SOURCE ROCK CHARACTERISTICS BASED ON GEOCHEMICAL ANALYSIS AND 1D BURIAL HISTORY MODELING IN THE "NAY" FIELD SOUTH SUMATRA BASIN

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ABSTRACT

The research is located in the "NAY" Field, South Sumatra Basin at NAY 1-4 Wells. This research was carried out with the aim of knowing the characteristics of source rock such as quantity, quality, maturity, and depositional environment using geochemical analysis, then analyzing the burial history in the study area which was visualized in 1D modeling using Petromod. The results showed that the dominant Well has effective source rock at Talang Akar Formation. Results of the 1-D Burial History modeling show that the NAY-1 Well is entering phase early mature at a depth of 2394 m at the Talang Akar formation in Early Pliocene (4.22 Ma) and starting to enter the mature phase at a depth of 2521 m in Middle Pliocene (3.27 Ma). The NAY-2 well is entering phase of early mature at a depth of 2521 m at the Talang Akar formation in Early Pliocene (2.64 Ma) and this formation is entering the mature phase at a depth of 2600 m which is Late Pliocene (1.32 Ma). The NAY-3 Well is still immature. Then the NAY-4 well entering phase of early mature at a depth of 2255 m at the Talang Akar Formation in Early Pliocene (2.27 Ma) and the Baturaja Formation at a depth of 2166 m in Late Pliocene (1.63 Ma). The results also show that the majority of the hydrocarbons found in this basin have a marine-terrestrial depositional environment.

Keyword: South Sumatra Basin, Source Rock, Burial History, Geochemistry, Depositional Environment.

INTRODUCTION

Oil and gas are one of the energy-producing natural resources which are included in fossil fuels or fossil energy. Over time, the need for fossil energy is increasing so that a search for prospects for hydrocarbon fields that have better potential value is carried out. Basin of South Sumatra is one of the main hydrocarbon producing basins in Indonesia, with a basin area of approximately 510 x 330 $km2$ and is a back arc basin located in the southeastern part of Sumatra Island (De Coster, 1974). The South Sumatra Basin is the object of research in this study and is the operational area of PT. Pertamina Hulu Rokan Zone 4, which is located in the "NAY" field.

In producing oil and gas, one of the important elements is source rock. Source rock is a sedimentary rock that contains organic material that may or has been able to produce petroleum, so that source rock is the initial source of oil and gas formation (Tissot & Welte, 1984). The geochemical method is a method used to analyze the quality, quantity and maturity level of source rock which plays an important role in the exploration process. (Peters and Cassa, 1994). Therefore this research was conducted to analyze the characteristics of the source rock using geochemical methods to determine the formation of hydrocarbons in source rock, the correlation of source rock and petroleum, as well as the characterization and history of their burial using the 1D basin modeling method. To determine potential and quality of source rock so that exploration and production activities are right on target.

RESEARCH METHOD

The method used in this study includes quality analysis using the parameters Total Organic Carbon (TOC) vs S2 and Hydrogen Index (HI) vs Tmax. Quantity analysis using the parameter TOC (Total Organic Carbon) vs S2 as well. Then the maturity analysis uses the parameters Depth vs Vitrinite Reflectance (Ro) and Depth vs Tmax. Analysis of the geochemistry data also carried out to determine the depositional environment and the origin of the organic material, from the kerogen type and maseral type. Furthermore, an analysis of the history of 1D burial was carried out to determine when and how a hydrocarbon was generated from source rock, to reconstruct the history of burial, erosion, thermal maturation of a source rock, and the rate of velocity sediment accumulation.

RESULT AND DISCUSSION

Source Rock Characteristics

This study has 4 research wells, namely NAY-1, NAY-2, NAY-3, and Nay-4 which produce the following analysis:

Organic Material Quantity

1. NAY-1 Well

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Analysis of the source rock characteristics in this well was carried out in the Talang Akar Formation based on TOC vs S2 values (Figure 1). The Talang Akar Formation has a TOC value of 1.15 – 1.23 wt% (Good) and S2 value of 1.61 – 2.43 (Poor – Fair).

2. NAY-2 Well

Analysis of the source rock characteristics in this well was carried out in the Talang Akar Formation based on TOC vs S2 values (Figure 2). The Talang Akar Formation has a TOC value of 1.47 – 3.11 wt% (Good – Very Good), S2 value 3.62 – 5.94 (Fair – Good).

3. NAY-3 Well

Analysis of the source rock characteristics in this well was carried out at Talang Akar, Gumai, and Baturaja Formations based on TOC vs S2 values (Figure 3). Talang Akar Formation has a TOC value of 0.90 – 1.04 wt% (Fair - Good) and S2 values 1.10 – 1.79 (poor). The Baturaja Formation has a TOC value of 0.83 wt% (Fair) and an S2 value of 1.14 (Poor). The Gumai Formation has a TOC value of 0.82 – 2.36 wt% (Fair – Very Good) and an S2 value of 0.46 – 0.91 (Poor).

4. NAY-4 Well

Analysis of the source rock characteristics in this well was carried out in the Talang Akar, Baturaja, Gumai, and Air Benakat Formations based on TOC vs S2 values (Figure 4). Talang Akar Formation has a TOC value of 0.82 – 6.21 wt% (Fair – Excellent) and S2 value 1.25 – 24.16 (Poor – Excellent). The Baturaja Formation has a TOC 0.02 – 1.83 wt% (Poor - Good) and an S2 value of 0.03 – 5.27 (Poor - Good). The Gumai Formation has a TOC value of 0.52 – 0.83 wt% (Fair) and an S2 value of 0.27 – 1.47 (Poor). Then the Air Benakat Formation has a TOC of 0.86 – 0.89 wt% (Fair) and an S2 value of 0.53 – 0.65 (Poor).

Organic Material Quality

1. NAY-1 Well

Analysis of the source rock characteristics in this well was carried out in the Talang Akar Formation based on TOC vs S2 values (Figure 5) and Tmax vs Hydrogen Index (HI) (Figure 6). The results showed that the organic material in the Talang Akar formation contains Type II-III which indicates an intermediate hydrogen content and is a mixture of oil and gas.

2. NAY-2 Well

Analysis of the source rock characteristics in this well was carried out in the Talang Akar Formation based on TOC vs S2 values (Figure 7) and Tmax vs Hydrogen Index (HI) (Figure 8). The results showed that the organic material in the Talang Akar formation contains Type II-III which indicates an intermediate hydrogen content and is a mixture of oil and gas.

3. NAY-3 Well

Analysis of the source rock characteristics in these wells was carried out in Talang Akar, Gumai, and Baturaja Formations based on TOC vs S2 (Figure 9) and Tmax vs Hydrogen Index (HI) values (Figure 10). The results showed that the organic material in the Talang Akar formation contained Type II which indicated oil prone. The Baturaja Formation and Gumai Formation contain Type III which indicates prone gas.

