SOURCE ROCK EVALUATION BASED ON GEOCHEMICAL DATA AND 1D BURIAL HISTORY MODELLING IN X BLOCK, SOUTH SUMATERA BASIN

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ABSTRACT

The study was conducted in the South Sumatra Basin using geochemical data consisting of three exploration wells to determine geochemical characteristics such as richness, quality, level of maturity, and the setting in which the source rock was deposited. Additionally, the study delved into the one-dimensional burial history of the study area. Subsequent phases of the research involved the analysis of three crude oil samples and three rock extract samples. This analytical process encompassed the utilization of gas chromatography (GC) and gas chromatography - mass spectrometry (GC-MS) data. By scrutinizing the biomarker parameters extracted through GC and GC-MS, the research sought to discern the specific characteristics of the depositional environment for each sample and establish a correlation between the source rock and the crude oil. Based on source rock evaluation, the three source rock wells are potential source rock. Based on biomarker analysis, TAN-1 and TAN-2 have an oxic terrestrial/fluvio-deltaic characteristics with a dominantly higher plant contributions. Samples RA-12, RA-17, and RA-61 have a suboxic – anoxic fluvio-deltaic characteristics with contributions of dominantly marine algae. The oil samples taken from these wells have a negative correlation with the source rock samples. Maturity analysis of the TAN-1, TAN-2, and TAN-3 wells is still in its immature phase based on one-dimensional burial history modeling.

Keyword: South Sumatra Basin, Geochemical Source Rocks, Biomarkers, Correlation, Burial History

INTRODUCTION

The South Sumatra Basin Formation is attributed to tectonic mechanisms involving the subduction of the Indo-Australian Plate. This plate is in motion, moving towards the north to northeast direction relative to the Eurasian Plate. This subduction zone encompasses the region situated to the west of Sumatera Island and to the south of Java Island. The subduction process influences various aspects of the South Sumatra region, including the geological conditions, tectonic activities, land shape, and structural composition. As a result of this plate subduction, distinct features such as a forward arc, magmatic activities, and a backarc have been generated in the area (Bishop, 2000).

The prominence of the South Sumatra Basin lies in being a significant hydrocarbon-producing region within Indonesia. Within this context, Block X occupies a position within the the sub-basin of South Palembang. Notably, the sub-basin of South Palembang is characterized as a hydrocarbon-rich back-arc magmatic basin, demonstrating active production of hydrocarbons (Bishop, 2000). Progress in the field of oil and gas exploration is currently increasing rapidly. Various exploration methods and techniques were developed to search for new hydrocarbons as well as to optimize existing discoveries. In order to optimize the exploration of hydrocarbons, it is necessary to conduct an evaluation study of the source rock producing the hydrocarbons and the correlation of the source rocks to the produced hydrocarbons. Hydrocarbon geochemistry can be used in narrowing the concentration of exploration areas to reduce exploration risk (Dow, 1994). Hence, a study was undertaken to assess the geochemical attributes of source rocks (including organic material richness, type, and maturity) within the Gumai, Baturaja, and Talang Akar Formations. The aim was to ascertain their viability as source rocks and establish a link between these formations and the crude oil discovered in multiple production wells situated within X Block.

The Gumai, the Talang Akar, and the Lahat Formation contribute to the source rock composition within the South Sumatra Basin. Hydrocarbons in this basin were obtained from lacustrine source rock of the Lahat Formation, also having Benakat Shale with Kerogen Types I, II (oil prone), III (gas prone), Hydrocarbon Index (HI) values ranging from 130 – 290 mgHC/g, levels of thermal maturation spanning from 0.64 - 1.40% Ro (Suseno et al., 1992 as cited in Bishop, 2001), and the Total Organic Carbon (TOC) content displaying fluctuations between 1.7 and 8.5 wt%.

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(Sarjono & Sardjito, 1989 cited in Bishop, 2001). Most of the Lahat Formation produces oil, while producing oil and gas at deeper deposited locations. Hydrocarbons are extracted from terrestrial coal and coaly shale source rocks that are commonly found along the half-graben boundary within the Talang Akar Formation, containing organic material types I, II, III, TOC content of around 1.5 – 8 wt% (good – very good), and within the Lower Talang Akar, the HI value ranges from 150 to 310 mgHC/g, and thermal maturity levels vary between 0.54 to 0.60% Ro and 0.82 to 1.30% Ro. The significant potential for hydrocarbon production exists in both the Baturaja Formation and Gumai Formation, attributed to the occurrence of limestone and shale within each respective formation (Bishop, 2001). The temperature gradient in the South Sumatra basin is around 49℃/km, so that oil will tend to be in deeper places than the Central Sumatra basin, which has a higher temperature. In certain deep areas of the basin, the Baturaja Formation and Gumai Formation have reached a level of maturity ranging from mature to early ripe, indicating the potential for thermal gas generation within the petroleum system (Bishop, 2001).

RESEARCH METHOD

Three source rock wells underwent geochemical analysis to discern the potential of the source rock. This assessment hinged on specific criteria: the abundance of organic matter, the makeup of organic constituents, and the level of organic material maturity (Peters & Cassa, 1994). Subsequently, biomarker analysis was conducted on both rock extract samples (three in total) and crude oil samples (also three in total). This endeavor aimed to establish the attributes of the crude oil, crucial for facilitating a correlation with the source rock through techniques such as an analysis using gas chromatography (GC), gas chromatography – mass spectrometry (GC-MS), and liquid chromatography (LC) methods.

