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Source Rock Potential of Nampol Formation Sumbermanjing Area, Malang, East Java, Indonesia Based on Geochemistry Analysis of the Selected Sample

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ABSTRACT - Nampol Formation of the Southern Mountains of eastern Java (Indonesia) has a distribution from its type location in Pacitan to the South Malang area. In the research area, this formation consists of clastic limestone with black shale inserts, claystone, siltstone, carbonate sandstone and claystone which are interpreted to be deposited in a restricted platform interior environment with closed water circulation. A total of three samples were analyzed to evaluate the organic matter content, kerogen type, thermal maturity, and hydrocarbon generating potential. Samples were taken from clastic carbonate deposits of the Nampol Formation. Based on the results of geochemical analysis, the three samples from the Nampol Formation have a TOC content of 3.48 - 26.18 wt% and possess good to excellent hydrocarbon generating potential. Hydrogen Index (HI) values for the studied samples ranged from 43 to 86 mg HC/g TOC and S_1+S_2 results ranged from 1.52 to 19.55 mg HC/g rock, indicating that the sample has the potential to produce gas. All three samples were dominated by Type III kerogen and were thus considered gas prone based on the HI vs. Tmax diagrams. The three samples were categorized as thermally immature based on Tmax pyrolysis analysis and Vitrinite Reflectance (VR) values in the range of 0.44 to 0.46 % Ro. Based on the results obtained, the black shale and coal in the Nampol Formation has the capability to generate hydrocarbon but are considered as an immature source rock that can be predicted to produce gas at its peak maturity.

Keywords: Malang, Nampol Formation, source rock, TOC

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INTRODUCTION

Nampol Formation of the Southern Mountains of eastern Java (Indonesia) has a distribution from its type location in Pacitan to the South Malang area. According to (Samodra, et al., 1992) Nampol Formation is 100 m thick which is composed of coarse to fine-sized clastic sedimentary rocks with alternating volcaniclastic rocks and lignite. Recent research has discovered that in the regional stratigraphic setting of the Southern Mountains of East Java there is the Nampol Formation which is considered to possess the capability to become a potential source rock with the discovery of organic material in the lithology of black shale, siltstone, claystone and coal inserts. The presence of black shale and black claystone in the Nampol Formation is demands further investigation through geological mapping and geochemical analysis to determine to total quantity organic matter, type of kerogen, and source rock thermal maturity.

The research area is located in the eastern part of Southern Mountain, more precisely in Sumbermanjing District, Malang Regency, East Java Province. It is located approximately 50 km from the Malang City which can be reached within 1 hour 30 minutes (Figure 1). The focus of this research is on the Nampol Formation possibilty to become a potential source rock due to their organic matter content.

The main objective of this research is to investigate the possibility of potential source rock.

DATA AND METHODS

Data collection in this study used 3 methods consisting of surface geological mapping, measuring section (MS), and rock sampling. The selected samples are then analyzed in the laboratory to determine total quantity organic matter, type of kerogen, and source rock thermal maturity. Analysis was carried out on 3 samples of source rock. Samples that taken were calcareous claystone, black shale, and shale coal with the size of a fist. The outcrop is initially dredged with a scrapper to a depth of ±20-30 cm to get samples that have not been contaminated. After being taken, the fresh sample was immediately wrapped in aluminum foil and put in a tight plastic bag to maintain sample quality (Figure 2).

A. Literature Review

1. Regional Stratigraphy

The Southern Mountains of East Java are generally composed of rocks with Neogene to Quaternary age. This area is mostly dominated by volcanic rock and limestone. Rock sequences are arranged based on detailed stratigraphy through selected paths and presented in a stratigraphic column (Figure 3).

The stratigraphic order from oldest to youngest is as follows:

- Arjosari Formation (Tma)

The Arjosari Formation consists of turbidite deposits or sediments that are influenced by shearing symptoms that alternate with volcanic rocks, of Late Oligocene Early Miocene age. At the bottom of the formation consists of breccia of various materials, sandstone, tuffaceous sandstone, claystone, sandy marl, and calcareous claystone, with pumice and limestone breccias inserted. The upper part is

Figure 1
Research area (source: Bing Maps).

interspersed with volcanic breccia, lava, and tuff. Based on its fossil content, the Arjosari Formation is thought to be in the late Oligocene - Late Early Miocene. The Arjosari Formation has a fingering relationship with the Mandalika Formation.

- Mandalika Formation (Tomm)

The Mandalika Formation is composed of volcanic rock with clastic (volcanic) inserts in a shallow marine environment. At the bottom of this formation is composed of repeating volcanic breccias, lava, tuff with inserts of tuffan sandstone, claystone and polymic breccias. In the center of the formation, it is composed of repeating volcanic breccias, lava and diminishing clastic sediments. At the top of the formation is composed of pillow lava with basalt breccia inserts and tuffan claystone.

- Intrusive Rocks (Tomi)

According to Samodra et al., (1992), breakthrough rocks intrusive the above formation with lithology in the form of: dacite, andesite, basalt, and diorite. This intrusive rock is in the form of stock, fractured, and localized appearance of a volcanic neck so that it affects the intruded rocks with the age of the Late Oligocene to the end of the Early Miocene, namely the Arjosari and Mandalika Formation. This intrusive rock affects the formation of hydrothermal altered rock and low grade metamorphic in the rock that is breached. This intrusive rock is estimated to be of Late Oligocene to early Middle Miocene age because the younger formations (Jaten, Wuni, Nampol, Oyo, and Wonosari Formation) are not affected.

- Jaten Formation (Tmj)

This formation is composed of terrestrial clastic sediments to shallow (restricted) seas containing debris from land and lignite inserts. The bottom of the unit is composed of conglomerate sandstone, quartz sandstone, tuffaceous sandstone, conglomerate, mudstone; interspersed with claystone and bituminous shale. The upper part is fine clastic sediment in the form of siltstone, claystone and sandy marl with tuff insertion. Fossil content in interspersed with carbonated claystones:, *Planorbulina* sp., *Cancris*, sp., *Elphidium*, sp., *Quiqueloculina*, sp., *Dentalina*, sp., ostracods, pelecypods and gastropods.