4. NAY-4 Well

Analysis of the source rock characteristics in this well was carried out in Talang Akar, Baturaja, Gumai, and Air Benakat Formations based on the TOC vs S2 values (Figure 11) and Tmax vs Hydrogen Index (HI) (Figure 12). The results showed that the organic material in the Talang Akar Formation and the Baturaja Formation contained Types II-III which indicated a mixed (oil/gas generating potential). The Gumai Formation and the Air Benakat Formation contain Type III which indicates prone gas.

Organic Material Maturity

1. NAY-1 Well

Analysis of the source rock characteristics in this well was carried out in Talang Akar Formation based on the values of Depth vs Ro (Figure 13) and Tmax vs Depth (HI) (Figure 14). The results showed that the organic material in Talang Akar formation was in the mature phase.

2. NAY-2 Well

Analysis of the source rock characteristics in this well was carried out in the Talang Akar Formation based on the values of Depth vs Ro (Figure 15) and Tmax vs Depth (HI) (Figure 16). The results showed that the organic material in the Talang Akar formation was in the mature phase.

3. NAY-3 Well

Analysis of the source rock characteristics in this well was carried out in Talang Akar, Baturaja, and Gumai Formations based on Depth vs Ro (Figure 17) and Tmax vs Depth (HI) values (Firgure 18). The results show that the organic material in the entire formation is in the immature phase.

4. NAY-4 Well

Analysis of the source rock characteristics in this well was carried out in the Talang Akar,

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Baturaja, Gumai, and Air Benakat Formations based on Depth vs Ro (Figure 19) and Tmax vs Depth (HI) values (Figure 20). The results show that the organic material in the entire formation is in the immature – early mature phase.

Origin of Organic Materials and Depositional Environment

Determination of the origin of organic material and depositional environment refers to the type of kerogen contained in the source rock (Waples, 1985). The results can be concluded that the NAY-1 & NAY-2 Wells which consist of the Talang Akar Formation produce kerogen type II-III quality so that it comes from organic material from marine algae to higher plants and enters the marine - terrestrial depositional environment. Then for the NAY-3 Well it consists of the Talang Akar Formation containing kerogen type II which indicates the origin of organic material from marine algae, and enters the marine depositional environment. The Baturaja and Gumai Formations in the NAY-3 Well contain kerogen type III which indicates the origin of higher plant material, so that it enters the terrestrial environment. The NAY-4 well consists of the Talang Akar and Baturaja Formations which contain types II-III indicating the origin of organic material from marine algae to higher plants, and enters the marine-terrestrial depositional environment. The Gumai and Air Benakat Formations contain type III which indicates the origin of organic material from higher plants, so that it enters the terrestrial depositional environment.

Burial History

The history of one-dimensional burial was carried out in all wells, to determine the process of when and how a hydrocarbon was generated from source rock, reconstructing the burial history, erosion, thermal maturation of a source rock, as well as the level of sediment accumulation.

Analysis of the history of burial in this study was carried out using several parameters including the geothermal temperature gradient which was obtained by conducting a Bottom Hole Temperature (BHT) analysis using Andrew Speed correction. When the drilling process is obtained the BHT value that passes through the formations, the BHT value needs to be corrected to determine the original temperature of the formation. Then the calculation is carried out by carrying out a crossplot on the BHT diagram and BHT (Andrew Speed) correction, resulting in a geothermal gradient of 12.4°C/1000 ft and 14.4°C/1000 ft after correction (Andrew Speed, 1984) (Figure 21). Then input the necessary data into the Petromod 2012 software and produce the following analysis:

1. NAY-1 Well

Analysis of the NAY-1 Well Based on the modeling that has been done on the Time vs Depth curve which has been calibrated with Vitrinite Reflectance (Ro) correction (Peters and Cassa, 1994) (Figure 22). The results show that the hydrocarbons in the NAY-1 well have entered the early mature phase at a depth of 2109 m in the Late Pliocene Baturaja formation (1.94 Ma). Then the early mature phase at a depth of 2394 m in the Talang Akar formation which is Early Pliocene (4.22 Ma) and this formation also enters the mature phase at a depth of 2521 m which is Middle Pliocene (3.27 Ma). In addition there is a geological event, namely the erosion of 1.60 Ma which is characterized by an uplift and causes part of the surface to be exposed and experience erosion. In this well the potential for hydrocarbons lies in Talang Akar Formation which has entered the oil window.

2. NAY-2 Well

Based on the modeling that has been done on the time vs depth curve which has been calibrated with Vitrinite Reflectance (Ro) correction (Peters and Cassa, 1994) (Figure 23). The results show that the hydrocarbons in the NAY-2 well have entered the early mature phase at a depth of 2521 m in the Talang Akar formation which is Early Pliocene (2.64 Ma) and this formation is also entering the mature phase at a depth of 2600 m which is Late Pliocene (1.32 Ma). Then there is also a geological event, namely the erosion of 1.60 Ma which is marked by an uplift and causes part of the surface to be exposed and experience erosion. In this well the potential for hydrocarbons lies in Talang Akar Formation which has entered the oil window.

3. NAY-3 Well

Maturity analysis of the NAY-3 well indicates that the source rock in this well has not reached maturity or is still immature (Figure 24). This is because the NAY-3 well is in a high area so it has not yet reached the depth where the source rock reaches maturity. In this well there is also a geological event, namely the erosion of 1.60 Ma which is characterized by an uplift and causes part of the surface erosion.

4. NAY-4 Well

Based on the modeling that has been done on the time (Time) vs depth (Depth) curve which has been calibrated with Vitrinite Reflectance (Ro) correction (Peters and Cassa, 1994) (Figure 25). The results show that the hydrocarbons in the NAY-2 well have entered

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the early mature phase at a depth of 2255 m in the Early Pliocene Talang Akar Formation (2.27 Ma) and the Late Pliocene Baturaja Formation at a depth of 2166 m (1.63 Ma). In addition, there is also a geological event, namely the erosion of 1.60 Ma which is characterized by an uplift and causes part of the surface to be exposed and experience erosion. In this well, the potential for hydrocarbons lies in Talang Akar Formation which has entered the oil window.

CONCLUSION

1. Source rock characteristics which includes analysis of the quantity, quality, and maturity of the organic material in this area indicate that the effective source rock is at Talang Akar Formation which is in the NAY-1, NAY-2 and NAY-3 wells. Then for other formations such as the Baturaja Formation, Gumai Formation, and the Air Benakat Formation indicate potential source rocks.
2. The history of burial began in the Oligocene to the early Pliocene, with hydrocarbons starting to enter the maturity phase during the Early Pliocene - Late Pliocene at a depth of 2109 - 2521 m which the oil window began to enter in the NAY-1 Well. At NAY-2 Well The history of burial began in the Oligocene to the early Pliocene, with hydrocarbons starting to enter the maturity phase during the Early-Late Pliocene at depths of 2521-2600 m entering the early mature to mature phase so that they have entered the oil window. Then at the NAY-3 well, the history of immersion began during the Oligocene to the early Pliocene, this well shows that the source rock has not reached maturity or is still immature. Because this well is in a high area, it has not yet reached the depth where the source rock reaches maturity. Whereas in the NAY-4 Well, the history of burial began in the Oligocene to the early Pliocene, with hydrocarbons starting to enter the maturity phase during the Early Pliocene - Late Pliocene at depths of 2166 - 2255 m and began to enter the oil window. In the historical analysis of all wells, there were geological events, namely uplift at the beginning of the Pleistocene which caused erosion.