RESULT AND DISCUSSION

- **Geochemical Analysis**

Organic Richness

The results of the analysis of the quantity of organic material in X Block (Figure 1) showed that the Gumai Formation showed a TOC value of 0.7 wt% (fair) and S2 value 0.6 (poor). The Baturaja Formation shows a value of 0.79 wt% (fair) and S2 1.05 (poor). The Talang Akar Formation 1.63 wt% (good) and S2 3.34 (fair). All of these results show that they are classified as source rock potential (Waples, 1985).

Organic Matter Quality

The analysis was performed by discerning the kerogen type and the inclination towards specific hydrocarbon types, determined through the Hydrogen Index (HI) content as outlined by Peters and Cassa (1994). Rock Eval Pyrolysis analysis was performed on three wells, namely TAN-1, TAN-2, and TAN-3, yielding the respective HI content (Table 1).

Table 1. Hydrogen Index Value and its Kerogen Type

Formation	Hydrogen Index (HI) mgHC/g	Kerogen Type (Peters and Cassa, 1994)
Gumai	53 – 209	III and II/III
Baturaja	80 – 237	III and II/III
Talang Akar	57 – 407	II/III

The Hydrogen Index data is then plotted into a Van Krevelen Diagram by comparing HI and Tmax. The results of the plot in the diagram show (Figure 2) that the Talang Akar Formation and the Baturaja Formation tend to have Type II/III kerogen (oil and gas prone) which is a mixture of organic materials from the sea such as marine algae, plant fat and organic materials from land such as higher plants or wood, characterizing sediment deposited in a transitional environment. The Gumai Formation has type III kerogen, which is derived from terrestrial organic material such as higher plants or wood or also knows as gas prone because it generates gas and a small amount of oil (Waples, 1985).

Organic Matter Maturity

Analysis of the maturity of the organic material was carried out by comparing the vitrinite reflectance data (% Ro) to depth (Figure 3), and Tmax data to depth (Figure 4). The results of the plot of %Ro and Tmax data against depth and by drawing a trend line of thermal maturity in Block X shows that the Gumai, Baturaja and Talang Akar Formations have not yet entered the depth of the oil window, in this case they are classified as source rocks that have the potential to produce hydrocarbons (Waples, 1985).

- **Biomarker Analysis**

Oil extract biomarker analysis was carried out on rock extract samples, namely TAN-1 (TAF), TAN-2 (TAF) and crude oil samples, namely RA-12 (TAF), RA-17 (BRF), and RA-61 (TAF).

Pristane/phytane ratio parameter is used as an indicator of the level of oxygen presence during diagenesis (Waples, 1985). Results of

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the Ph/C crossplot$_{18}$ vs Pr/C$_{17}$ (Figure 5) shows that the source rock samples are in a terrestrial oxic environment, while the crude oil samples are shown to be in an anoxic – suboxic transitional environment.

Triterpane parameters are also used in organic facies analysis using the m/z 191 extended terpane distribution (Figure 6 and 7). Each sample has a high concentration of C_{30} hopanes (peak 6), low concentrations of moretane (peak 7), low concentrations of terpane tricyclics indicate an environment of fluvio-deltaic origin (Robinson, 1987). Oleanane is also present, which indicates a biomarker of organic material commonly found in delta sequences. By looking at these parameters it can be interpreted that the natural environment or organic facies of the rock extract and crude oil samples is fluvio-deltaic.

Crossplot analysis of the C_{27}, C_{28}, C_{29} sterane distribution is used to determine the depositional environment of organic material. High percentages of C_{27} indicates organic material derived from marine phytoplankton, high percentages of C_{28} indicates the dominant contribution of lacustrine algae, and the value of C_{29} indicates the dominant contribution of the higher plants of the terrestrial environment. The crossplot results show that the rock extract sample was deposited in a terrestrial environment according to Huang and Meinschein (1979) and has a C_{29} sterane composition which is more dominant than C_{27} and C_{28} so that it can be indicated that the type of organic material is dominated by higher plants. Conversely, taking into account the distribution of C_{27}, C_{28}, and C_{29} on the oil samples of RA-17, RA-12, and RA-61, those indicated an estuarine or shallow lacustrine setting. This inference is supported by the prevalence of higher values for C_{27} and C_{29} compared to C_{28} (Figure 8).

The hopane/sterane and pristane/phytane parameter is used to determine the organic facies. Total Hopanes/Steranes vs Pr/Ph analysis (Figure 9) shows that the rock extract samples were deposited in an oxic environment and were influenced by the input of organic material from the terrestrial environment, while the crude oil samples were in anoxic – suboxic environment with organic material in the form of algae due to the influence of the marine environment.

Then the Triterpane Maturity analysis (C_{30} Moretane/Hopane vs Tm/Ts) is employed to assess the maturity stage of the organic material. It is known that rock extract samples have is already in late mature phase, while crude oil samples is still immature (Figure 10).

The liquid chromatography method is used to determine quality aspects by separating saturated, aromatic, NSO components (nitrogen, sulfur and oxygen), and asphalt. In the rock extract sample, the crossplot diagram between the values of the saturated, aromatic, and NSO+asphalt components shows that the incidence of increasing maturity, is characterized by a relatively high non-hydrocarbon (NSO+asphalt) content and low saturated/aromatic oil, it can be said that the sample rock extract is still in an immature state. The results of the source rocks's liquid chromatography are related to the triterpane maturity diagram which shows the results are inversely proportional because the high value of NSO+asphalt indicates that the rock extract sample has been through biodegradable phase so that the organic material decreases in maturity. Meanwhile, the crude oil samples showed increasing maturity characterized by low non-hydrocarbon (NSO+asphalt) content and high saturated/aromatic oil. It can be concluded from the three crude oil samples, that the RA-61 well is experiencing a lower maturity than RA-12 and RA-17 even though the three have not yet reached the mature phase (Figure 11).