- Wuni Formation (Tmw)

The Wuni Formation is composed of volcanic rock from Middle Miocene volcanic activity, with the insertion of clastic sediments of volcanic origin, deposited in a shallow marine environment around

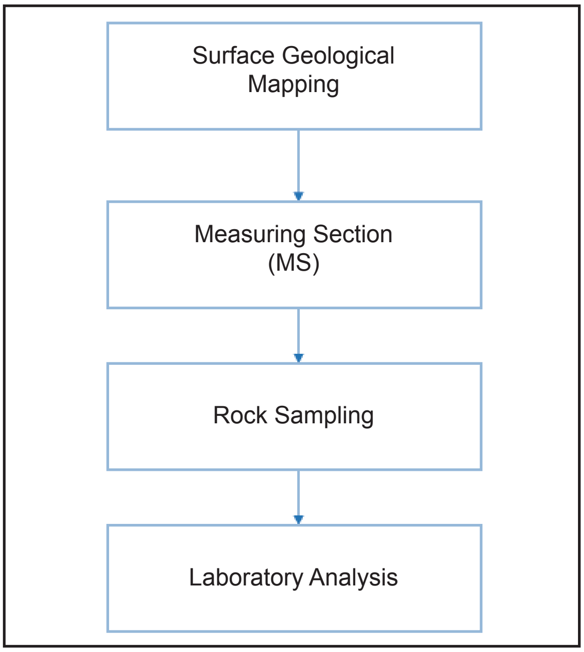

Figure 2
Research flow chart.

the Early Miocene highlands. This unit is composed of volcanic breccia and tuff; inserts tuffaceous sandstone, tuffaceous silt-stone, claystone, limestone, and lignite. Fossils in this unit are very rare. Based on its stratigraphic position which is younger than the Jaten Formation, this unit is thought to be in the middle of the Middle Miocene.

- Nampol Formation (Tmn)

This unit is a collection of coarse to fine clastic rocks, interspersed with volcanic rocks and lignite. The bottom of this unit is composed of repeating tuffaceous sandstone, siltstone, and claystone, with volcanic breccia, conglomerate sandstone, and lignite inserted. The upper part is more calcareous, consisting of repeating sand-stone, siltstone, claystone; inserts tuff and lignite. The Nampol Formation is formed in a shallow marine environment adjacent to the loop area with a formation thick-ness of about 100 m.

- Oyo Formation (Tmo)

The Oyo Formation is a collection of clastic limestones whose formation is influenced by volcanic activity. Consists of tuffaceous sandstone, calcareous sandstone, calcareous siltstone, sandy limestone, conglomerate limestone; inserting sandy tuff, marl and conglomerate limestone; inserts sandy tuff, marl and reef limestone. The lower part of the unit is generally tuffaceous, the higher the tuff element decreases and turns into limestone. Based on the fossil content of small planktonic foraminifera, the Oyo formation has a Middle Miocene age. This formation is formed in a marine environment with a depth of 20-100 m.

- Wonosari Formation (Tmwl)

This unit is a limestone deposit that is late Middle Miocene and formed in a shallow marine environment. The lower part of the unit is more clastic in nature; consists of sandy limestone (calcarenite) with calcareous sandstones. The upper part is com-posed of reef limestone, interspersed with calcarenite, marl, and conglomerate lime-stone. This formation is very rich in small planktonic foraminifera which based on the assemblage they contain have an age of N13-N16 or Middle Miocene to early Late Miocene.

2. Regional Structural Geology

There are three major structural patterns in Java (Pulunggono & Martodjojo, 1994). First, the north-east-southwest direction (Meratus direction) which was formed in the Late Cretaceous - Early Eocene age. Second, north-south direction (Sunda direction) which was formed in the Early Eocene-Early