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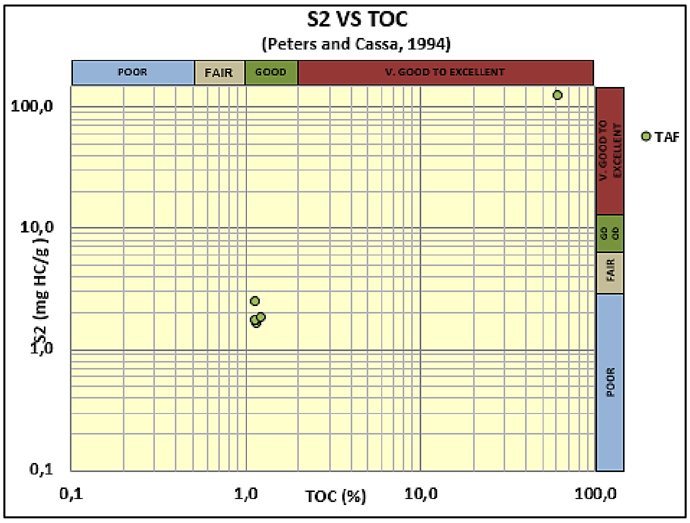

Figure 1. Crossplot Diagram S2 vs TOC of NAY-1 Well (Peters dan Cassa, 1994)

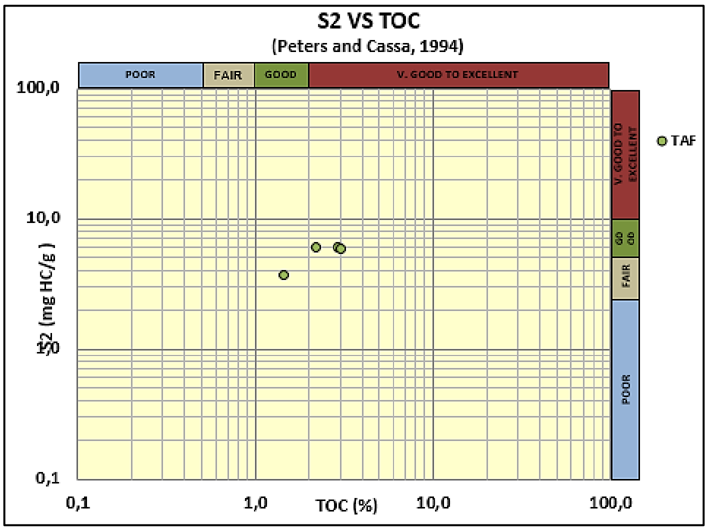

Figure 2. Crossplot Diagram S2 vs TOC of NAY-2 Well (Peters dan Cassa, 1994)

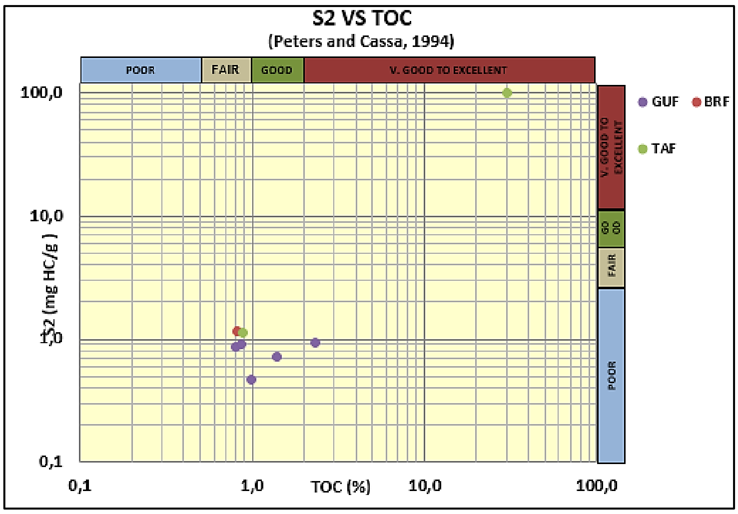

Figure 3. Crossplot Diagram S2 vs TOC of NAY-2 Well (Peters dan Cassa, 1994)

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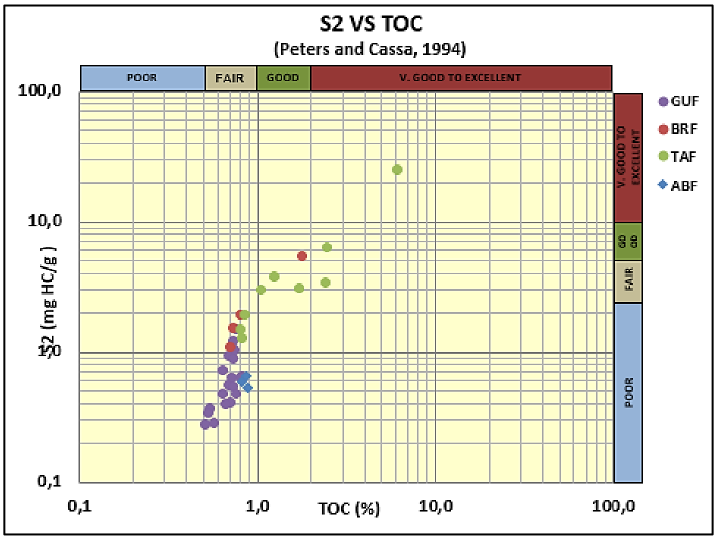

Figure 4. Crossplot Diagram S2 vs TOC of NAY-4 Well (Peters dan Cassa, 1994)

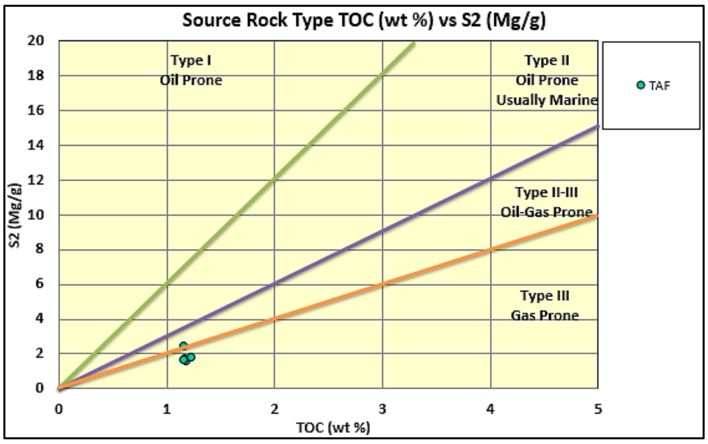

Figure 5. Crossplot Diagram S2 vs TOC quality of NAY-1 Well (Peters dan Cassa, 1994)