- **Oil-Source Rock Correlation**

It can be concluded from the analysis that has been carried out that there is a negative correlation between the source rock sample wells and the crude oil sample wells. The difference lies in the contribution of the dominant organic material, in this case TAN-1 and TAN-2 show the dominance of organic material of higher plants under oxic environmental conditions, while RA-12, RA-17, and RA-61 have dominant organic material of marine algae under conditions anoxic-suboxic environment. However, these two types of samples come from the same depositional environment, namely Fluvio-deltaic. Differences in environmental conditions between source rock and petroleum samples are due to sea level rise that occurs in the Talang Akar Formation so that the depositional environment changes from oxic to anoxic. Also characterized by a depth that indicates the higher the surfaces, means it has the characteristics of a marine depositional environment. Therefore, a deduction can be drawn that the lower side of the Talang Akar source rock wells comprise of fluvio – deltaic deposits, while as one moves higher up, the depositional environment transitions to marine deposits, aligning with the location of oil wells.

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- **Burial History**

Maturity analysis of the TAN-1, TAN-2, and TAN-3 wells is seen from two factors, namely the position of the three wells which are at high altitudes so that the temperature below the surface is not at its maximum to produce mature hydrocarbons and is supported by geochemical data which shows an average of Vitrinite Reflectance is 0.43% Ro which shows that the three wells in the study area have immature source rock.

There were no oil shows in the three wells considering that the three wells are potential source rocks. However, it is interpreted that the depths that have the potential to be oil kitchens are the depths that are in the TAN-1, TAN-2, and TAN-3 wells because they have reached the appropriate pressure and temperature conditions to produce hydrocarbons.

CONCLUSION

Based on the geochemical analysis of the source rock, it can be classified according to Waples (1985) that all the source rock in the TAN-1, TAN-2, and TAN-3 wells is potential *source rock.*

Biomarker analysis shows that source rock and crude oil wells originate from fluvio-deltaic with the contribution of higher plants (TAN-1 and TAN-2) and marine algae (RA-12, RA-17, RA-61). Biomarker analysis showed that there was no correlation between rock extract and crude oil samples but both were of fluvio-deltaic origin.

Based on one dimensional burial history modelling, it has been established that in comparison to the Gumai Formation and the Baturaja Formation, the Talang Akar Formation exhibits a greater potential as a source rock. This conclusion is underpinned by the prevalence of shale lithology and the presence of sea level rise. This is indicated within Talang Akar formation that has higher TOC value.

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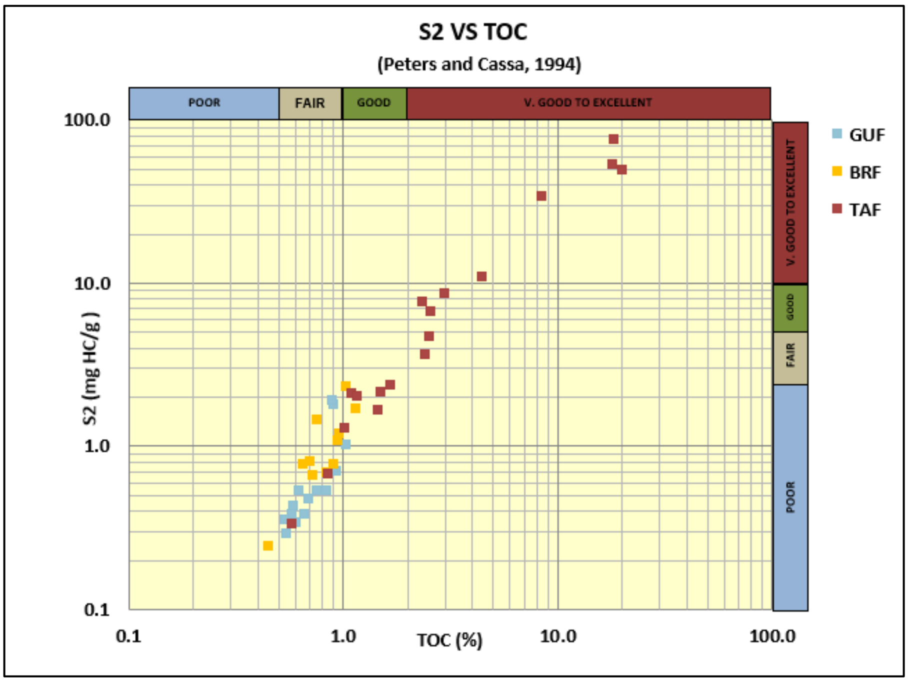

Figure 1. The Relationship between S2 vs TOC (Peters and Cassa, 1994)