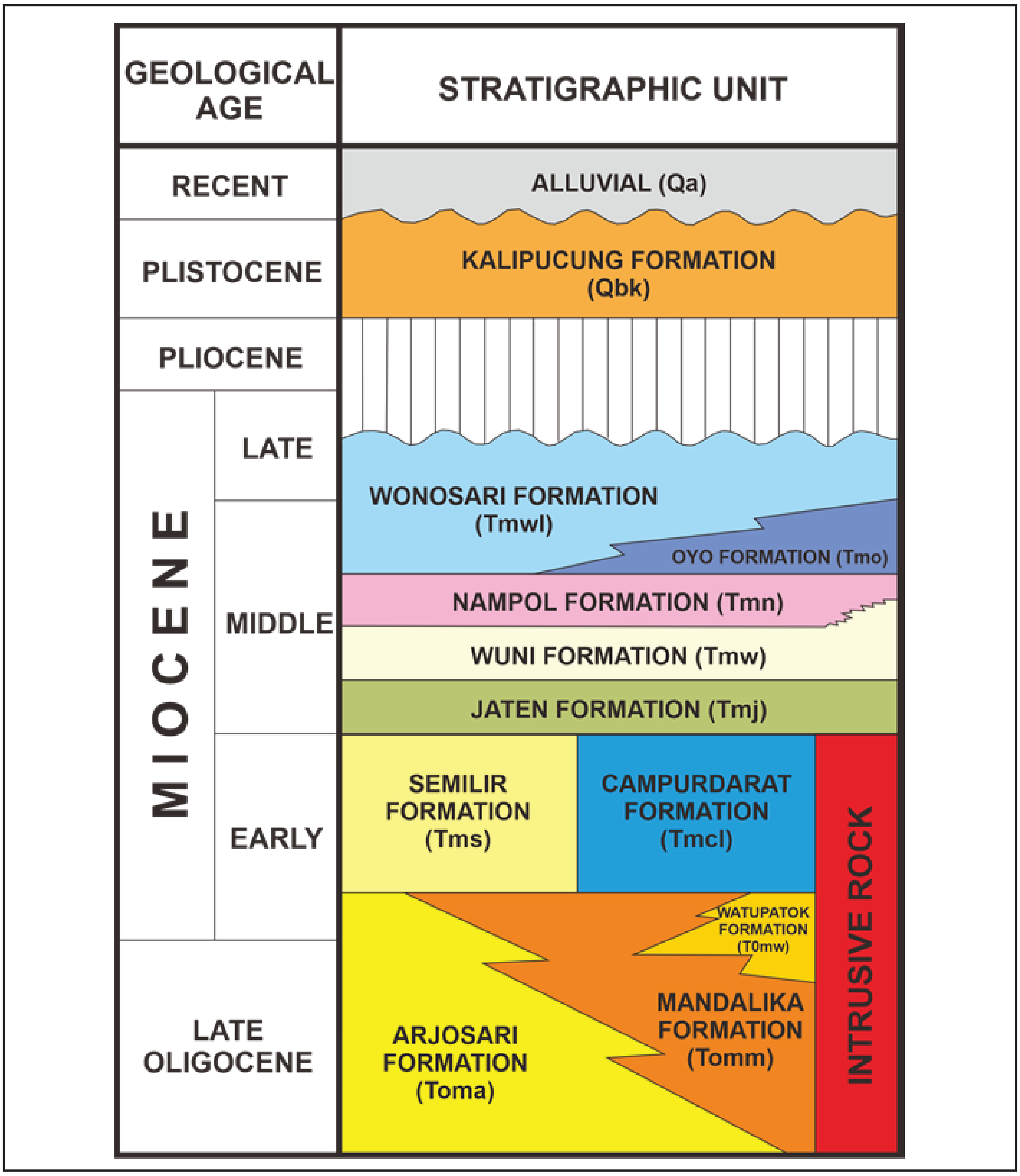

Figure 3
Southern mountain East Java stratigraphy (Samodra & Wiryosujono, 1989).

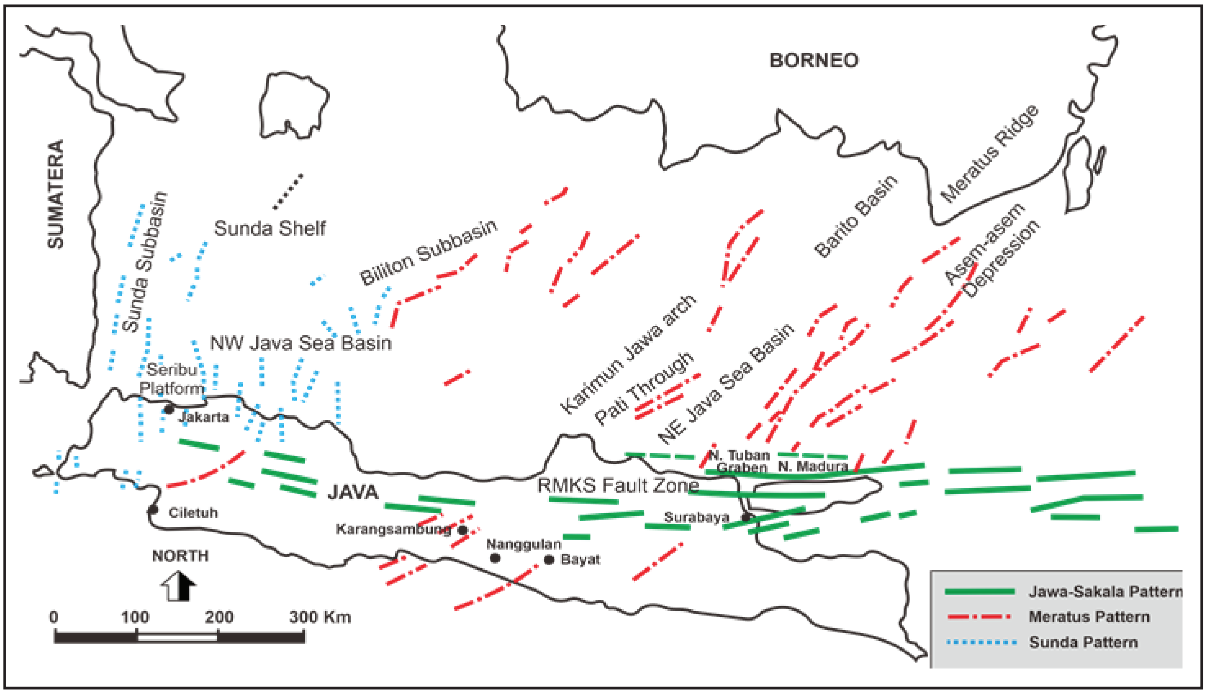

Figure 4
The main structural pattern of Java Island (Pulunggono & Martodjojo, 1994).

Oligicene age. Third, the west-east direction (Javanese direction) which was formed at the Late Oligocene age by compression forces from the subduction in the southern part of Java Island (Figure 4).

RESULTS AND DISCUSSION

A. Lithological Characteristics

The rock sampling locations were at the observation sites FB-01 and MM-05 on the stratigraphic measuring section track of Bambang River (Figure 9) and Sumbernanas River . Meanwhile, for the rock sample, DA-62 is on the selected observation location in Sekarbanyu District, Sumbermanjing, Malang (Figure 5 and Figure 10).

The outcrop of the Nampol Formation in Sekarbanyu at location DA-62 is composed of calcarous claystone, siltstone, clastic limestone, and black shale. Calcareous claystone, grey fresh color, containing shell fragments. Siltstone, grey colored. Clastic limestone, milky white colored, containing mollusk shell fragments. Black shale with parallel lamination structure, containing organic material and shell fragments (Figure 6).

The outcrop of the Nampol Formation on the Bambang River traverse at location FB-01 is composed of intercalation of clastic limestones and calcareous claystones. Clastic limestone is yellowish white with a large grain size of fine sand (1/8-1/4 mm), with a layer thickness of ± 1 m. Calcareous claystone, grey fresh color, contains lignite inserts and shell fragments (Figure 7).

The outcrop of the Nampol Formation on the Sumbernanas River traverse at location MM-05 is composed of clastic limestone and calcareous claystone. Clastic limestone is yellowish white with a large grain size of fine sand (1/8-1/4 mm), with a layer thickness of ± 1 m. Calcaroeus claystone, grey colored, contains lignite inserts and shell fragments (Figure 8).