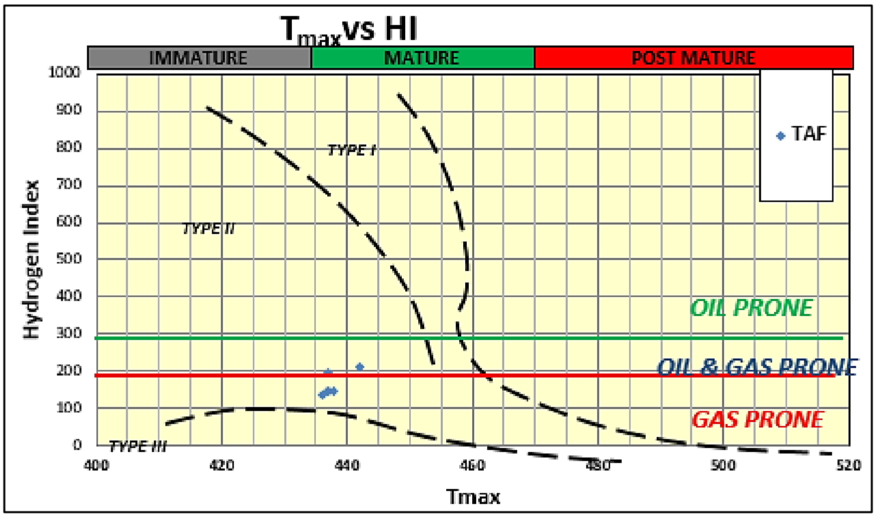

Figure 6. Crossplot Diagram Tmax vs HI of NAY-1 Well (Peters dan Cassa, 1994)

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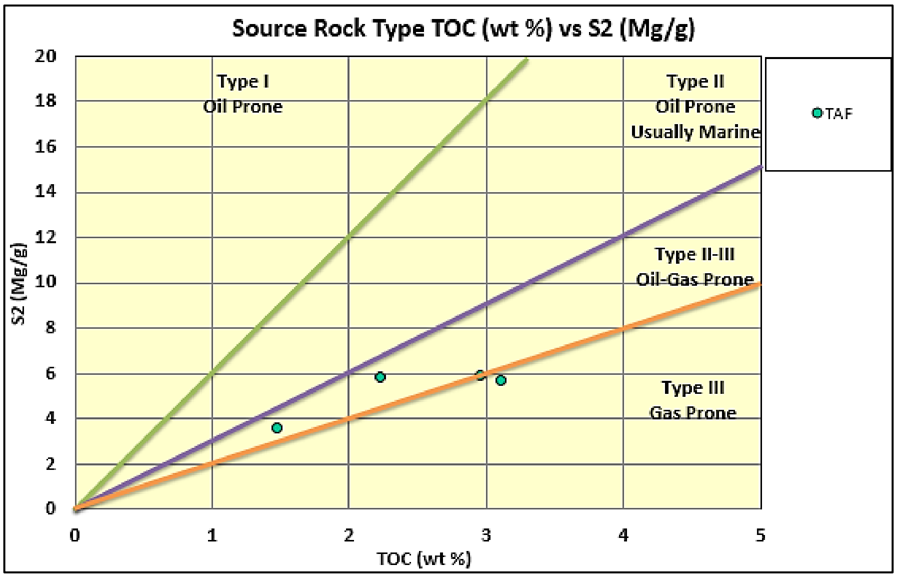

Figure 7. Crossplot Diagram S2 vs TOC quality of NAY-2 Well (Peters dan Cassa, 1994)

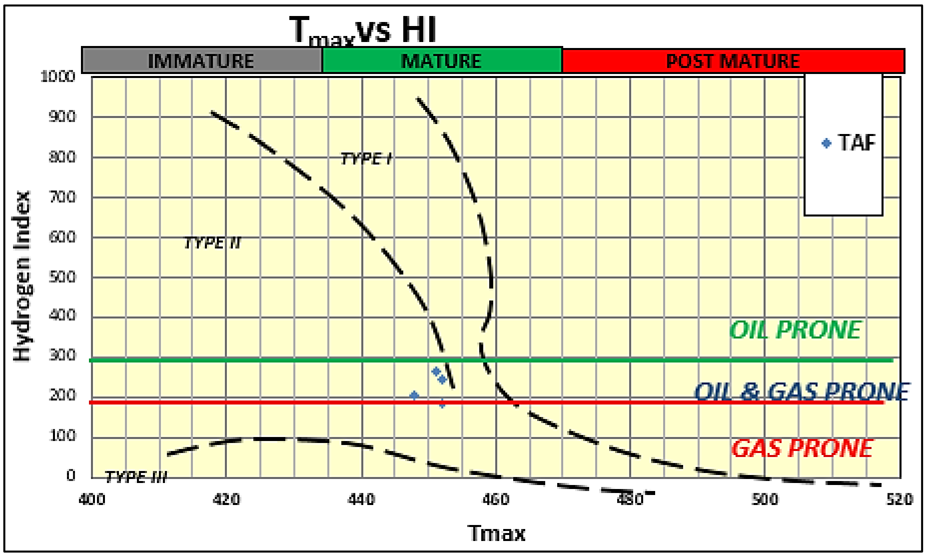

Figure 8. Crossplot Diagram Tmax vs HI of NAY-2 Well (Peters dan Cassa, 1994)

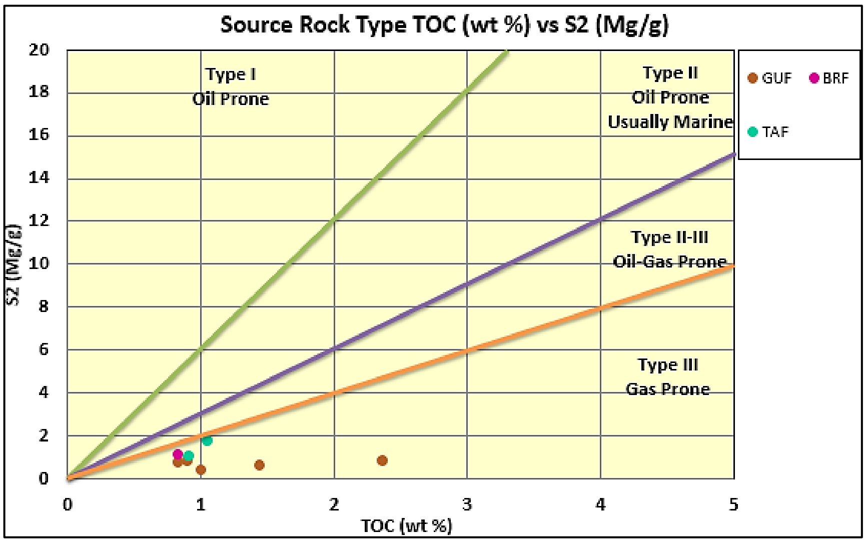

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Figure 9. Crossplot Diagram S2 vs TOC quality of NAY-3 Well (Peters dan Cassa, 1994)