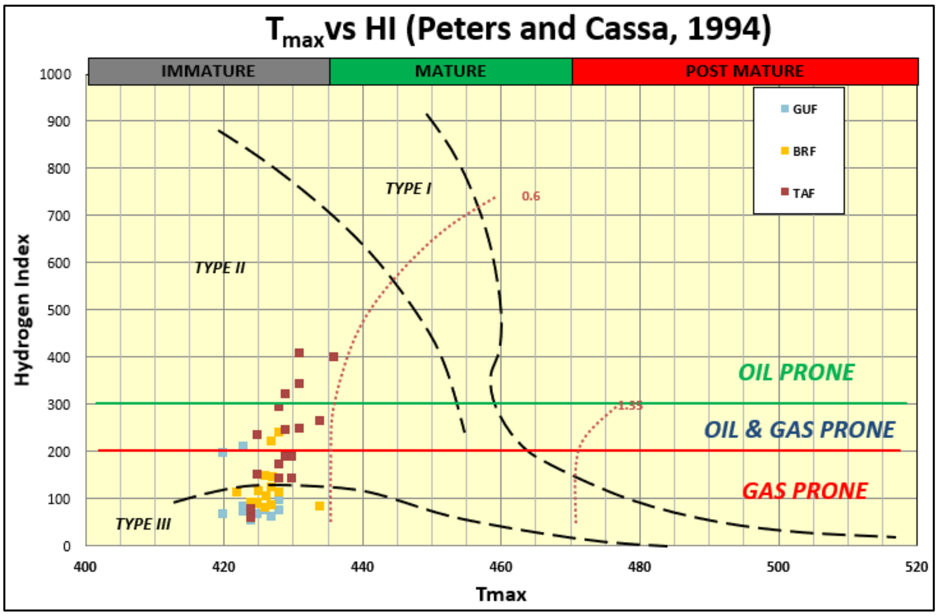

Figure 2. Kerogen Type Diagram which represent the plot Tmax vs HI (Peters and Cassa, 1994).

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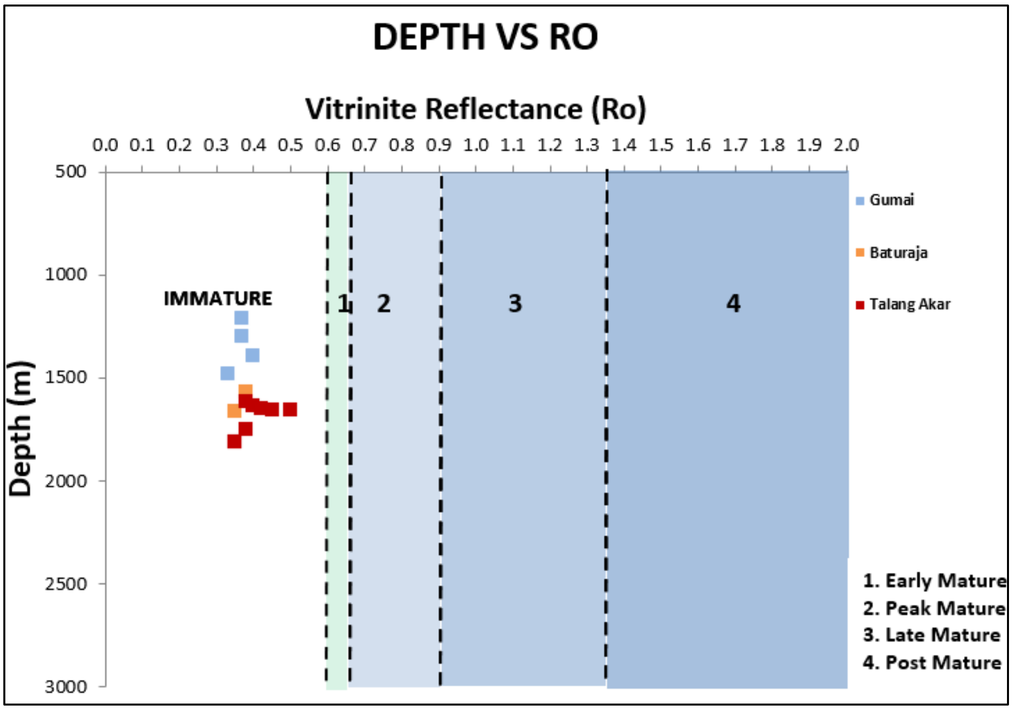