B. Potential Source Rock

The results of TOC analysis (Table 1) on the source rock samples in the study area showed TOC values of 3.48 - 26.18 wt.% were categorized as good to very good in gener-ating hydrocarbons according to Peters (1986) and Waples (1985). The cross-plot of TOC values was carried out on the values of S1+S2 to determine the total generating potential of hydrocarbons that could be produced by each sample. The plotting results show that the total hydrocarbon potential that can be produced for the sample ‘LP01’ is not good; ‘LP62’ is fair; and ‘LP05’ is good (Figure 9).

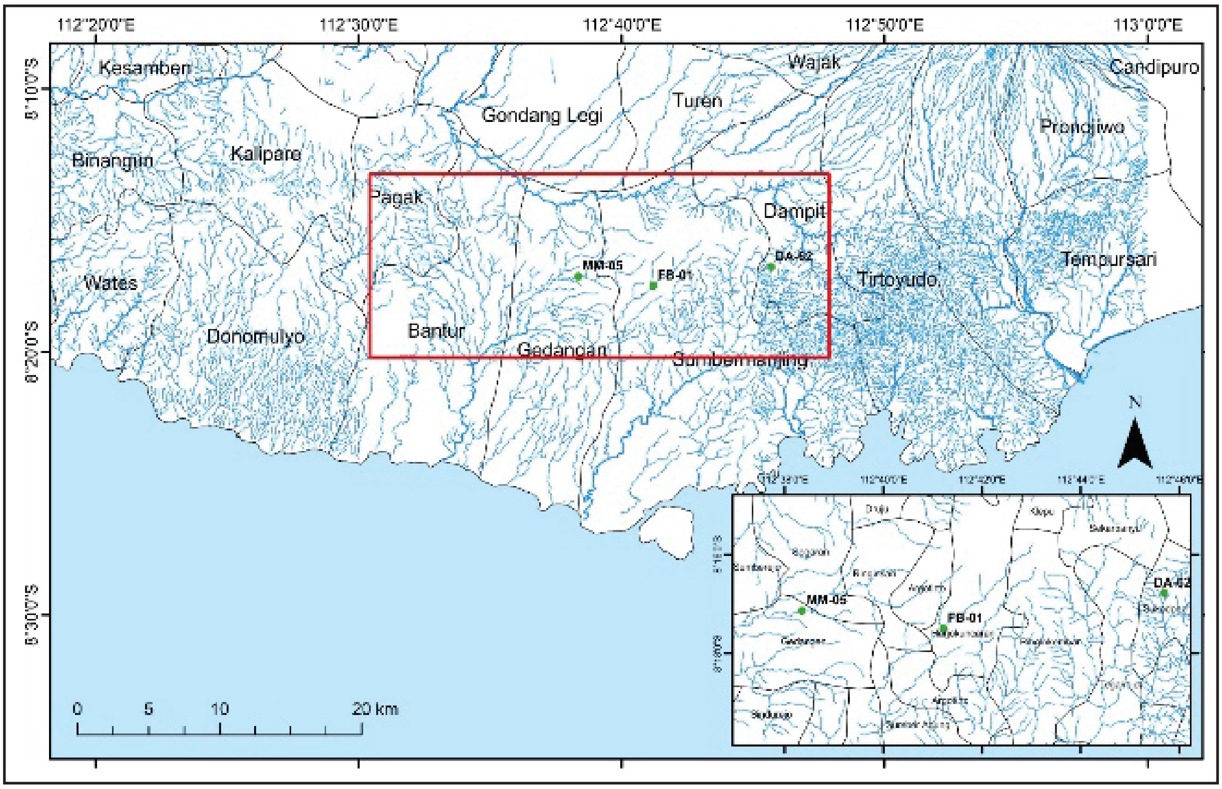

Figure 5
Map Samples are marked with a green dot.

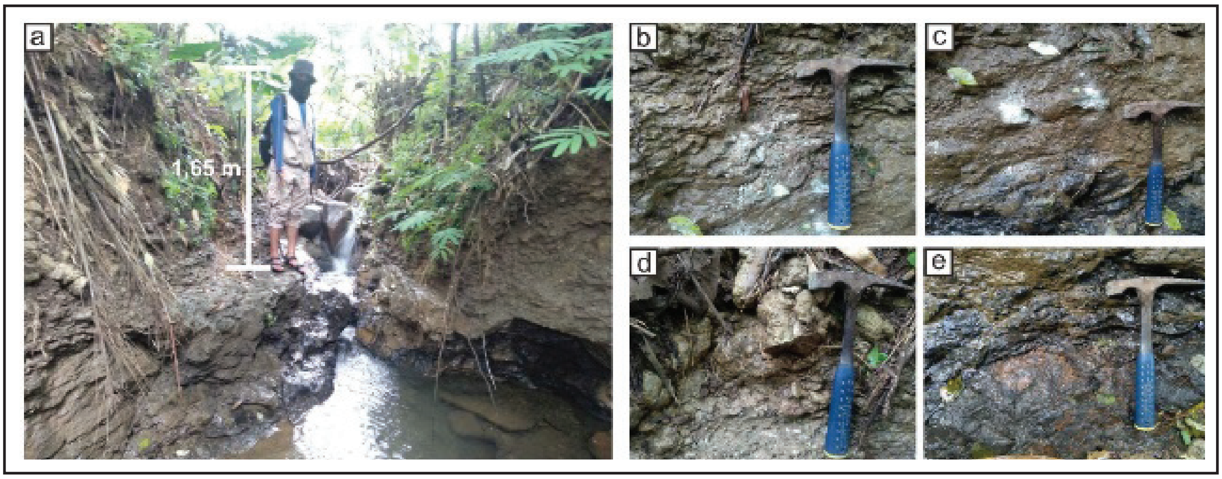

Figure 6
Location of source rock sampling. (a) Location : DA-62 (Sekarbanyu). (b, c, d) Calcareous claystone, siltstone, and clastic limestone. (e) Black shale sampled for geochemical analysis.