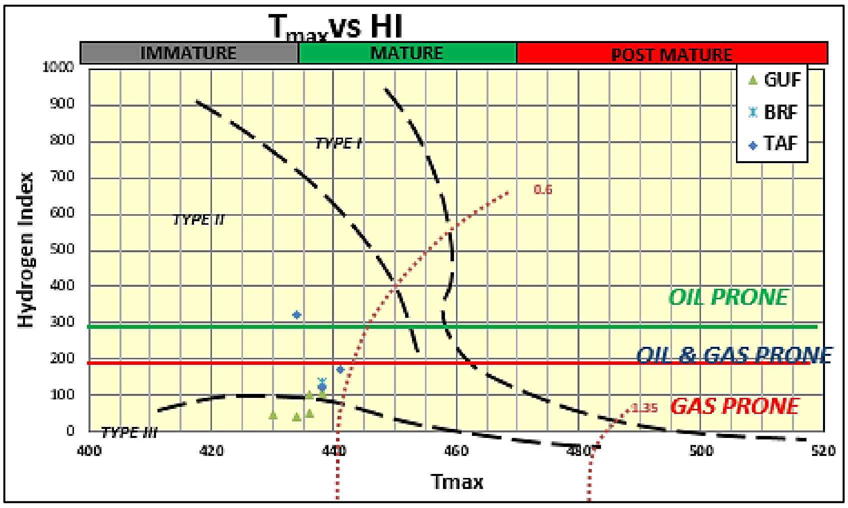

Figure 10. Crossplot Diagram Tmax vs HI of NAY-3 Well (Peters dan Cassa, 1994)

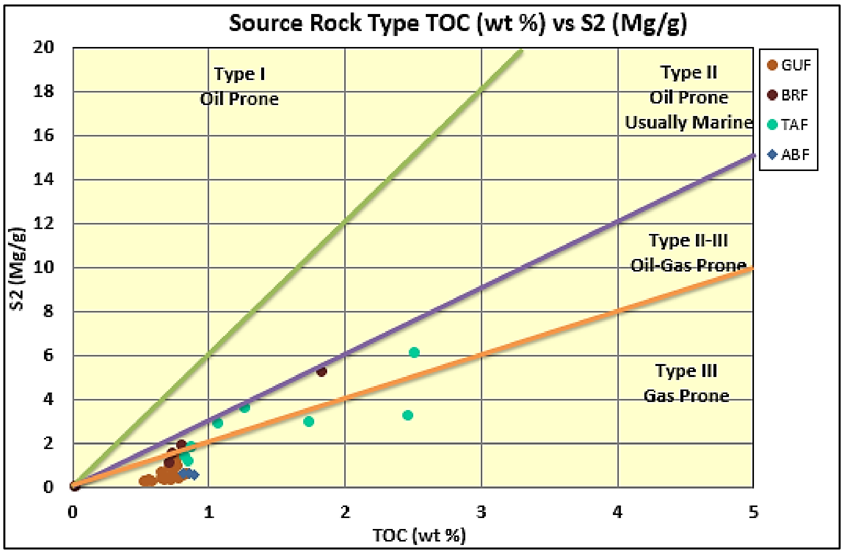

Figure 11. Crossplot Diagram S2 vs TOC quality of NAY-4 Well (Peters dan Cassa, 1994)

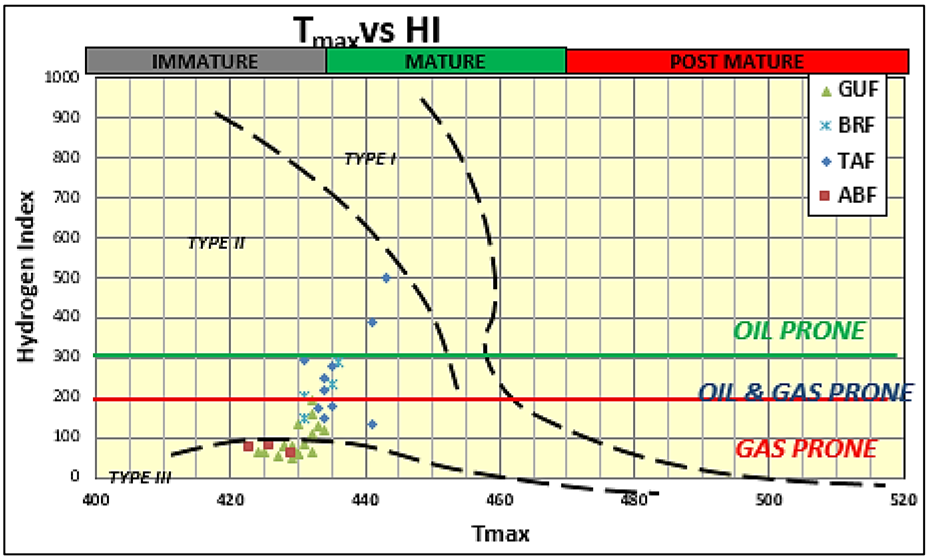

Figure 12. Crossplot Diagram Tmax vs HI of NAY-4 Well (Peters dan Cassa, 1994)

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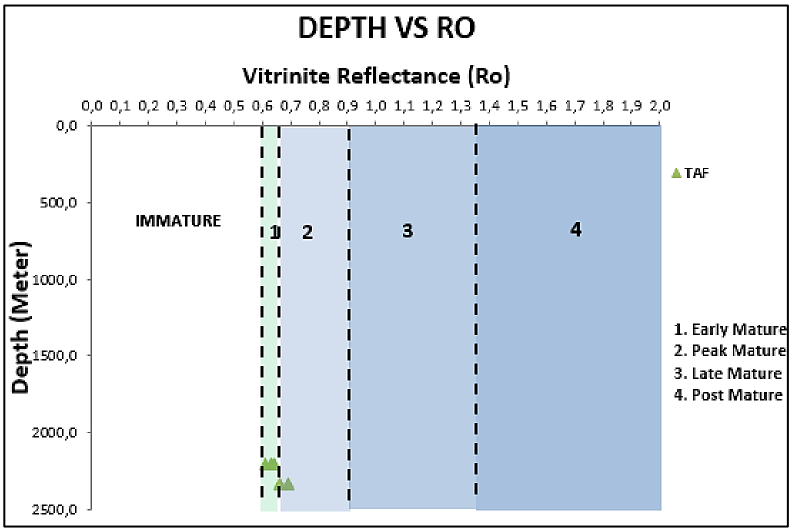

Figure 13. Crossplot Diagram Depth vs Ro of NAY-1 Well (Peters dan Cassa, 1994)