Figure 3. Maturity Diagram through the plot of Depth vs Ro

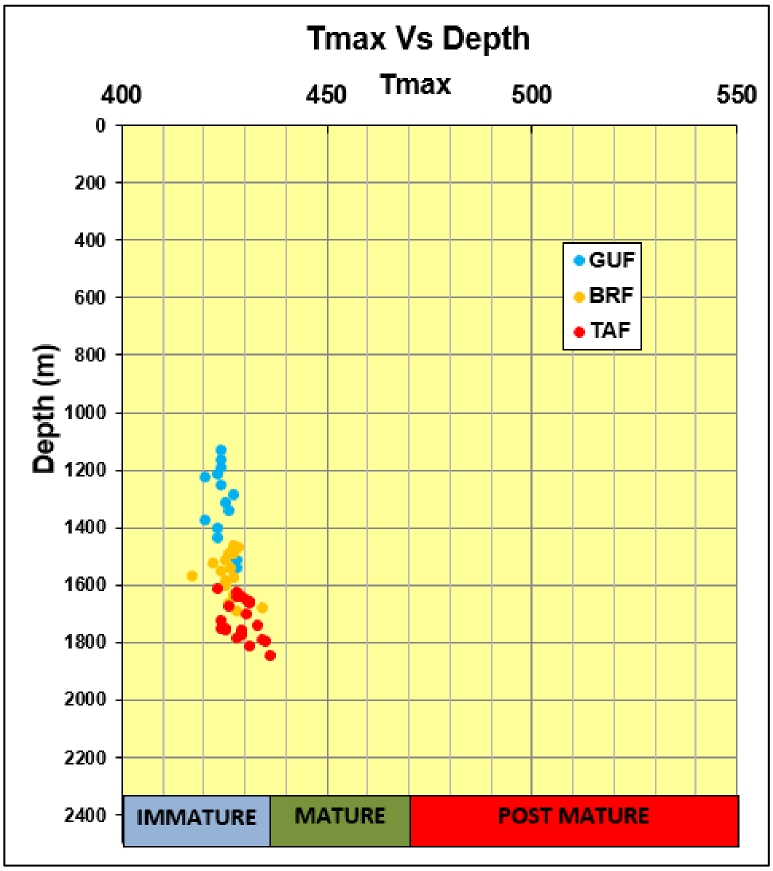

Figure 4. Maturity Diagram through the plot of Depth vs Tmax

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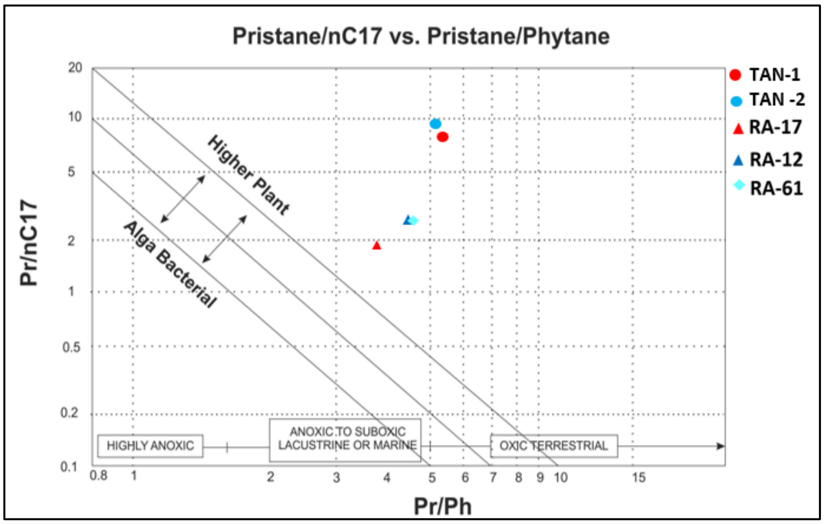