The diagram of the content of Total Organic Carbon (TOC) versus Potential Yield (PY) (Figure 11) shows the potential for hydrocarbons in the study area which is indicated by the level of richness of organic material content. This diagram shows that two samples from the Nampol Formation showed good organic material quality with TOC values of 3.48 wt% and 4.01 wt% and PY of 1.52 and 3.66 mgHC/g, respectively. Another sample showed very good organic material quality with a TOC value of 26.18% and a PY value of 19.55 mgHC/g. The three samples tend to form gas (gas prone) with one of the samples, code LP 05, possess the possibility to become a potential or effective source rock (Figure 12).

Based on the hydrogen index (HI) and of S_2/S_3 values, it can be infered that the type of organic material in the three samples is Type III kerogen (Figure 13). This kerogen contains humic organic matter

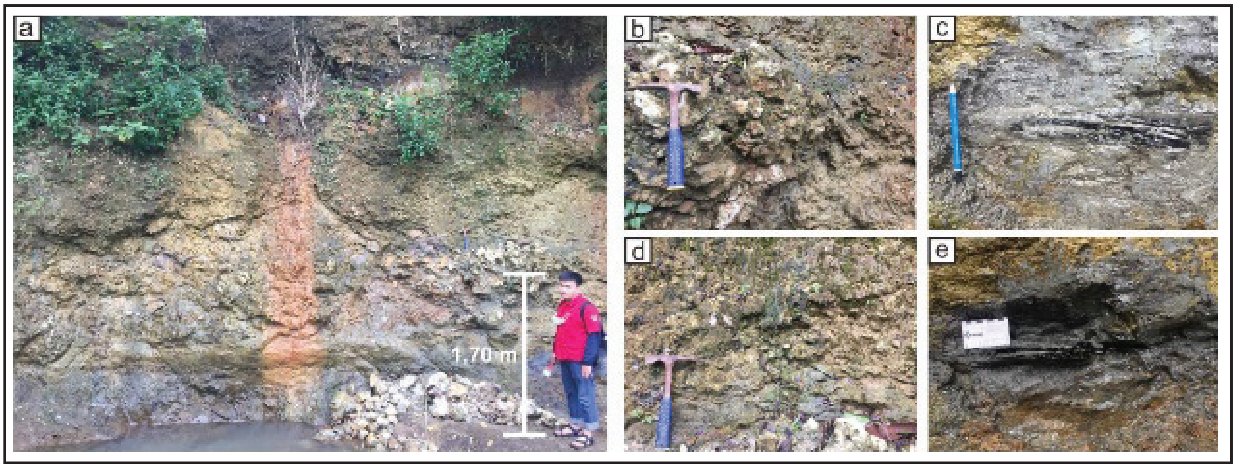

Figure 7
Location of source rock sampling. (a) Location: FB-01 (Bambang River, Argotirto). (b,c,d) Intercalation of clastic limestone and carbonated claystone. (e) Sampled lignite inserts for geochemical analysis.

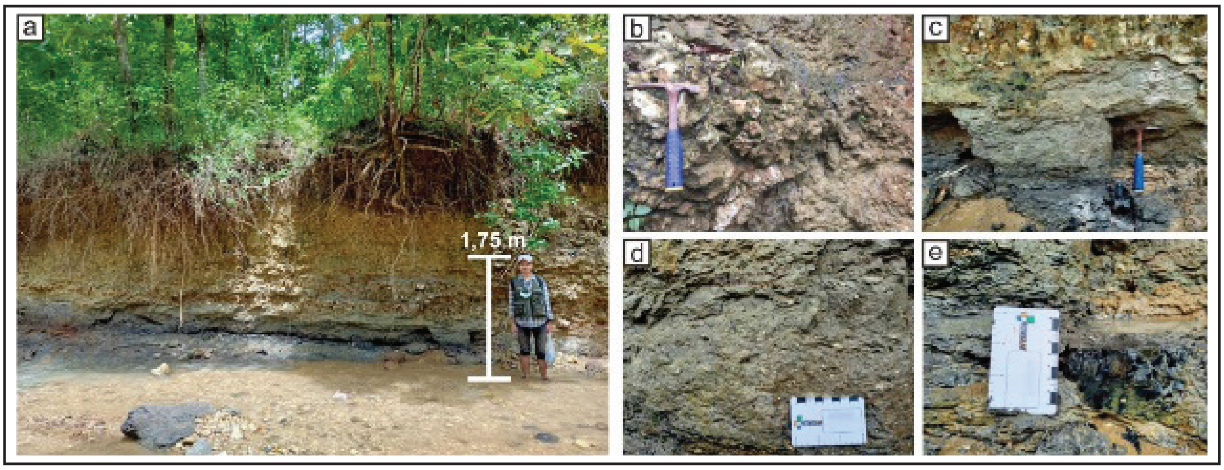

Figure 8. Location of source rock sampling. (a) Location : MM-05 (Sumbernanas River, Ringinsar) (b,c,d) Clastic limestone and calcareous claystone. (e) Sampled lignite inserts for geochemical analysis.

Table 1
Results of TOC and Rock-Eval Pyrolysis analysis on rock samples in the Nampol Fm.

	Sample ID	Lithology	TOC (wt.%)	mg/gm rock			Tmax (°C)	Oil Production Index (OPI)	Potential Yield (S_1+S_2)	Hydrogen Index	Oxygen Index	%R
				S_1	S_2	S_3						
1	LP1	Calc.claystone	3,48	0,04	1,48	0,38	430	0,03	1,52	43	11	0,44
2	LP 62	Shale	4,01	0,22	3,44	2,19	417	0,06	3,66	86	55	0,46
3	LP 05	Shaly Coal	26,18	0,27	19,28	11,82	408	0,01	19,55	74	45	0,45

S_1 = Free Hydrocarbons
S_2 = Pyrolysable Hydrocarbons
S_3 = Organic CO_2
Oil Production Index = Transformation Ratio = $S_1/(S_1+S_2)$
T_{max} = Temperature of Maximum S_2
Oxygen Index = $(S_3/TOC) \times 100$
*Pyrolysis by Rock Eval II; TOC content by Leco Analyzer
Hydrogen Index = $(S_2/TOC) \times 100$
*** = Not Detected

derived from woody plants containing cellulose from land plants (equivalent to vitrinite in coal (Waples & Curiale, 1999).