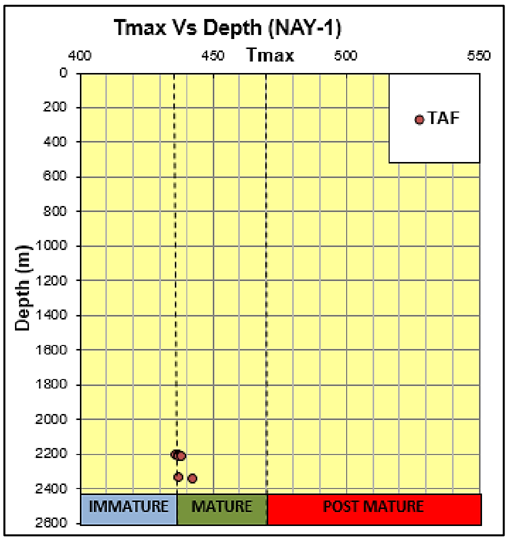

Figure 14. Crossplot Diagram Tmax vs Depth of NAY-1 Well (Peters dan Cassa, 1994)

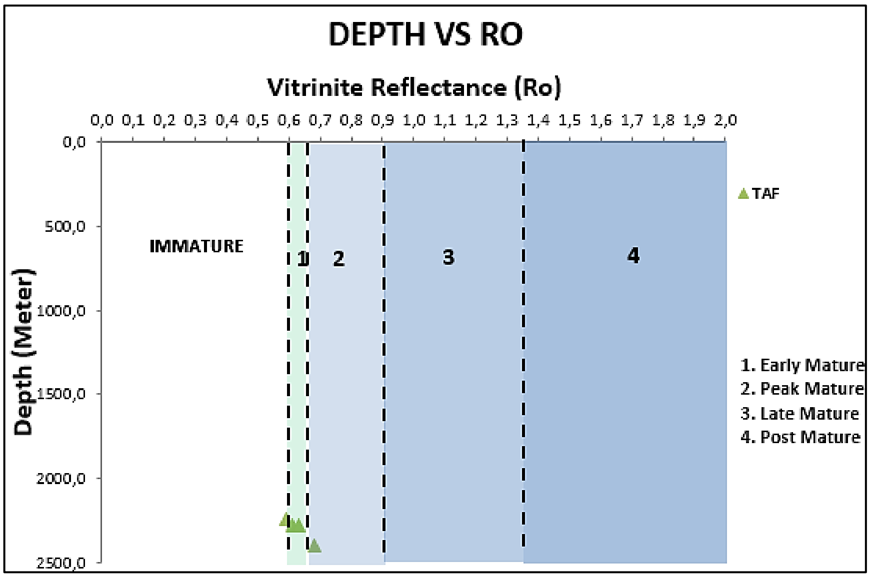

Figure 15. Crossplot Diagram Depth vs Ro of NAY-2 Well (Peters dan Cassa, 1994)

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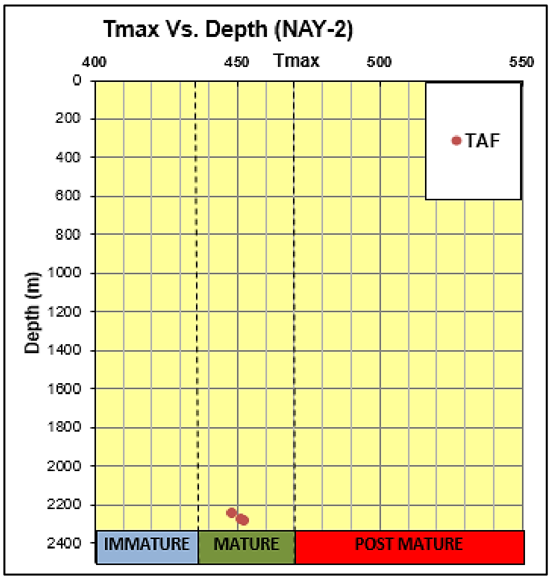

Figure 16. Crossplot Diagram Tmax vs Depth of NAY-2 Well (Peters dan Cassa, 1994)

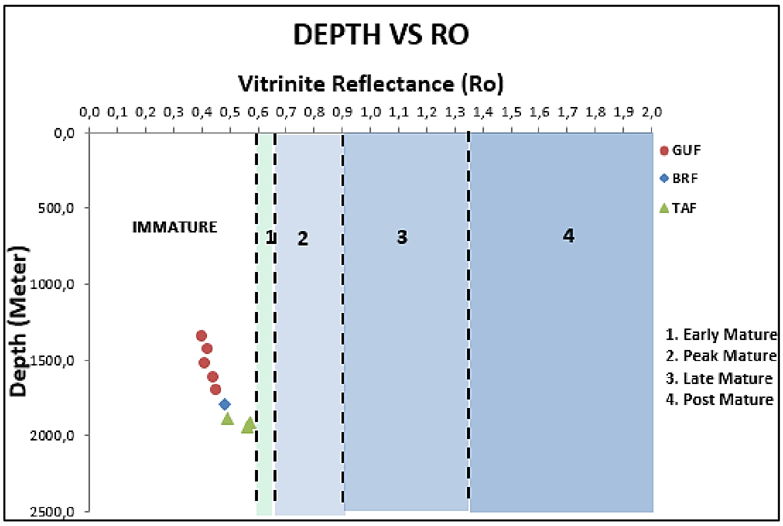

Figure 17. Crossplot Diagram Depth vs Ro of NAY-3 Well (Peters dan Cassa, 1994)

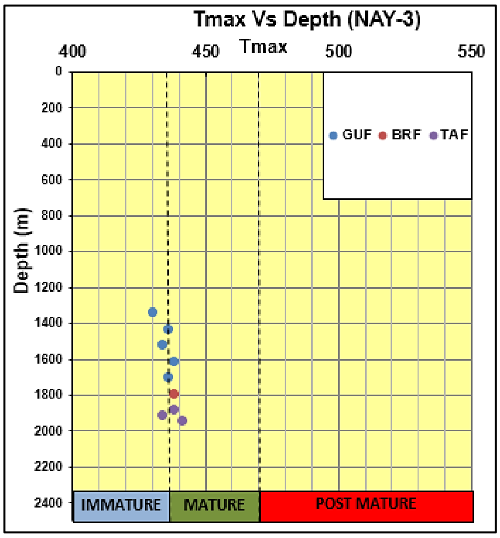

Figure 18. Crossplot Diagram Tmax vs Depth of NAY-3 Well (Peters dan Cassa, 1994)