Figure 5. Pristane/nC_{17} vs Pristane/Phytane Diagram Crossplot

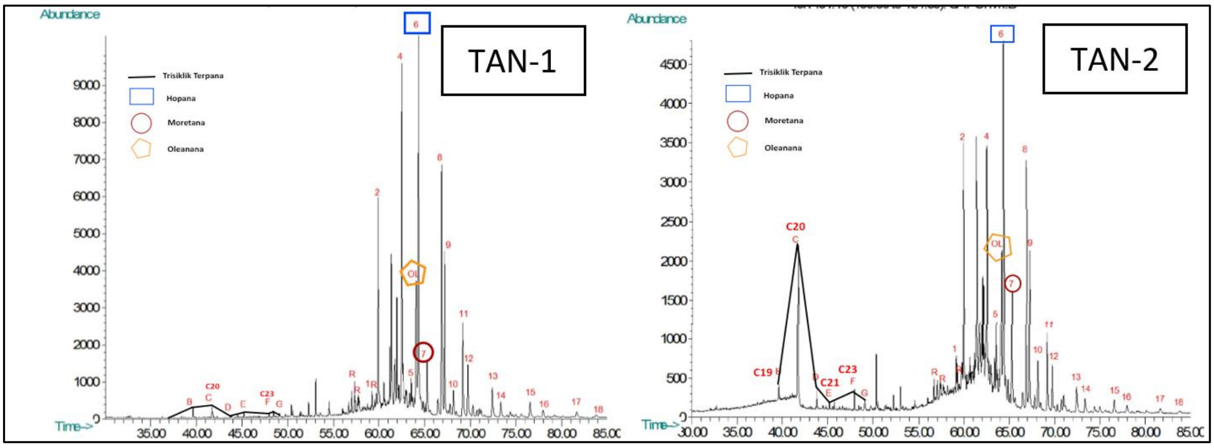

Figure 6. Triterpane (m.z 191) Chromatogram on Rock Extract Samples

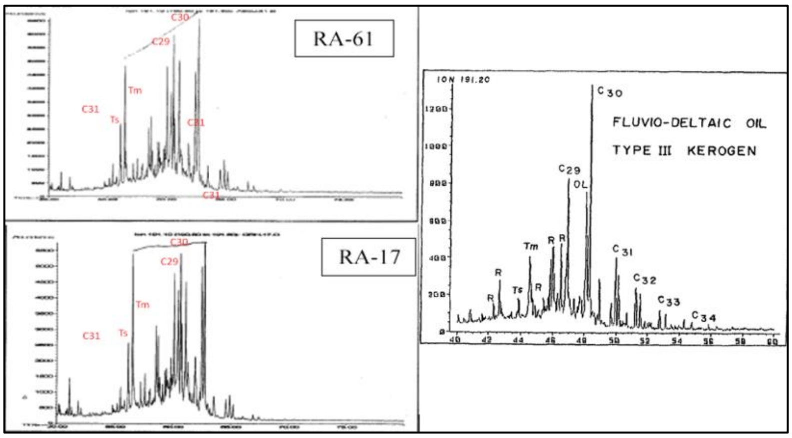

Figure 7. Triterpane (mx/z 191) Chromatogram on Crude Oil Samples

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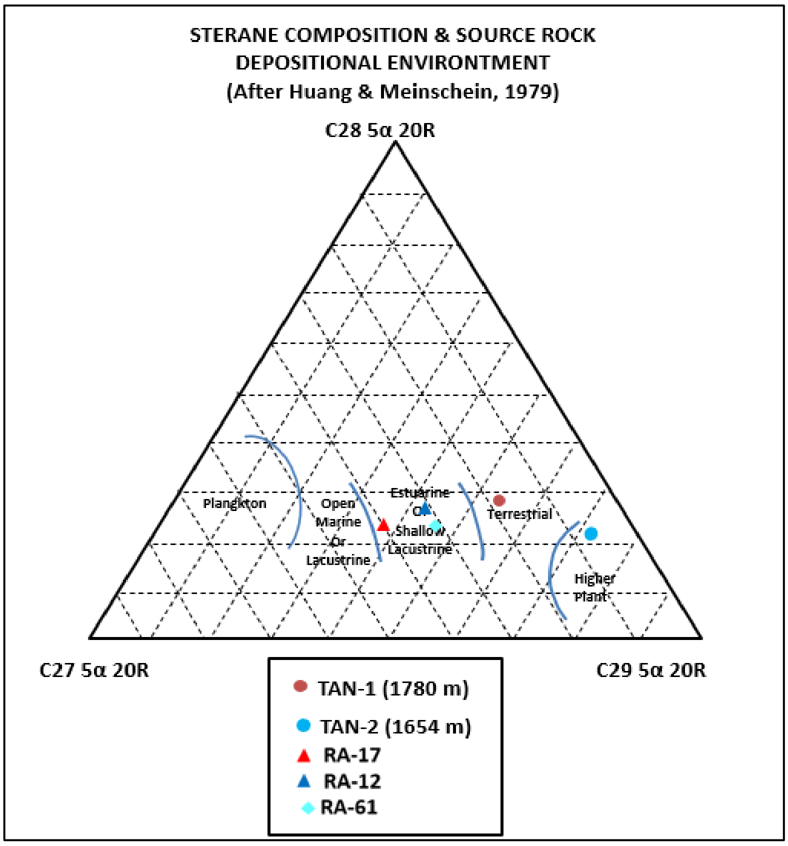

