentograms (**Figure 7**) show the distribution of 17 α (H)-hopane originating from bacteria which is predominated by C₃₀ α (H)-hopane. In this case, the abundance of C₃₀ hopane (peak 18 in **Figure 7**) is higher than that of C₂₉ hopane (peak 17 in **Figure 7**). This indicates that the crude oil has been derived from a clastic origin facies source rock rather than carbonate one (see **Figure 7**). High concentrations of tricyclic exposure (peaks 1-9, **Figure 7**), indicating an algal origin (Volkman, 1986, Azevedo et al., 1992). No higher plant compounds such as bicadinanes (resins), oleananes (OL) were detected in the triterpane ion fragmentogram. The absence of oleananes is thought to indicate the absence of a terrestrial source of organic material in the form of flowering plants or may be caused by samples originating from an older age than the Upper Cretaceous or may belong to the Pre-Tertiary age (Moldowan et al., 1985).

Thermal maturity describes the reactions caused by heat to convert organic materials into petroleum. Kerogen in the source rock is thermally converted into oil and gas and migrates towards the reservoir. Thermal processes associated with sediment burial occurred over millions of years. The level of thermal maturity of the Pualaka and Suai

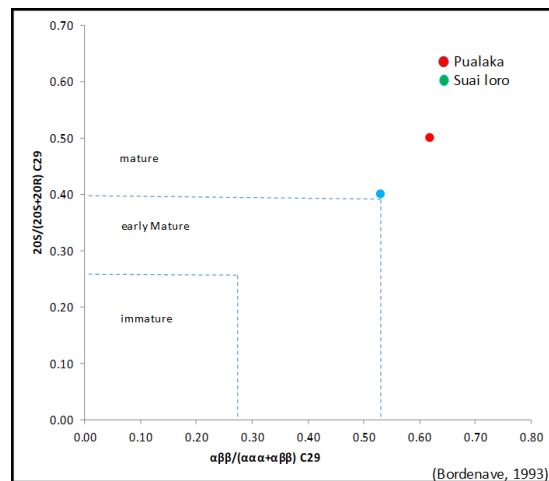


Fig. 8. The sterane biomarker plots C₂₉ $\beta\beta/(\beta\beta+\alpha\alpha)$ and C₂₉ S/(20S+20R) describe the level of thermal maturity of the Pualaka and Suai Loro crude oil samples.

Loro samples can be estimated based on the 20S/20R C₂₉ steranes (peaks 11/15 in **Figure 5**) and $\alpha\beta\beta/(\alpha\alpha\alpha+\alpha\beta\beta)$ C₂₉ sterane ratios [(peaks 12 to 14)/(12 to 14 + 11 and 15)] as the results of saturation analysis using GC-MS m/z 217. The 20S/20R C₂₉ ratio is 0.50 and 0.44, as well as the $\alpha\beta\beta/(\alpha\alpha\alpha+\alpha\beta\beta)$ C₂₉ ratio results of 0.62 and 0.53 in the Pualaka and Suai Loro samples, indicating that the oils have reached a relatively mature stage (**Figure 8**).

3. Conclusions

To summarize, it is apparent, on the basis of many similar characteristics, that the two crude oil samples may belong to one family. They both are interpreted to derive from a suboxic, mixed types II-III kerogen, contained relatively high concentration of shales in comparison to carbonate, deposited in a transitional marine environment, having relatively high maturation. The absence of oleananes may also indicate that the crude oils could have Pre-Tertiary geological age. It has been demonstrated that by applying the inversion geochemistry technique, the possibility of source rock that might be thought to have produced the crude oil samples can be well interpreted.

The main keyword used to determine the possibility of the source rock of crude oil is its geological age, in this case is the Pre-Tertiary age. Sedimentary rocks in the Maliana Basin that are likely to be source rocks based on their geological age may belong to two formations, namely the Babulu and Aitutu Formations. Both formations have many similar aspects. For example, they both are thought to have been deposited in a marine environment. However, there is a significant difference between them. The strong difference is in their lithological composition. From field geological data, it can be interpreted that the Babulu Formation is thought to have been deposited in a marine environment with a shale-dominated lithology, while the Aitutu Formation was detected as having a relatively predominant carbonate lithology, even though its depositional environment was also marine. Therefore, on the basis of similarity in the geological conditions, it is most probably that the source rock of the two crude oils is the Babulu Formation. To further confirm this conclusion, a

detail geochemical biomarker analysis should be carried out for these two formations.

Acknowledgements

The authors would like to thank Instituto de Geociências de Timor-Leste - Instituto Público (IGTLIP) for permission to use the data and to publish the paper.

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