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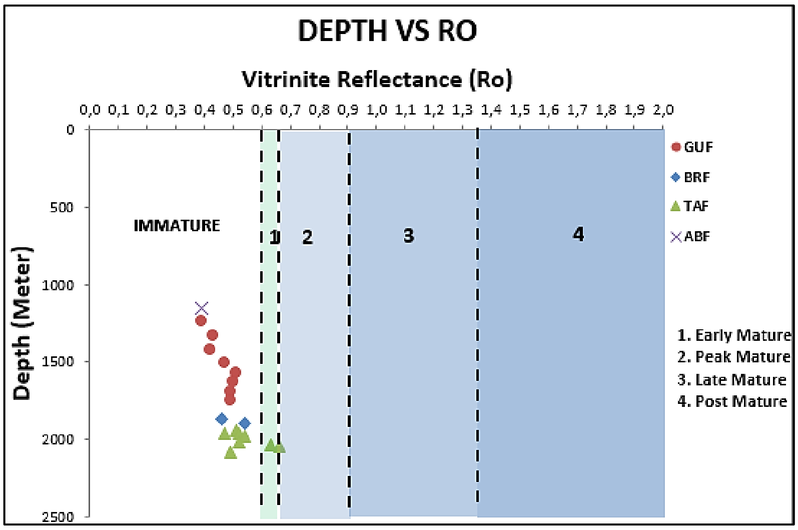

Figure 19. Crossplot Diagram Depth vs Ro of NAY-4 Well (Peters dan Cassa, 1994)

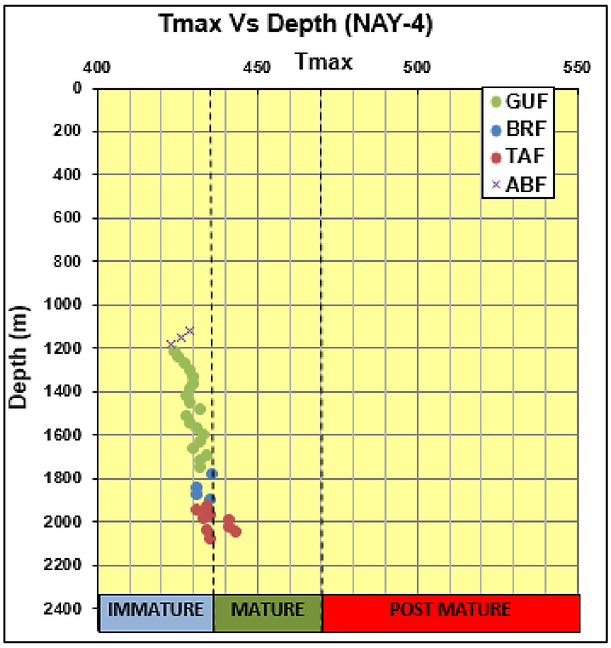

Figure 20. Crossplot Diagram Tmax vs Depth of NAY-4 Well (Peters dan Cassa, 1994)

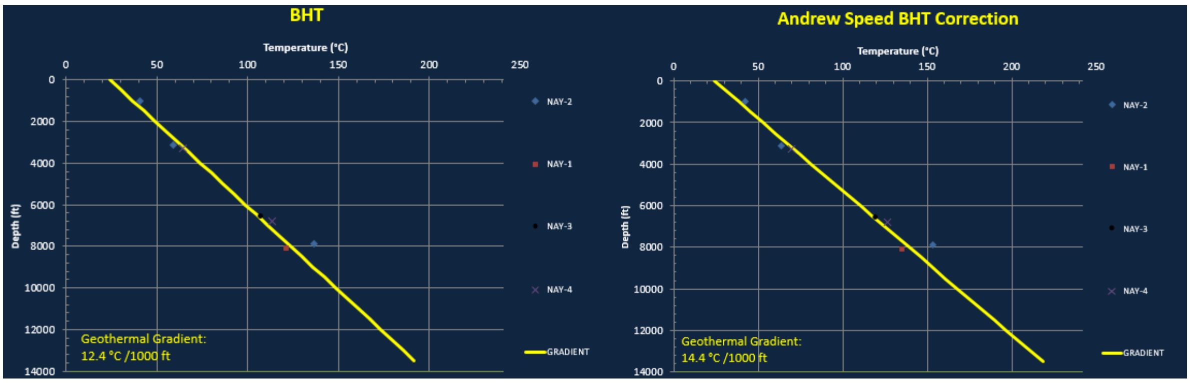

Figure 21. Crossplot Diagram BHT & BHT Correction (Andrew Speed, 1984)

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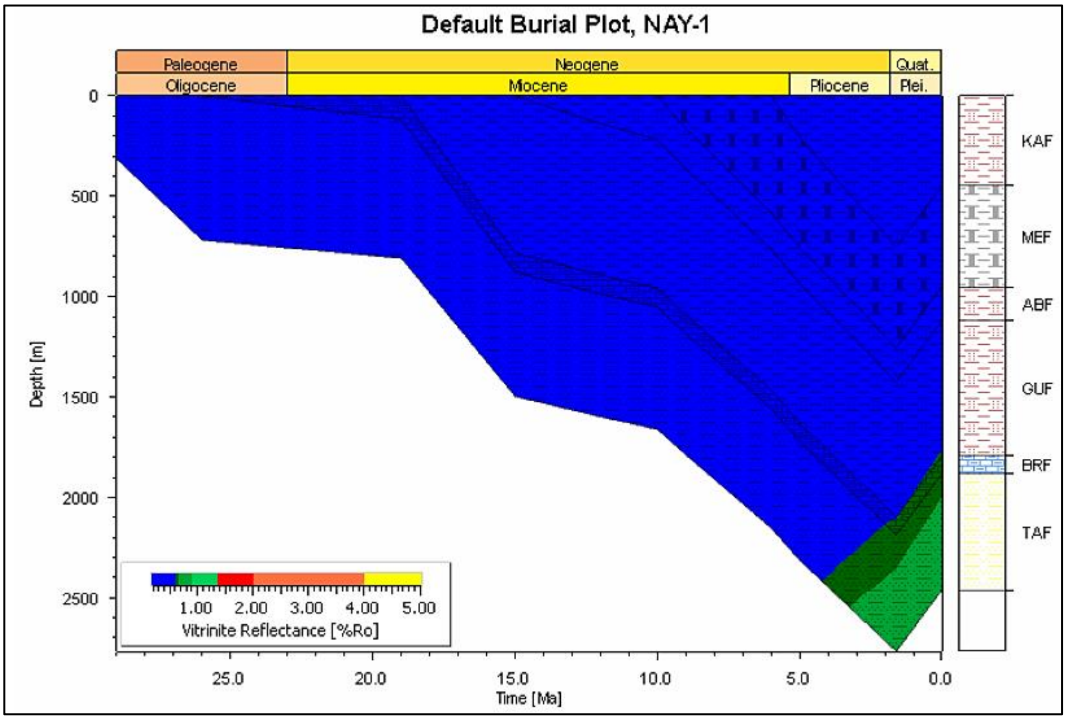

Figure 22. Burial History Modelling of NAY-1 Well (Petromod, 2012)