Figure 8. The Composition of Sterane from the Rock Extract and Crude Oil Samples

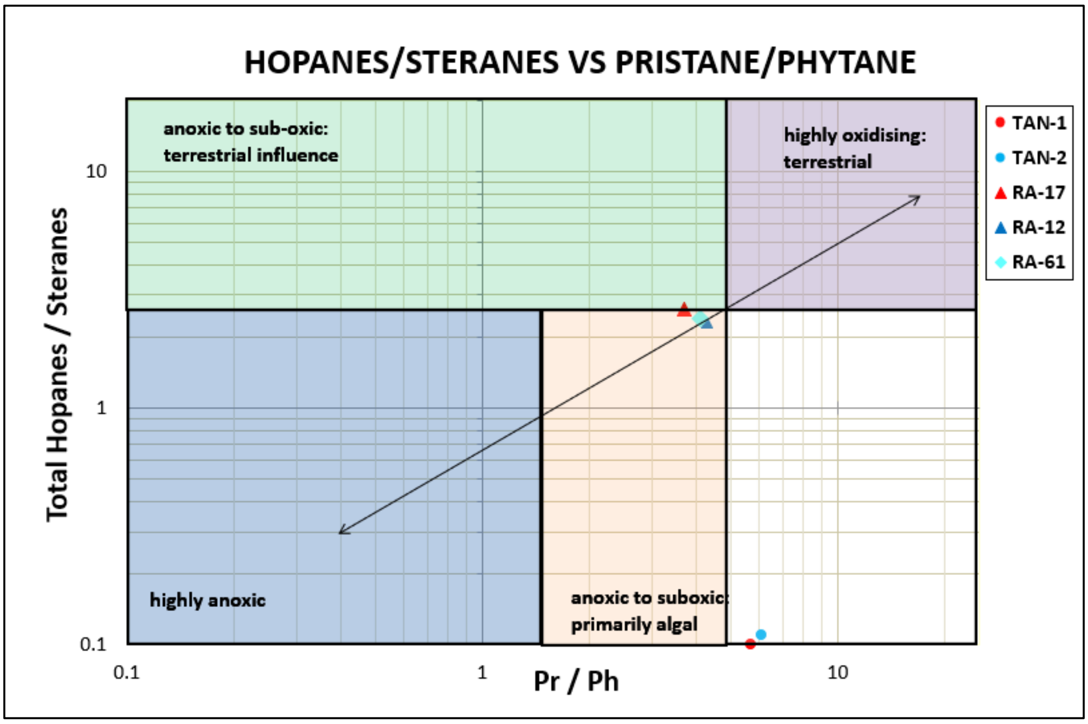

Figure 9. Hopanes/Sterane vs Pristane/Phytane Crossplot

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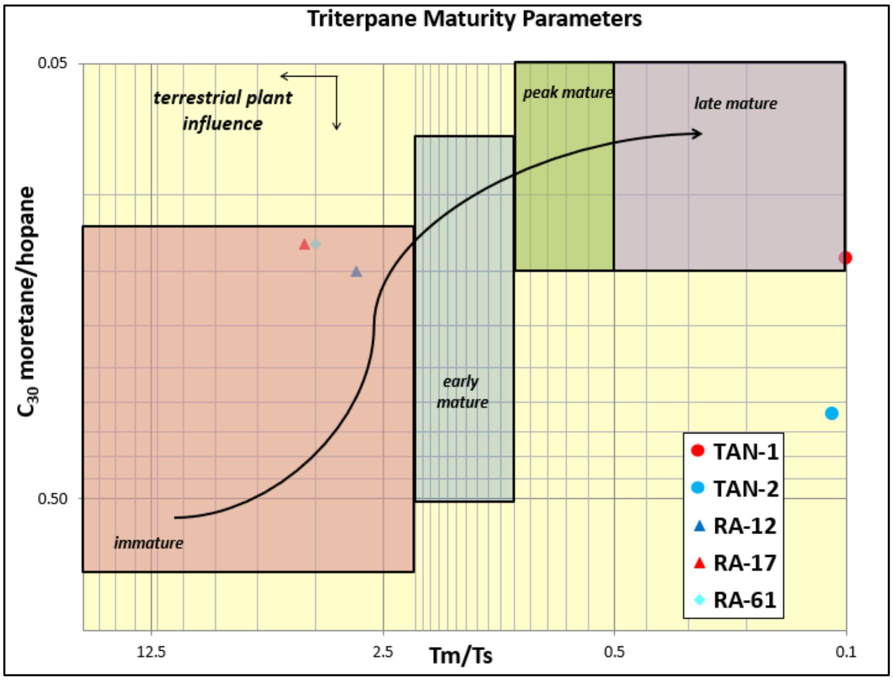

Figure 10. C_{30} Moretane/Hopane vs Tm/Ts Crossplot

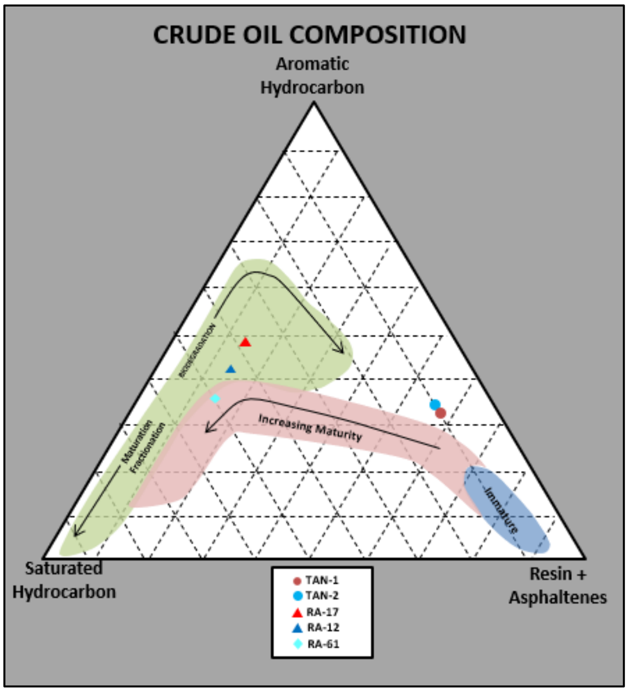

Figure 11. Crude Oil Composition

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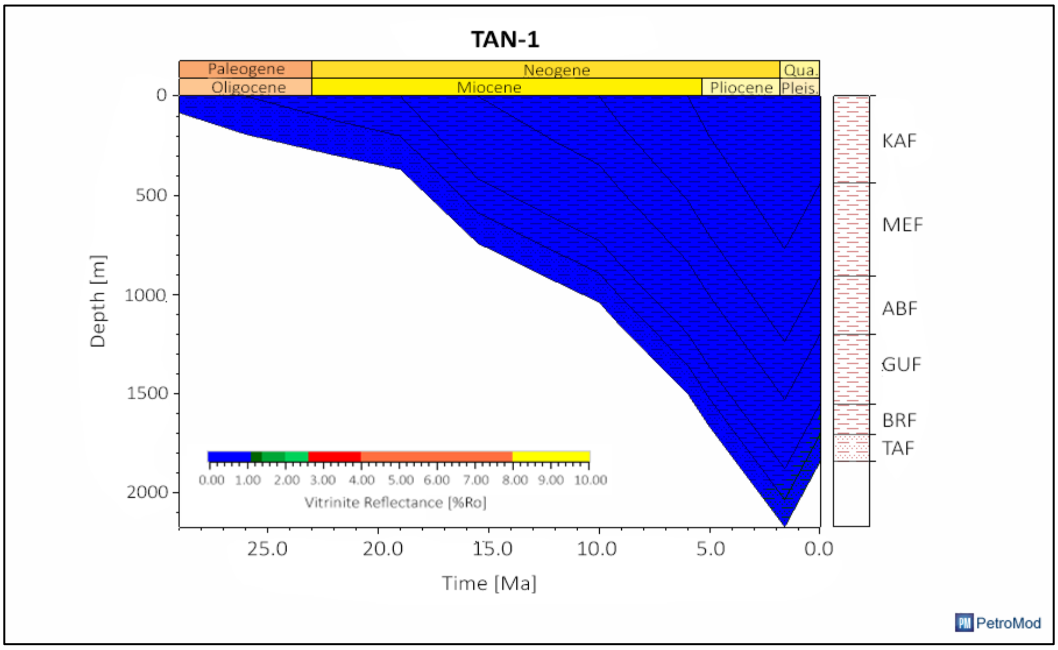