Most of this kerogen form in paralic swamps, abandoned river channels, and in regions where sediment supply is low, incised valleys contain these sediments as estuarine or coastal plain deposits.

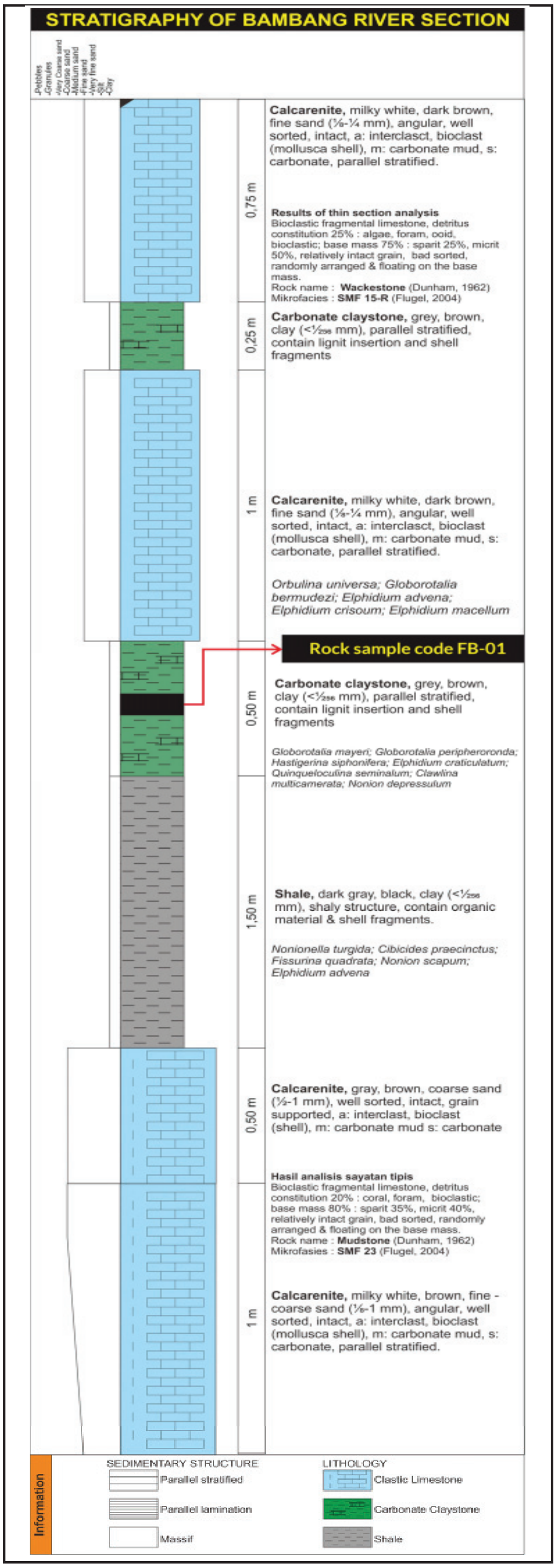

Figure 9
Stratigraphy of Bambangriver measuring section
with a stratigraphical position of FB-01 rock sample.

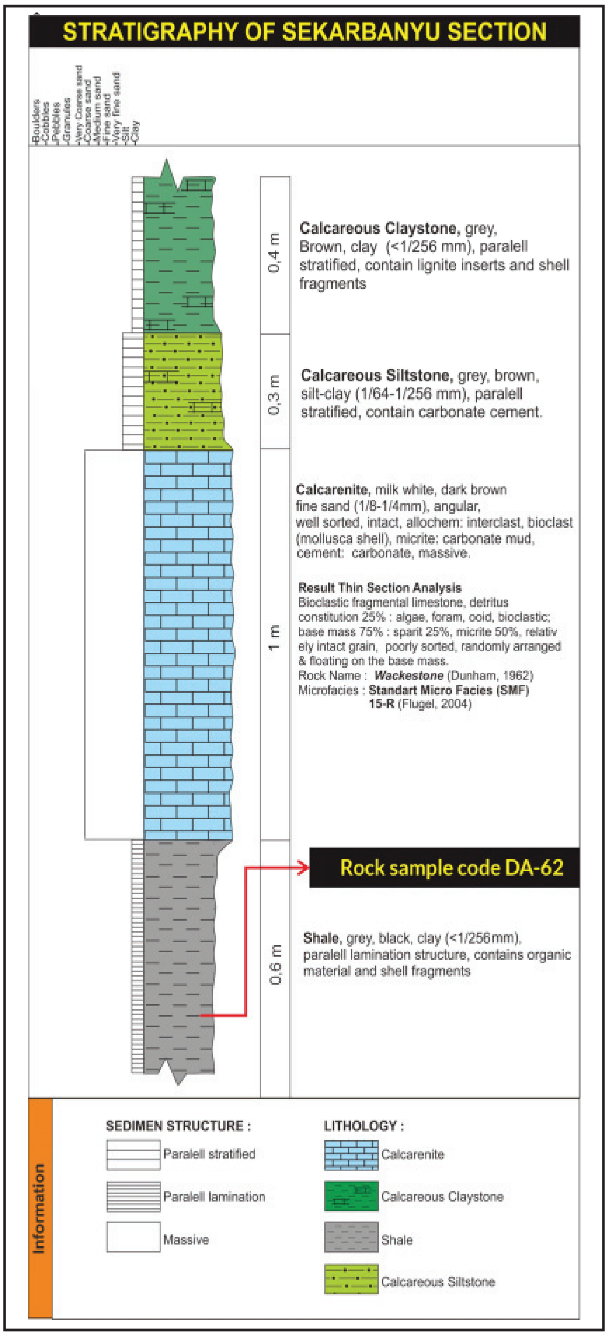

Figure 10
Stratigraphy of Sekarbanyu section with
a stratigraphical position of DA-62 rock sample.