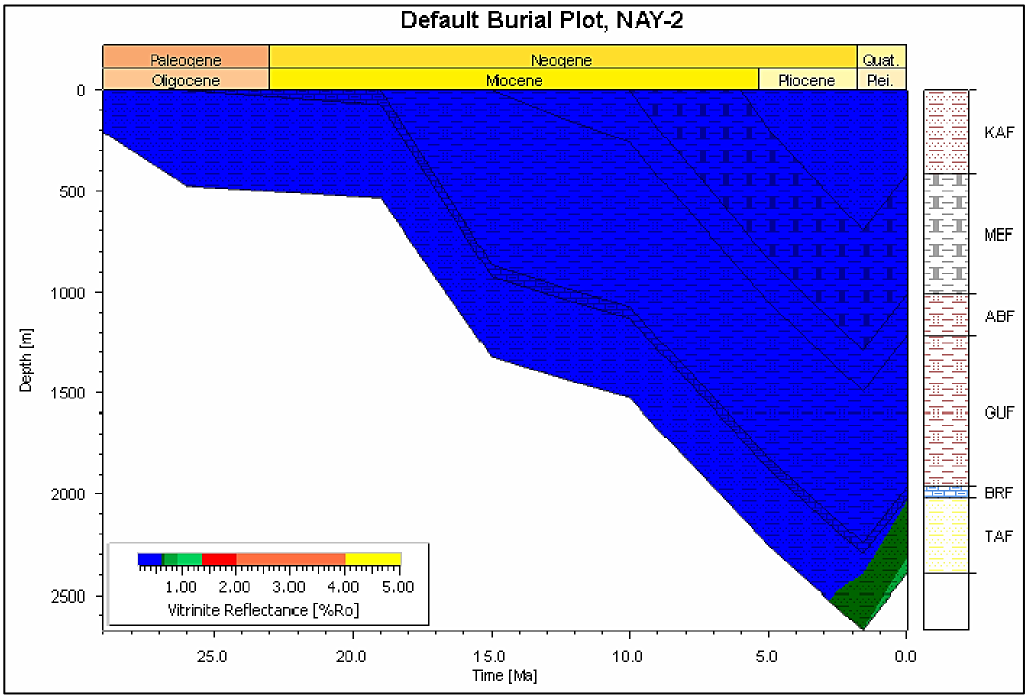

Figure 23. Burial History Modelling of NAY-2 Well (Petromod, 2012)

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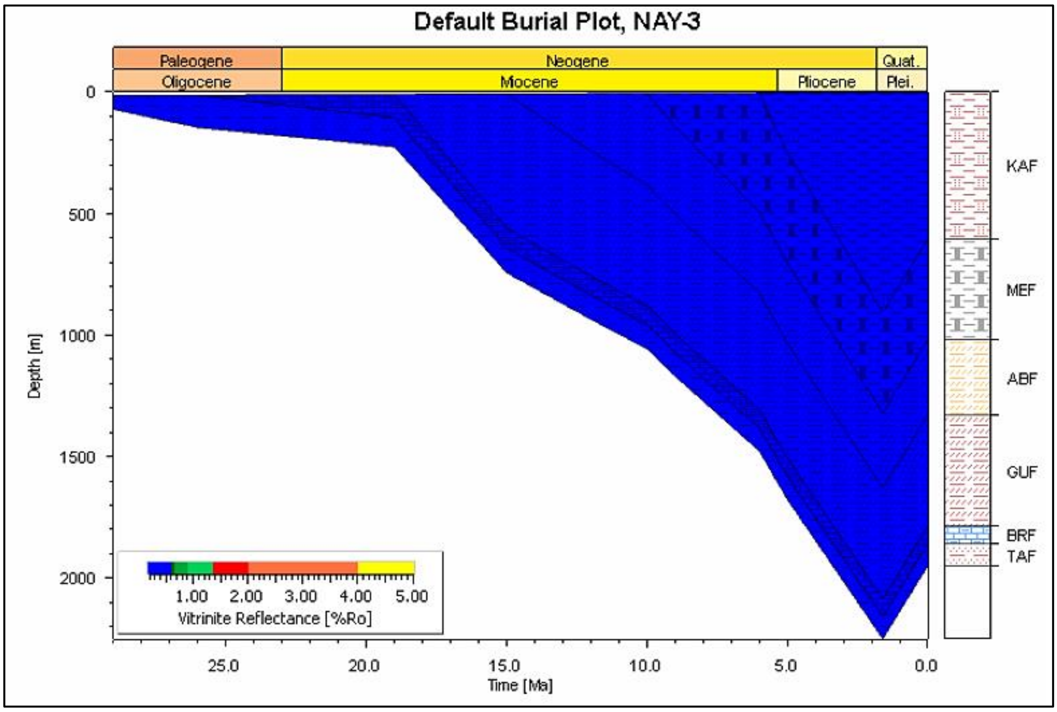

Figure 24. Burial History Modelling of NAY-3 Well (Petromod, 2012)

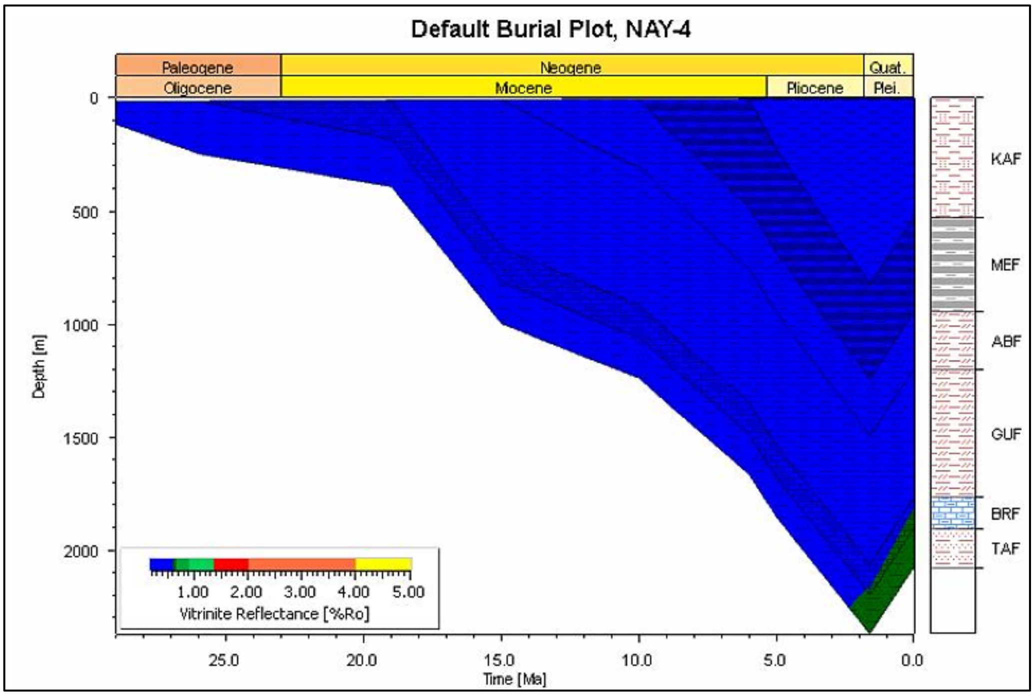

Figure 25. Burial History Modelling of NAY-4 Well (Petromod, 2012)

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