Figure 12. Burial History Modelling of TAN-1

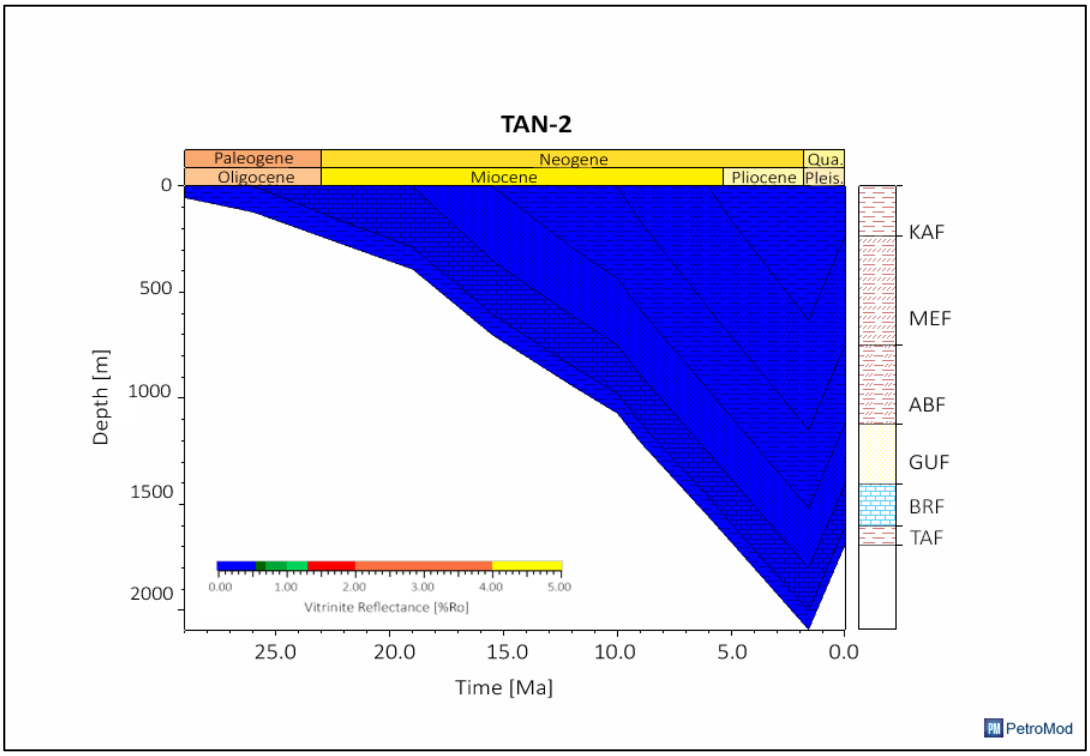

Figure 13. Burial History Modelling of TAN-2

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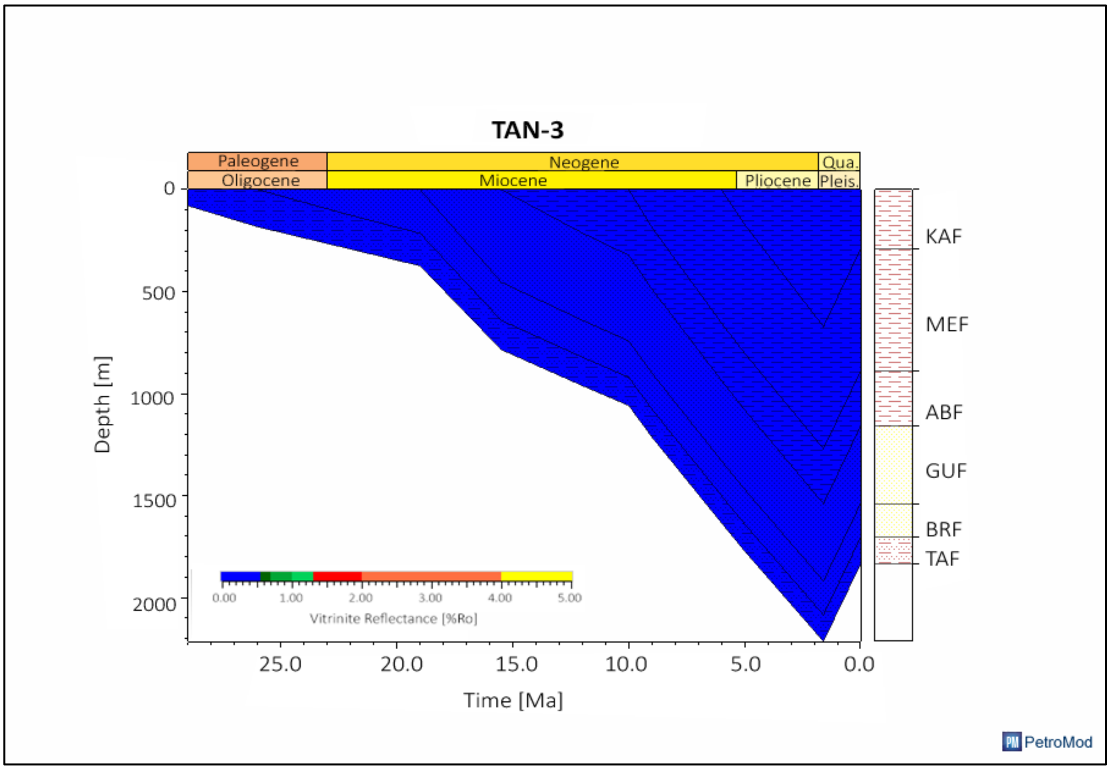

Figure 14. Burial History Modelling of TAN-3

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