The thermal maturity of rock samples was determined using vitrinite reflectance (VR) and Rock-Eval Pyrolysis analyses. From the results of the analysis of vitrinite reflectance in rock samples, values of <0.5%Ro are obtained. The rock samples are thermally immature to become hydrocarbon source rocks, according to Peters & Cassa (1994) type, and thermal maturity of a source rock. These maps are a necessary step toward determining the stratigraphic and geographic extent of a pod of

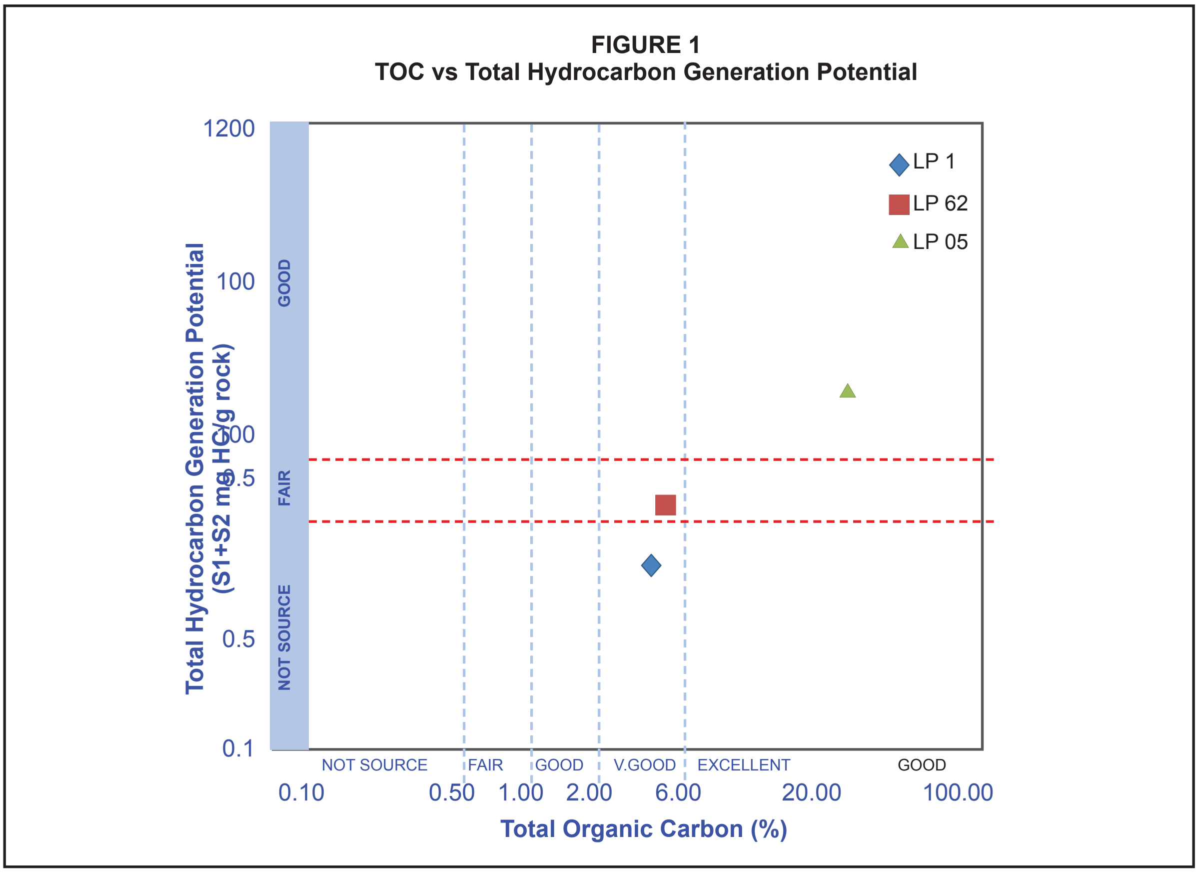

Figure 11
Cross-plot between Total Organic
Carbon (TOC) and Potential Yield (PY) content.

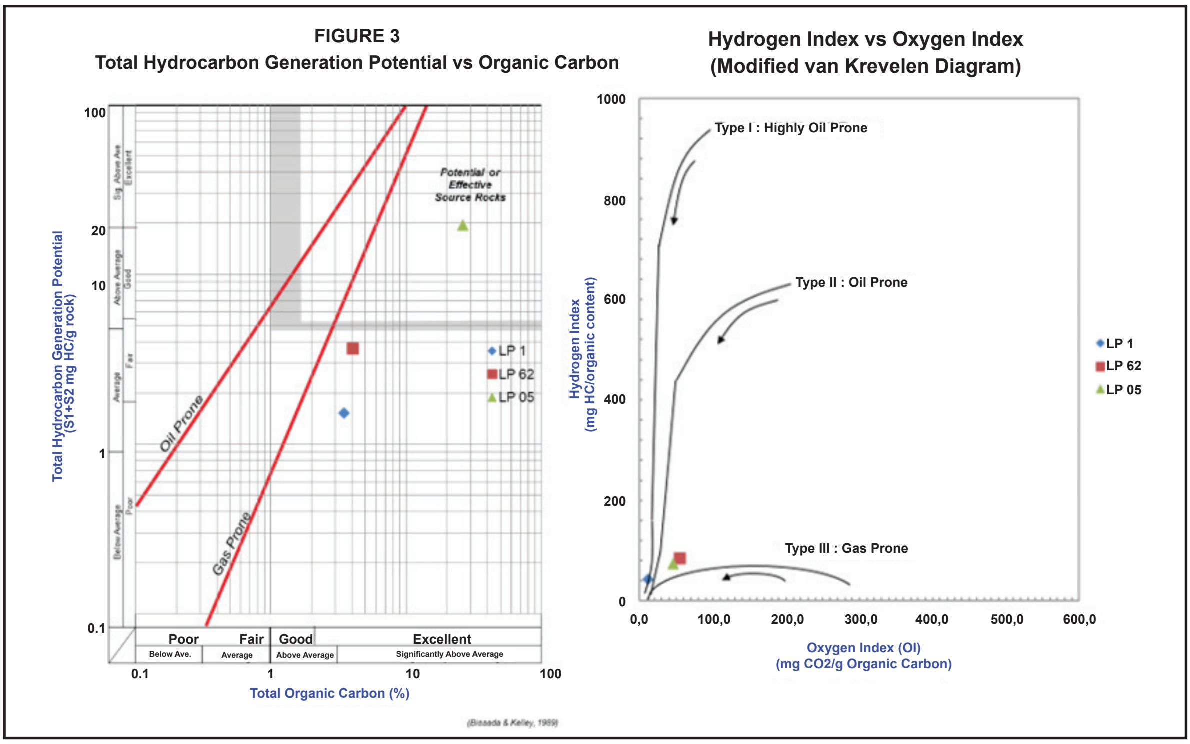

Figure 12
Diagram of Total Organic Carbon (TOC) versus Potential Yield (PY) content (left).
Cross plot between Oxygen Index (OI) and Hydrogen Index (HI) values (right). All three samples is gas prone.

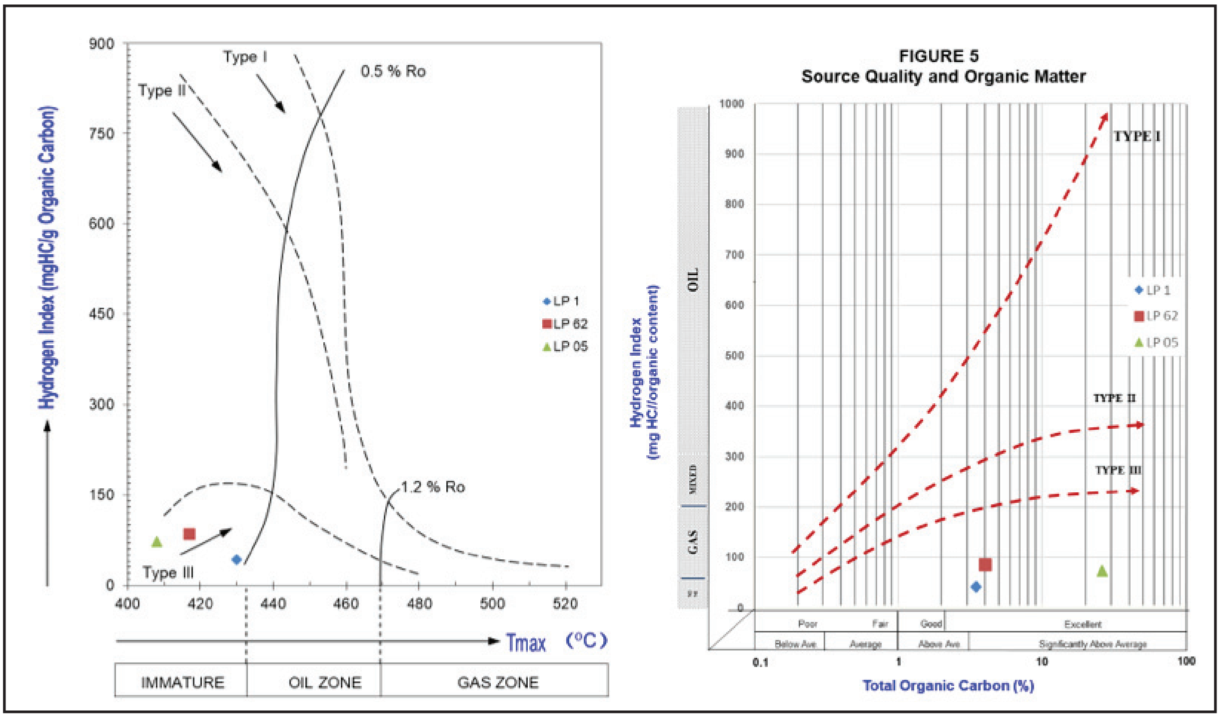

Figure 13
Cross plot between Tmax and Hydrogen Index (HI) values (left). Cross plot between TOC and Hydrogen Index (HI) values (right). The organic material from three samples were all classified as type III kerogen.

active source rock in a petroleum system, and they are based on geochemical analyses of rock samples from outcrops and wells that are displayed on logs. These geochemical well logs are based on Rock-Eval pyrolysis, total organic carbon, vitrinite reflectance, and other rapid, inexpensive (Peters & Cassa, 1994) classification of source rock maturity based on vitrinite reflectance value. Meanwhile, Rock-Eval pyrolysis data revealed that the maximum kerogen-breaking temperature for the three samples' was ranged from 408 to 430°C. The rock samples are classified as Immature source rock according to Tissot & Welte (1978)'s Tmax classification and its relationship with the source rock's thermal maturity (Table 2).

CONCLUSIONS

Based on the results obtained, it can be concluded that black shale and coal in the Nampol Formation are a potential source rock. Potential source rock is defined by Waples (1985) as immature sedimentary rocks that capable of generating and expelling hydrocarbons, if their level of maturity were higher. In our research, we interpret that Nampol Formation source rock are immature. Therefore, at a deeper and higher temperature basins condition, it have the capability to generate hydrocarbons and tend to produce gas. For further research, it is envisaged to discover the possibility of oil seeps presence in the Southern Mountains, allowing for the correlation between oil and source rock.

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GLOSSARY OF TERMS

Symbol	Definition	Unit
TOC (Total Organic Carbon)	The amount of organic material in source rocks as represented by the weight percent of organic carbon	%wt

Symbol	Definition	Unit
HI (Hydrogen Index)	The number of hydrogen atoms per unit volume divided by the number of hydrogen atoms per unit volume of pure water at surface conditions.	mg HC/g
VR (Vitrinite Reflectance)	A measurement of the maturity of organic matter with respect to whether it has generated hydrocarbons or could be an effective source rock.	%Ro
Tmax	The temperature at which the maximum rate of hydrocarbon generation occurs in a kerogen sample during pyrolysis analysis	ºC

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